New Mexico Register / Volume XXXI, Issue 6 / March 24, 2020

STATE GAME COMMISSION MEETING AND RULE MAKING NOTICE

The New Mexico State Game Commission ("Commission") has scheduled a regular meeting and rule hearing for Thursday April 30, 2020 beginning at 9:00 a.m. at the Grant County Administration Center, 1400 Highway 180 East, Silver City, NM 88061, to hear and consider action as appropriate on the following: presentation of proposed changes to the Hunting and Fishing - Manner and Method of Taking rule.

Synopsis:

The proposal is to amend the Hunting and Fishing - Manner and Method of Taking rule, 19.31.10 NMAC, which will become effective May 19, 2020. The current Hunting and Fishing - Manner and Method of Taking rule is a permanent rule.

The proposed new rule no longer allows traps and foot snares as a method of sport harvest for cougar. This proposed deletion is necessary to align with the recently approved Bear and Cougar rule, 19.31.11 NMAC. A full text of changes will be available on the Department's website at: www.wildlife.state.nm.us.

Interested persons may submit comments on the proposed changes to the Hunting and Fishing - Manner and Method of Taking rule at: DGF-Manner-and-Method-Rule@state.nm.us, or individuals may submit written comments to the physical address below. Comments are due by 1:00 p.m. on April 28, 2020. The final proposed rule will be voted on by the Commission during a public meeting on April 30, 2020. Interested persons may also provide data, views or arguments, orally or in writing, at the public rule hearing to be held on April 30, 2020.

Full copies of text of the proposed new rule, technical information related to proposed rule changes, and the agenda can be obtained from the Office of the Director, New Mexico Department of Game and Fish, 1 Wildlife Way, Santa Fe, New Mexico 87507, or from the Department's website at www.wildlife.state.nm.us/commission/proposals-under-consideration/. This agenda is subject to change up to 72 hours prior to the meeting. Please contact the Director's Office at (505) 476-8000, or the Department's website at www.wildlife.state.nm.us for updated information.

If you are an individual with a disability who is in need of a reader, amplifier, qualified sign language interpreter, or any other form of auxiliary aid or service to attend or participate in the hearing or meeting, please contact the Department at (505) 476-8000 at least one week prior to the meeting or as soon as possible. Public documents, including the agenda and minutes, can be provided in various accessible formats. Please contact the Department at 505-476-8000 if a summary or other type of accessible format is needed.

Legal authority for this rulemaking can be found in the General Powers and Duties of the State Game Commission 17-1-14, et seq. NMSA 1978; Commission's Power to establish rules and regulations 17-1-26, et seq. NMSA 1978.

New Mexico Register / Volume XXXI, Issue 7 / April 7, 2020

MODIFICATION TO THE STATE GAME COMMISSION MEETING AND RULE MAKING NOTICE Due to Executive Order 2020-004 Issued by Governor Michelle Lujan Grisham

The New Mexico State Game Commission ("Commission") will be hosting a virtual meeting and rule hearing on Thursday April 30, 2020 beginning at 9:00 a.m. This will replace the previously scheduled meeting at the same time at the Grant County Administration Center, 1400 Highway 180 East, Silver City, NM 88061. For instructions on how to virtually attend this meeting, visit the Department's website at: http://www.wildlife.state.nm.us/commission/webcast/. The purpose of this meeting is to hear and consider action as appropriate on the following: presentation of proposed changes to the Hunting and Fishing - Manner and Method of Taking rule.

Synopsis:

The proposal is to amend the Hunting and Fishing - Manner and Method of Taking rule, 19.31.10 NMAC, which will become effective May 19, 2020. The current Hunting and Fishing - Manner and Method of Taking rule is a permanent rule.

The proposed new rule no longer allows traps and foot snares as a method of sport harvest for cougar. This proposed deletion is necessary to align with the recently approved Bear and Cougar rule, 19.31.11 NMAC. A full text of changes will be available on the Department's website at: www.wildlife.state.nm.us.

Interested persons may submit comments on the proposed changes to the Hunting and Fishing - Manner and Method of Taking rule at: DGF-Manner-and-Method-Rule@state.nm.us, or individuals may submit written comments to the physical address below. Comments are due by 1:00 p.m. on April 28, 2020. The final proposed rule will be voted on by the Commission during a virtual public meeting on April 30, 2020. Interested persons may also provide data, views or arguments, orally or in writing, at the virtual public rule hearing to be held on April 30, 2020.

Full copies of text of the proposed new rule, technical information related to proposed rule changes, and the agenda can be obtained from the Office of the Director, New Mexico Department of Game and Fish, 1 Wildlife Way, Santa Fe, New Mexico 87507, or from the Department's website at www.wildlife.state.nm.us/commission/proposals-under-consideration/. This agenda is subject to change up to 72 hours prior to the meeting. Please contact the Director's Office at (505) 476-8000, or the Department's website at www.wildlife.state.nm.us for updated information.

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Legal authority for this rulemaking can be found in the General Powers and Duties of the State Game Commission 17-1-14, et seq. NMSA 1978; Commission's Power to establish rules and regulations 17-1-26, et seq. NMSA 1978.

This is an amendment to 19.31.10 NMAC, section 12, effective May 19, 2020. Additional sections are not included because no changes are proposed.

19.31.10.12 BIG GAME AND TURKEY:

A. Legal hunting hours: A person may only take or attempt to take any big game species or turkey during the period from one-half hour before sunrise to one-half hour after sunset. It is unlawful to take or attempt to take big game or turkey outside of legal hunting hours.

B. Killing out of season: It is unlawful to take or attempt to take any big game species or turkey outside of the established hunting season.

C. Bag limit: It is unlawful for any person to take any big game species or turkey other than the legal bag limit as specified on their big game or turkey license or as indicated by the hunt code, or for any bear hunter to take a sow with cub(s), or any cub less than one year old, or for any cougar hunter to take a spotted cougar kitten or any female accompanied by spotted kitten(s).

D. Exceeding the bag limit on big game:

(1) It is unlawful for any person to hunt for or take more than one animal of any big game species per year unless otherwise allowed by state game commission rule.

(2) It is unlawful for any person to hunt for or take more than two cougars per year unless otherwise allowed by state game commission rule.

E. Exceeding the bag limit on turkey: It is unlawful for any person to hunt for or take more than two bearded turkeys during the spring turkey season or more than one turkey during the fall turkey season unless otherwise specifically allowed by 19.31.16 NMAC.

F. Proof of sex or bag limit: It is unlawful for anyone to transport or possess the carcass of any big game species or turkey without proof of sex or bag limit (except donated parts when accompanied by a proper possession certificate). Proof of sex or bag limit shall be:

(1) Bear and cougar – External genitalia of any bear or cougar killed shall remain naturally attached to the pelt and be readily visible until the pelt has been inspected and pelt-tagged by a department official.

(2) Barbary sheep and oryx – The horns of any Barbary sheep or oryx taken shall remain naturally attached to the skull or skull plate until arriving at a residence, taxidermist, meat processing facility or place of final storage.

(3) Deer – The antlers of any buck deer taken shall remain naturally attached to the skull or skull plate until arriving at a residence, taxidermist, meat processing facility or place of final storage. The scalp and both ears of any antlerless deer or the naturally attached female genitalia shall accompany the carcass in the same manner.

(4) Elk – The antlers of any bull elk taken shall remain naturally attached to the skull or skull plate until arriving at a residence, taxidermist, meat processing facility or place of final storage. The scalp and both ears of any antlerless elk or the naturally attached female genitalia shall accompany the carcass in the same manner.

(5) Pronghorn - The horns, scalp and both ears of any pronghorn taken shall remain naturally attached to the skull or skull plate and must accompany the carcass until arriving at a residence, taxidermist, meat processing facility or place of final storage. If the horns of a female pronghorn are longer than its ears, and the bag limit is F/IM, the external genitalia must remain naturally attached to the hide/carcass, as appropriate, and be visible to provide proof of legal bag limit until arriving at a residence, taxidermist, meat processing facility or place of final storage.

(6) Bighorn sheep - The horns of any ram shall remain naturally attached to the skull or skull plate and the external genitalia of any ewe taken shall remain naturally attached to the hide/carcass, and be visible until arriving at a residence, taxidermist, meat processing facility or place of final storage.

(7) Persian ibex - The horns of any ibex shall remain naturally attached to the skull or skull plate. If the horns of any female ibex are 15 inches or longer the external genitalia shall remain naturally attached to the hide/carcass, and be visible until arriving at a residence, taxidermist, meat processing facility or place of final storage.

(8) Turkey – When the bag limit is a bearded turkey, the beard and a small patch of feathers surrounding the beard shall remain with the carcass, and be visible until arriving at a residence, taxidermist, meat processing facility or place of final storage.

(9) Javelina – The skull of each javelina shall be proof of bag limit and must be retained until arriving at a residence, taxidermist, meat processing facility or place of final storage.

G. Tagging of harvested game:

(1) Physical Tagging of harvested game: Licensed hunters of any big game species or turkey, who have chosen to receive a department issued tag at application or purchase, upon harvesting an animal, shall immediately and completely notch out the appropriate month and day on the carcass tag. Prior to moving any part of the carcass from the kill site, the licensed hunter shall remove the entire backing material from the carcass tag and adhere it to the appropriate location on the carcass leaving the entire face of the tag visible. If the species or sex harvested requires the use of an antler or horn tag the licensed hunter shall, prior to moving any part of the carcass from the kill site, remove the entire backing material from the antler/horn tag and adhere it to the appropriate location on the antler or horn leaving the entire face of the tag visible. All tags shall remain attached to the carcass, antlers or horns until it is delivered to a meat processing facility, taxidermist, placed in final cold storage or if required, is inspected and documented or pelt tagged by a department official. The antler/horn tag is not required to be attached or used on antlerless/hornless animals.

(2) Electronic Tagging of harvested game: Licensed hunters of any big game species or turkey, who have chosen to electronically tag their game at application or purchase, upon harvesting an animal, shall immediately access the department's electronic tagging (e-tag) application to receive an e-tag number specific to the license. The licensed hunter will legibly write the e-tag number, customer identification number, and the date of harvest on any durable material using permanent ink and shall attach one piece to the big game species or turkey on the appropriate location on the carcass and another piece to the antler or horns as required prior to moving any part of the carcass from the kill site. All e-tag pieces shall remain attached to the carcass, antlers or horns until it is delivered to a meat processing facility, taxidermist, placed in final cold storage or if required, is inspected and documented or pelt tagged by a department official. An antler/horn e-tag is not required to be attached or used on antlerless/hornless animals.

(3) The proper location to attach all carcass tags and e-tags:

(a) The proper location to attach the carcass tag or e-tag on any game species is to attach it conspicuously on the hock tendon on either hind leg.

(b) The proper location to attach the carcass tag or e-tag on javelina is to adhere it to the head/skull around the nose.

(c) The proper location to attach the carcass tag or e-tag on a turkey is to adhere it around the leg above the foot and below the feathers on the thigh.

(d) The proper location to attach the carcass tag or e-tag on a bear or cougar is to adhere it around the ankle area of the hide above the foot. Bear and cougar carcass tags authorize possession of those animals until pelt tagged in accordance with state game commission rule or for five days from date of kill, whichever comes first.

(i) Any bear or cougar killed shall be tagged with a pelt tag furnished free of charge by the department.

(ii) The hunter who kills the bear or cougar or the hunter's designee must present the unfrozen skull and pelt to a department official for tooth removal and pelt tagging within five calendar days from the date of harvest, before the pelt can be frozen, processed, tanned or salted by a taxidermist, or before taking the pelt out of New Mexico, whichever comes first.

(iii) Any hunter who appoints a designee to present the skull and pelt for pelt tagging is required to contact a conservation officer prior to having the pelt inspected and tagged.

(iv) The pelt tag shall remain attached until the pelt is tanned.

(v) Skulls with mouths closed may not be accepted until the mouth is opened by the hunter or designee.

(vi) Licensed bear or cougar hunters or their designees who provide false or fraudulent information regarding the required information including, but not limited to, sex, date or location of harvest shall be assessed 20 revocation points pursuant to 19.31.2 NMAC.

(e) The proper location to attach an antler tag or e-tag is to adhere the tag around the main beam of the antler between any of the points or tines as close to the base as possible to prevent the tag from coming off.

(f) The proper location to attach a horn tag or e-tag is to adhere the tag around the horn as close to the base as possible to prevent the tag from coming off.

H. It is unlawful:

(1) for any licensed hunter to fail to properly tag their big game species or turkey with the carcass and antler tag or e-tag as prescribed;

(2) to possess any portion of a big game or turkey carcass that does not have a properly notched carcass tag attached to it or a completed e-tag attached to it, except lawfully taken game that is accompanied by a proper possession certificate or department invoice;

(3) to possess any bear or cougar or parts thereof which has not been pelt tagged within five days of kill, has been taken out of state prior to pelt tagging or has not otherwise been pelt tagged in accordance with state game commission rule;

(4) for any person to transport or possess the carcass of any big game species or turkey without proof of sex naturally attached or proof of legal bag limit until the carcass arrives at a residence, taxidermist, meat processing facility, place of final storage or if required, is inspected and documented or pelt tagged by a department official, except lawfully taken game that is accompanied by a proper possession certificate or department invoice;

(5) to use a carcass or antler tag that is cut, torn, notched or mutilated. Cut, torn, notched or mutilated tags are no longer valid for the take of a big game species or turkey; or

(6) to use a previously issued carcass or antler tag once a duplicate has been obtained or to use the carcass, antler tag or e-tag of any other person. Any previous carcass or antler tag assigned to a license which is replaced by a duplicate is void and no longer valid for the take of a big game species or turkey.

I. Once-in-a lifetime hunts: It is unlawful for any person to apply for, receive or use any once-in-a lifetime license if they have ever held a once-in-a lifetime license for that species which has the same bag limit or eligibility requirements.

J. Youth only (YO), mobility impaired (MI), Iraq/Afghanistan veterans (I/A) and military only (MO) hunts or military discounted licenses: It is unlawful for anyone to apply for or receive or use any YO, MI, I/A or MO license or any military discounted license except as allowed by state game commission rule.

K. License sale: It is unlawful for anyone to sell or offer for sale any hunting, fishing or trapping license, permit or tag which has been issued by the department, or to sell or offer for sale any commercial collection permit or scientific collection permit.

L. Use of dogs in hunting:

(1) It is unlawful to use dogs to hunt or pursue big game species or turkey, except for bear and cougar.

(2) Dogs may be used only to hunt bear and cougar during open seasons unless otherwise restricted. It is unlawful to:

(a) hunt for or pursue bear or cougar with dog(s) on the Valle Vidal except holders of bear entry permits for the hunting of bear only;

(b) hunt for or pursue bear or cougar with dog(s) during any September big game bow season statewide except as otherwise allowed by state game commission rule;

(c) release dog(s) to pursue or hold bear or cougar outside of legal hunting hours or during closed season or in a closed area or zone;

(d) to pursue bear or cougar with dog(s) without the licensed hunter, who intends to kill or who kills the bear or cougar, present continuously from the initial release of any dog(s).

(3) It is unlawful to use dog(s) to assist in the recovery of wounded or dead big game or turkey except as follows:

(a) Dog(s) may be used to assist in the recovery of wounded game provided that no more than two dogs may be used at any one time to locate a wounded or dead deer, elk, pronghorn, bighorn sheep, Barbary sheep, oryx, Persian ibex, javelina or turkey.

(b) Dog(s) used to assist in the recovery of deer, elk, pronghorn, bighorn sheep, Barbary sheep, oryx, Persian ibex, javelina or turkey shall be leashed and under the control of the handler at all times and cannot be used to pursue or harass wildlife. No person assisting in the recovery of a wounded animal may shoot or kill the animal being tracked unless they are a licensed hunter for that species, season and area and they intend to tag the animal as their own.

M. Use of bait: It is unlawful for any person to take or attempt to take any big game species or turkey by use of baiting or for any person to take or attempt to take big game or turkey from an area which has not been completely free of bait (including in feeders) for at least 10 days. Preexisting legitimate livestock salt and mineral and natural attractants such as cultivated fields, water, orchards, natural kills, carrion or offal are not considered bait unless they have been moved or placed there from another location. It is unlawful to create, maintain or use any bait station in hunting bear or cougar. It is unlawful to use any scent attractant in hunting bears.

N. Live animals: It is unlawful to use live protected species as a decoy in taking or attempting to take any big game species or turkey.

O. Hunting captive big game species: It is unlawful to take or attempt to take any big game species within any fence or enclosure, or by use of any fence or enclosure, which significantly restricts or limits the free ingress or egress of that big game species except as allowed by permit from the department. Any fence which is 7.5 feet tall or taller shall be considered game proof and hunting within any such enclosure, even if there are open gate(s), is unlawful. Exception: Net wire fencing commonly used as sheep or goat fencing which is not taller than four feet is not considered to significantly restrict or limit the free ingress or egress of any protected species.

P. Use of calling devices: It is unlawful to use any electronically or mechanically recorded calling device in taking or attempting to take any big game species or turkey, except javelina, bear and cougar.

Q. Automatic firearms: It is unlawful to take or attempt to take any big game species or turkey with a fully automatic firearm.

R. Bullets: It is unlawful to take or attempt to take any big game species or turkey by the use of a prohibited bullet.

S. Drugs and explosives: It is unlawful to use any form of drug to capture, take or attempt to take any big game species or turkey unless specifically authorized by the department, or to use arrows driven by explosives, gunpowder or compressed air.

T. Legal sporting arm types:

(1) It is unlawful to use any sporting arm type for big game species other than those defined under big game sporting arms except for cougar and javelina which may be taken with those defined under any sporting arm. For cougar and javelina, compressed air guns must be .22 caliber or larger and shotguns must fire a single slug or #4 buckshot or larger.

(2) It is unlawful to use any sporting arm type for a big game species which does not correspond with the hunt code authorized sporting arm type.

(3) It is unlawful to use sporting arms for turkey other than a shotgun firing shot, bow or crossbow.

U. Hunting on the wrong ranch, in the wrong area or in the wrong GMU: It is unlawful for any person to hunt in any location, GMU or ranch other than that area specified on their license or permit unless otherwise allowed by state game commission rule.

(1) A landowner whose contiguous deeded property extends into an adjacent GMU(s) may enter into a written agreement with the department to hunt big game on the contiguous deeded property of the ranch. This permission shall be requested annually, at the local department office, in person or in writing by the landowner at least one week prior to the desired hunt dates. The landowner must show proof of ownership and property location. The season dates, bag limit and sporting arm type will be determined by the GMU where the majority of the deeded property lies. Landowners who enter into this agreement may not hunt the GMU where the minority of the contiguous property lies during that minority GMU's season dates if different from the majority dates. Unit-wide and ranch-wide properties are not eligible for this agreement for those species for which the unit-wide or ranch-wide agreement applies.

(2) A licensed big game hunter may hunt a landowner's contiguous private property which extends into an adjoining GMU(s) only when a department agreement exists and must adhere to the department issued agreement unless otherwise restricted by state game commission rule.

V. Restricted areas on White Sands missile range:

(1) It is unlawful to drive or ride in a motor vehicle into an area signed "no hunting" or otherwise restricting hunting or as documented on a map or as presented during the hunt's briefing, except if the hunter or driver is escorted by official personnel;

(2) It is unlawful for a licensed hunter to enter an area signed "no hunting" or otherwise restricting hunting except if the hunter is escorted by official personnel; and

(3) It is unlawful for a licensed security badged hunter to hunt or take any oryx in an area other than their "to be assigned" area.

W. Validity of licenses and unitizations: All big game and turkey licenses shall be valid only for the specified dates, eligibility requirements or restrictions, legal sporting arms, bag limit, and area specified by the hunt code printed on the license including those areas designated as public or private land per a current unitization agreement between the department and U. S. bureau of land management, state land office or other public land holding entity.

X. Hunting on public land with a private land only license: It is unlawful to hunt big game on any public land with a private land only license. Public land as used in this section shall mean any federally owned or managed property, any state owned or managed property, or any private property which is part of a unitization hunting agreement, ranch wide agreement or unit wide agreement for the species being hunted, any private property which the department has paid for public access for the species being hunted or any New Mexico state game commission owned or managed property.

Y. Collars or tracking devices: It is unlawful to attach any collar or electronic tracking device to any big game species or turkey except as specifically authorized by the department.

Z. License purchase: Bear or cougar hunters must purchase their bear or cougar license at least two calendar days prior to taking or attempting to take any bear or cougar. It is unlawful for any bear or cougar hunter to take or attempt to take a bear or cougar within two calendar days of purchasing their license.

AA. Zones: It is unlawful to pursue, take or attempt to take a bear or cougar in a closed zone. Zones will close pursuant to 19.31.11 NMAC.

BB. Valle Vidal: It is unlawful to hunt bear or cougar on the Valle Vidal except for properly licensed bear or cougar hunters that also possess a Valle Vidal elk hunting license (only during the dates and with the sporting arm type specified on their elk license) and holders of a Valle Vidal bear entry permit (only during their entry permit hunt dates).

CC. Cougar ID: It is unlawful for any person to hunt for cougar without having completed the department's cougar ID course and having the verification code printed on their license.

~~**DD. Cougar trapping season:** It is unlawful to trap or foot snare cougar outside of the season established for furbearer trapping or to kill any cougar which has been trapped or foot snared in a cougar zone which is closed.~~

~~**EE. Use of traps and foot snares for cougar:** Licensed trappers who also hold a valid cougar license may use traps or foot snares to harvest cougars on state trust land, or private land with written permission from the landowner or person authorized to grant permission. Neck snares are not permitted. Restrictions for cougar take using traps or foot snares shall follow the regulations on methods, trap specification, trap inspection, wildlife removal as defined in 19.32.2 NMAC. No trap with a jaw spread of larger than 6.5 inches or 7 inches if outside laminated shall be allowed.~~

~~**(1)** It is unlawful to set a foot snare for cougar in GMU 27 and those portions of GMU 26 designated by the United States fish and wildlife service as critical habitat for jaguar.~~

~~**(2)** It is unlawful to kill any cougar captured on BLM or US Forest Service land by the use of traps or foot snares unless authorized by the director.~~

~~**(3)** It is unlawful to take any cougar with a neck snare or prohibited trap.~~

~~FF~~DD. Use of cellular, Wi-Fi or satellite cameras: It is unlawful for any person to use any cellular, Wi-Fi or satellite camera for the purpose of hunting or scouting for any big game animal. Exception: This section does not apply to cellular or satellite phones which are kept on one's person and not used remotely or department employees and their designees while performing their official duties.
[19.31.10.13 NMAC - Rp, 19.31.10.13 NMAC, 4-1-2019; A, 5-19-2020]

HISTORY OF 19.31.10 NMAC:
Pre-NMAC History: The material in this part was derived from that previously file with the Commission of Public Records - State Records Center and Archives:
DFR 67-5 Basic Regulation No. 500, Concerning Method and Manner of Hunting, Taking, Possessing, Disposing, and Transporting of Game Animals, Birds, Fish or Bullfrogs, or parts thereof, Taken in New Mexico, Use and Occupancy of Lands and Waters Administered, Owned, Controlled or Managed by the State Game Commission, 5-25-67.
DGF 68-11 Basic Regulation No. 525, Concerning Method and Manner of Hunting, Taking, Possessing, Disposing, and Transporting of Game Animals, Game Birds, Game Fish or Bullfrogs, or parts thereof, Taken in New Mexico, the Use and Occupancy of Lands and Waters Administered, Owned, Controlled or Managed by the State Game Commission, 8-21-68.
DGF 72-6 Basic Regulation 550 Governing Water Pollution, Water Diversion, Animal Releases, Possession of Game, Manner of Hunting and Fishing, and Use of Department Lands, 5-31-72.
Regulation No. 612 Basic Regulation Governing Water Pollution, Water Diversion, Animal Releases, Possession of Game, Manner of Hunting and Fishing, Use of Department Lands, Retention of Protected Species, Permits and Licenses Issued, and the Hunter Safety Certificate Requirement, 3-2-82.

Regulation No. 677 Basic Regulation Governing Water Pollution, Possession of Game, Permits and Licenses Issued, Retention and Importation of Protected Species, Manner of Hunting and Fishing, Use of Department Lands, Hunter Training Course Required, Hunting License Revocation, Camping Near a Water Hole, 6-25-90.
Order No. 5-91 Requiring that Live-Firing Courses by Taught only by Department of Game and Fish and Volunteer Hunter Education Instructors Certified in Live-Firing Instruction, 10-3-91.

NMAC History:
19 NMAC 31.1, Hunting and Fishing - Manner and Method of Taking, 3-1-95.
19.31.10 NMAC, Hunting and Fishing - Manner and Method of Taking - Amended 4-1-2018.
19.31.10 NMAC, Hunting and Fishing - Manner and Method of Taking - Replaced 4-1-2019.
19.31.10 NMAC, Hunting and Fishing - Manner and Method of Taking - Amended 4-1-2020.
19.31.10 NMAC, Hunting and Fishing - Manner and Method of Taking - Amended 5-19-2020.

History of Repealed Material:
19.31.10 NMAC, Hunting and Fishing - Manner and Method of Taking - Repealed 4-1-2007.
19.31.10 NMAC, Hunting and Fishing - Manner and Method of Taking - Repealed 11-7-2016.
19.31.10 NMAC, Hunting and Fishing - Manner and Method of Taking - Repealed 4-1-2019.

Final Adopted Rule

This is an amendment to 19.31.10 NMAC, section 12, effective May 19, 2020.

19.31.10.12 BIG GAME AND TURKEY:

A. Legal hunting hours: A person may only take or attempt to take any big game species or turkey during the period from one-half hour before sunrise to one-half hour after sunset. It is unlawful to take or attempt to take big game or turkey outside of legal hunting hours.

B. Killing out of season: It is unlawful to take or attempt to take any big game species or turkey outside of the established hunting season.

C. Bag limit: It is unlawful for any person to take any big game species or turkey other than the legal bag limit as specified on their big game or turkey license or as indicated by the hunt code, or for any bear hunter to take a sow with cub(s), or any cub less than one year old, or for any cougar hunter to take a spotted cougar kitten or any female accompanied by spotted kitten(s).

D. Exceeding the bag limit on big game:

(1) It is unlawful for any person to hunt for or take more than one animal of any big game species per year unless otherwise allowed by state game commission rule.

(2) It is unlawful for any person to hunt for or take more than two cougars per year unless otherwise allowed by state game commission rule.

E. Exceeding the bag limit on turkey: It is unlawful for any person to hunt for or take more than two bearded turkeys during the spring turkey season or more than one turkey during the fall turkey season unless otherwise specifically allowed by 19.31.16 NMAC.

F. Proof of sex or bag limit: It is unlawful for anyone to transport or possess the carcass of any big game species or turkey without proof of sex or bag limit (except donated parts when accompanied by a proper possession certificate). Proof of sex or bag limit shall be:

(1) Bear and cougar – External genitalia of any bear or cougar killed shall remain naturally attached to the pelt and be readily visible until the pelt has been inspected and pelt-tagged by a department official.

(2) Barbary sheep and oryx – The horns of any Barbary sheep or oryx taken shall remain naturally attached to the skull or skull plate until arriving at a residence, taxidermist, meat processing facility or place of final storage.

(3) Deer – The antlers of any buck deer taken shall remain naturally attached to the skull or skull plate until arriving at a residence, taxidermist, meat processing facility or place of final storage. The scalp and both ears of any antlerless deer or the naturally attached female genitalia shall accompany the carcass in the same manner.

(4) Elk – The antlers of any bull elk taken shall remain naturally attached to the skull or skull plate until arriving at a residence, taxidermist, meat processing facility or place of final storage. The scalp and both ears of any antlerless elk or the naturally attached female genitalia shall accompany the carcass in the same manner.

(5) Pronghorn - The horns, scalp and both ears of any pronghorn taken shall remain naturally attached to the skull or skull plate and must accompany the carcass until arriving at a residence, taxidermist, meat processing facility or place of final storage. If the horns of a female pronghorn are longer than its ears, and the bag limit is F/IM, the external genitalia must remain naturally attached to the hide/carcass, as appropriate, and be visible to provide proof of legal bag limit until arriving at a residence, taxidermist, meat processing facility or place of final storage.

(6) Bighorn sheep - The horns of any ram shall remain naturally attached to the skull or skull plate and the external genitalia of any ewe taken shall remain naturally attached to the hide/carcass, and be visible until arriving at a residence, taxidermist, meat processing facility or place of final storage.

(7) Persian ibex - The horns of any ibex shall remain naturally attached to the skull or skull plate. If the horns of any female ibex are 15 inches or longer the external genitalia shall remain naturally attached to the hide/carcass, and be visible until arriving at a residence, taxidermist, meat processing facility or place of final storage.

(8) Turkey – When the bag limit is a bearded turkey, the beard and a small patch of feathers surrounding the beard shall remain with the carcass, and be visible until arriving at a residence, taxidermist, meat processing facility or place of final storage.

(9) Javelina – The skull of each javelina shall be proof of bag limit and must be retained until arriving at a residence, taxidermist, meat processing facility or place of final storage.

G. Tagging of harvested game:

(1) **Physical Tagging of harvested game:** Licensed hunters of any big game species or turkey, who have chosen to receive a department issued tag at application or purchase, upon harvesting an animal, shall immediately and completely notch out the appropriate month and day on the carcass tag. Prior to moving any part of the carcass from the kill site, the licensed hunter shall remove the entire backing material from the carcass tag and adhere it to the appropriate location on the carcass leaving the entire face of the tag visible. If the species or sex harvested requires the use of an antler or horn tag the licensed hunter shall, prior to moving any part of the carcass from the kill site, remove the entire backing material from the antler/horn tag and adhere it to the appropriate location on the antler or horn leaving the entire face of the tag visible. All tags shall remain attached to the carcass, antlers or horns until it is delivered to a meat processing facility, taxidermist, placed in final cold storage or if required, is inspected and documented or pelt tagged by a department official. The antler/horn tag is not required to be attached or used on antlerless/hornless animals.

(2) **Electronic Tagging of harvested game:** Licensed hunters of any big game species or turkey, who have chosen to electronically tag their game at application or purchase, upon harvesting an animal, shall immediately access the department's electronic tagging (e-tag) application to receive an e-tag number specific to the license. The licensed hunter will legibly write the e-tag number, customer identification number, and the date of harvest on any durable material using permanent ink and shall attach one piece to the big game species or turkey on the appropriate location on the carcass and another piece to the antler or horns as required prior to moving any part of the carcass from the kill site. All e-tag pieces shall remain attached to the carcass, antlers or horns until it is delivered to a meat processing facility, taxidermist, placed in final cold storage or if required, is inspected and documented or pelt tagged by a department official. An antler/horn e-tag is not required to be attached or used on antlerless/hornless animals.

(3) **The proper location to attach all carcass tags and e-tags:**

(a) The proper location to attach the carcass tag or e-tag on any game species is to attach it conspicuously on the hock tendon on either hind leg.

(b) The proper location to attach the carcass tag or e-tag on javelina is to adhere it to the head/skull around the nose.

(c) The proper location to attach the carcass tag or e-tag on a turkey is to adhere it around the leg above the foot and below the feathers on the thigh.

(d) The proper location to attach the carcass tag or e-tag on a bear or cougar is to adhere it around the ankle area of the hide above the foot. Bear and cougar carcass tags authorize possession of those animals until pelt tagged in accordance with state game commission rule or for five days from date of kill, whichever comes first.

(i) Any bear or cougar killed shall be tagged with a pelt tag furnished free of charge by the department.

(ii) The hunter who kills the bear or cougar or the hunter's designee must present the unfrozen skull and pelt to a department official for tooth removal and pelt tagging within five calendar days from the date of harvest, before the pelt can be frozen, processed, tanned or salted by a taxidermist, or before taking the pelt out of New Mexico, whichever comes first.

(iii) Any hunter who appoints a designee to present the skull and pelt for pelt tagging is required to contact a conservation officer prior to having the pelt inspected and tagged.

(iv) The pelt tag shall remain attached until the pelt is tanned.

(v) Skulls with mouths closed may not be accepted until the mouth is opened by the hunter or designee.

(vi) Licensed bear or cougar hunters or their designees who provide false or fraudulent information regarding the required information including, but not limited to, sex, date or location of harvest shall be assessed 20 revocation points pursuant to 19.31.2 NMAC.

(e) The proper location to attach an antler tag or e-tag is to adhere the tag around the main beam of the antler between any of the points or tines as close to the base as possible to prevent the tag from coming off.

(f) The proper location to attach a horn tag or e-tag is to adhere the tag around the horn as close to the base as possible to prevent the tag from coming off.

H. It is unlawful:

(1) for any licensed hunter to fail to properly tag their big game species or turkey with the carcass and antler tag or e-tag as prescribed;

(2) to possess any portion of a big game or turkey carcass that does not have a properly notched carcass tag attached to it or a completed e-tag attached to it, except lawfully taken game that is accompanied by a proper possession certificate or department invoice;

(3) to possess any bear or cougar or parts thereof which has not been pelt tagged within five days of kill, has been taken out of state prior to pelt tagging or has not otherwise been pelt tagged in accordance with state game commission rule;

(4) for any person to transport or possess the carcass of any big game species or turkey without proof of sex naturally attached or proof of legal bag limit until the carcass arrives at a residence, taxidermist, meat processing facility, place of final storage or if required, is inspected and documented or pelt tagged by a department official, except lawfully taken game that is accompanied by a proper possession certificate or department invoice;

(5) to use a carcass or antler tag that is cut, torn, notched or mutilated. Cut, torn, notched or mutilated tags are no longer valid for the take of a big game species or turkey; or

(6) to use a previously issued carcass or antler tag once a duplicate has been obtained or to use the carcass, antler tag or e-tag of any other person. Any previous carcass or antler tag assigned to a license which is replaced by a duplicate is void and no longer valid for the take of a big game species or turkey.

I. **Once-in-a lifetime hunts:** It is unlawful for any person to apply for, receive or use any once-in-a lifetime license if they have ever held a once-in-a lifetime license for that species which has the same bag limit or eligibility requirements.

J. **Youth only (YO), mobility impaired (MI), Iraq/Afghanistan veterans (I/A) and military only (MO) hunts or military discounted licenses:** It is unlawful for anyone to apply for or receive or use any YO, MI, I/A or MO license or any military discounted license except as allowed by state game commission rule.

K. **License sale:** It is unlawful for anyone to sell or offer for sale any hunting, fishing or trapping license, permit or tag which has been issued by the department, or to sell or offer for sale any commercial collection permit or scientific collection permit.

L. **Use of dogs in hunting:**

(1) It is unlawful to use dogs to hunt or pursue big game species or turkey, except for bear and cougar.

(2) Dogs may be used only to hunt bear and cougar during open seasons unless otherwise restricted. It is unlawful to:

(a) hunt for or pursue bear or cougar with dog(s) on the Valle Vidal except holders of bear entry permits for the hunting of bear only;

(b) hunt for or pursue bear or cougar with dog(s) during any September big game bow season statewide except as otherwise allowed by state game commission rule;

(c) release dog(s) to pursue or hold bear or cougar outside of legal hunting hours or during closed season or in a closed area or zone;

(d) to pursue bear or cougar with dog(s) without the licensed hunter, who intends to kill or who kills the bear or cougar, present continuously from the initial release of any dog(s).

(3) It is unlawful to use dog(s) to assist in the recovery of wounded or dead big game or turkey except as follows:

(a) Dog(s) may be used to assist in the recovery of wounded game provided that no more than two dogs may be used at any one time to locate a wounded or dead deer, elk, pronghorn, bighorn sheep, Barbary sheep, oryx, Persian ibex, javelina or turkey.

(b) Dog(s) used to assist in the recovery of deer, elk, pronghorn, bighorn sheep, Barbary sheep, oryx, Persian ibex, javelina or turkey shall be leashed and under the control of the handler at all times and cannot be used to pursue or harass wildlife. No person assisting in the recovery of a wounded animal may shoot or kill the animal being tracked unless they are a licensed hunter for that species, season and area and they intend to tag the animal as their own.

M. **Use of bait:** It is unlawful for any person to take or attempt to take any big game species or turkey by use of baiting or for any person to take or attempt to take big game or turkey from an area which has not been completely free of bait (including in feeders) for at least 10 days. Preexisting legitimate livestock salt and mineral and natural attractants such as cultivated fields, water, orchards, natural kills, carrion or offal are not considered bait unless they have been moved or placed there from another location. It is unlawful to create, maintain or use any bait station in hunting bear or cougar. It is unlawful to use any scent attractant in hunting bears.

N. Live animals: It is unlawful to use live protected species as a decoy in taking or attempting to take any big game species or turkey.

O. Hunting captive big game species: It is unlawful to take or attempt to take any big game species within any fence or enclosure, or by use of any fence or enclosure, which significantly restricts or limits the free ingress or egress of that big game species except as allowed by permit from the department. Any fence which is 7.5 feet tall or taller shall be considered game proof and hunting within any such enclosure, even if there are open gate(s), is unlawful. Exception: Net wire fencing commonly used as sheep or goat fencing which is not taller than four feet is not considered to significantly restrict or limit the free ingress or egress of any protected species.

P. Use of calling devices: It is unlawful to use any electronically or mechanically recorded calling device in taking or attempting to take any big game species or turkey, except javelina, bear and cougar.

Q. Automatic firearms: It is unlawful to take or attempt to take any big game species or turkey with a fully automatic firearm.

R. Bullets: It is unlawful to take or attempt to take any big game species or turkey by the use of a prohibited bullet.

S. Drugs and explosives: It is unlawful to use any form of drug to capture, take or attempt to take any big game species or turkey unless specifically authorized by the department, or to use arrows driven by explosives, gunpowder or compressed air.

T. Legal sporting arm types:

(1) It is unlawful to use any sporting arm type for big game species other than those defined under big game sporting arms except for cougar and javelina which may be taken with those defined under any sporting arm. For cougar and javelina, compressed air guns must be .22 caliber or larger and shotguns must fire a single slug or #4 buckshot or larger.

(2) It is unlawful to use any sporting arm type for a big game species which does not correspond with the hunt code authorized sporting arm type.

(3) It is unlawful to use sporting arms for turkey other than a shotgun firing shot, bow or crossbow.

U. Hunting on the wrong ranch, in the wrong area or in the wrong GMU: It is unlawful for any person to hunt in any location, GMU or ranch other than that area specified on their license or permit unless otherwise allowed by state game commission rule.

(1) A landowner whose contiguous deeded property extends into an adjacent GMU(s) may enter into a written agreement with the department to hunt big game on the contiguous deeded property of the ranch. This permission shall be requested annually, at the local department office, in person or in writing by the landowner at least one week prior to the desired hunt dates. The landowner must show proof of ownership and property location. The season dates, bag limit and sporting arm type will be determined by the GMU where the majority of the deeded property lies. Landowners who enter into this agreement may not hunt the GMU where the minority of the contiguous property lies during that minority GMU's season dates if different from the majority dates. Unit-wide and ranch-wide properties are not eligible for this agreement for those species for which the unit-wide or ranch-wide agreement applies.

(2) A licensed big game hunter may hunt a landowner's contiguous private property which extends into an adjoining GMU(s) only when a department agreement exists and must adhere to the department issued agreement unless otherwise restricted by state game commission rule.

V. Restricted areas on White Sands missile range:

(1) It is unlawful to drive or ride in a motor vehicle into an area signed "no hunting" or otherwise restricting hunting or as documented on a map or as presented during the hunt's briefing, except if the hunter or driver is escorted by official personnel;

(2) It is unlawful for a licensed hunter to enter an area signed "no hunting" or otherwise restricting hunting except if the hunter is escorted by official personnel; and

(3) It is unlawful for a licensed security badged hunter to hunt or take any oryx in an area other than their "to be assigned" area.

W. Validity of licenses and unitizations: All big game and turkey licenses shall be valid only for the specified dates, eligibility requirements or restrictions, legal sporting arms, bag limit, and area specified by the hunt code printed on the license including those areas designated as public or private land per a current unitization agreement between the department and U. S. bureau of land management, state land office or other public land holding entity.

X. Hunting on public land with a private land only license: It is unlawful to hunt big game on any public land with a private land only license. Public land as used in this section shall mean any federally owned or managed property, any state owned or managed property, or any private property which is part of a unitization hunting agreement, ranch wide agreement or unit wide agreement for the species being hunted, any private property which the department has paid for public access for the species being hunted or any New Mexico state game commission owned or managed property.

Y. Collars or tracking devices: It is unlawful to attach any collar or electronic tracking device to any big game species or turkey except as specifically authorized by the department.

Z. License purchase: Bear or cougar hunters must purchase their bear or cougar license at least two calendar days prior to taking or attempting to take any bear or cougar. It is unlawful for any bear or cougar hunter to take or attempt to take a bear or cougar within two calendar days of purchasing their license.

AA. Zones: It is unlawful to pursue, take or attempt to take a bear or cougar in a closed zone. Zones will close pursuant to 19.31.11 NMAC.

BB. Valle Vidal: It is unlawful to hunt bear or cougar on the Valle Vidal except for properly licensed bear or cougar hunters that also possess a Valle Vidal elk hunting license (only during the dates and with the sporting arm type specified on their elk license) and holders of a Valle Vidal bear entry permit (only during their entry permit hunt dates).

CC. Cougar ID: It is unlawful for any person to hunt for cougar without having completed the department's cougar ID course and having the verification code printed on their license.

[~~**DD. Cougar trapping season:** It is unlawful to trap or foot snare cougar outside of the season established for furbearer trapping or to kill any cougar which has been trapped or foot snared in a cougar zone which is closed.~~

~~**EE. Use of traps and foot snares for cougar:** Licensed trappers who also hold a valid cougar license may use traps or foot snares to harvest cougars on state trust land, or private land with written permission from the landowner or person authorized to grant permission. Neck snares are not permitted. Restrictions for cougar take using traps or foot snares shall follow the regulations on methods, trap specification, trap inspection, wildlife removal as defined in 19.32.2 NMAC. No trap with a jaw spread of larger than 6.5 inches or 7 inches if outside laminated shall be allowed.~~

~~**(1)** It is unlawful to set a foot snare for cougar in GMU 27 and those portions of GMU 26 designated by the United States fish and wildlife service as critical habitat for jaguar.~~

~~**(2)** It is unlawful to kill any cougar captured on BLM or US Forest Service land by the use of traps or foot snares unless authorized by the director.~~

~~**(3)** It is unlawful to take any cougar with a neck snare or prohibited trap.~~]

[~~**FF.**~~] **DD. Use of cellular, Wi-Fi or satellite cameras:** It is unlawful for any person to use any cellular, Wi-Fi or satellite camera for the purpose of hunting or scouting for any big game animal. Exception: This section does not apply to cellular or satellite phones which are kept on one's person and not used remotely or department employees and their designees while performing their official duties.

[19.31.10.12 NMAC - Rp, 19.31.10.12 NMAC, 4/1/2019; A, 5/19/2020]

NMAC Transmittal Form

Volume: XXXI **Issue:** 10 **Publication date:** 5/19/2020 **Number of pages:** 5 **(ALD Use Only) Sequence No.**

Issuing agency name and address: New Mexico Department of Game and Fish

Agency DFA code: 516

Contact person's name: Elise Goldstein

Phone number: 505-476-8032

E-mail address: Elise.Goldstein@state.nm.us

Type of rule action:

New ☐ **Amendment** ☑ **Repeal** ☐ **Emergency** ☐ **Renumber** ☐

(ALD Use Only) Most recent filing date:

Title number: 19 **Title name:** Natural Resources and Wildlife

Chapter number: 31 **Chapter name:** Hunting and Fishing

Part number: 10 **Part name:** Hunting and Fishing - Manner and Method of Taking

Amendment description (If filing an amendment): Amending one section

Amendment's NMAC citation (If filing an amendment): Section 12 of 19.31.10 NMAC

Are there any materials incorporated by reference? **Yes** ☐ **No** X

Please list attachments or Internet sites if applicable.

If materials are attached, has copyright permission been received? **Yes** ☐ **No** ☐ **Public domain** ☐

Specific statutory or other authority authorizing rulemaking:

Sections 17-1-14, et seq. NMSA 1978; Sections 17-1-26, et seq. NMSA 1978

Notice date(s):	Hearing date(s):	Rule adoption date:	Rule effective date:
March 24, 2020	Apr. 30, 2020	Apr. 30, 2020	May 19, 2020

Concise Explanatory Statement For Rulemaking Adoption:

Findings required for rulemaking adoption:

Findings MUST include:

- **Reasons for adopting rule, including any findings otherwise required by law of the agency, and a summary of any independent analysis done by the agency;**
- **Reasons for any change between the published proposed rule and the final rule; and**
- **Reasons for not accepting substantive arguments made through public comment.**

The rulemaking was undertaken to amend the Manner and Method of Taking rule, 19.31.10 NMAC, which will become effective May 19, 2020.

The following provisions in the Bear and Cougar rule have been deleted: allowing use of traps and snares as a legal method sport harvest for cougars. The same provision is now being deleted in the Manner and Method of Taking rule so that the two rules align.

There have been no changes between the published proposed rule and the final rule. No public comments have been submitted. To view information regarding this rulemaking, please visit www.wildlife.state.nm.us/commission/meeting-agendas/ and click on the Hearing Archive tab.

Issuing authority (If delegated, authority letter must be on file with ALD):

Name: Michael B. Sloane

Check if authority has been delegated ☐

Title: Director

Signature: (BLACK ink only) [signature]

Date signed: 4/30/2020

Exhibit 3

Manner and Method Rule Amendment 19.31.10 NMAC

April 30, 2020

New Mexico State Game Commission Meeting

Virtual meeting via webcast

Wildlife Management Division

Alignment to Bear and Cougar Rule

- Bear and Cougar Rule Finalized Nov 2019
- No longer allows traps as a method of sport harvest
- Need to strike sub-sections DD and EE of 19.31.10.12 to conform to Bear and Cougar Rule changes
- No public comment received

Questions

Exhibit 4

WILEY

Experimental Evaluation of Population Trend and Harvest Composition in a Wyoming Cougar Population

Author(s): Charles R. Anderson, Jr. and Frederick G. Lindzey

Source: *Wildlife Society Bulletin (1973-2006),* Vol. 33, No. 1 (Spring, 2005), pp. 179-188
Published by: Wiley on behalf of the Wildlife Society
Stable URL: https://www.jstor.org/stable/3784854

Experimental evaluation of population trend and harvest composition in a Wyoming cougar population

Charles R. Anderson, Jr. and Frederick G. Lindzey

Abstract Cougar (*Puma concolor*) management has been hindered by inability to identify population trends. We documented changes in sex and age of harvested cougars during an experimentally induced reduction in population size and subsequent recovery to better understand the relationship between sex–age composition and population trend in exploited populations. The cougar population in the Snowy Range, southeast Wyoming, was reduced by increased harvest (treatment phase) from 58 independent cougars (>1 year old) (90% CI=36–81) in the autumn of 1998 to 20 by the spring of 2000 (mean exploitation rate=43%) and then increased to 46 by spring 2003 following 3 years of reduced harvests (mean exploitation rate=18%). Pretreatment harvest composition was 63% subadults (1.0–2.5 years old), 23% adult males, and 14% adult females (2 seasons; $n=22$). A reduction in subadult harvest, an initial increase followed by a reduction in adult male harvest, and a steady increase in adult female harvest characterized harvest composition trends during the treatment phase. Harvest composition was similar at high and low densities when harvest was light, but proportion of harvested subadult males increased at low density as they replaced adult males removed during the treatment period (high harvest). While sex ratio of harvested cougars alone appears of limited value in identifying population change, when combined with age class the 2 appear to provide an index to population change. Composition of the harvest can be applied to adaptively manage cougar populations where adequate sex and age data are collected from harvested animals.

Key words adaptive management, cougar, exploitation, population trend, *Puma concolor*, sex–age composition

Several authors have noted the need for reliable techniques to adequately monitor cougar population changes (e.g., Shaw 1981, Lindzey 1991, Anderson et al. 1992, Riley 1998). While populations have been monitored with long-term, intensive capture efforts over relatively small areas (Ashman et al. 1983, Anderson et al. 1992, Ross and Jalkotzy 1992, Lindzey et al 1994, Logan and Sweanor 2001), reliable and affordable techniques to monitor population trends for large-scale management programs remain elusive.

Cougar management traditionally has employed harvest levels to achieve specific population objectives with little understanding of the quantitative effect that differing harvest levels have on cougar population demographics. Sex and age classes of cougars exhibit different and relatively predictable movement patterns (Barnhurst 1986). These differences, in turn, presumably expose each group to differing risks of being harvested. This concept has been applied to managing black bear (*Ursus americanus*) populations in many western states

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(Garshelis 1990). Barnhurst (1986) investigated the vulnerability of cougars to sport hunting as a step toward understanding how to interpret harvest data. He proposed that vulnerability to harvest would be related to the frequency at which differing sex- and age-class cougars cross roads because cougars are generally hunted using trailing hounds, typically from roads or trails. The vulnerability index he developed from road-crossing frequencies suggested that transient males were most vulnerable, followed by resident males, transient females, resident females both without young and with young >6 months old, and finally resident females with young ≤6 months old.

Conceptually, the likelihood of a specific sex or age class of cougar being harvested would reflect its relative abundance in the population multiplied by its relative vulnerability. The least-vulnerable individuals should become prominent in the harvest only after the population had been reduced in size by removal of more vulnerable cougars. Our objective was to test the hypothesis that sex and age composition of the harvest would vary predictably with population size in a cougar population primarily hunted using hounds.

Study areas

Experimental population

The Snowy Range, located in southeast Wyoming about 30 km west of Laramie, was a 2,760-km^2 timbered region including a 2,170-km^2 portion of the Medicine Bow National Forest surrounded by private, Bureau of Land Management, and state-owned lands. This terminal mountain range was surrounded by sagebrush (*Artemisia tridentata*) grasslands except on the southern end, where it was connected to contiguous habitat by a 14-km-wide segment of the Medicine Bow Mountains. Cougars occupied about 1,700 km^2 of this area during winter. Wyoming State Highway 230 on the west, United States Interstate 80 on the north, the Laramie River and Sand Creek drainages on the east, and Colorado highways 125 and 127 on the south bounded the Snowy Range. The area was topographically diverse, ranging in elevation from about 2,100 m in the valleys to 3,652 m at Medicine Bow Peak. Vegetation communities were dominated by sagebrush grasslands in the peripheral valleys; lodgepole pine (*Pinus contorta*) stands with interspersed quaking aspen (*Populus tremuloides*), Rocky Mountain juniper (*Juniperus scopulorum*), and limber pine (*Pinus flexilis*) at mid-elevations; and Engelmann spruce (*Picea engelmannii*)–subalpine fir (*Abies lasiocarpa*) forests with occasional limber pine at higher elevations (Alexander et al. 1986). Understory dominants in the mid- and high-elevation communities included huckleberry (*Vaccinium scoparium*), buffalo berry (*Shepherdia canadensis*), serviceberry (*Amelanchier alnifolia*), snowberry (*Symphoricarpos* spp.), and common juniper (*J. communis*). Riparian areas were composed primarily of willow (*Salix* spp.) with interspersed narrowleaf cottonwood (*P. angustifolia*) at low elevations.

Abundant roads provided good access to most cougar habitat in the Snowy Range. Annual harvest was relatively constant during the 5 years before our study, ranging from 9–12 cougars.

Comparison population

The northern portion of the Laramie Range included an isolated mountain range near the cities of Casper and Wheatland in southeast Wyoming and encompassed 2,960 km^2 of timbered habitat. Elevation ranged from 1,620 m in the eastern valleys to 3,132 m at Laramie Peak. Ponderosa pine (*P. ponderosa*) stands dominated low to mid elevations, with lodgepole pine common at mid to high elevations. Low-elevation, nonforested regions and interspersed meadows were vegetated by grasses, forbs, and shrubs. Riparian areas consisted primarily of willow with occasional aspen pockets. Other forest species occurring at low levels included limber pine, subalpine fir, Douglas-fir (*Pseudotsuga menziesii*), and Engelmann spruce.

Annual harvest in Laramie Peak averaged 11 cougars during the 5-year period before harvest treatment, ranging from 7–16 cougars per year. The Wyoming Game and Fish Department changed its management objective from sustained harvest of a stable to increasing population to reducing the population through increased harvest in 1996 and increased harvest quotas from 10 to 34 for the next 7 seasons. Regional Wyoming Game and Fish Department personnel believed the Laramie Peak cougar population was at a relatively high density prior to 1996 based on increased cougar sightings, depredation incidents, and hunter interviews.

Methods

We trailed cougars using hounds and immobilized them upon capture with a mixture of 5 mg/kg

Telazol® (Aveco Co., Inc., Cherry Hill, N.J.) and 1 mg/kg xylazine hydrochloride delivered in a hypodermic dart fired from a CO_2 pistol; we reversed the effects of xylazine hydrochloride using yohimbine hydrochloride (0.15 mg/kg). We tagged independent cougars (>1 year old and solitary) with standard VHF radiocollars (Model 9D, warranty battery life=3 years) and dependent young with 22-g ear-tag transmitters (Model 7PN, warranty battery life=295 days; Advanced Telemetry Systems, Inc., Isanti, Minn.); we equipped transmitters with mortality-sensing options. We also attached a uniquely numbered ear tag to all captured cougars. We recorded sex, age, weight, and morphometric measurements at capture. We estimated age (juvenile <1 year, subadult 1-2.5 years, adult ≥3 years) from tooth wear, canine ridge eruption, spotting progression, and evidence of previous lactation for females (Shaw 1979, Ashman et al. 1983, Lindzey et al. 1989, Laundre et al. 2000) or known birth date for cougars born to radiocollared females based on female denning behavior. We located radiotagged cougars weekly from fixed-wing aircraft between December 1997 and May 2001 and once per month from June 2001-April 2003.

We used radiotelemetry to identify female denning behavior (consecutive locations at the same location), timing of family breakup, and emigration of subadults. We assumed emigration when an individual dispersed from its mother, had not yet exhibited territorial behavior, and we were no longer able to detect its radio signal. We estimated age of juveniles of unknown birth date by applying the growth-curve models developed in the Northern Great Basin (Laundre and Hernandez 2002) after adjusting them for differences detected when comparing model estimates to size of known-age juveniles in the Snowy Range (C. R. Anderson, unpublished data).

Experimental design

We manipulated size of the Snowy Range cougar population using regulated hunter harvest to reduce and then allow recovery of the population; all cougars harvested during the study except 2 were taken using hounds. The cougar-hunting season was open from 1 September-31 March, but most cougar harvest did not occur until mid-November, when snow conditions were adequate for tracking cougars using trained hounds; >90% of cougars harvested in Wyoming were taken using hounds (Wyoming Game and Fish Department 2003). Annual harvest levels were regulated by a quota system in which the season was closed if the quota was met before 31 March. Young (<1 year old) cougars and females with young at side were legally protected from harvest. We concurrently monitored sex and age composition of the population and the harvest and annually tested predictions of harvest composition based on abundance of sex- and age-class cougars in the population and their relative harvest vulnerability (Barnhurst 1986). We predicted that harvest composition would be predominantly subadults (possibly more females) during the pretreatment year (high density, low harvest), shift to adult males during the first year of treatment (from high to moderate density, high harvest), shift from adult males to adult females during the second treatment year (from moderate to low density, high harvest), and return to subadults during the post-treatment period (increasing population, low harvest) where the subadult segment would initially consist primarily of males and eventually consist primarily of females as the population approached pretreatment levels. We examined annual changes in harvest composition of adult males, adult females, and subadults using the Fisher's exact test; we applied 1-tailed tests to compare the first 4 seasons where changes were predicted and 2-tailed tests to examine the recovery period when composition was not expected to change greatly. We also examined the relationship between proportion of adults in the female harvest and estimated harvest rate using simple linear regression analysis, expecting adult female harvest composition to increase with harvest level.

We then compared harvest composition documented in the Snowy Range to that observed in Laramie Peak. Although we did not monitor density in this area, it represented a geographic population (i.e., occupied cougar habitat surrounded by inhospitable, unoccupied landscapes) similar to the Snowy Range, contained a similar amount of cougar habitat, had adequate hunter access to facilitate population reduction, and the population was exposed to harvest levels similar to those we applied in the Snowy Range before and during the treatment period. We assumed that harvest composition from this area would show similar trends to those documented in the Snowy Range if harvest composition changed predictably with population size in harvested populations. We tested for differences in annual harvest composition between populations using the Fisher's exact test (2-tailed). We also determined ages from counts of cementum annuli of harvested adult females in both populations to determine whether age of adult females declined as the population declined following high harvest levels.

Age-class estimates

We assigned harvested and captured cougars to age class based on tooth wear, presence or absence of a canine ridge, evidence of spots or foreleg bars, evidence of previous lactation if female (Anderson and Lindzey 2000), and counts of bands in the cementum of premolars removed from harvested cougars. We first gave priority to evidence of previous lactation in females (subadult: nipples white and ~4–6 mm wide; adult: nipples dark or mottled and ~8–10 mm wide), followed by annuli age (subadult=1–2 yr), canine ridge eruption (absent=subadult), and finally foreleg bars (dark=subadult or young adult) and spots (present=subadult or young adult). To evaluate reliability of our aging techniques, we compared ages estimated from counts of cementum bands to ages estimated with the other criteria for those cougars that were captured and later harvested.

Population estimates

During the first winter (Dec 1997–Apr 1998), we conducted intensive capture efforts in 2 regions of the Snowy Range to obtain an initial density estimate and to create a marked sample for subsequent mark-recapture efforts. We captured cougars in a 439-km^2 area in the southeast region and a 382-km^2 area in the west-central region of the Snowy Range; 90% of cougar harvests in the Snowy Range came from these primarily public land areas (Wyoming Game and Fish Department mountain lion harvest data base, Lander, Wyo.). We estimated density for the 2 areas by summing number of cougars marked and tracks of known, unmarked cougars. We included unmarked cougars only if track characteristics (identified as male or female via planter pad width and stride length; Fjelline and Mansfield 1988) and number and size of young accompanying a female suggested a unique individual and when tracks were located outside traditional use areas of radiocollared cougars identified from previous telemetry locations. The initial density estimates from the 2 areas were then applied to the remainder of cougar habitat in the Snowy Range to estimate population size for the study area. Cougar habitat was delineated using elevations and topography used by radiocollared cougars February–April, 1998.

We applied the Lincoln-Peterson estimator (Pollock et al. 1990) to calculate annual, pre-hunting-season (autumn) population estimates of independent cougars. Post-hunting-season (spring) population estimates were pre-season estimates minus harvest removals and estimated natural mortality from our marked sample. We attempted to meet assumptions of the technique by modifying our sampling design and using information from radiotagged cougars. We addressed geographic closure by recapturing during late autumn and winter months when emigration and immigration were least likely (Ross and Jalkotzy 1992). We addressed the demographic closure assumption by adjusting for deaths based on records from radiocollared cougars and by considering young cougars in our marked sample independent at the mean age family groups became loosely associated (prior to dispersal), and thus available for recapture (e.g., harvest), by the beginning of the recapture period (15 Nov, average date of sufficient snow for hunting). Because cougar captures relied heavily on adequate snow conditions for tracking that varied temporally and spatially, maintaining equal capture effort throughout the study area was not possible and reduced our ability to assure equal capture probabilities across cougars. To minimize potential biases from capture heterogeneity and provide sufficient time to sample the entire study area, we treated the entire winter sampling period (15 Nov–31 Mar) as a single capture effort and counted each individual detected only once in the recapture sample regardless of the number of times they were actually detected. Because captured cougars remained ear-tagged throughout the study but transmitter failures occasionally occurred, we assumed individuals that had established territories prior to transmitter failure and that had been monitored until the previous summer were still in the population and available during the following winter recapture period; on 10 of 12 occasions where transmitters failed, marked residents were subsequently recaptured or harvested.

The capture sample was independent, radiotagged cougars in the population at the beginning of the recapture sampling period (15 Nov) during both treatment and recovery periods. The recapture sample was cougars harvested by hunters during the hunting seasons of the treatment periods, but, because harvests were intentionally reduced during the recovery period (winters of 2000–2001, 2001-2002, and 2002-2003), we augmented the recapture sample by hunting the study area after hunters had finished. During our hunting we tagged and released unmarked cougars, recorded marked cougars recaptured, and recorded presence of individual, unmarked cougars (defined earlier) we were unable to capture. We included cougars marked in the population prior to 15 November each year in our initial capture sample and those captured from 15 November-31 March in our recapture sample. We recorded capture effort as number of hunter days for successful hunters (no data for unsuccessful hunters) and number of days spent tracking and capturing cougars by study personnel. Post-season population estimates were pre-season estimates minus harvest and mortality from other causes estimated from our marked sample during the recapture period. We estimated 90% confidence intervals around pre-season population estimates following Pollock et al. (1990). We estimated autumn sex and age composition of the population by adding unmarked cougars harvested during that year's hunting season to our sample of marked cougars.

Results

We tagged 16 independent and 13 dependent male and 17 independent and 15 dependent female cougars between December 1997 and February 2002. Twenty-one marked, independent cougars were harvested during the treatment and recovery phases of the project, and 9 marked cougars (5 adult males, 4 adult females) were alive at the end of the study. Cougar ages estimated using cementum annuli counts were in agreement with other aging criteria in 14 of 18 comparisons and within 1 year for 3 others (Anderson 2003). We noted that ages of dependent young of known birth date in the Snowy Range were consistently underestimated ($\bar{x}$=1.47 mo, SD=1.26, n=13) using the Northern Great Basin growth-curve models (Laundre and Hernandez 2002) and therefore added the mean difference to estimate ages for litters of unknown birth date.

Dependent cougars became independent at an average age of 14 months (range = 11-17 months, n = 7); 2 litters became independent following the death of their mother at 14 and 17 months old (1 natural, 1 harvest). Association among family members became progressively looser over the month before independence. Thus, to account for recruitment in our recapture sample, we included marked dependent young as subadults if they were 13 months of age by 15 November each season. Emigration occurred between April and September for 8 of 9 emigrants monitored; 1 subadult male emigrated during January.

Population estimates

We tagged 18 cougars in the study area and identified 6 others from tracks after 60 days of trapping and tracking in the southeast and 45 days in the west-central section of the Snowy Range during winter 1997-1998. We estimated independent cougar density at 3.42/100 km^2 in the southeast (15 cougars/439 $km^2 \times 100$) and 2.35/100 km^2 in the west-central region (9 cougars/383 $km^2 \times 100$). Cougar habitat in the Snowy Range during this period, estimated from characteristics of habitat used by marked cougars February-April 1998, was 1,720 km^2. We estimated 50 independent cougars in the Snowy Range in spring 1998 (45-55 depending on the density estimate applied). A harvest quota of 25 was then set for the next 2 hunting seasons (treatment; 1998-1999 and 1999-2000) to elicit the desired (about 50%) reduction in the Snowy Range cougar population.

Harvests were 25 and 17 cougars for the 2 treatment seasons, resulting in an estimated population of 20 independent cougars by spring 2000 (Table 1). Harvest quotas were then reduced to 6-8 cougars per season to facilitate population recov-

Table 1. Pre (autumn) and post-harvest (spring) cougar population estimates[a] from the Snowy Range, Wyoming, USA, autumn 1998–spring 2003. Note population decline following 2 years of high harvest and population increase following 3 years of light harvest.

Season	n_1	n_2	m_2	$\hat{n}_{pre}$ (90% CI)	No. harvested	% natural mortality	$\hat{n}_{post}$
1998/99	15	25	6	58 (36–81)	25	11	30
1999/00	19	17	8	39 (28–50)	17	9	20
2000/01	15	21	9	34 (26–42)	8	0	26
2001/02	15	25	10	37 (29–44)	6	0	31
2002/03	11	39	7	59 (42–76)	8	9	46

[a] $\hat{n}_{pre} = [(n_1 + 1)(n_2 + 1) / (m_2 + 1)] - 1$, where n_1 = number marked and released in first sample, n_2 = number captured in second sample, and m_2 = number captured in second sample that were marked from first sample. $\hat{n}_{post} = (\hat{n}_{pre} - \text{harvest}) - [(\% \text{ natural mortality}) (\hat{n}_{pre} - \text{harvest})]$.

ery. The population increased to an estimated 46 independent cougars by spring 2003 (Table 1). The number of hunter-days totaled 47 and 79 during the 2-year treatment period and 27, 50, and 21 days during the 3-year recovery period; high hunter effort during the second treatment year and the second recovery year were due to excessive time spent hunting by an individual hunter each year (30 and 36 days, respectively). We spent 60, 54, and 68 days tracking and marking cougars to augment the recapture sample during the recovery phase.

Cougar harvest composition in response to manipulation

Cougar harvest ($n=22$) composition during the pretreatment period was composed primarily of subadults (36% F, 27% M) followed by adult males (23%) and finally adult females (14%; Figure 1). As harvest levels increased and the population declined in size, there was an initial increase (40%) followed by a decrease (24%) in proportion of adult males in the harvest and a consistent increase in the proportion of adult females (14 to 24 to 41%). Subadult harvest declined from the pretreatment period (from 63 to 36%) but was consistent during the treatment period (35%) and was primarily composed of females (28 and 29%). Subadult cougars again dominated the harvest after harvest quotas were reduced, but subadult male composition was relatively higher than during pretreatment and treatment periods until the third year of recovery when the population returned to pretreatment levels. Annual harvest composition among adult males, adult females, and subadults differed significantly ($P \leq 0.034$) from the pretreatment period through the first year post-treatment and was similar ($P \geq 0.664$) during the 3-year recovery phase.

We compared harvest records from Laramie Peak, the comparison population, to harvest records from the Snowy Range including the first 3 years of harvest (harvest levels below quota) in Laramie Peak and 2 years of harvest treatment and the first year post-treatment in the Snowy Range. During the 3-year period, harvest declined and pri-

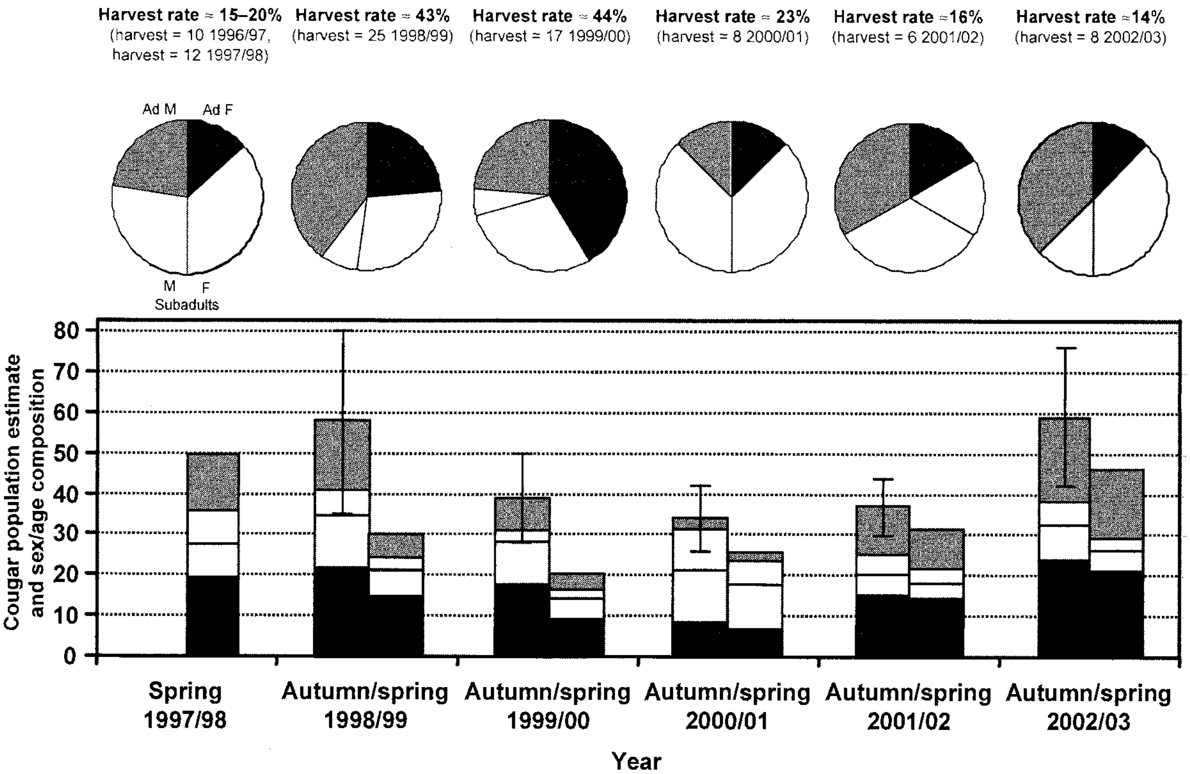

Figure 1. Sex–age composition of cougar harvest (pie charts) from the Snowy Range, Wyoming, relative to population change through increased (1998–2000) and reduced (2000–2003) harvest levels (order of sex–age classes in bar graphs follow pie charts). Harvest composition and rate prior to 1999 represent harvest years 1996–1997 and 1997–1998 combined (first column). The population estimate for spring 1998 was determined from mountain lion density detected from capture and tracking efforts during winter 1997–1998; subsequent population estimates were derived using mark–recapture methods. Error bars represent 90% confidence intervals. Number of cougars known to be in the population each spring were 22, 12, 15, 18, 20, and 34, respectively.

marily consisted of adult males initially, followed by adult females, and finally subadults in both populations (Figure 2); annual harvest composition was similar between populations ($P \geq 0.217$). Mean annuli age of adult females declined following the first treatment year from 6–8 years old to 3–4 years old the second year in both populations. Unlike the Snowy Range, unrestricted harvests continued in Laramie Peak for the next 4 years, resulting in annual oscillations in harvest level and harvests of primarily subadults (Figure 2); adult females averaged 4.3 years of age during this period.

Characteristics of female cougar harvest

We noted that proportion of adults in the female harvest increased with harvest rate, ranging from 20% with a 21% harvest rate to 58% with a harvest rate of about 44% (Figure 1), but this relationship was not statistically significant ($r^2=0.40, F_{1,6}=3.32, P=0.13$). Sixteen adult and 19 subadult females were harvested (total harvest=64) in the Snowy Range during the 2-year treatment and 3-year post-treatment periods. Of 8 marked adult females harvested, 4 were without young, 3 had young at the time, and we suspect the last female may have had young when harvested because we had seen kitten tracks with her 2 months earlier. All harvested females with young were taken during the treatment period (>40% harvest rate).

Discussion

The Snowy Range cougar population recovered in numbers after 2 years of intensive harvest (~43% of independent cougars) followed by 3 years of light harvest (~18% of independent cougars). Recovery of the population was facilitated by immigration of males and recruitment of females from within the population as found in other recovering cougar populations (Lindzey et al. 1992, Logan and Sweanor 2001). Composition of the harvest from pretreatment through the 2 years of heavy harvest supported our predictions based on predicted relative vulnerability of the various sex and age classes. The most vulnerable classes were harvested until their reduced abundance in the population

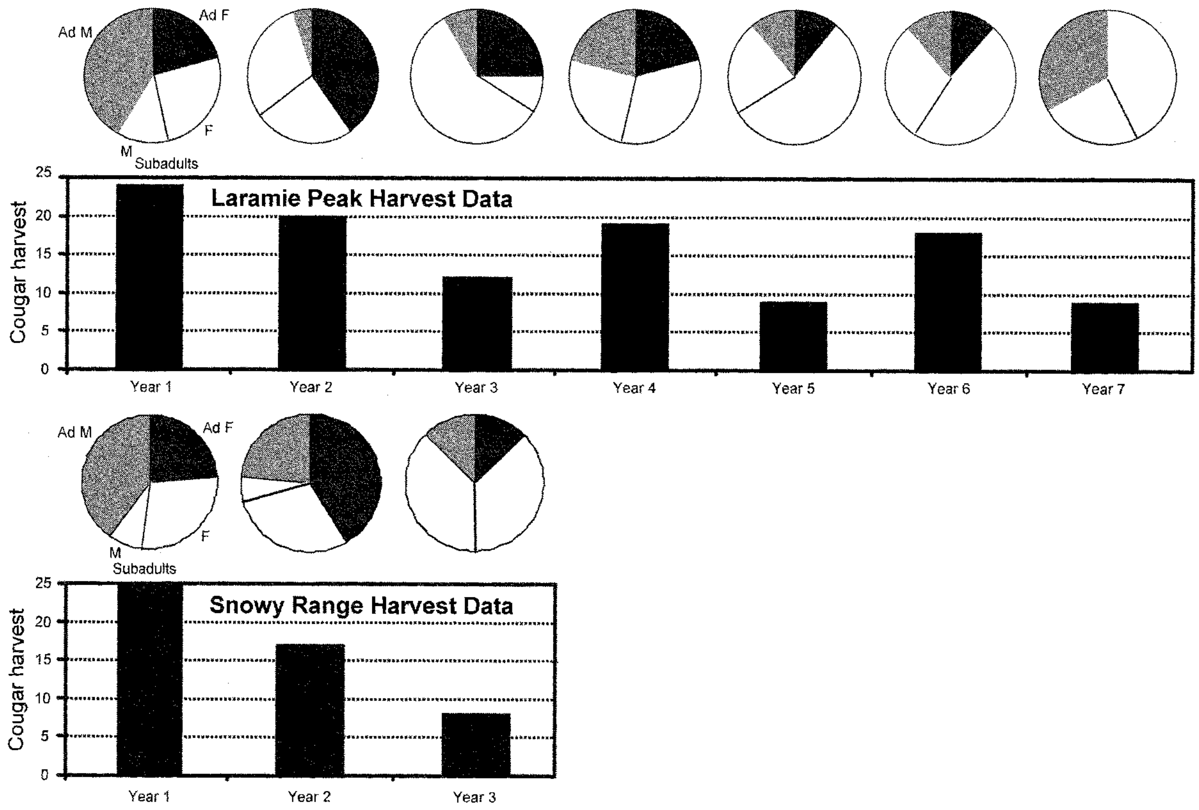

Figure 2. Comparison of total harvests (bar graphs) and harvest composition (sex–age class; pie charts) from Laramie Peak and the Snowy Range in southeast Wyoming. Cougar harvest quotas were not met, except in the Snowy Range during years 1 and 3. Note similarities in harvest levels and composition between populations exposed to similar harvest treatments.

exposed the next most vulnerable class, terminating in a harvest dominated by adult females (Figure 1). The increase in adult females in the harvests coincided with a decrease in size of this hunted population, suggesting that proportion of adult females in harvests may be a useful indicator of trends in other hunted cougar populations. The similarity of composition trends in the Snowy Range and Laramie Peak populations during the initial years of intensive harvest suggests that the intensive harvest in the Laramie Peak population had achieved its goal of reducing population size in this area. Decline in average age of harvested females in both populations further suggested that harvests had similar effects on the 2 populations.

While factors other than composition of hunted cougar populations (e.g., weather patterns, changes in legal access) can influence harvest level, none should result in adult females dominating the harvest if they are not proportionately the most abundant sex or age class present in the population. Experienced cougar hunters often can differentiate males and females from track size, presence of scrapes, or body characteristics if the cougar is seen, but selective hunters tend to harvest males. Further, our experience suggests that hunters tend to be most selective when competition for available cougars is low. When demand exceeds harvest quotas, competition among hunters appears to result in less-selective hunting, and harvest should reflect the relative abundance or vulnerability of sex and age classes. Snow conditions also can affect hunting success (>90% of cougars harvested in Wyoming are hunted using hounds and most require snow cover), but this should influence harvest rate, not the relative vulnerability of the sex and age classes. Access, influenced by weather events or land-ownership patterns, can create ephemeral or more permanent refuges within cougar management areas. In these situations harvests may be maintained by adjacent, unavailable adult females providing young females for the harvest (e.g., Figure 2). We identified areas of suitable cougar habitat in the Laramie Peak area that received no cougar harvest and apparently were functioning as refuges. The similar abundance of subadult females in the pretreatment Snowy Range harvest and post-treatment harvests from Laramie Peak illustrates the contribution of refuges to maintaining harvests and underscores the need to monitor harvest composition over a number of years before drawing inferences about trend in the population from harvest composition. Subadult females in the pretreatment Snowy Range harvest reflected their relative abundance and vulnerability to harvest, while their dominance in later harvests from Laramie Peak apparently reflected their abundance in the portion of the area accessible to hunters. Examination of composition of earlier harvests should help identify whether the harvest reflects a lightly hunted population or one that has been reduced with harvests being supported by young produced by adjacent, unavailable adult females. Prior harvests in the Laramie Peak area were composed of progressively more adult females, suggesting the population had been reduced in size.

Management implications

Cougar managers typically have used harvest level and occasionally sub-quotas typically aimed at protecting females to achieve population objectives, although both imply knowledge of population size. While observations suggest that cougar populations can sustain harvest rates of up to 20–30% (Ashman et al. 1983, Ross and Jalkotzy 1992), the effect of harvests on populations will differ depending on sex and age of cougars removed. Harvest of males, the cohort most easily replaced by immigration, and subadult females, which can be quickly replaced by female young produced in the population, will have less impact on the population than harvest of adult females, which are more difficult to replace. Adult females that die are most often replaced by the population's female progeny and less often by immigrating subadults because most female progeny are philopatric (Lindzey et al. 1989,

Duggin Wroe's dog, Luna, corners male cougar number 610. Photo by Hall Sawyer.

Anderson et al. 1992, Logan and Sweanor 2001).

Monitoring levels of adult females in cougar harvests to index the effect the harvest is having on the population is intuitive. Sensitivity analyses by Martorello and Beausoleil (2003) suggest that cougar populations are most sensitive to survival of this sex and age class. Adult females provide the resiliency in a population that allows it to respond to loss of members. This approach will work well in an adaptive management framework, where harvest composition goals are set to achieve specific population objectives. Hunting programs can simply be modified until harvest composition indicates that desired population and recreation objectives are being met. The proportion of adult females in the Snowy Range harvest when the more vulnerable sex and age classes had been removed and the population was beginning to decline was about 25%, while the population appeared to sustain a harvest composed of 10-15% adult females (Figure 1). The 25% estimate came from a single experiment and should be used with caution in other programs because cougar populations more isolated than the Snowy Range or that contain more refuge areas may respond differently to similar harvest rates of adult females. Also, because harvest from a single management area in a single year may be too small to support inferences, and harvest level may vary because of weather events, combining years or adjacent management areas for analyses may be appropriate.

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Fred Lindzey (above) is the assistant unit leader for the Wyoming Cooperative Fish and Wildlife Research Unit, and an associate professor in the Department of Zoology and Physiology at the University of Wyoming. He received his B.S. from Texas A&M, his M.S. from Utah State University, and his Ph.D. from Oregon State University. Fred's current research interests focus primarily on big game and predator ecology.

Associate editor: *Crête*

THE MOUNTAIN LION IN NEVADA

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0-4101

THE MOUNTAIN LION IN NEVADA

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1983

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The mountain lion (Felis concolor) is one of the most intriguing large game species in Nevada and the controversies surrounding this great cat have often become embroiled in a battle between fact and fiction, love and hate, and conservation and exploitation.

In its simplist interpretation the lion has been merely laying claim to the land it has freely roamed since the Pleistocene epoch. The recent invasion of its realm by the modern American and his livestock, followed by the bounty hunter, the fur hunter, and the sport hunter, contradicted that claim and resulted in a reduction of Nevada's mountain lion populations, as well as a conflict in ideologies among the people of the state. Hopefully, now, in a more enlightened period, we may, in some way, find a means of compromising the forces which have been working against the mountain lion's survival. In order to do this a basic understanding of the lion's life history is required so identified conflicts can be resolved or mitigated. If the myths are separated from the facts, and people are willing to try and resolve their differences, then a management plan which will provide for sustained mountain lion populations can be implemented.

In March 1972, the Nevada Department of Wildlife initiated a study of the mountain lion as a part of the Ruby-Butte deer project (Papez 1976) in eastern Nevada. The objective was to determine the status of lion populations within this highly valuable deer area and evaluate them in relation to deer populations. Within two years this objective was changed to: a) establish population estimates of mountain lions by mountain range or management area statewide, b) establish basic habitat requirements, 3) establish a harvest management program. From that period on, increased emphasis was placed upon lion capture and marking with the more sophisticated telemetry devices which were being manufactured. This program involved lion monitoring from both land and air and was instrumental in expanding our life history data base as well as providing an approach toward estimating the annual population status of key mountain ranges. The findings which resulted from this study were then utilized in formulating an approach toward estimating statewide lion populations.

In doing this, the Department was essentially moving toward the development and implementation of a Unit Harvest Management scheme. This management approach was a direct result of pressures arising from three distinct groups of people, all of whom had different interests:

1. The livestock industry which wanted stringent predator control.
2. The professional mountain lion guide who wanted the freedom of taking clients where he desired, with minimum restrictions in season length, harvest, or area of hunt.
3. The protectionist who basically wanted no harvest of the mountain lion.

The role of the Department of Wildlife was, therefore, one of attempting to develop a plan which satisfied most interests as well as meeting the legislative mandate of preserving viable mountain lion populations for the future. In the latter years of the study, while developing a Unit Management approach, Department personnel throughout the state were assigned to pertinent jobs in their local areas, the study areas, or both.

ACKNOWLEDGMENTS

Dave Ashman was the principal investigator assigned to the mountain lion study during most of its ten year duration. A rough draft, which was partially used in the preparation of this manuscript, was written by Dave prior to his resignation from the Department in 1982.

Personnel from the United States Fish and Wildlife Service cooperated in this study from its initiation by providing experienced lion hunters with trained hounds and much of the necessary equipment. The late Dick Hall, a U.S. Fish and Wildlife Service lion hunter in Nevada from 1956-79, unselfishly provided a vast storehouse of knowledge, time and experience during the first 7 years of the study. Jim Buhler and Richard Holcomb, also government lion hunters, provided able assistance in capturing lions during the last 3 years of study.

Many Department of Wildlife employees assisted in the field work, some of which was done under the most adverse winter conditions. A listing of them would include almost the entire Game Division staff and most of the Regional game personnel, all of whom willingly assisted in study design, equipment procurement, and endless hours of field work. Allan Flock, Jim Jeffress and Gregg Tanner provided help beyond the normal call of duty.

Dave Beatty of Telonics, Inc. was instrumental in designing and manufacturing the telemetry equipment which was used so successfully during the later years of the study. A phone call to Dave saved many a day when there were equipment crises.

Glen C. Christensen was responsible for data analysis, rewriting and editing of this manuscript. In doing so he drew freely upon the talents of George Tsukamoto, Mike Hess and Mike Wickersham of the Nevada Department of Wildlife and Harley Shaw of the Arizona Game and Fish Department.

DESCRIPTION OF THE STUDY AREAS

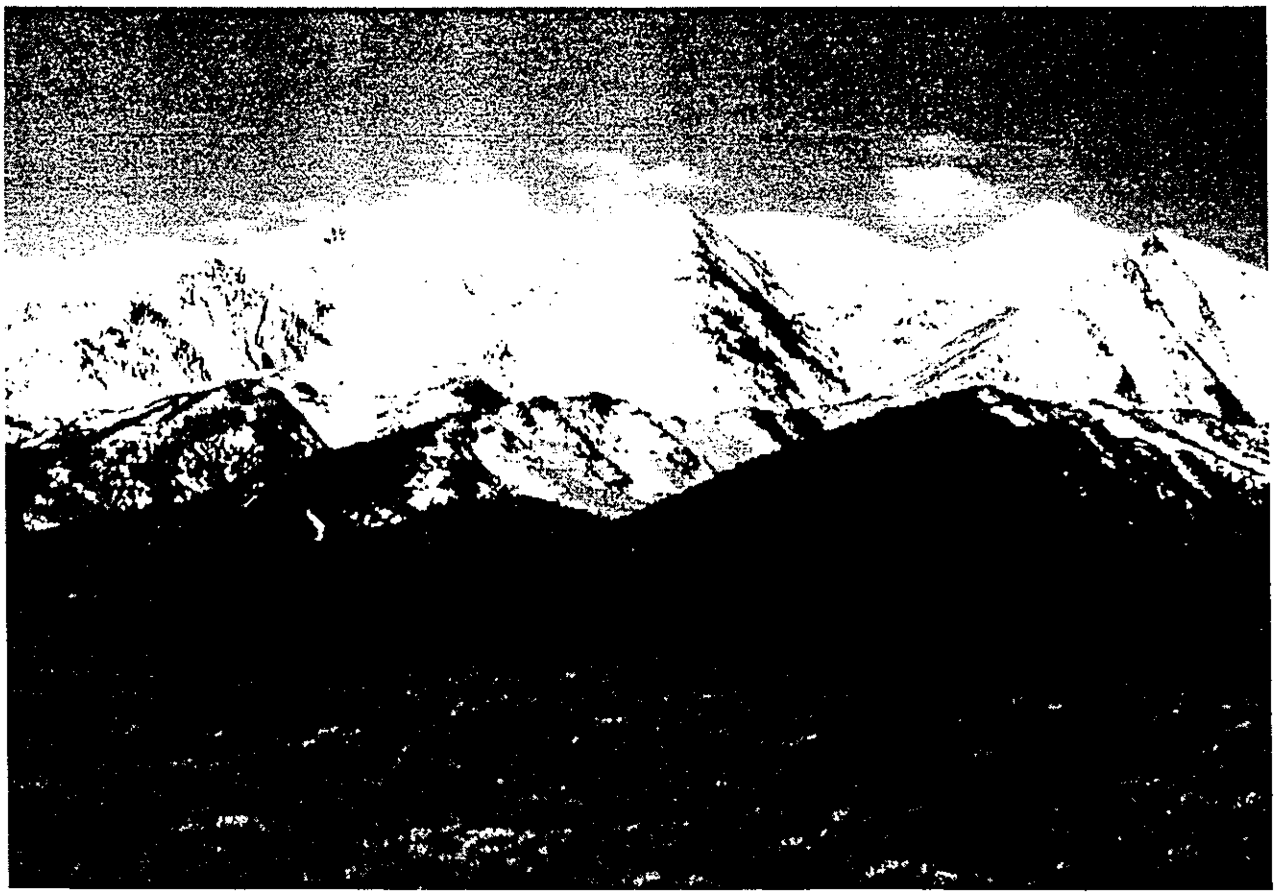
Location

The principle study areas were located in the Ruby Mountains (eastern Nevada) and in the Monitor Range (central Nevada). Additional, but less extensive work was conducted in the following ranges: Schell Creek, Cherry Creek-Egan, Spruce, White Pine, Toana, Maverick Springs, Snake, Jarbidge and Antelope-Fish Creek, all of them being grouped in Northeastern and Central Nevada (Figure 1).

RUBY MOUNTAINS--The Ruby Mountains are composed of three distinct divisions: the East Humboldt Range, Ruby and South Ruby (Figure 2). The East Humboldt Range, which comprises the northern portion, is located north of Secret Pass and south of Wells encompassing an area of 221 square miles. This division embraces extensive summer range for both mule deer (Odocoileus hemionus) and lions. Winter range is limited due to deep snow which forces the deer to migrate considerable distances south and east (Papez 1976).

The Ruby division, located between Secret Pass and Harrison Pass, is the largest unit and contains 362 square miles of mule deer and mountain lion summer and winter range.

The South Ruby division is primarily winter range for mule deer and lions, although some fair to good summer range is present on the west slopes between Harrison Pass and Overland Pass. This area embraces 270 square miles, but generally lacks good water distrubution and high quality deer habitat.



South Ruby Mountain Range Lion Habitat

The entire Ruby study area encompasses approximately 853 square miles. The northern third of the Ruby Range and the majority of East Humboldt Range are composed of intermixed private and public lands.

MONITOR RANGE--The Monitor Range extends 97 miles north to south between the general vicinity of Eureka and Tonopah, Nevada. Most of the field work was conducted on the northern 25 miles of the range, primarily from Dobbin summit north, which included an area of 335 square miles (Figure 3), nearly all of which is on public lands.

General Characteristics of the Environment

Detailed descriptions of the topography, soil, climate and vegetation, which are applicable to the study areas, are presented in the Nevada Department of Wildlife publication titled "The Ruby-Butte Deer Herd" (Papez 1976). Generally, these descriptions also apply to mountain lion habitat throughout the state, with some local modifications, which are well covered by Billings (1951).

In brief, the physiographic characteristics are typical of the Great Basin. The mountains and valleys trend in a north-south direction with elevations ranging from 5,500 feet in the valleys to heights of 9,000-11,000 feet for the mountain peaks. The exceptional Wheeler Peak, in the Snake Range, crests at over 13,000 feet.

Monitor Range Lion Habitat

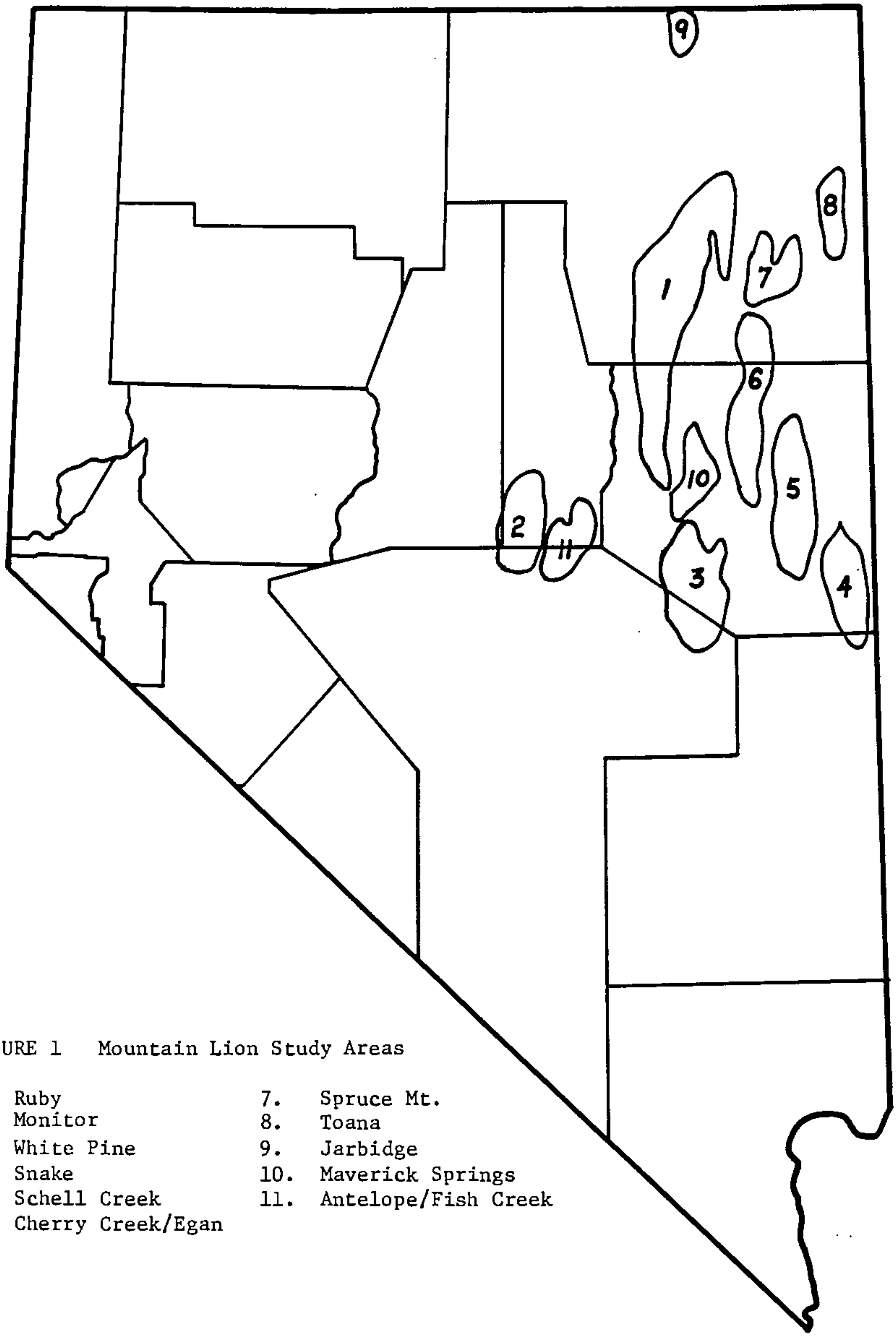


FIGURE 1 Mountain Lion Study Areas

1. Ruby
2. Monitor
3. White Pine
4. Snake
5. Schell Creek
6. Cherry Creek/Egan
7. Spruce Mt.
8. Toana
9. Jarbidge
10. Maverick Springs
11. Antelope/Fish Creek

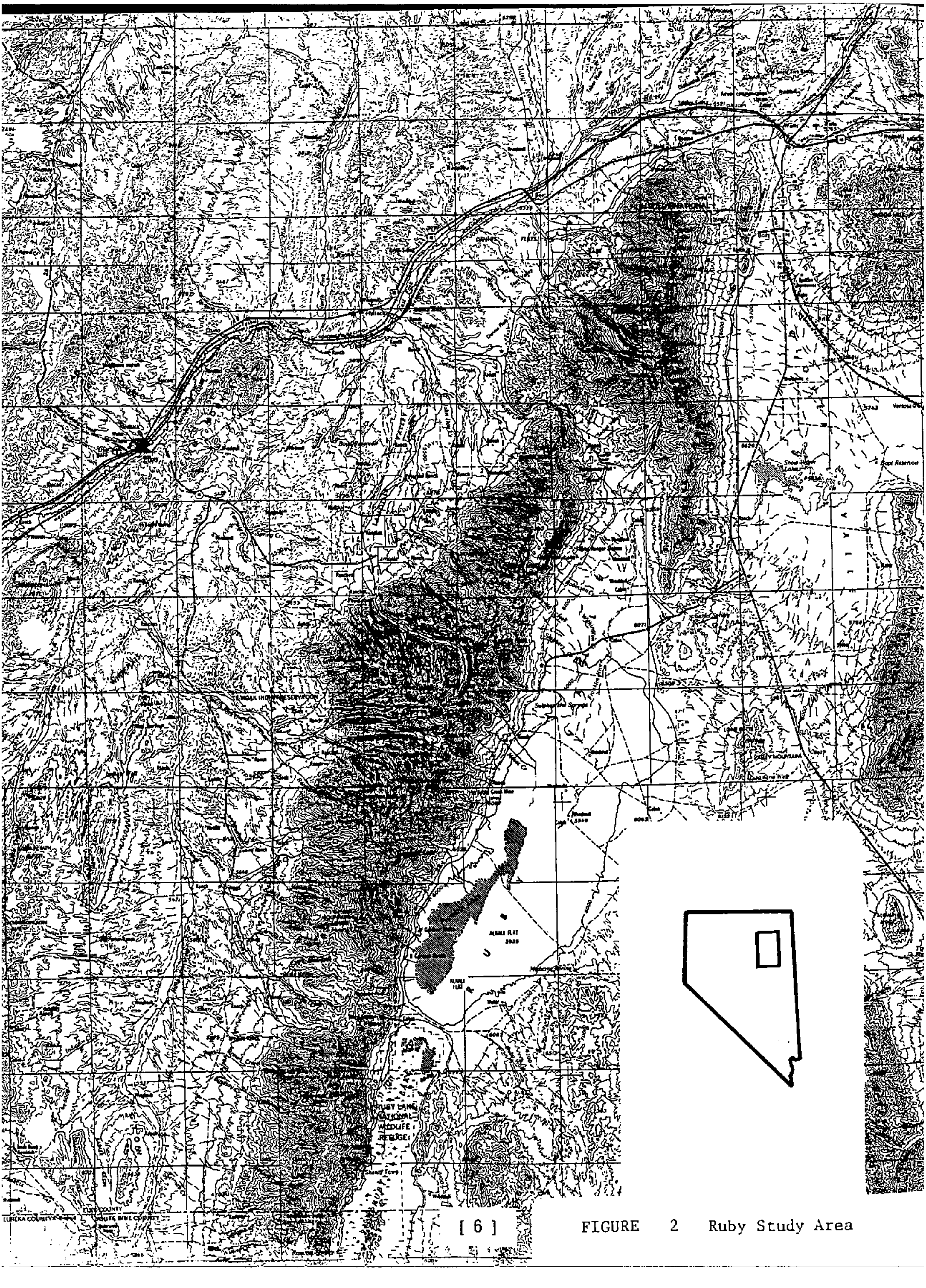


FIGURE 2 Ruby Study Area

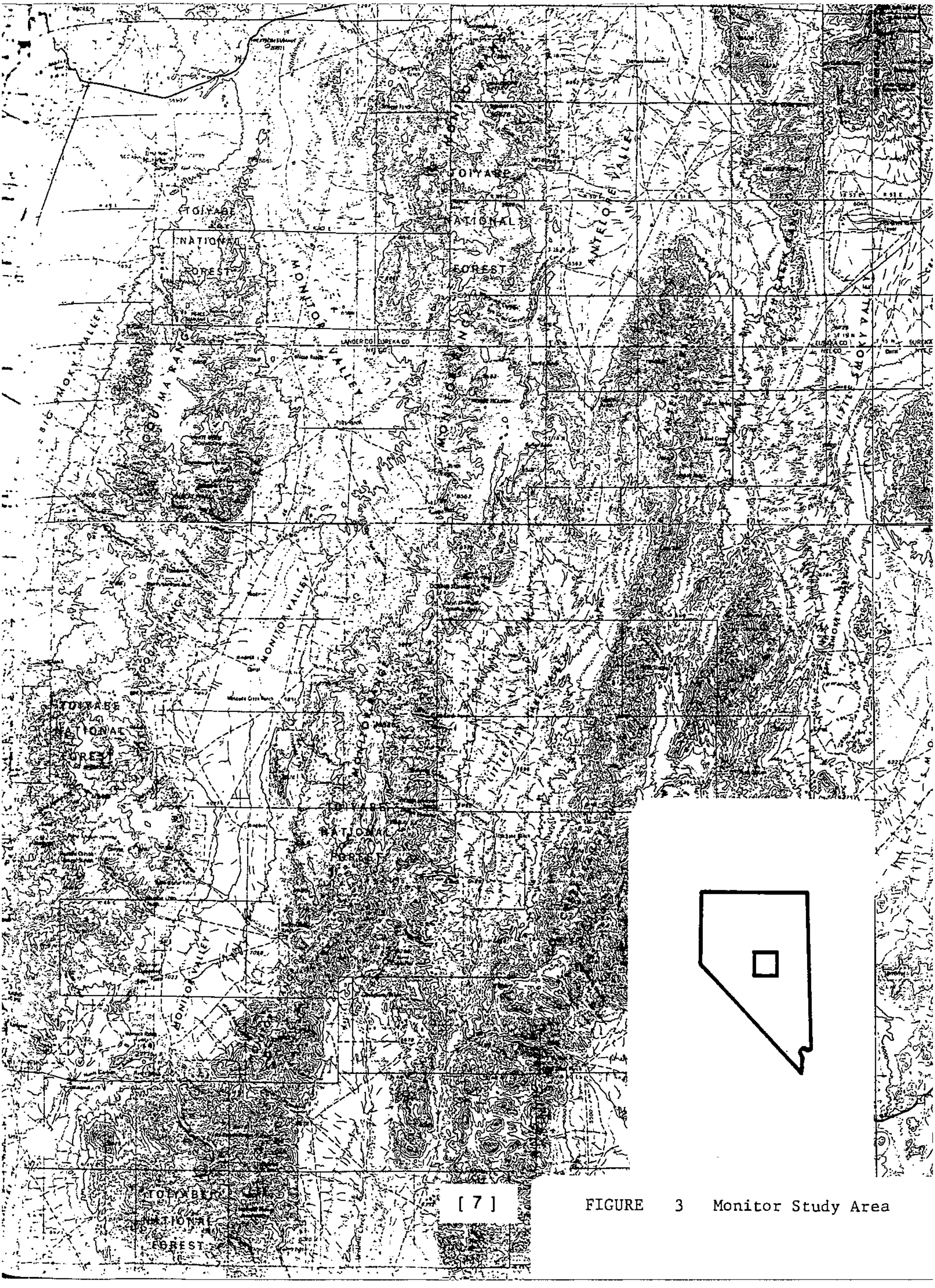


FIGURE 3 Monitor Study Area

The climate is typically one of hot, dry summers and cold, wet winters. Maximum precipitation occurs in late winter and early spring and varies considerably by site, being 13-15 inches annually at elevations above 7,500 feet in the study area. Temperatures vary dramatically over a 24-hour period and it is not unusual to record a 50°F spread between the morning low and the afternoon high. Similarly, there is also a great variation between the winter lows and summer highs, such as a -43°F minimum and 107°F maximum recorded in Elko, Nevada. The wide ranging temperatures are a feature of the Great Basin area which makes it prudent for one to carry a down sleeping bag the year around.

The vegetation is typified by a Sagebrush Zone which dominates the valley floors and the lower foothills. Big sage (Artemisia tridentata) is the major species. Big sage and black sage (Artemisia nova) are also well represented in the other vegetational zones which occur in the study area. At the lower elevations of the deer summer range, which would also demark the mountain lion ranges, big sage is associated with bitterbrush (Purshia tridentata) and rabbitbrush (Chrysothamnus vicidiflorus).

On the foothills above the sagebrush zone, but below 7,500 feet, a belt of Pinyon-Juniper (Pinus monophylla - Juniperus osteosperma) becomes the dominant type. This pygmy forest is a very important transitional zone for deer as they move through it from their summer and winter ranges. The major understory plants are sagebrush, bitterbrush, rabbitbrush and serviceberry (Amalanchier alnifolia). Pinyon-Juniper is not significantly present in the Ruby Mountains north of Harrison pass; however, in the Monitor study area it is the dominant vegetation at the lower elevations.

Elevations above 7,500 feet to 9,500 feet are characterized by mountain brush. This summer range is an extremely important zone for deer, and consequently mountain lions, and is dominated by quaking aspen (Populus tremuloides), mountain mahogany (Cercocarpus ledifolius), snowbrush (Ceonothus velutinus), chokecherry (Prunus virginianus), willow (Salix spp.) and wild rose (Rosa spp.).

Along the crests of the mountains at elevations above 9,500 feet, the Alpine-Subalpine forest is found. Limber pine (Pinus flexilus), whitebark pine (Pinus albicaulis) and occasionally white fir (Abies concolor) and bristlecone pine (Pinus aristata) are the dominant trees. Prominent understory species are snowbrush, dwarf juniper (Juniperous communis) and bearberry (Arctostaphylos uva-ursi).

METHODS

Harvest data, which included U.S. Fish and Wildlife Service depredation removal and the Nevada Department of Wildlife sport harvest records, were reviewed to identify mountain ranges throughout the state that contained lion populations. Sight records, of lions or their tracks, obtained by professional government lion hunters, sport hunters and guides, and Department personnel were used to augment harvest data in compiling distribution maps. All records were plotted on 1/250,000 topographic maps and the area of occupied lion habitat was delineated and square miles computed.

The primary methods used for obtaining data was through lion capture, marking and recapture, and from radio-telemetry monitoring. The majority of the capture efforts were conducted during winter months when the ground was covered with snow and tracks could be located by driving roads, snowmobiling or on foot. Once fresh tracks were found, trained hounds owned by government hunters would be started and followed until a successful capture was made or the hounds had to be pulled off the trail due to severe weather, darkness, exhaustion or other reasons. Once a lion was cornered, its weight was estimated and the proper drug dosages prepared for tranquilizing. During the first six years of the study the drugs Sernylan (Phencyclidine hydrochloride) and Sparine (Promazine hydrochloride) were used in combination, with a ratio of 1-3 parts Sparine to 1 part Sernylan, depending on the dart syringe capacity (1.5-3.0 cc). These drugs were used at a rate of 0.1 cc per each 20 pounds of body weight. During the last 4 years of the study the drug Ketaset/Vetalar (Ketamine hydrochloride) was used with considerable success, although the volume required (1 cc per 20 pounds) did present some difficulties because occasionally not all of the drug was absorbed by the muscle. All drugs were manufactured by Park, Davis & Company, Detroit, Michigan. All Cap-Chur syringes, powder charges and guns were supplied through Palmer Chemical and Equipment Company, Douglasville, Georgia.

After immobilization each animal was sexed, weighed and aged. Any injuries, other abnormalities and ectoparasites were recorded. Females were checked for indications of pregnancy, estrus or nursing. Tooth replacement, amount of stain and wear, and a measurement of the upper canines from the gum line to the tips of the labial side of the tooth were recorded for selected lions. During subsequent recapture or harvest any changes were noted. Numbered metal ear tags were placed on some lions early in the study but due to losses were discontinued in favor of numbered rope collars. Once the telemetry program gained momentum radio collars were used. Following data collection and marking the lion was placed in a protected location and allowed to recover.

During the period of 1973-75 lions were instrumented with low frequency radio collars (31 MHz) manufactured by Thomas Owens, Sacramento, California. These collars were either solar powered or a combination solar/nickel cadmium battery units with a life expectancy of less than 6 months. A variety of receiving equipment was used to locate and monitor the radioed lions, but none of it was entirely satisfactory.

During late 1977 more reliable radio collars were obtained from Telonics, Inc., of Mesa, Arizona. These units were of a higher frequency (159 MHz) and were entirely operated by lithium batteries with a theoretical life of up to 44 months. The receiving unit (Telonics Model TR-2) had a direct frequency reading and self-contained rechargeable power pack. Searches and monitoring were conducted from small aircraft and from the ground. Aerial reception varied from 2-50 miles and ground reception from 0.5-20 miles. Some radio collars incorporated a motion sensing device (mercury switch) where non-movement after 5 hours caused an increase in pulse rate (mortality mode) and this feature proved to be very helpful.

FINDINGS

The Mountain Lion

The mountain lion, locally called the cougar, puma, panther or just plain lion, is endemic to Nevada. It is the largest of the unspotted cats in the United States and the sexes are colored alike. The color of adults is tawny or greyish above and whitish below with dark brown on the tip of the long tail, backs of ears and sides of nose. The young are spotted with blackish-brown on a pale fawn ground color. Males are larger than females.

Ninety-seven lions were captured and marked between March 1972 and February 1982 (Table 1). Three of these were captured in western Nevada and 94 from the primary study areas in central and eastern Nevada. The sex and age composition was 57 males and 40 females of which 46 were classified as adults, 16 as subadults and 35 as kittens (see age section for classification criteria).

Fifty-two of the 97 lions were captured and recaptured 116 times and located 695 times through radio telemetry monitoring (Table 2). Many hours and miles were logged in tracking lions on foot which further added to the knowledge of a particular animal. Daily, monthly and seasonal movements were determined for several lions. This monitoring effort made it possible to gain insight on many of the life history subjects presented in this section. Additional information was obtained through the examination of lions killed (for depredations or by sport harvest) during the course of the study.

Distribution

Since mountain lions are adaptable to a great variety of environmental conditions, they are able to occupy most of the mountain ranges in Nevada and are found from the hot southern deserts to the coldest extremes of the northeastern mountains. A generalized distribution map which depicts the probable extent of the mountain lion's range, when considering habitat types and prey base as well as documented lion occurrence, is presented in Figure 4. Based on this map it is estimated that there are 27,811 square miles of mountain lion habitat in Nevada.

Reproduction

Breeding Age -- The average estimated age of first conception for nine female lions which were examined was 29 months, with a range of 22-40 months. Using a 90-day gestation period (Asdell 1964) the average age for giving first birth was 32 months. Eaton and Velander (1977) found that 4 captive females in Washington state had first birth between 26.5-30 months of age. They also reported that the earliest record of a lion giving birth was 21 months.

No data for sexual maturity of male lions was obtained during this study.

TABLE 1. MOUNTAIN LIONS CAPTURED IN NEVADA, 1972-82.

Lion No.	Sex	Estimated Age at Capture	Age Group*	Weight (lbs.)	Date Captured
1	M	7 years	A	147	3-17-72
2	F	18-20 months	SA	95	4-4-72
3	M	18-20 months	SA	--	4-8-72
4	F	6 years	A	--	4-14-72
5	M	20-24 months	SA	123	5-2-72
6	M	6 years	A	--	12-17-73
7	M	2 years	A	144	11-22-75
8	F	3 years	A	105	1-9-73
9	M	7 months	K	55	1-9-73
10	M	18-20 months	SA	--	1-17-73
11	F	16-18 months	SA	79	12-12-75
12	F	18-20 months	SA	--	1-17-73
13	F	18-20 months	SA	105	1-17-73
14	F	4 years	A	95	1-29-73
15	M	5 years	A	152	5-8-73
16	M	20-24 months	SA	--	12-4-73
17	M	18-20 months	SA	128	1-8-74
18	M	7 months	K	55	1-24-74
19	M	7 months	K	50	2-8-74
20	M	7 months	K	53	2-8-74
21	F	4 years	A	110	2-2-74
22	M	4 months	K	35	2-1-74
23	F	4 months	K	30	2-2-74
24	F	4 months	K	28	2-2-74
25	M	5 months	K	42	2-6-74
26	M	5 months	K	42	2-6-74
27	M	15-16 months	K	122	1-28-75
28	M	15-16 months	K	118	1-28-75
29	F	9 years	A	115	1-29-75
30	M	5 months	K	39	1-29-75
31	M	5 months	K	40	1-30-75
32	F	15-16 months	K	--	2-19-75
33	F	17-19 months	SA	--	2-21-75
34	M	2 years	A	130	4-1-75
35	M	6 years	A	155	4-11-75
36	F	13-14 months	K	71	11-21-75
37	F	16-18 months	SA	91	12-18-75
38	F	16-18 months	SA	93	12-18-75
39	M	16-18 months	SA	115	12-19-75
40	F	18-22 months	SA	--	1-7-76
41	F	5 years	A	84	1-8-76
42	M	2 months	K	23	1-11-76
43	M	15-16 months	K	123	1-6-76
44	F	2 years	A	88	1-11-77
45	M	3 years	A	133	1-14-77
46	M	17-19 months	SA	140	1-21-77
47	F	15-16 months	K	81	1-12-78
48	M	15-16 months	K	100	1-13-81
49	F	20-24 months	SA	85	1-23-78
50	M	10+ years	A	145	1-24-78
51	M	8-9 years	A	--	1-25-78
52	M	3 months	K	--	2-2-78
53	F	14-15 months	K	78	2-18-78

TABLE 1. MOUNTAIN LIONS CAPTURED IN NEVADA, 1972-82. (cont.)

Lion No.	Sex	Estimated Age at Capture	Age Group*	Weight (lbs.)	Date Captured
54	M	14-15 months	K	80	2-18-78
55	F	20-24 months	SA	85	6-30-77
56	F	14-15 months	K	70	2-18-78
57	M	6 years	A	128	2-19-78
58	M	3 years	A	137	3-18-78
59	F	6 years	A	--	1-7-79
60	F	4 months	K	--	1-14-79
61	M	3 years	A	135	1-26-79
62	M	5 years	A	--	3-19-79
63	F	9-10 years	A	87	1-17-79
64	M	3 months	K	33	1-17-79
65	F	3 months	K	33	1-17-79
66	M	3 months	K	35	1-17-79
67	M	2 years	A	112	1-19-79
68	M	3 years	A	128	2-21-79
69	F	4 years	A	94	1-30-79
70	F	4 months	K	40	1-30-79
71	M	5 years	A	145	11-30-79
72	F	10+ years	A	93	1-31-79
73	F	18-20 months	SA	--	2-24-79
74	M	9 months	K	68	5-31-79
75	F	9 months	K	--	5-22-79
76	F	9 months	K	64	5-22-79
77	M	2 years	A	--	6-6-79
78	M	3 years	A	132	1-17-80
79	M	6 years	A	--	1-20-80
80	F	9-10 years	A	112	1-24-80
81	F	3 years	A	--	1-14-80
82	F	3 years	A	--	2-5-80
83	F	2 years	A	95	2-14-80
84	M	2 years	A	123	2-22-80
85	M	3 years	A	162	2-23-80
86	M	8 months	K	73	2-27-80
87	M	10+ years	A	149	5-21-80
88	M	6 years	A	121	4-29-80
89	M	18-20 months	SA	133	5-1-80
90	F	6 years	A	100	7-21-80
91	M	3 years	A	--	11-27-80
92	M	3 years	A	--	4-3-81
93	F	2 years	A	--	4-22-81
94	M	9 months	K	87	4-28-81
95	M	3 years	A	143	4-30-81
96	M	9 months	K	83	2-12-82
97	M	3 months	K	27	2-9-82

* A - Adult (24 months +)
SA - Subadult (17-23 months)
K - Kitten (0-16 months)

The location of capture for the above lions is as follows: Ruby Mountains (52), Cherry Creek-Egan (12), Monitor-Antelope (8), Schell Creek (7), Snake (4), White Pine (3), Toana (3), and one each in the Diamond-Fish Creek, Maverick, Spruce, Toiyabe, Pine Nut, Pine Grove, Wellington Hills and Independence.

TABLE 2. NUMBER OF CAPTURES AND RADIO LOCATIONS FOR 52 MOUNTAIN LIONS IN NEVADA, 1972-82.

Lion No.	Sex	No. of Captures	No. Radio-Locations	No. Months Followed
1	M	6	0	10
2	F	3	0	32
3	M	6	4	34
5	M	2	0	3
6	M	2	0	49
7	M	2	0	1
8	F	2	54	24
10	M	2	0	6
12	F	2	0	--
13	F	3	0	13
14	F	3	26	6
15	M	5	1	21
18	M	3	0	52
21	F	2	0	18
29	F	1	0	7
34	M	2	0	6
35	M	3	6	38
36	F	4	116	77
39	M	2	0	48
40	F	3	0	46
45	M	2	0	20
46	M	2	0	19
47	F	2	16	13
48	M	1	0	5
50	M	3	36	19
51	M	1	0	24
54	M	2	0	24
57	M	2	16	44
58	M	2	43	15
61	M	2	0	13
62	M	2	7	3
63	F	2	7	5
67	M	2	27	35
68	M	2	6	3
71	M	2	12	5
73	F	1	5	5
75	F	2	62	36
76	F	2	46	28
77	M	2	18	12
78	M	2	1	7
79	M	1	21	23
80	F	1	21	23
82	F	1	21	22
84	M	2	6	5
85	M	2	34	18
87	M	1	17	19
88	M	3	28	17
89	M	2	13	6
92	M	2	8	2
94	M	2	6	7
95	M	2	7	4
96	M	1	4	3
		116	695	

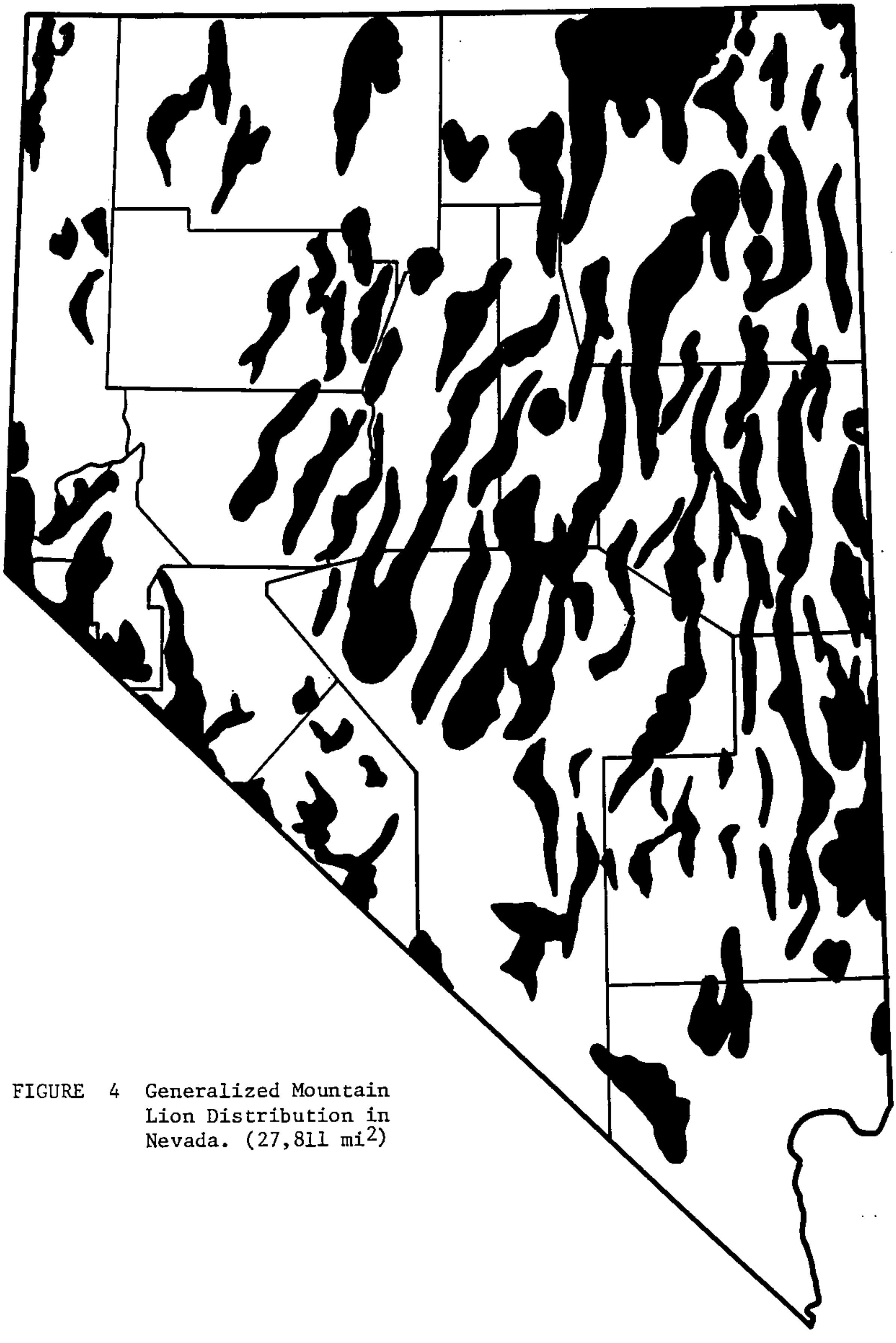


FIGURE 4 Generalized Mountain Lion Distribution in Nevada. (27,811 mi^2)

Time of Birth -- The month of birth was calculated for 135 litters by projecting forward for prenatal litters and backdating for postnatal litters. No kittens older than 12 months (estimated age) were included in the calculations (see section on aging for criteria). The majority of reproductive tracts examined were from females in the latter stages of pregnancy. Prenatal young were aged based on crown-rump measurements or by the overall size of the fetuses in the case of U.S. Fish and Wildlife Service records. The following measurements are believed to be a reasonably accurate means of determining prenatal monthly age classes:

(1) First month ------ 25 mm or less
(2) Second month ----- 26-125 mm
(3) Third month ------ 126 mm or larger

Kittens were born in every month of the year with a peak occurring during the months of June-July (Figure 5). During April-September a total of 94 litters were recorded (70%) as compared to 41 litters (30%) during the remainder of the year. Robinette et al. (1961) computed birth months for 145 litters in Nevada and Utah and found the peak months to be June-September. In central Idaho Seidensticker et al. (1973) reported most births occurred during late spring and early summer.

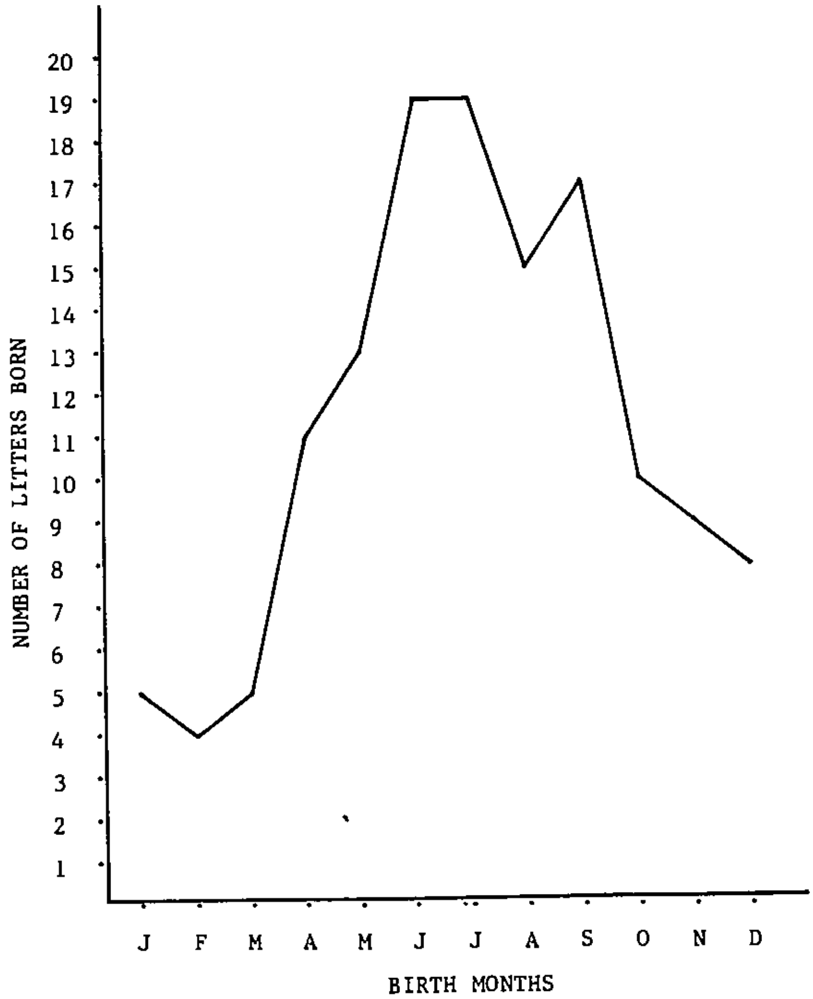


Figure 5. Birth Months for 135 Mountain Lion Litters in Nevada, 1956-82.

Frequency of Litters -- Data from 12 adult female lions indicated that the reproductive cycle (time between litters) ranged from 11.5-24 months and averaged 17.4 months.

Litter Size and Survival -- Examination of 36 prenatal litters revealed an average litter size of 3.08 kittens. The number of kittens per litter varied from 1 to 5 as shown in Table 3.

As the kittens grew there was a gradual loss and the number of kittens observed with their mothers declined to an average of 2.23 by the 12th month. Table 4 shows this loss by estimated age group. In analyzing Tables 3 and 4 it would appear that the prenatal litter size of 3.08 kittens is probably higher than the actual number of kittens born. Furthermore, the litter size for the 4-month age group (2.59) would reflect losses from birth to that time. Therefore, it is felt that the actual birth rate lies somewhere between the two and 2.8 kittens was used as the average litter size when calculations requiring this were needed.

TABLE 3. PRENATAL LITTER SIZES OF MOUNTAIN LION KITTENS.

	Number of Kittens per Litter					Total Sample	Average Litter Size
	1	2	3	4	5		
Number of Litters	1	7	18	8	2	36 litters (111) kittens	3.08

TABLE 4. MOUNTAIN LION KITTEN SURVIVAL BY AGE GROUPS.

	Number Kittens with Mother				Total Sample		Average Litter Size
	1	2	3	4	Families Observed	Kittens Observed	
Estimated Age							
4 months	3	14	21	3	41	(106)	2.59
5-11 months	6	19	15	2	42	(97)	2.31
12 months	6	25	15	1	47	(105)	2.23
TOTAL	15	58	51	6	130	(308)	2.37

Currier (1976) reported the average litter sizes for Colorado as 1.6 (13)*, California 2.0 (8)*, Arizona 2.2 (11)*, and Idaho 2.4 (33)*, while captive lions in Washington averaged 2.6 (92)*. The sample size in all of these states, except Washington, was very small.

The rate of kitten survival in Nevada is good and when coupled with the lions' high reproductive potential it can be speculated that mountain lions are capable of rapidly replacing individuals that are removed from the population.

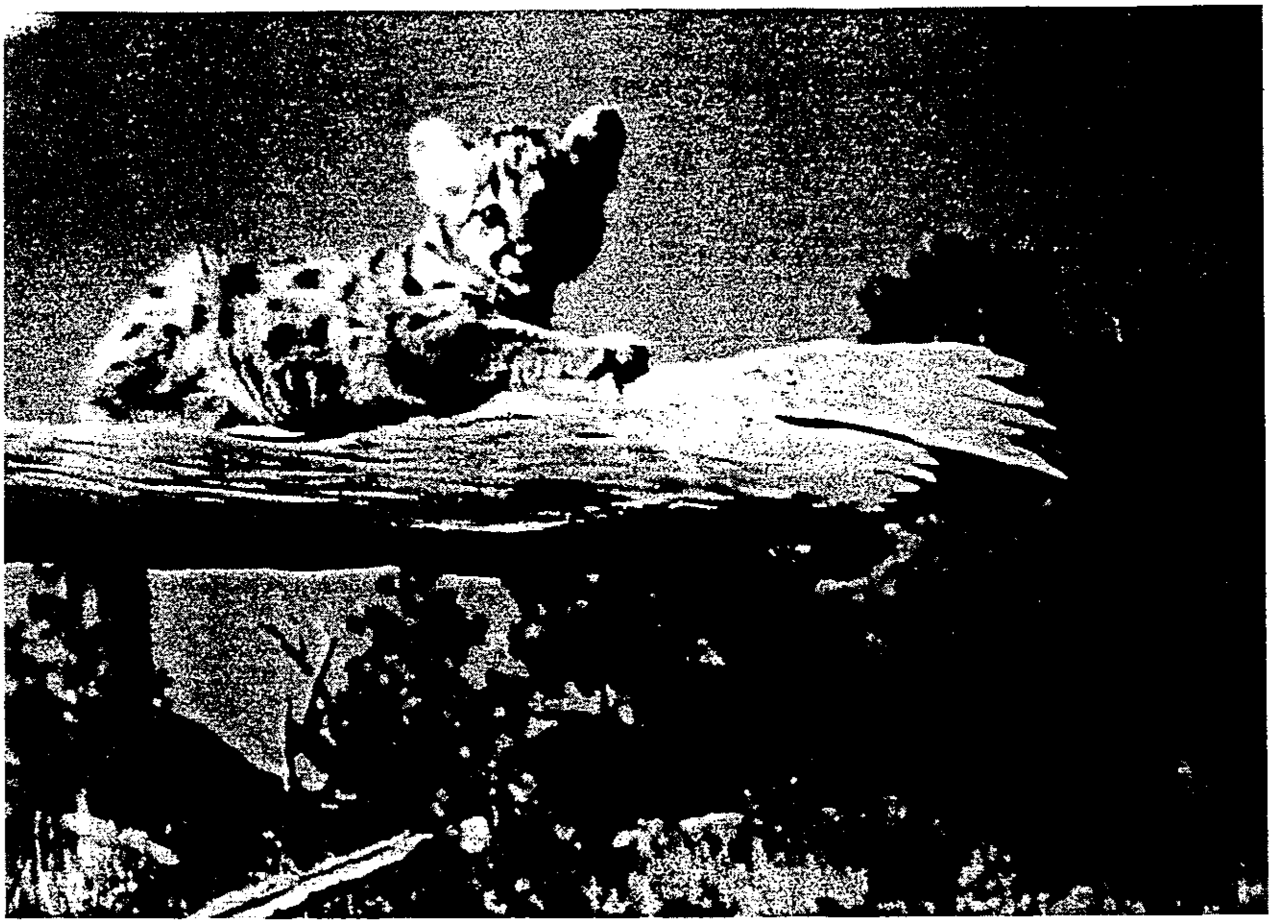
*Number of kittens in sample shown in parenthesis

Population Turnover -- Data relating to population turnover was restricted primarily to the Ruby Division, where records from track counts, captures and recaptures, and radio-telemetry locations indicated that the lion population consisted of approximately 35 animals. During the period of 1954-60 there was a sustained mortality on this population of at least 11 lions per year (30% of total). In 1974 and 1975 thirty lions were known to have been removed from the population, with sport hunting accounting for the highest percentage. Yet, three years later (1978), following the initiation of very restrictive sport hunting regulations, this population appeared to have recovered to its former level. This conforms with the findings of Robinette, et al. (1977) who felt that the annual recruitment and mortality of cougars in their Utah study area was 32%.

It appears that under moderate to heavy exploitation (30%-50% removal) Nevada lion populations have the recruitment capability of rapidly replacing annual losses.

Sex Ratios -- U.S. Fish and Wildlife Service and Nevada Department of Wildlife records for the period between 1954 and 1982 show that 83 litters containing 198 kittens had a sex composition of 89 females and 109 males (100 F; 125.5 M). The data clearly shows an unequal sex ratio, in favor of males; however, a large number of litters recorded by the U.S. Fish and Wildife Service were not sexed and the data base to date may not be representative of true conditions.

Aging -- The terminology used for classifying mountain lion age groups has been confusing to say the least. The term kitten is commonly applied to young lions and in some instances this appellation is used until the youngster finally leaves its mother (approximately 2 years old). Under this connotation the kitten can be newborn, with obvious kitten-like characteristics, or an immature lion which, on superficial examination, cannot be differentiated from an adult -- a broad category indeed. Shaw (1980) not only uses the term kitten but also classifed lions in the age group of 0-2 years as subadults. This probably can be attributed to "lion talk" between the professional hunter and the researcher, where they recognize a difference but have not defined it. Seidensticker (1973) related that "as a lion grows older, it passes through a series of relatively discrete behavioral stages: kitten, transient adult, resident adult." He also referred to small kittens and big kittens (over a year old). In this case behavioral stages and age groups could become confusing. Hornocker (1970) refers to kittens, juveniles and adults but offered no criteria for distinguishing them, other than calling a 1 year old a



A Mountain Lion Kitten at Less than 4 Months Showing Distinct Spotting.

kitten. Currier (1976) did set up a rudimentary classification for three age groups: kitten, adolescent and adult, but it is very generalized and there is some major overlap in criteria. The term yearling has also popped up in the literature and in lion discussions and could be interpreted as being interchangeable with kitten or subadult, but also has the connotation of distinguishing a large kitten from a small one. The need for some approach toward standardization of terminology and relating it to criteria has been evident for some time (Mountain Lion Workshop 1976).

When this study was initiated some broad criteria for the general classification of age groups was adopted. As the study progressed additional criteria, primarily relating to tooth eruption and growth, were incorporated into the key. Even now the distinction between the three proposed age groups (kittens, subadults and adults) often requires a subjective evaluation. However, the criteria presented in Table 5, if used, certainly will help eliminate some of the general age classification confusion.

A further refinement, for aging juveniles by months and adults by year, was explored through the use of tooth eruption sequences, growth, stain and wear. Sufficient data was not collected to be statistically sound, and initial ages had to be estimated; however, this information could be a starting point for additional research toward determining ages more accurately.

Teeth from 94 kittens and subadults were examined to develop the eruption

TABLE 5. CRITERIA FOR A GENERAL CLASSIFICATION OF MOUNTAIN LION AGE GROUPS.

KITTENS (0- 16 months)

* 1. Body weight.
2. Pelage spotting; fading by 3rd or 4th month.
3. Still with mother.
4. Deciduous teeth present or permanent teeth erupting. (See Table 6 for a guide to estimating kitten ages).
5. If all teeth are permanent then canines are not fully extended. Canine length is less than 28 mm in males and 23 mm in females.

SUBADULT (17 - 23 months) - Has passed through juvenile period but not yet attained typical adult characteristics.

* 1. Body weight.
2. Pelage spotting still present on insides of front legs.
3. Not sexually mature. Females not nursing (small teats and no areola).
4. May or may not be with mother.
5. Full extension of canines. Canines measure 28-31 mm in males and 23-25 mm in females.
6. Teeth ivory white in color, not stained.

ADULTS (24 months or over)

* 1. Body weight.
2. Independent of mother.
3. No spotting on pelage or very faint.
4. Sexually mature. Evidence of nursing in females, large teats and presence of areola (may not be evident in young females just entering this age group).
5. Tooth wear and/or stain. (See Table 8 for a guide to estimating adult ages.)

* The following standards are based on weights from Table 1.

Kittens
Males - up to 123 lbs.
Females - up to 81 lbs.
Weight differences between kittens and subadults are obvious up through approximately 9 months. From this age on there can be an overlap and other criteria must be used in conjunction with weight.

Subadults
Males - 115-140 lbs.
Females - 79-105 lbs.

Adults
Males - 112-162 lbs.
Females 84-115 lbs.

TABLE 6. A GUIDE FOR ESTIMATING AGES OF MOUNTAIN LION KITTENS BY TOOTH ERUPTION SEQUENCES.

Age (Months)	Sequence of Permanent Tooth Eruption
2	Complete set of deciduous teeth; permanent P^2 and M^1 erupted
3	Permanent incisors erupted
4	Upper canines and P^4 erupt
5	M_1 and lower canines erupt
6	P^3 erupts
7	P_4 erupts
8	P_3 erupts; upper canines 50-60% extended from gum lines (males: 16-18 mm, females: 12-14 mm)
9 & 10	P^4, M_1, and P^3 become fully extended
11 & 12	P_4 and P_3 fully extended; upper canines 70-80% extended (males: 20-22 mm, females: 15-17 mm)
13 & 14	Upper canines 80-90% extended (males: 24-27 mm, females: 19-21 mm)
15 & 16	Upper canines fully extended by 16th month (males: 28-31 mm, females: 23-25 mm)

TABLE 7. CRITERIA FOR ESTIMATING AGES OF ADULT MOUNTAIN LIONS.

2 YEARS OLD

1. Canines white, no staining.
2. No wear on incisors 1 and 2. Third incisor may show slight wear.
3. Tips of canines show little or no wear.

3 and 4 YEARS OLD

1. Canines lightly stained.
2. Slight wear on highest point of crown of third incisor. Area of wear 1-4 mm across.
3. Incisors 1 and 2 with little or no wear.
4. Tips of canines with little or no wear (2 mm or less).

5 and 6 YEARS OLD

1. Canines moderately stained.
2. Third incisor worn to within 1-4 mm of crest of incisors 1 and 2.
3. Incisors 1 and 2 have slight to moderate wear along crown.
4. Tips of canines with obvious wear (3-5 mm worn off).

7-9 YEARS OLD

1. Canines darkly stained.
2. Third incisor worn level with incisors 1 and 2 and to within 1-4 mm of gum line.
3. Tips of canines flattened to nearly rounded.
4. Dentine exposed on incisors.

10 + YEARS OLD

1. All incisors worn nearly to gum line, or missing.
2. Canines worn rounded to blunt, darkly stained.

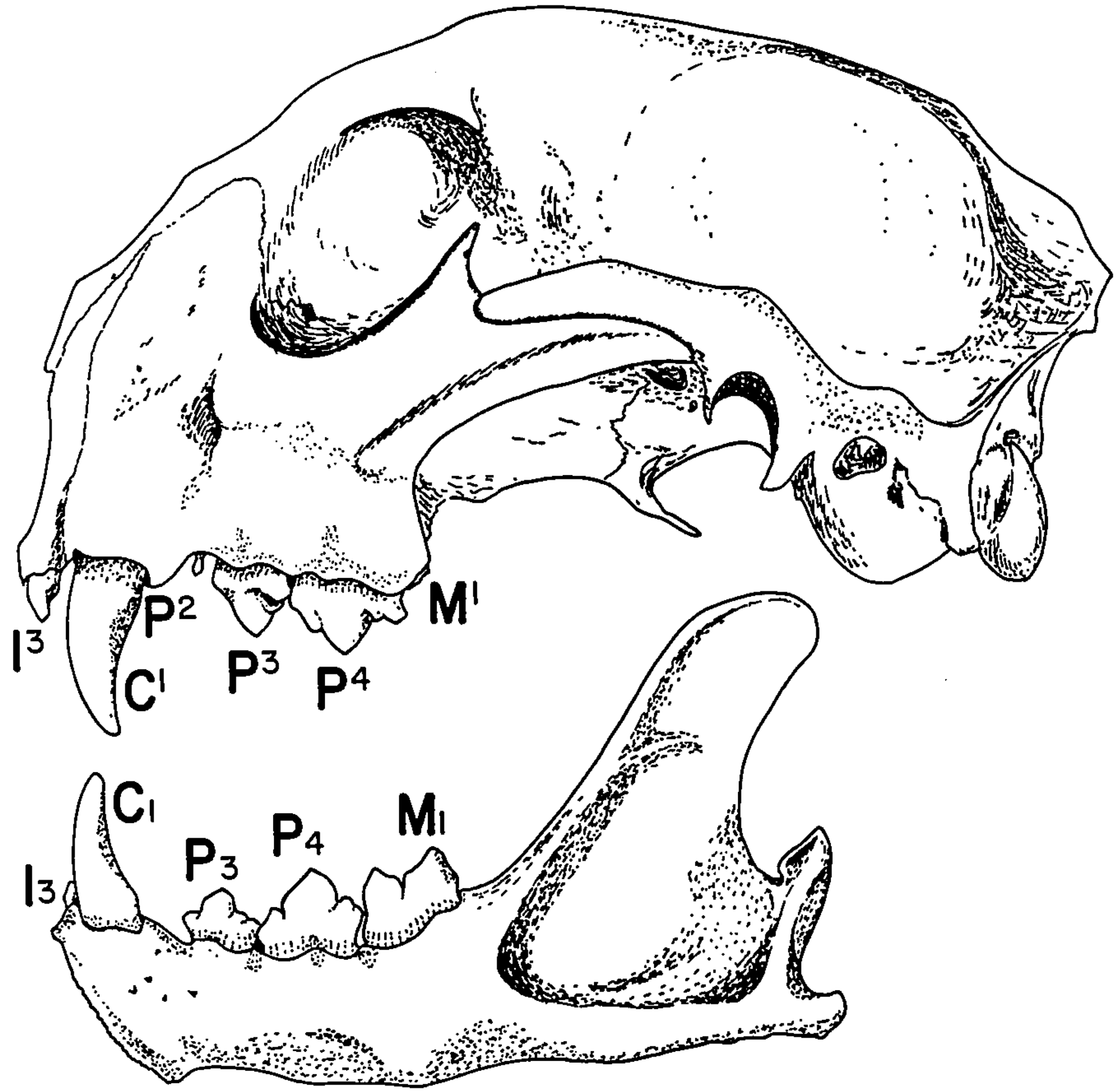


FIGURE 6 Lateral view of a mountain lion skull with letter/number designations for permanent dentition.
Drawing by M. Alderson.

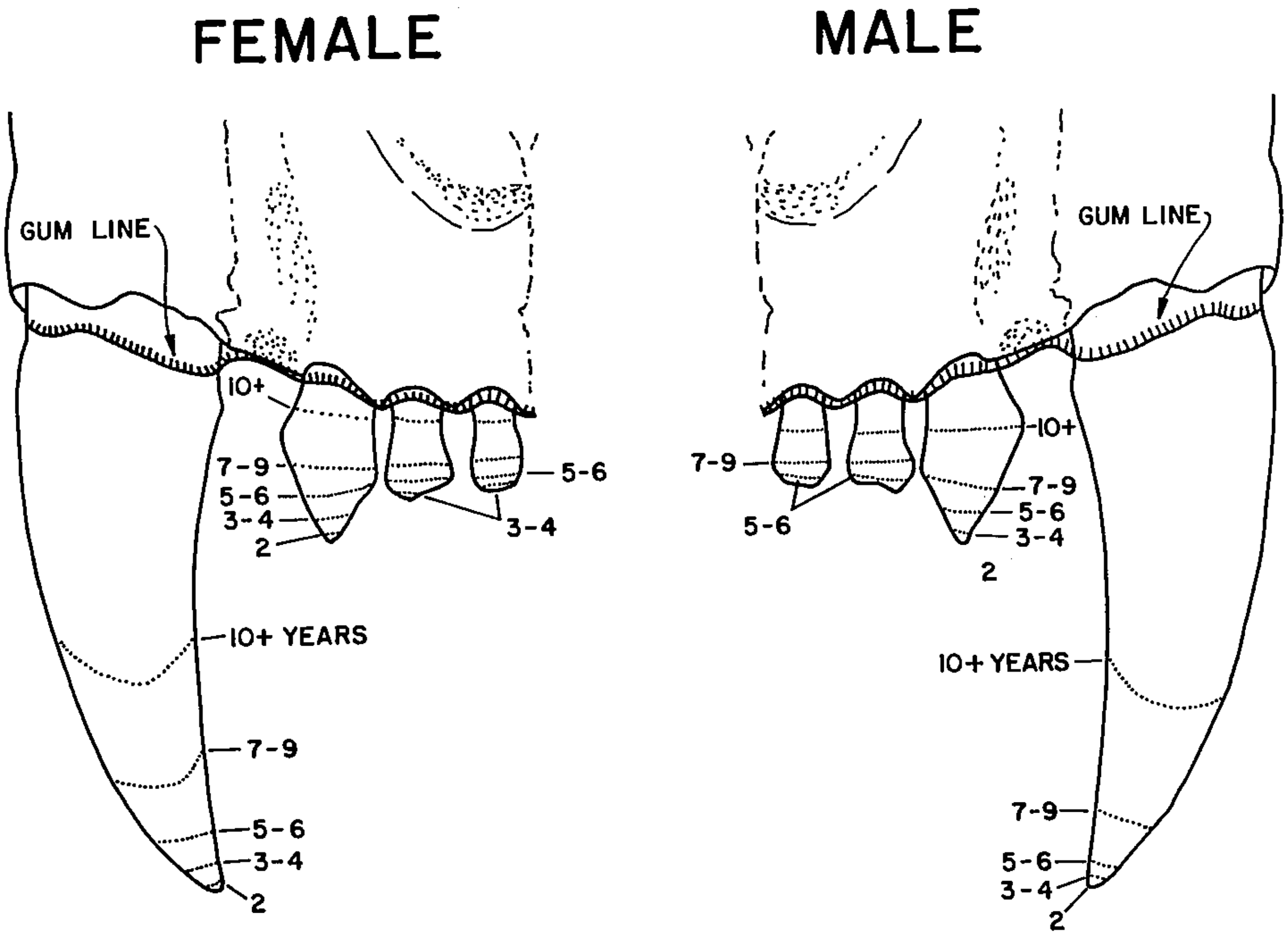


FIGURE 7 Frontal view of upper teeth of female and male mountain lions displaying relative wear by adult age classes.
Drawing by M. Alderson.

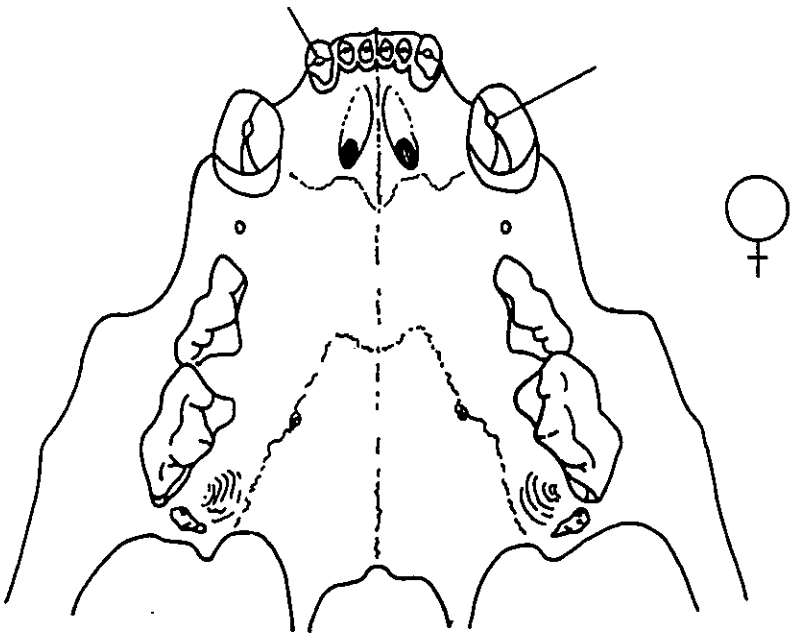


FIGURE 8 Ventral view of the upper dentition of a 3-4 year old female mountain lion showing wear points on apex of third incisor and canine teeth.
Drawing by M. Alderson

sequences and to formulate the aging guide shown in Table 6. Of this number 21 were kittens or subadults which had been captured, marked, their age estimated, and then released. When these animals moved into the adult age group they provided information concerning tooth stain and wear which was used to help develop Table 7. Figures 6, 7 and 8 illustrate permanent dentition and adult lion tooth wear patterns.

Although not shown in Table 7 there is some evidence available to show that there is differential wear on the canines and incisors of males versus females.

Weights -- Only limited data was collected on the weights of newborn kittens. Nine fetuses, judged to be in the last 2 weeks before birth, had a weight range of 0.77-1.17 pounds. Two kittens estimated to be 1-3 days of age weighed 1.06 and 1.17 pounds.

The weights of all captured lions are provided in Table 1. Based on 21 lions the adult males ranged from 112 to 162 pounds and had an average weight of 137 pounds. Thirteen adult females ranged from 84 to 115 pounds and averaged 98 pounds. The average weights recorded for lions in California was 105.8 pounds for males and 76.5 pounds for females; in Arizona, 114.5 pounds for males and 72.6 pounds for females; and in Utah, 136.9 pounds for males and 92.5 pounds for females (Sitton, 1977).

Movements

Dispersal of Juveniles -- Data was obtained from 8 family groups as to the approximate age of the kittens when they separated from their mothers. The range in ages was 10.5 months to 19 months with an average of 14 months. It was observed on several occasions that following separation from their mothers the young frequently remained in their home range for a time before finally dispersing.

To become established as part of the breeding population a newly independent mountain lion normally progresses through three phases:

(1) Independent kitten or subadult -- upon leaving its mother.
(2) Transient - when searching for a new home range.
(3) Resident - upon establishment of a new home range.

This behavioral pattern is similar to that observed by Seidensticker, et al. 1973, with the important exception that Seidensticker called all transient and resident lions adults. In contrast, the data from this study shows that when using the age classification groups in Table 5 transients can be kittens, subadults or adults and residency can be established by subadults. Behavioral patterns do not necessarily establish the age of the lion.

The transient phase can be very limited, particularly with females, as was observed with lion number 13 who stayed in the mountain range of her birth, was bred at the approximate age of 24 months, and established a home range immediately adjacent to her mother's (number 14).

Documented movements recording the dispersal of 16 young mountain lions in the Ruby Mountains and vicinity are shown in Figure 9. Eleven of these lions stayed within the mountain range where trapped (and believed to have been born) and 8 left to become established in another mountain range. Travel routes were unknown for the lions that left their home range but it is presumed they sometimes had to cross wide, barren valleys to reach their new residence. Of the 8 males tracked only 2 remained in the mountain range where first captured and presumably born. Females generally did not move as far as males (averaging 18 miles as compared to 31 miles for males) and they tended to remain in the mountain range where they appeared to have been born. Extreme movements of 36 miles for a female and 57 miles for a male lion were noted. The initial dispersal of independent kittens or subadults from their home ranges appears to be an important characteristic which contributes towards maintaining viable populations throughout their habitat. For example, in areas where mountain lions are heavily exploited (see Mortalities), such as in the Ruby Mountains, the influx of transient lions is essential in order to maintain a population.

Home Range -- Sufficient data was obtained from radio-tracking, recaptures and track sightings to at least partially construct the home range size of 13 lions. This data covered a time period which ranged from 15-77 months per lion and involved anywhere from 17-116 locations per lion (Table 8). Male lions had home ranges three times as large as females averaging 224 square miles as compared to 69.5 square miles (Figures 10-22). It is believed that smaller home ranges in the Ruby Mountains were due to higher deer densities compared with the other mountain ranges. Females occupying the South Ruby portion had considerably larger estimated home ranges than females living in higher deer density habitat in the North Rubies.

Home range overlap was documented for both adult females and adult males; however, sufficient long-term data was not collected to determine if resident lions were being recorded in all cases. In fact, the high lion turnover rate in the study area made it very difficult to distinguish between transients and residents, and in determining resident home ranges some judgements had to be made. Male home ranges either partially or completely overlapped those of neighboring adult females. Less overlap was found between members of the same sex, although on occasion there was considerable overlap during certain seasons. This occurred most frequently during the middle of winter when both deer and lions were concentrated and again during the spring and early summer (primary breeding season).

Both adult males and females tended to use the same areas month after month and year after year within their home ranges. This behavior was similar to that described by Hornocker (1969) and Seidensticker et al. (1973) in Idaho. However, there were some differences between characteristics recorded in Idaho lion populations and those observed in Nevada: (1) males were observed to fight and were not generally tolerant of each other in regard to intrusions into their home ranges, and (2) there was no obvious differences, in regard to home range size, between unexploited and exploited lion populations.

Seasonal Movements -- With the advent of winter snows in late fall the deer move to lower elevations or migrate to traditional winter ranges. The mountain lion normally follows, but may go to the wintering grounds of another herd. In doing so there may be a movement to a different mountain range and long distances can be traversed (Figures 12 and 13).

Lions usually avoided north-facing slopes in the winter when snow was deep and crossed from one drainage to another by descending to the mouth of the canyon. South-facing slopes received the most use because of less snow and the presence of greater numbers of deer. Snow, however, did not always deter the mountain lion, and they have been noted to cross over mountain passes covered with 3 to 5 feet of snow with little difficulty.

During the summer months the lions' movements were not restricted by environmental factors. North-facing slopes, which were cooler and had more vegetation than south-facing slopes, were preferred. The vegetative cover in the Ruby Mountains is sparse above 9,000 feet (subalpine zone) and lions tended to use these areas much less than the lower elevations where aspen, mountain mahogany and taller shrubs were prevalent. The highest elevation at which a lion was located was 10,400 feet and the lowest was 6,100 feet. The elevational zone of highest use by lions in eastern and central Nevada is between 6,500 and 8,500 feet where deer and other prey species are most abundant.

Movements of Deer in Relation to Lions -- On one occasion deer were observed fleeing in response to a lion's presence, while in other instances they tended to either ignore the lion or they appeared only slightly nervous, often looking in the direction of the lion. Most of these observations were made when deer were in open areas which lacked suitable stalking cover for lions. In one instance several deer were seen to wander into a dense grove of mahogany trees where a lion was present. Within a few minutes the deer walked out of the trees, seemed to be uneasy and frequently looked back in the direction of the lion but did not run. On another occasion several deer were noted to be fearful of a nearby lion and they ran approximately 300-400 yards until they reached an open hillside where they stopped and began to feed.

Food Habits -- The most comprehensive study on food habits of the mountain lions in Nevada was made by Robinette, et al. (1959). Although the emphasis in this study was not directed toward food habits, data was collected when possible. These findings showed that mountain lions ate a variety of prey species ranging in size from wood rats (Neotoma spp.) to elk (Cervus canadensis). The staple food was the mule deer. In some areas feral horses rated second in importance if deer densities were low. In the Ruby Mountains, beaver (Castor canadensis) were a favorite food source and were readily available. Another prey species not listed, but of local importance in southern Nevada, was the bighorn sheep (Ovis canadensis).

Two hundred lion scats were examined during the ten years of field effort and the following food items (listed in approximate order of importance) were found: mule deer, porcupine (Erithizon dorsatum), cottontail rabbit (Sylvilagus spp.), jackrabbit (Lepus californicus), feral horse, beaver, domestic sheep, wood rat, blue grouse (Dendragapus obscurus), coyote (Canis latrans), bobcat (Lynx rufus), unknown rodents, and elk.

In addition to scats, the contents of 14 lion stomachs were examined. This information is presented in Table 9.

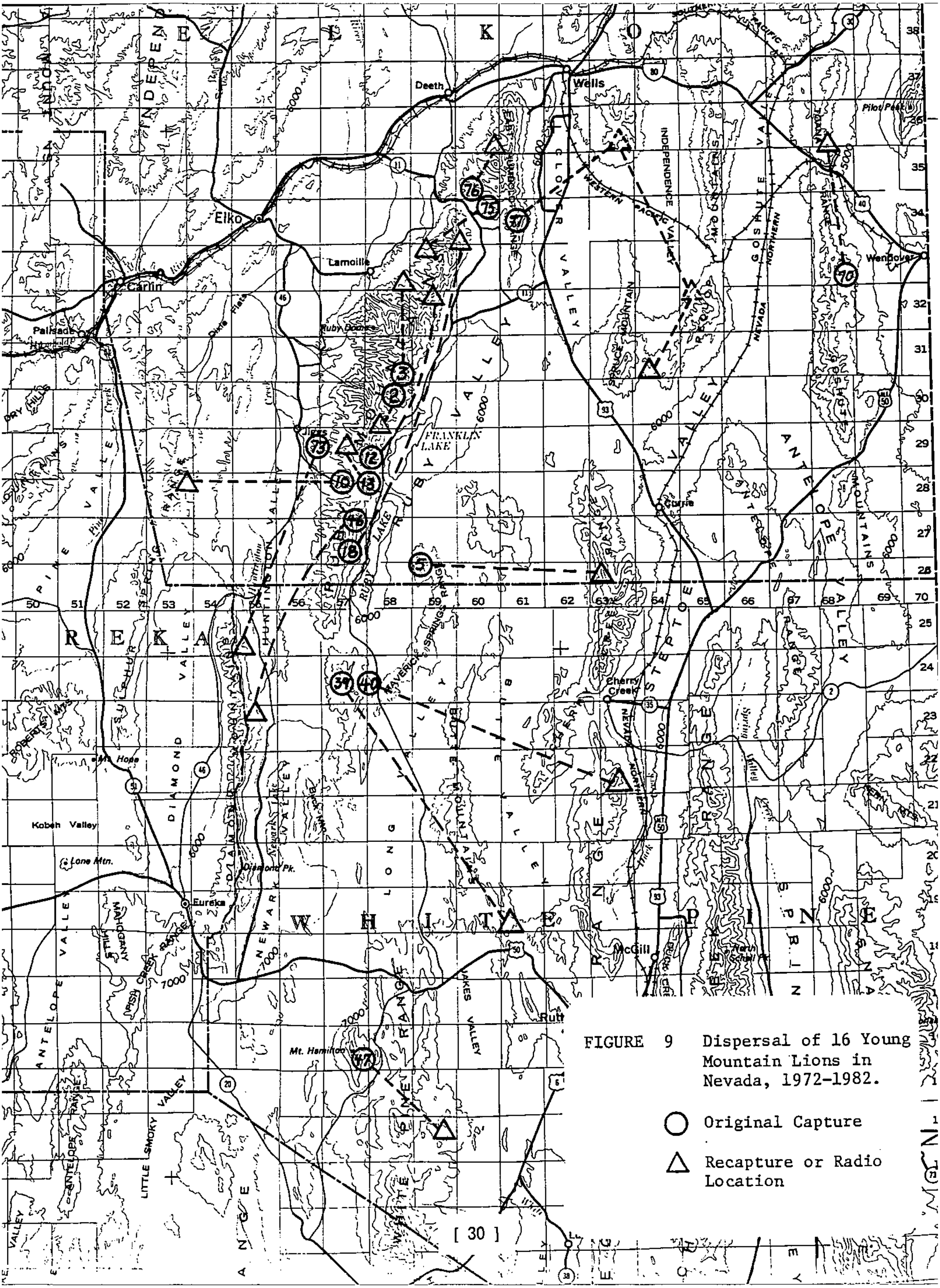


FIGURE 9 Dispersal of 16 Young Mountain Lions in Nevada, 1972-1982.

○ Original Capture

△ Recapture or Radio Location

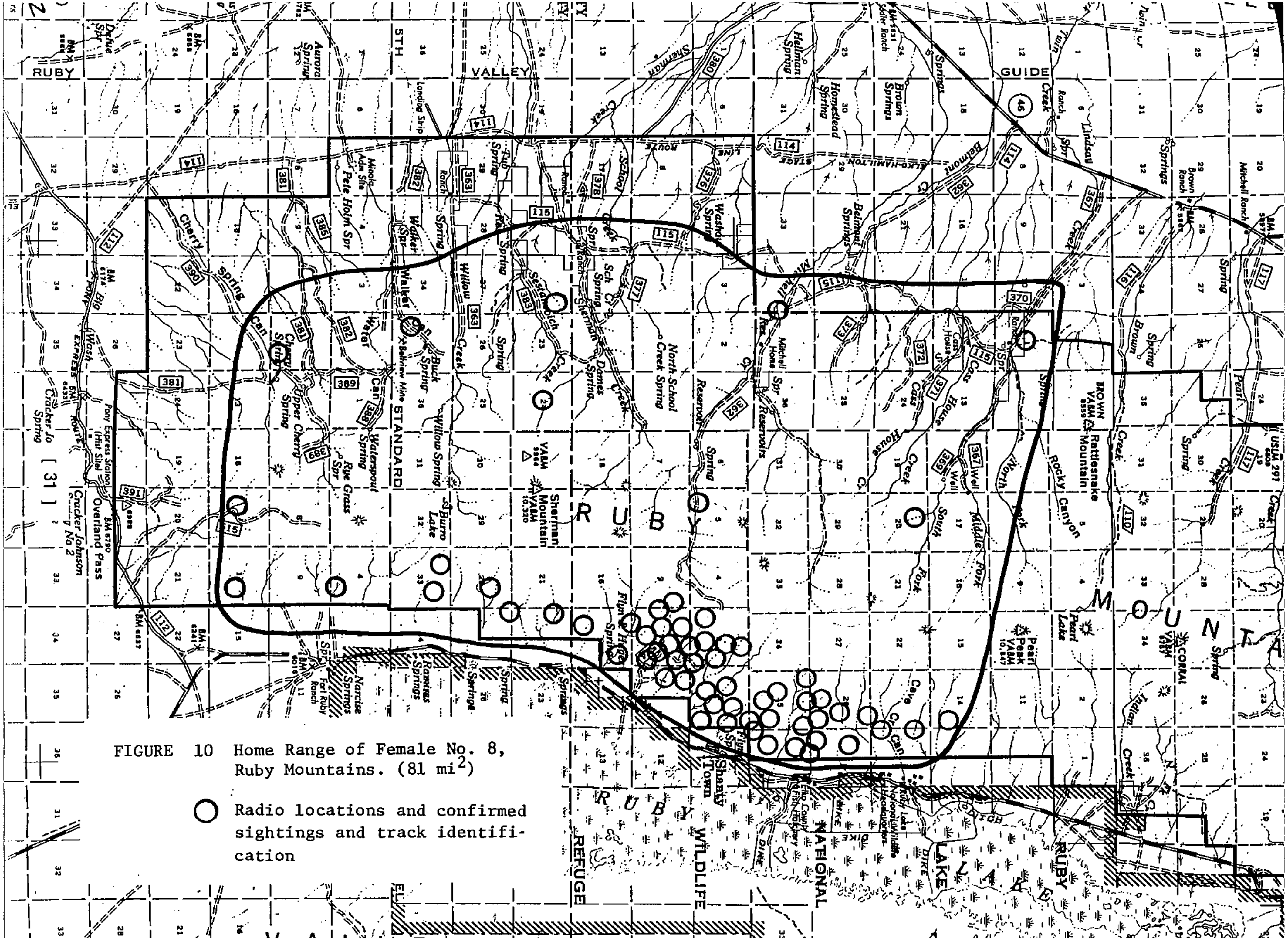


FIGURE 10 Home Range of Female No. 8, Ruby Mountains. (81 mi^2)

○ Radio locations and confirmed sightings and track identification

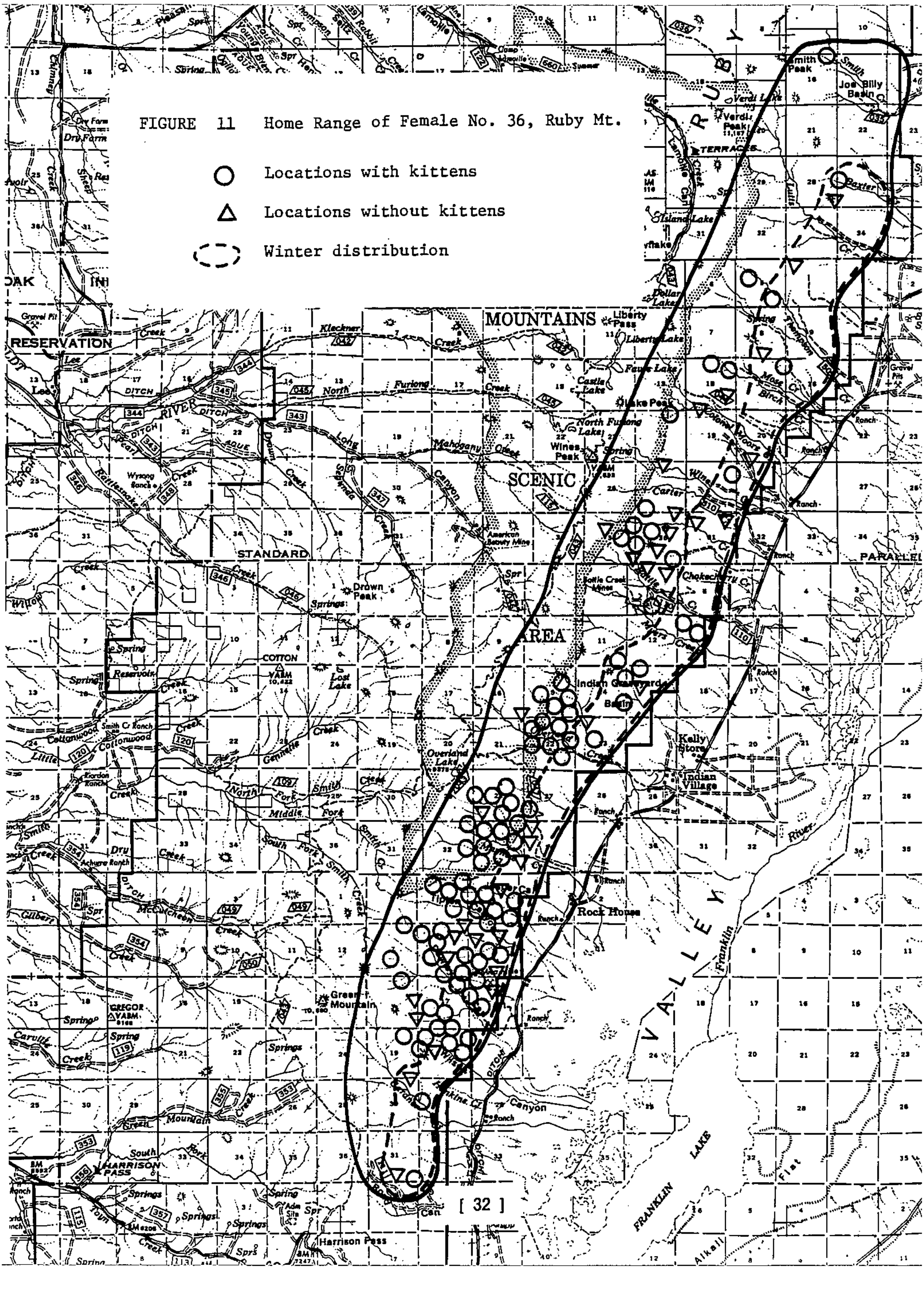


FIGURE 11 Home Range of Female No. 36, Ruby Mt.

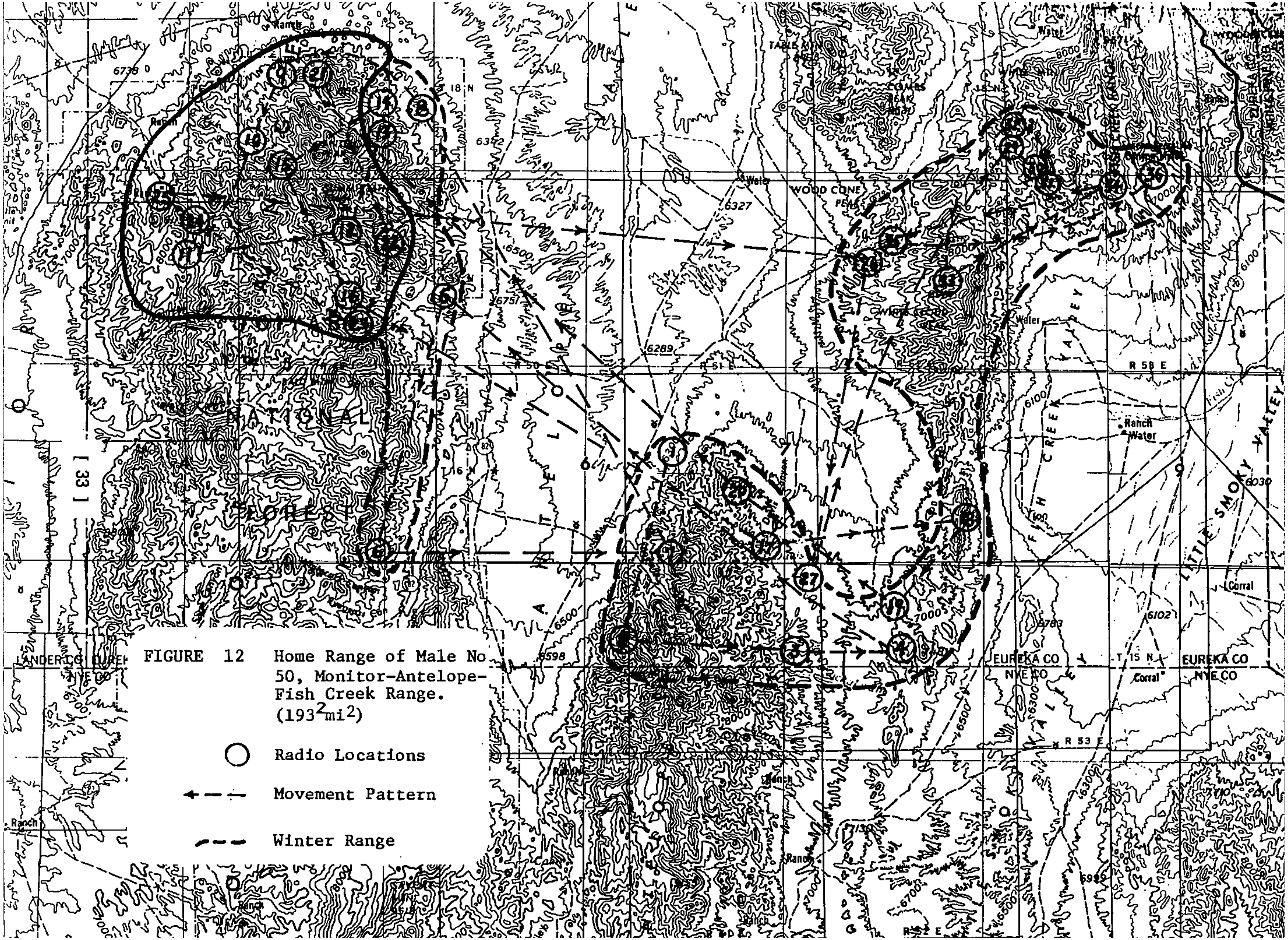


FIGURE 12 Home Range of Male No 50, Monitor-Antelope-Fish Creek Range. (193^{2}mi^2)

Radio Locations

Movement Pattern

Winter Range

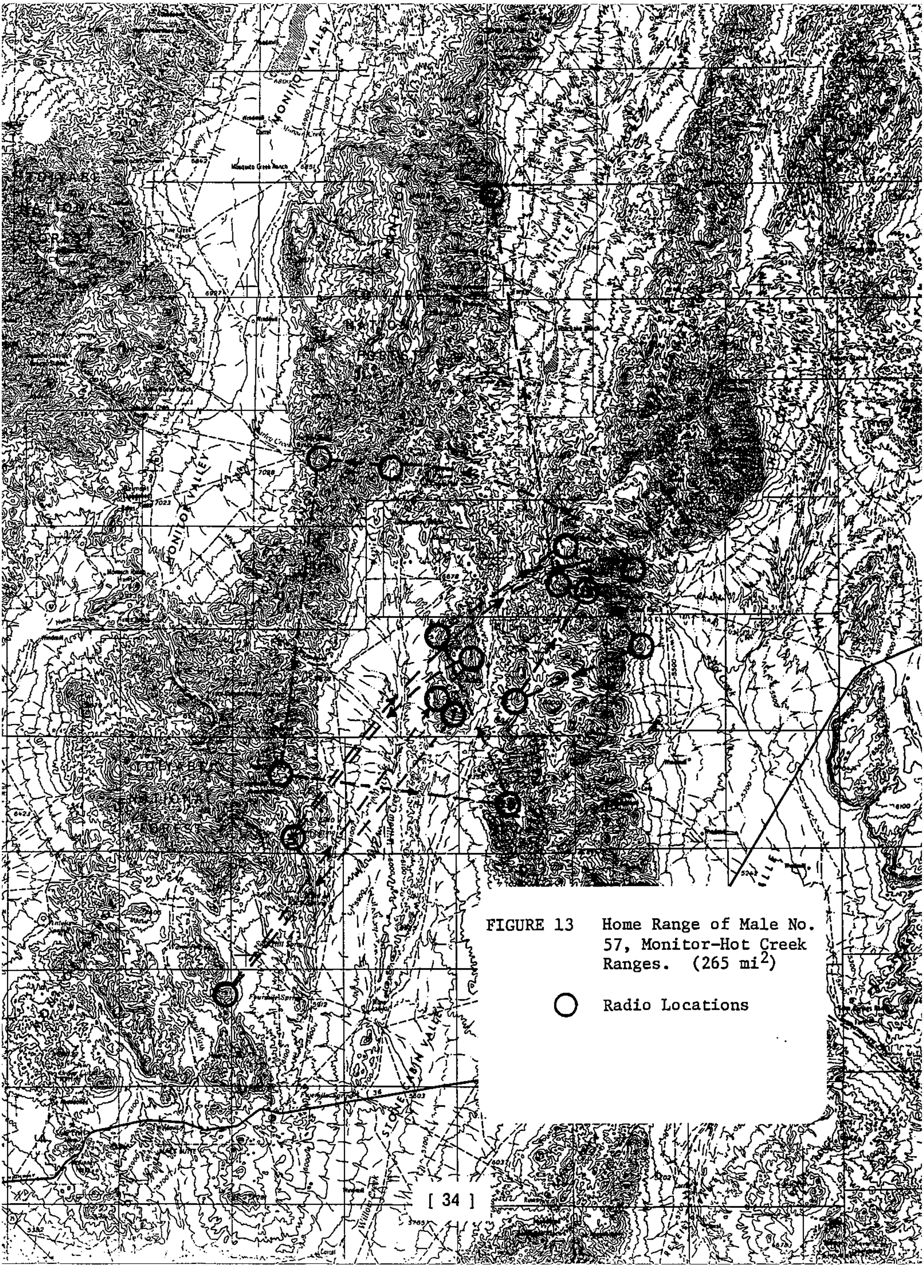


FIGURE 13 Home Range of Male No. 57, Monitor-Hot Creek Ranges. (265 mi^2)

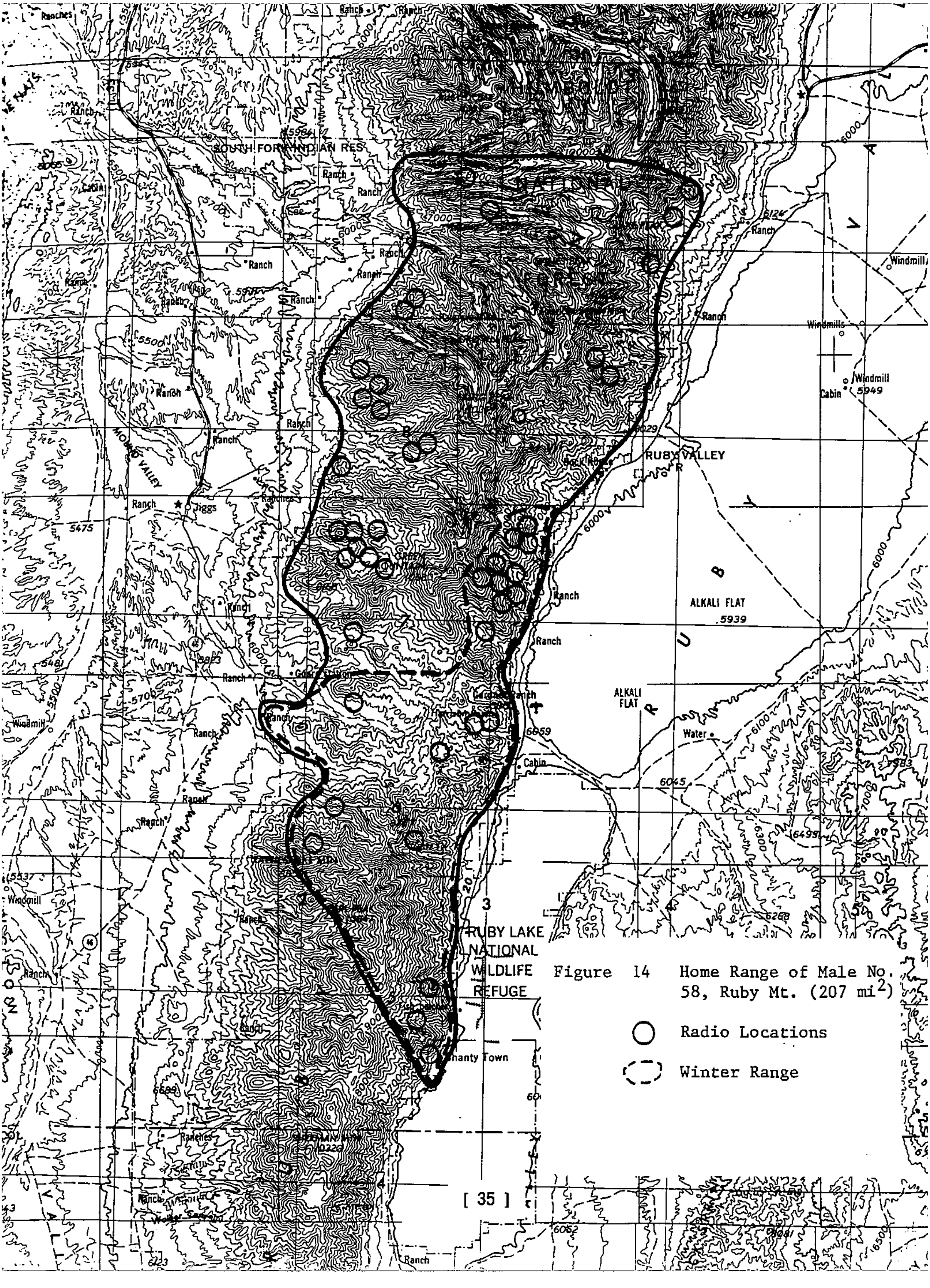


Figure 14 Home Range of Male No. 58, Ruby Mt. (207 mi^2)

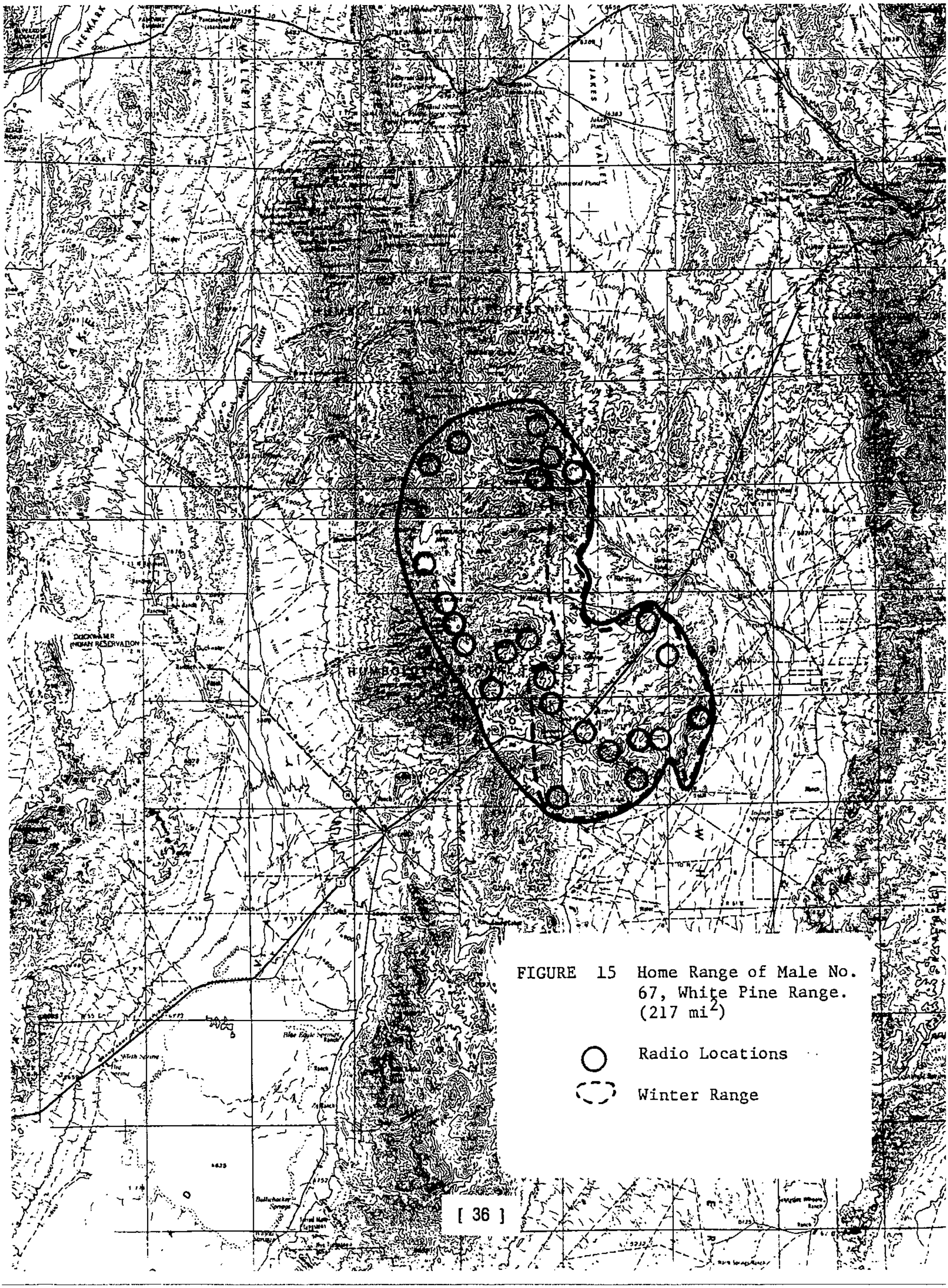


FIGURE 15 Home Range of Male No. 67, White Pine Range. (217 mi^2)

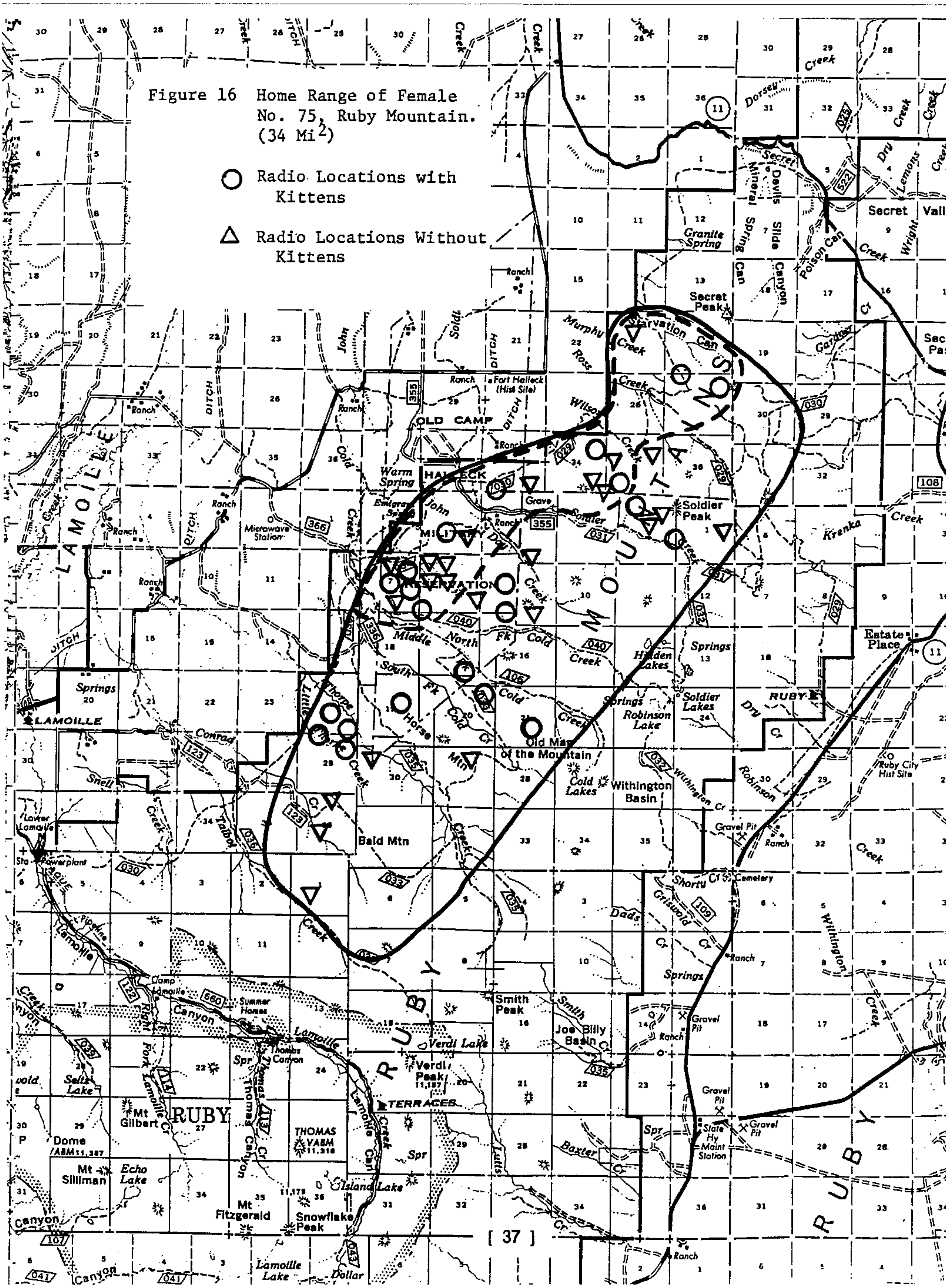


Figure 16 Home Range of Female No. 75, Ruby Mountain. (34 Mi^2)

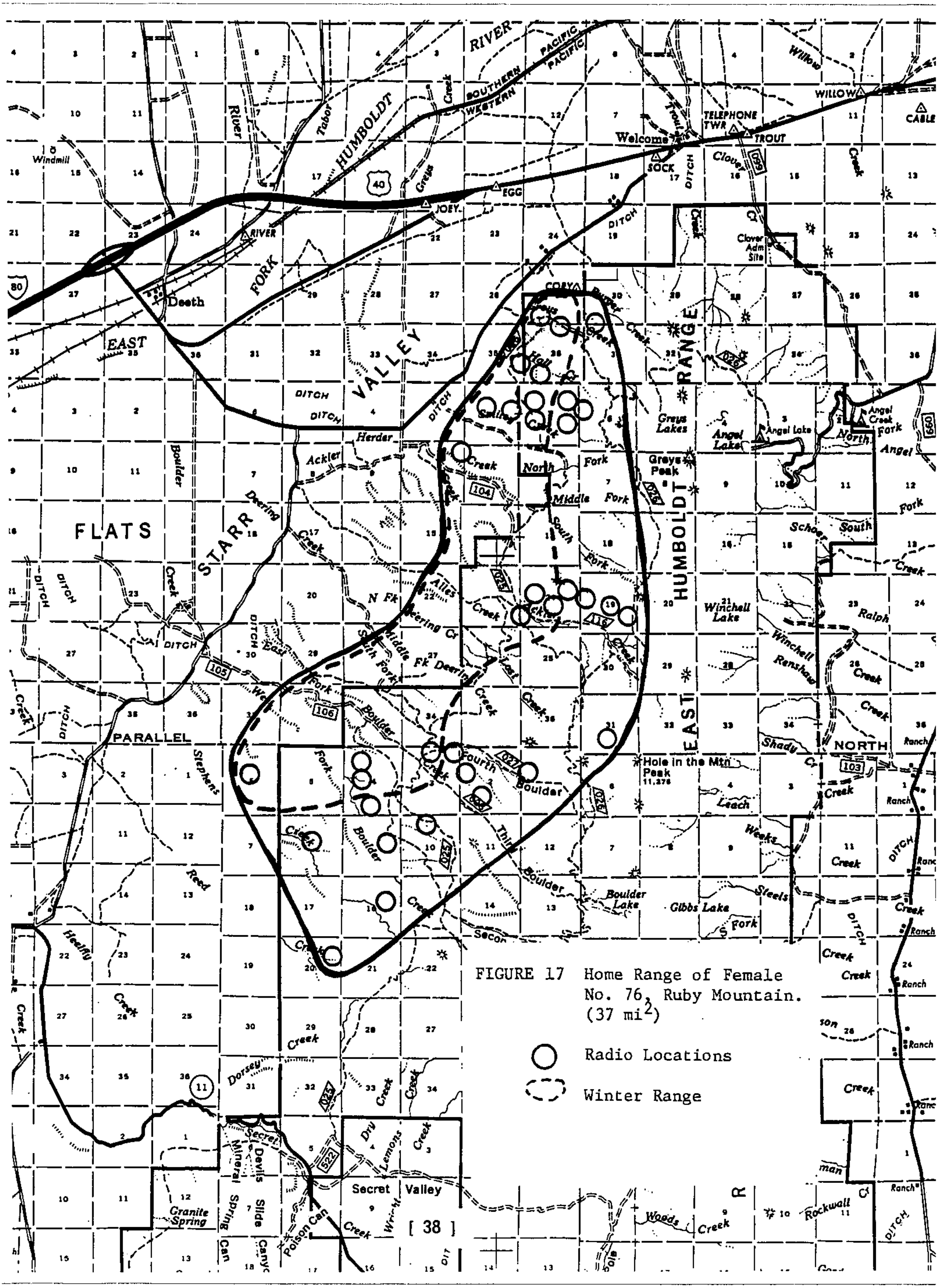


FIGURE 17 Home Range of Female No. 76, Ruby Mountain. (37 mi^2)

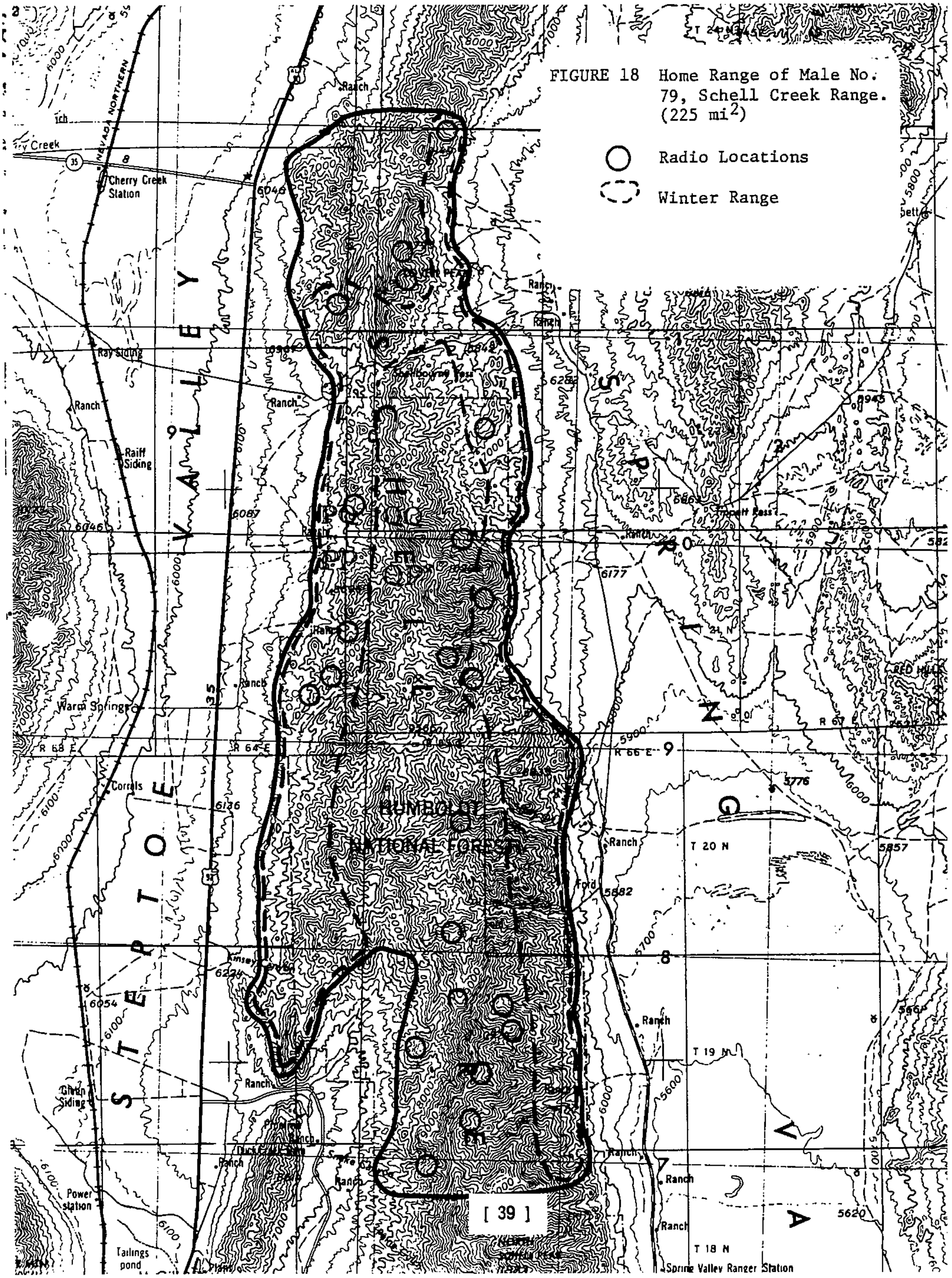


FIGURE 18 Home Range of Male No. 79, Schell Creek Range. (225 mi^2)

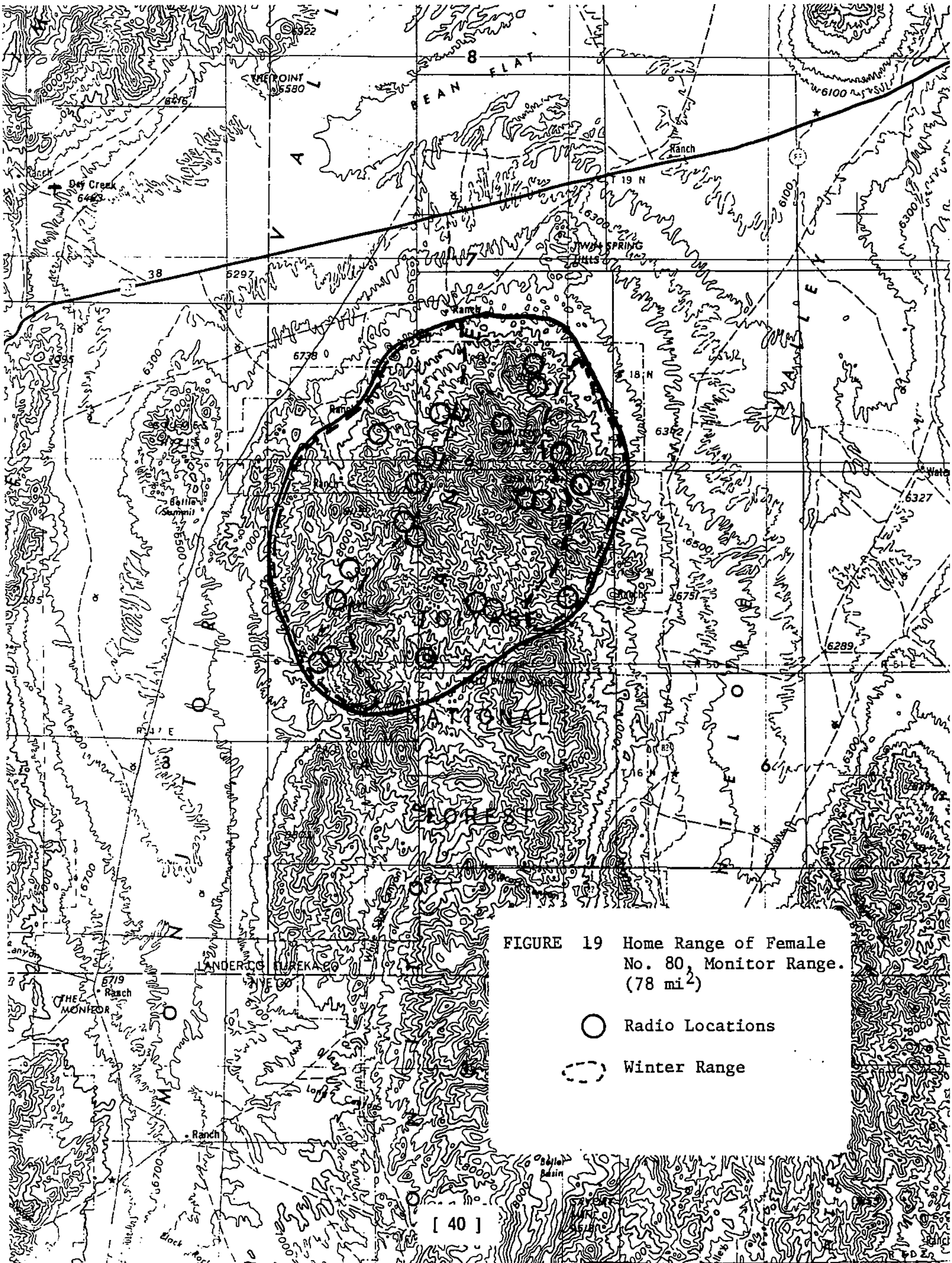


FIGURE 19 Home Range of Female No. 80, Monitor Range. (78 mi^2)

◯ Radio Locations

Winter Range

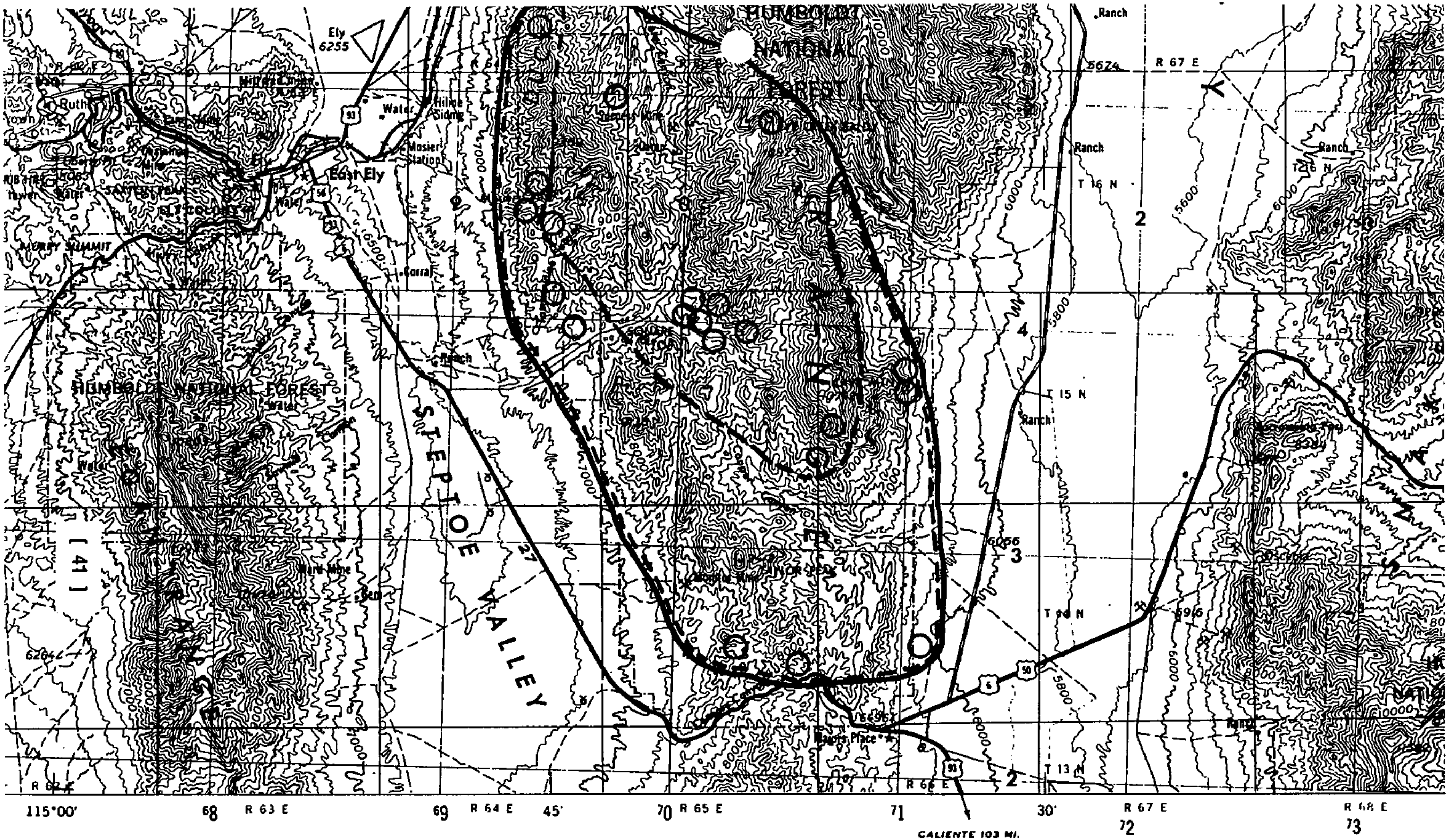


FIGURE 20 Home Range of Female No. 82, Schell Creek Range. (130 mi^2)

○ Radio Locations

( ) Winter Range

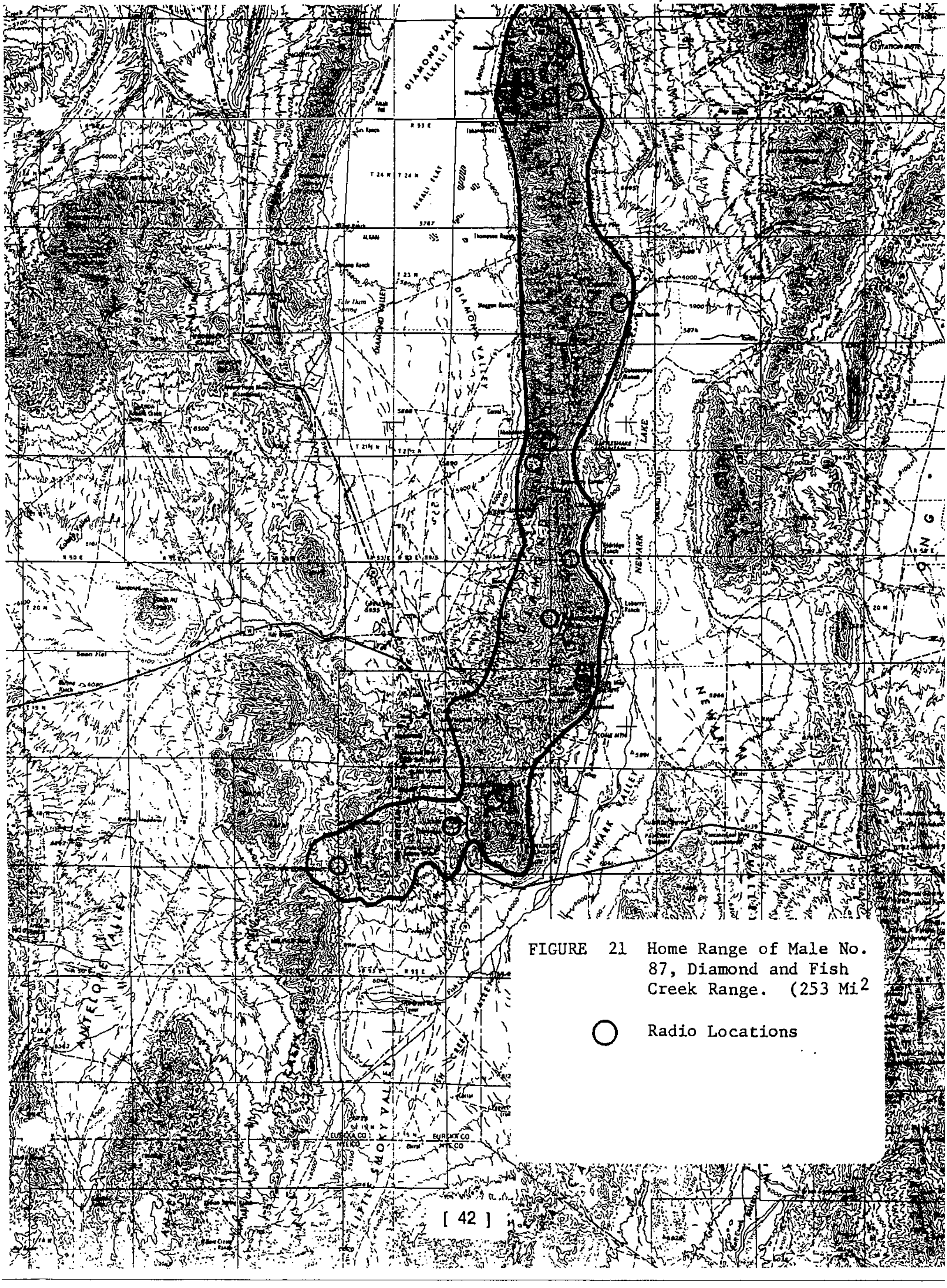


FIGURE 21 Home Range of Male No. 87, Diamond and Fish Creek Range. (253 Mi^2

Radio Locations

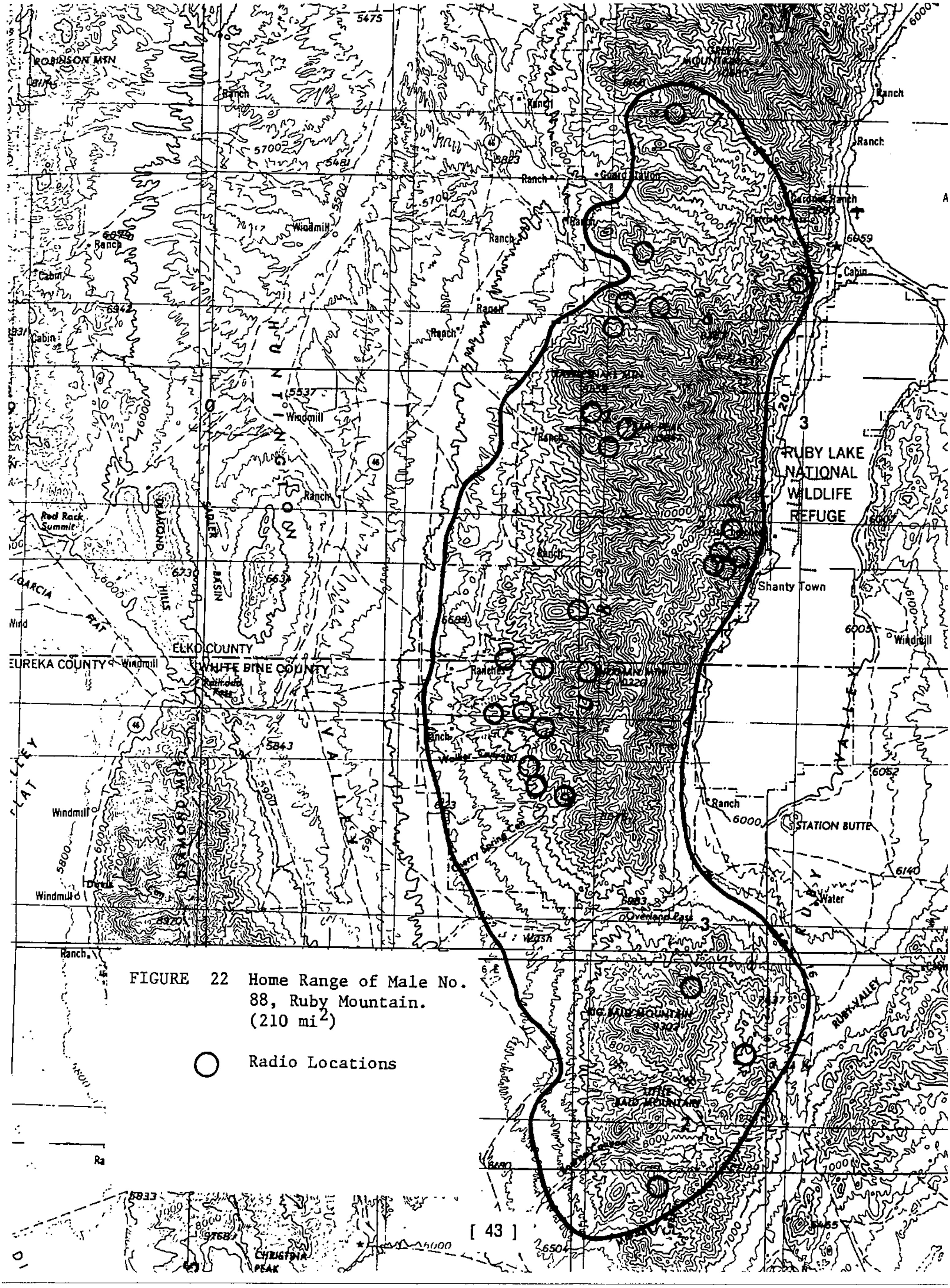


FIGURE 22 Home Range of Male No. 88, Ruby Mountain. (210 mi^2)

○ Radio Locations

TABLE 8. NUMBER OF RECORDED LOCATIONS AND HOME RANGE SIZE OF 13 ADULT MOUNTAIN LIONS IN NEVADA, 1972-82.

Lion No.	Sex	Initial Age	Mountain Range	No. of Radio Locations	Home Range Size (mi^2)	Period Covered
8	F	3 yr.	Ruby	54	81	1/73-1/75
36	F	13 mo.	Ruby	116	57	3/78-2/82
50	M	10 yr.	Monitor-Antelope	36	193	1/78-8/80
57	M	6 yr.	Monitor-Hot Creek	16	265	2/78-8/79
58	M	3 yr.	Ruby	43	207	3/78-7/79
67	M	2 yr.	White Pine	27	217	1/79-12/81
75	F	9 mo.	Ruby	62	34	5/79-12/81
76	F	9 mo.	Ruby	46	37	5/79-9/81
79	M	6 yr.	Schell Creek	21	225	1/80-12/81
80	F	9 yr.	Monitor	21	78	1/80-12/81
82	F	3 yr.	Schell Creek	21	130	2/80-12/81
87	M	10 yr.	Diamond-Fish Creek	17	253	5/80-6/82
88	M	6 yr.	Ruby	28	210	4/80-7/81

TABLE 9. ANALYSIS OF 14 MOUNTAIN LION STOMACHS COLLECTED IN EASTERN NEVADA.

Food Item	Number of Stomachs	Percent Occurrence	Percent Volume
Mule Deer	9	64.3	52.0
Porcupine	4	28.5	18.8
Domestic Sheep	2	14.3	15.5
Jackrabbit	1	7.1	2.3
Bobcat	1	7.1	3.8
Mountain Lion	1	7.1	3.8
Coyote	1	7.1	3.8
			100.0

Mortalities

Livestock Depredations — Since 1916 the U.S. Fish and Wildlife Service has attempted to control mountain lion populations in those states where livestock depredations were considered a problem. The Service still maintains this posture in Nevada, although they recognize that mountain lions are resident wildlife, classified as game animals, and that the State has authority for overall management of the species. However, the Service, under the terms of a cooperative agreement, has the authority for control of mountain lion depredations. This agreement states that mountain lions may be taken:

1. When they are causing or are about to cause damage to personal property. This will be coordinated with the respective State wildlife agency on a case-by-case basis; or

2. During nongrazing seasons in specific geographical areas where they have been causing damage and could not be captured during the depredation season and continuing damage is expected during the ensuing grazing season. This post-grazing season corrective control on mountain lions may be done after consultation with and concurrence of the respective State wildlife agency on a case-by-case basis; or

3. Under preventive control measures in a historically, serious, documented depredation area. Preventive control may be authorized by the Area Manager when previous steps have failed and after consultation with and concurrence of the State wildlife agency.

As a compliment to this cooperative agreement, and also as a guide for the Department, the Nevada Department of Wildlife Board of Commissioners has adopted Commission Policy No. 14 which relates to Animal Damage Control. This policy is attached in Appendix A.

SHEEP - In Nevada, mountain lion depredations upon domestic sheep has always been a controversial issue. Since domestic sheep summer use areas often coincide with occupied mountain lion habitat most depredations occur during this time. After the lambs are sold in the fall the adult and replacement ewes are usually trucked or trailed to winter ranges. Some bands of sheep in eastern Nevada are trailed as far as 400 miles (round trip) to and from winter and summer ranges. The winter sheep bands are not normally preyed upon by mountain lions to any significant degree. However, if sheep are allowed to move into tree cover or near rock outcrops, depredations are likely to occur.

The pregnant ewes are trailed or transported from the winter ranges to lambing grounds which are used during the spring months until higher elevations are free of snow and the forage has made its initial growth. These staging areas are located on public (B.L.M.) or occasionally private lands. Lion depredations on lambing grounds, although not normally as severe as on summer ranges, do occur on occasion.

Fifteen lambs killed by a mountain lion overnight.
The carcasses were gathered together to take the photo.

Although the number of sheep grazed in Nevada 20 or 30 years ago is not accurately known, it has been estimated that there were 3 to 4 times as many then as today. As recently as 1978 there was an estimated 80,000-90,000 adult sheep utilizing summer ranges in eastern Nevada. Total numbers, including lambs, were approximately 160,000-180,000 head. Since 1980 the summer ranges in eastern and central Nevada have been stocked with approximately 130,000-150,000 head of sheep (adults and lambs) per year. Table 10 lists the mountain ranges (or geographic areas) in these summer ranges and also depicts the number of domestic sheep and estimated lion populations for each area. Assuming these estimates are reasonable there is a ratio of one lion for each 1,346 sheep on these summer ranges.

The confirmed sheep losses to lions in eastern and central Nevada for the years 1978-81 are as follows:

YEAR	MINIMUM NUMBER SHEEP LOST	APPROXIMATE DOLLAR VALUE
1978	230	$16,100
1979	231	14,300
1980	380	28,700
1981	234	16,600

In some cases unconfirmed kills (those reported by herders but not verified) occurred in addition to the confirmed losses. However, these losses are believed to be less than 20% of the confirmed losses. Even if the number of sheep killed by lions was double the confirmed loss the percentage would be small compared to the total number of sheep grazed. For example, in 1982 (Table 10) an estimated 140,000 sheep were grazed in eastern and part of central Nevada. If lions killed 500 sheep the loss would amount to only 0.35% of the total number grazed. Even though total losses are not significant to the livestock industry as a whole, impacts to an individual operator are, at times, quite significant. For example, in 1978 one operator in the Ruby Mountains lost sheep valued at $6,100 during a 3-month period and another operator, in the Schell Creek Range, sustained losses of $8,000 during the same year.

CATTLE AND HORSES - For some unexplained reason cattle are not preyed upon by lions in Nevada to a significant degree. Both lions and cattle use the same areas during the summer months. Cattle are as available or even more so than are domestic sheep. The basic difference between cattle and sheep operations is the sheep are herded in large dense groups while cattle are allowed to roam individually within an allotted area. Cattle can become somewhat concentrated at times when they must congregate around a water supply or along a stream where succulent vegetation is available. The large size of cattle may preclude some attacks by lions but calves usually weigh less than 400 pounds and can easily be killed by an adult lion. Counts which are made when cattle are turned out in the spring and again when rounded up in the fall show losses from all causes are small. This indicates that lion depredations on cattle in Nevada is probably not significant in most areas.

Occasionally there are reports of lions attacking, injuring or killing domestic horses. Since most horses are kept within the confines of a corral or fenced pasture and away from lion habitat, depredations are infrequent.

TABLE 10. SUMMER USE AREAS FOR DOMESTIC SHEEP, AND MOUNTAIN LION POPULATION ESTIMATES IN EASTERN AND CENTRAL NEVADA, 1982.

Mountain Range	Number of Domestic Sheep[1]	Estimated Number of Adult Lions Present[2]
Jarbidge, Copper Basin, Tennessee Mountain	25,000	14
Independence, Bull Run	17,000	9
Stag Mountain	1,000	0
Ruby Mountains	22,000	20
Simpson Park	4,000	7
Roberts Mountain	10,000	4
Diamond Mountains	6,000	7
Butte Mountains	6,000	3
Cherry Creek	6,000	7
North Egan-Ward Mountain	12,000	10
North Schell Creek	22,000	12
Antelope	1,000	2
Kern Mountain	4,000	3
Snake (White Pine County)	4,000	6
TOTALS	140,000	104

[1] In most cases the number of sheep includes lambs, calculated at 1 lamb per each adult ewe. Some bands, e.g., Stag Mountain, are dry ewes.

[2] See population section for information on arriving at lion population estimates.

Depredation Harvest Reports

The U.S. Fish and Wildlife Service first began keeping records of the number of lions taken by government trappers and hunters in 1917 (Table 11). The sex of lions killed was recorded for the years 1917-1956 and again from 1969-1981. More males (527) were taken than females (438) with a ratio of 100 F : 120 M. During 1917-1968 many lions were removed in anticipation of future problems and the lion hunters were particularly active from 1956 through 1961. This preventative treatment resulted in lions being killed that were not responsible for depredations. In recent years (1969-1981) most of the lions which were harvested were known to be killing sheep and this was confirmed by examination of stomach contents.

Lion Mortalities in Eastern Nevada

The highest deer populations, the greatest number of lions, and the heaviest use of lion habitat by domestic sheep all center in eastern Nevada. Furthermore, eastern Nevada has historically been one of the better lion sport hunting areas and, consequently, became a favorite area of guides and their clientele. It is no wonder then that most conflicts revolving around the mountain lion occur in this portion of the state.

In analyzing data from the Ruby Mountains, the Cherry Creek-Egan area, and the Schell Creek Range, all of which have a long history of domestic sheep depredations, it was found that there were 146 documented lion mortalities during the period of 1972-81 (Table 12). Of this number 61 (41.8%) were directly associated with domestic sheep depredations.

From 1969-1982, when both sport hunting and depredation harvest have been recorded, there has been 645 lions killed for sport and 272 for depredations statewide (Table 13). The depredating lion harvest of less than 30% clearly shows that on a statewide basis the sheep depredation problem is not nearly as serious as in the study area and again demonstrates the conflict that arises from placing sheep in lion country. Over a similar period of time (1972-82) depredating lions comprised 54% of the mortality recorded from the 97 lions which were marked for this study (Table 14). So once again it becomes apparent that lions and sheep do not mix well. However, an important point to recognize is that the reverse side of the coin shows that there are many lions in the State that are not involved in depredations and that the present agreement between the Department of Wildlife and the U.S. Fish and Wildlife Service concerning livestock depredations, and restricting lion kills to the offending animal, is a great advancement in proper lion management.

Sport Harvest

The lion's classification was changed by regulation from unprotected (predator) to game animal in 1965. The initial impact of this classification was the requirement of a valid hunting license to hunt mountain lion and some restriction in the method of taking. This provision precluded the taking of lions at any time other than from sunrise to sunset and also defined legal weapons as shotgun, rifle, or bow and arrow. The season was defined as either sex, year-round and no limit was set nor was a tag required.

TABLE 11. U.S. FISH AND WILDLIFE SERVICE MOUNTAIN LION REMOVAL IN NEVADA, 1917-81.

Fiscal Year	Female	Male	Sex Unknown	Total
1917	5	3	--	8
1918	2	3	--	5
1919	3	3	--	6
1920	1	1	--	2
1921	1	2	--	3
1922	2	0	--	2
1923	0	0	--	0
1924	0	3	--	3
1925	1	3	--	4
1926	1	0	--	1
1927	1	1	--	2
1928	2	3	--	5
1929	3	0	--	3
1930	1	1	--	2
1931	2	2	--	4
1932	0	0	--	0
1933	2	0	--	2
1934	0	0	--	0
1935	0	0	--	0
1936	0	0	--	0
1937	0	0	--	0
1938	2	1	--	3
1939	6	2	--	8
1940	3	7	--	10
1941	1	4	--	5
1942	3	7	--	10
1943	3	1	--	4
1944	1	2	--	3
1945	1	0	--	1
1946	3	3	--	6
1947	0	2	--	2
1948	3	2	--	5
1949	2	3	--	5
1950	23	31	--	54
1951	33	44	--	77
1952	27	31	--	58
1953	30	36	--	66
1954	38	43	--	81
1955	52	40	--	92
1956	75	80	--	155
1957	--	--	116	116
1958	--	--	181	181
1959	--	--	108	108
1960	--	--	133	133

TABLE 11. U.S. FISH AND WILDLIFE SERVICE MOUNTAIN LION REMOVAL IN NEVADA, 1917-81. (cont.)

Fiscal Year	Female	Male	Sex Unknown	Total
1961	--	--	116	116
1962	--	--	69	69
1963	--	--	87	87
1964	--	--	97	97
1965	--	--	99	99
1966	--	--	50	50
1967	--	--	51	51
1968	--	--	70	70
1969	19	28	28	61
1970	9	11	26	46
1971	10	8	2	20
1972	5	8	1	14
1973	7	4	0	11
1974	4	8	0	12
1975	10	10	0	20
1976	5	14	0	19
1977	7	10	1	18
1978	7	17	0	24
1979	8	16	0	24
1980	11	12	0	23
1981	3	17	0	20
TOTALS	438	527	1,221	2,186

TABLE 12. LION MORTALITIES FROM 3 MOUNTAIN RANGES IN EASTERN NEVADA CONTAINING DOMESTIC SHEEP, 1972-81.

Mountain Range	No. Sheep Killed[1]	Avg. Kill/ Incident	No. Lions Removed on Depredations			No. Lions Removed by Hunters & Others		
			F	M	Total	F	M	Total
Ruby Mountains	205	10.25	8	12	20	8	16	24
Cherry Creek-Egan Range	294	9.19	10	22	32	10	11	21
Schell Creek	305	9.84	1	8	9	19	21	40
TOTALS	804	9.76	19	42	61	37	48	85

[1]Number of sheep killed includes only those sheep found and confirmed by District Field Assistants (trappers) or lion hunters.

TABLE 13. STATEWIDE SPORT AND DEPREDATION HARVEST FY 1970 THROUGH 1982.

Year	Tags	Sport Harvest	Depredation Harvest	Total Harvest
1969-70	436	42	47	89
1970-71	377	55	20	75
1971-72	259	43	20	63
1972-73	363	76	14	90
1973-74	428	91	11	102
1974-75	327	87	12	99
1975-76	261	54	20	74
1976-77	106	10	19	29
1977-78	145	22	18	40
1978-79	181	26	24	50
1979-80	272	33	24	57
1980-81	374	39	23	62
1981-82	459	67	20	89
		645 (70.4%)	272 (29.6%)	917

TABLE 14. CAUSE OF 48 MORTALITIES FROM A MARKED SAMPLE OF 97 MOUNTAIN LIONS IN NEVADA, 1972-82.

Cause of Mortality	Sex M	Sex F	Total	% of Total
Sport Hunting	10	3	13	27.1
Depredation (sheep)	22	4	26	54.2
Study Related	2	2	4	8.3
Natural	4	1	5	10.4
TOTAL	38	10	48	100.0

In 1968, a tag requirement was imposed, and although no limits were established, it became possible to record sport hunter harvest. A major change occurred in 1970 when a limit of one lion per person was set and a six month season established. During this period, the requirement that all harvested lions be validated by a representative of the Department of Wildlife within five days after the kill was also established. This regulation presented the Department the first real opportunity to collect biological data.

In 1976, twenty-six mountain lion management areas were described statewide and a harvest quota established for each to control the sport harvest. This Controlled Quota Hunt was the most restrictive season ever established for mountain lion in Nevada.

In 1979, the Controlled Quota Hunt was modified for six of the management areas, whereby a kill objective was established which allowed the hunting of lions in the area assigned until the predetermined harvest objective was reached. In 1981 this Harvest Objective hunting season concept was applied to all 26 management areas.

Sportsman participation in lion hunting has fluctuated considerably through the decade of the 1970's as a result of the many and varied season frameworks and regulations. Despite the increase in human population the sport harvest of mountain lion has not increased during the past 10 years. The sales of resident lion tags have never exceeded 500 and averaged 275 over the 1968-81 period. The resource is presently meeting the demand for sport harvest. Table 15 presents the sport harvest data from the years 1969-70 and

Sport Harvest of Mountain Lion Is Almost Exclusively Accomplished with the Aid of Trained Hounds.

TABLE 15. MOUNTAIN LION - TAG SALES, HARVEST AND HUNTER SUCCESS.

	TAG SALES			HARVEST*			HUNTER SUCCESS %		
Year	Resident	Non-Res	Total	Resident	Non-Res	Total	Resident	Non-Res	Total
1969-70	414	22	436	30	12	42	7.2	54.5	9.6
1970-71	341	36	377	37	18	55	10.9	50.0	14.6
1971-72	220	39	259	29	14	43	13.2	35.9	16.6
1972-73	289	74	363	40	36	76	13.8	48.6	20.9
1973-74	314	114	428	52	39	91	16.6	34.2	21.3
1974-75	281	46	327	57	30	87	20.3	65.2	26.6
1975-76	221	40	261	37	17	54	16.7	42.5	20.7
1976-77	98	8	106	18	2	10	8.2	25.0	9.4
1977-78	129	16	145	16	6	22	12.4	37.5	15.2
1978-79	146	36	181	18	8	26	12.3	21.0	14.1
1979-80	225	47	272	20	13	33	9.0	27.6	12.2
1980-81	313	61	374	25	14	39	7.9	22.9	10.4
1981-82	421	38	459	44	23	67	10.4	60.5	14.6

*Sport Hunter Harvest Only

1981-82. A summary of the sport hunting seasons and regulations in Nevada since the lion was classified as a game animal in 1965 is presented in Appendix B.

Population Estimates

The mountain lion is a low density predator of secretive nature whose traits make it very difficult to monitor. Several methods were used to estimate mountain lion populations and after experimenting with a number of census techniques it was determined that there were three methods which, depending on local circumstances, were best suited for use in Nevada. These were: 1) Analysis of harvest data, 2) Track counts, and 3) Home range size.

Harvest Data -- The annual harvest can reflect the population level and the analysis of historical and current harvest data provides a base which can be used in making judgements concerning population trends. Hunter success measures the ease with which the sport hunter obtains his quarry and, barring unusual circumstances which must be taken into account, will reflect availability.

In examining both sport harvest and depredation harvest records from the time that they were both recorded statewide (1969-70 through 1981-82) it is obvious that the harvest rate has never been high (Table 13). The greatest influence on the sport harvest appears to have been the initiation of the hunter quota system in 1976-77. This resulted in over a 50% decrease in harvest when comparing the 7 years prior to the quota system and the 6 years following it. However, as hunters are becoming adjusted to the system, and refinements have been made to encourage them into the quota areas, the harvest is again climbing to what appears to be normal levels. Depredations harvest, for the most part, has remained relatively constant (Statewide) with a seven year harvest average of 20 lions annually before the hunter quota system and a six year average of 21 lions annually following the quota system. On an overall basis the statewide lion population trend between 1969-82 appears to be stable.

Track Counts -- Two track count methods have been used: ground surveys and aerial surveys. The ground surveys were begun 3-6 days after a fresh snowfall and were made on foot, with snowmobiles, or by driving roads with pick-up trucks. Each track was classified, if possible, as to sex and estimated age using criteria similar to that recently described by Shaw (1979). The ground count required sampling a large area in a short time frame in order to provide a representative sample. Due to man-time commitments annual ground count surveys are not possible to implement on a statewide basis.

Aerial surveys were done with a helicopter and in a manner similar to the ground surveys except that nearly every drainage in a predetermined geographic area was flown. Each drainage was flown twice, once following the bottom and again following the south exposures where lions were most likely to be found during the winter months. Once a track was sighted the helicopter was landed or hovered over the track while one observer disembarked and the track was classified and recorded. All helicopter surveys were completed in 2 days or less so accuracy could be maintained. Snow, air and light conditions had to be optimum in order to observe tracks, land, and record data. This is the preferred method and was utilized in the major mountain lion areas during the later years of the study. Since the termination of the study this method has not been used because of the high cost.

Home Range -- It was found in eastern Nevada that adult female lions had an average home range of 69.5 square miles and males 224 square miles. However, it was also noted that the home range size for individual lions varies considerably from one mountain range to another. It was recognized that the data available on home range sizes was not as comprehensive as desired; however, it was the most accurate data available for use in computing lion densities.

Mountain Lion Population Estimates by Mountain Range -- When the Harvest Quota system was implemented in 1976 (this was a Department of Wildlife recommendation to resolve controversies over lion management between protectionists, depredation harvest proponents, and sport harvest proponents) it was necessary to define mountain lion management areas, estimate the number of lions (all age classes) in each, and set a harvest quota which would not exceed the annual recruitment to the population.

It was found that track count information was simply too limited in nature to provide a statewide approach toward determining lion populations. However, long-term harvest data did provide a general idea as to the lion population status on a statewide basis. In utilizing this information, as well as the available deer density data, Regional personnel were able to form opinions as to the general quality of the lion habitat in their areas of concern. These judgements and data were then coupled with the basic lion home range parameters from the study area and utilized to formulate lion density factors for the inhabited mountain ranges in Nevada (Table 16). Field personnel then computed the square miles of occupied habitat (based on long-term distribution records) and with this information in hand they then calculated the estimated lion populations. Population estimates have been made since 1976 and in carrying these forward to 1982 it has been computed that 792 mountain lions occupy 27,811 square miles in 104 mountain ranges in Nevada (Table 16).

Harvest Quota Calculations -- The Department of Wildlife's mountain lion harvest objective is to harvest the number of lions which can safely be removed by both depredation and sport hunting and still maintain a viable breeding population (sustained yield). The estimated annual recruitment for lion populations in Nevada is believed to be about 30% (see Population Turnover). Therefore, a harvest objective for 1982 would be 0.3 x 792 (estimated lion population) = 237 lions. However, this objective was tempered on the conservative side by using a factor of 0.25 rather than 0.3 and instead of using the population estimate of 792 lions the number 550 (which represented the estimated lion population in areas opened to hunting) was used. This resulted in a harvest quota of .25 x 550 = 138 lions. Some local adjustment was made to this quota by area biologists and the final quota for 1982 was 135 lions.

This system of arriving at a harvest quota clearly denotes the maximum number of lions which could be harvested. It then reflects a conservative attitude by slightly reducing the recruitment factor for making computations, and it makes allowances for areas of concern by individual biologists who can request further reasonable reductions or increases.

TABLE 16. MOUNTAIN LION POPULATION ESTIMATES BY MANAGEMENT AREA AND MOUNTAIN RANGE IN NEVADA, 1982.

Management Area	Mountain Range	Estimated Miles² Occupied Habitat	Density Ratio:[1] 1 Lion per Mi² of Habitat	Average No. of Lions Present[2]
1	Buffalo Hills	128	1/40	3
	Fox Mountain	104	1/40	3
	Granite	155	1/40	4
	Hays Canyon	426	1/40	10
	Subtotal	813		20
2	Virginia	-	-	0
	Fox	-	-	0
	Peavine	-	-	0
3	Sheldon Refuge	121	1/40	3
	Blackrock-Pine Forest	558	1/40	14
	Jackson	215	1/40	4
	Subtotal	894		21
4	Humboldt	369	1/40	9
	Sonoma	178	1/40	4
	Tobin	139	1/40	3
	Subtotal	686		16
5	Santa Rosa	578	1/25	23
6	Independence-Bull Run	712	1/40	18
	Tuscarora	378	1/40	9
	Subtotal	1,090		27
7	Bear Mountain - L & D	180	1/40	5
	Jarbidge	464	1/25	19
	Merritt-Mahoganies-Tennessee Mountain	378	1/40	9
	Snake	265	1/40	7
	Granites	216	1/40	5
	Pequop	441	1/40	11
	Pilot	48	1/40	1
	Toana	487	1/40	12
	Subtotal	2,479		69
8	Goose Creek-Delano	495	1/40	12

[1] High Density = 1 lion/25 mi^2, low-moderate density = 1 lion/40 mi^2 of occupied habitat.

[2] No. of lions present includes all age classes with 60% as adults and subadults and 40% as kittens still with their mothers. Estimates are for yearlong or summer ranges.

TABLE 16. MOUNTAIN LION POPULATION ESTIMATES BY MANAGEMENT AREA AND MOUNTAIN RANGE IN NEVADA, 1982. (cont.)

Management Area	Mountain Range	Estimated Miles^2 Occupied Habitat	Density Ratio:[1] 1 Lion per Mi^2 of Habitat	Average No. of Lions Present[2]
10	Buck & Bald	234	1/40	6
	Maverick-Medicine	218	1/40	5
	Ruby	850	1/25	34
	Dolly Varden	50	1/40	1
	Wood Hills	87	1/40	2
	Butte	219	1/40	5
	Subtotal	1,658		53
11	Kern	156	1/40	4
	Moriah	255	1/25	10
	Schell Creek-Antelope	672	1/40	27
	Snake	302	1/25	12
	Subtotal	1,385		53
12	Cherry Creek-Egan	594	1/25	24
13	Timpahute	305	1/40	8
	Grant-Quinn	618	1/40	15
	Seaman	106	1/40	3
	White Pine-Horse	614	1/40	15
	Worthington	27	1/40	1
	Subtotal	1,670		42
14	Cortez	234	1/40	6
	Diamond	359	1/40	9
	Roberts Mountain	210	1/25	8
	Fish Creek	207	1/40	5
	Subtotal	1,010		28
15	Shoshone	268	1/40	7
	Simpson Park	337	1/40	8
	Sulfur Springs	296	1/40	7
	Toiyabe	396	1/40	10
	Battle Mountains	77	1/40	2
	Fish Creek-Augusta	209	1/40	5
	Subtotal	1,583		39
16	Toquima	553	1/40	14
	Monitor-Hot Creek-Antelope	1,812	1/25	72
	Pancake	133	1/40	3
	Subtotal	2,498		89

[1]High Density = 1 lion/25 mi^2, low-moderate density = 1 lion/40 mi^2 of occupied habitat.

[2]No. of lions present includes all age classes with 60% as adults and subadults and 40% as kittens still with their mothers. Estimates are for yearlong or summer ranges.

TABLE 16. MOUNTAIN LION POPULATION ESTIMATES BY MANAGEMENT AREA AND MOUNTAIN RANGE IN NEVADA, 1982. (cont.)

Management Area	Mountain Range	Estimated Miles^2 Occupied Habitat	Density Ratio:[1] 1 Lion per Mi^2 of Habitat	Average No. of Lions Present[2]
17	Paradise	210	1/40	5
	Toiyabe-Shoshone	977	1/25	39
	Subtotal	1,187		44
18	Clan Alpine	392	1/40	10
	Desatoya	346	1/40	9
	Stillwater-East Range	325	1/40	8
	Subtotal	1,063		27
19	Carson-Peavine	266	1/40	7
	Virginia	161	1/40	4
	Subtotal	427		11
20	Wellington-Pine G.-Sweetwater	279	1/40	7
	Wassuk	468	1/40	12
	Excelsior-Anchorite	298	1/40	7
	Pilot Peak	91	1/40	2
	Subtotal	1,136		28
21	Monte Cristo	152	1/40	4
	Silver Peak-Montez	354	1/40	9
	Magruder-Sylvania	230	1/40	6
	White Mountains	149	1/40	4
	Subtotal	885		23
22	Egan	950	1/40	24
	Schell Creek	448	1/40	11
	Fairview-Bristol	187	1/40	5
	Highland Peak	111	1/40	3
	Subtotal	1,696		43
23	Fortification	129	1/40	3
	Wilson-White Rock	679	1/40	17
	Subtotal	808		20
24	Delamar	336	1/40	8
	Clover-Cedar	650	1/40	16
	Pahroc	97	1/40	2
	Subtotal	1,083		26

[1]High Density = 1 lion/25 mi^2, low-moderate density = 1 lion/40 mi^2 of occupied habitat.

[2]No. of lions present includes all age classes with 60% as adults and subadults and 40% as kittens still with their mothers. Estimates are for yearlong or summer ranges.

TABLE 16. MOUNTAIN LION POPULATION ESTIMATES BY MANAGEMENT AREA AND MOUNTAIN RANGE IN NEVADA, 1982. (cont.)

Management Area	Mountain Range	Estimated Miles² Occupied Habitat	Density Ratio: 1 Lion per Mi² of Habitat	Average No. of Lions Present[2]
25	Armagosa	20	1/40	1
	Reveille	56	1/40	1
	Stonewall	30	1/40	1
	Sheep Range	295	1/40	7
	Groom Range	63	1/40	2
	Kawich	227	1/40	6
	Belted-Paiute Mesa	342	1/40	9
	Subtotal	1,033		27
26	Spring Range	518	1/40	13
27	Virgin	47	1/40	1
	Morman	67	1/40	2
	Subtotal	114		3
29	Pine Nut	428	1/40	11
	GRAND TOTAL	27,811		792

[1]High Density = 1 lion/25 mi^2, low-moderate density = 1 lion/40 mi^2 of occupied habitat.

[2]No. of lions present includes all age classes with 60% as adults and subadults and 40% as kittens still with their mothers. Estimates are for yearlong or summer ranges.

Goals

Goal: Maintain Nevada's mountain lion populations.

1. Problem: Changing and differing public attitudes about the mountain lion's worth and role in the ecosystem make it a difficult species to manage.

   a. Strategy: Continue to closely monitor lion populations and the affects of sport hunting, and depredation removal. Maintain comsumptive use levels consistent with the lion's ability to sustain that use.

2. Problem: Lion depredations on livestock and wildlife represents an ongoing problem.

   a. Strategy: Continue a cooperative agreement with the U.S. Fish and Wildlife Service and insure that only offending depredating lions are removed.

   b. Strategy: Where mountain lion depredations are found to be responsible for suppressing the segment of a wildlife population at or below the "threshold" level the mountain lion population involved may be reduced temporarily to allow the suppressed wildlife prey population to increase thereby ultimately resulting in a potential increase in the mountain lion population due to the larger prey base.

3. Problem: Human-lion conflicts can be anticipated in the future with continuing urban growth.

   a. Strategy: Develop a program to rapidly and safely handle lion complaints in urban areas.

RECOMMENDATIONS

There are several areas where further study could provide answers and direction for mountain lion management in Nevada. Some of these are:

1. More refined population estimates are needed, especially for low to moderate lion densities.

2. Additional investigations should be made in regard to home range overlap.

3. Lion population turnover should be determined more precisely for both exploited and unexploited populations.

4. Additional data is needed on the effects of lion predation on deer. This was an area that was not adequately investigated during this study. Do lions, in fact, exert control over low-moderate density deer populations?

5. Lion aging techniques should be pursued with an effort to obtain adequate information to supplement and validate the keys presented in this publication.

6. It is felt that lion density ratios should be modified slightly in order to provide more latitude for the field biologist when developing his lion harvest quota recommendations. The following changes are recommended:

   1/25 should be changed to 1/20-30
   1/40 should be changed to 1/31-45

7. It is apparent to the editor that there were many lost opportunities during the conduct of this study. The plan for achieving the study objectives and the monitoring system for seeing that the annual work program was accomplished, even though in place, was not adhered to. Consequently the researcher often strayed from the study plan and at times data was not collected or was recorded incorrectly. Such failings are not uncommon in Fish and Wildlife research where the dilution of manpower, because of pressing everyday needs, often results in insufficient supervision and/or monitoring. However, since Nevada is still faced with becoming even more involved with mountain lion research, past inadequacies should be recognized and every effort made to strengthen the supervision and monitoring of future studies.

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APPENDIX A

STATE OF NEVADA
BOARD OF WILDLIFE COMMISSIONERS

Commission Policy No. 14

Ammendment No. 1

Number: 14(1)

Title: Animal Damage Control

References: NRS 501.105, 501.110, 503.470, 503.595, 567.010 through 567.090, CGR No. 1(8) and CGR No. 4(2).

First Reading: March 13, 1981
Second Reading: April 17, 1981
Effective Date: April 17, 1981

PURPOSE

To inform the public and guide the Department of Wildlife in actions relating to animal damage contol.

In accordance with NRS 501.181, the Board of Wildlife Commissioners shall establish policies for the protection, propagation, restoration, transplanting, introduction and management of wildlife in this state. Further, the Commission shall establish policies for areas of interest including animal damage control.

POLICY

1. Major mammalian predators (coyote, mountain lion, bobcat) will be managed to minimize livestock losses from predation and minimize excessive wildlife losses from predation without endangering the existence or natural role of these predators in the ecosystem.

2. Nonpredatory wildlife will be managed to minimize their vulnerability to excessive predation. Animal damage extension efforts will be encouraged to assist private operators in husbandry practices to minimize the vulnerability of domestic livestock predation.

3. Support continued federal leadership in the Animal Damage Control program because of the national need for development and use of more efficient and humane control methods.

4. Recognize the U.S. Fish and Wildlife Service, Division of Animal Damage Control, as the authority for predator control under cooperative agreement with the Department of Wildlife, where the Department of Wildlife is an active participant in documenting the need for control programs, in planning and execution of control programs, and in enhancing public understanding of these programs.

The Department shall prepare an annual work program for predator control needed for the management of wildlife and recommend that a maximum of $20,000 annually be forwarded from the wildlife account in the state general fund to the state predatory animal and rodent committee for predatory animal control work as provided in Chapter 567 of NRS.

5. Initiate predator control efforts on the basis of the best biological information available.

6. Direct predator control efforts including sport hunting and trapping, whenever possible to prevent damage before it occurs in specific areas known to be recurring problem areas or alleviate damage as soon as possible after it occurs.

7. Direct predator control efforts at the offending animal, in so far as possible and feasible.

8. Employ predator control methods which are selected on the basis of the species involved, utilizing currently approved methods in the proper mix according to the needs. These methods may include aerial hunting, M-44, trapping, snares, denning and predacides.

   a. Predacides should only be used in certain preventative and corrective damage control operations using a delivery system which is selective, effective and efficient.

   b. Aerial hunting will be conducted only under Department of Wildlife damage control permit and limited to bobcats and coyotes. Such permits shall be issued only to the U.S. Fish and Wildlife Service or to landowners or tenants of land or property that is being damaged by wildlife.

9. The Department upon issuance of a depredation permit and with the aid and cooperation of the complainant, may take all available professional and economically feasible measures to alleviate or lesson the depredation problem.

PROCEDURE

NRS 503.595 provides that after the owner or tenant of any land or property has made a report to the Department indicating that such land or property is being damaged or destroyed, or is in danger of being damaged or destroyed, by wildlife, the Department may, after thorough investigation and pursuant to such regulations as the Commission may promulgate, cause such action to be taken as it may deem necessary, desirable and practical to prevent or alleviate such damage or threatened damage to such land or property.

The Commission has adopted regulations authorizing the Director or his designee to issue wildlife depredation permits. Specific permit programs include:

1. An annual wildlife depredation permit may be issued to the State Supervisor, U.S. Fish and Wildlife Service, Division of Animal Control, to take depredating mountain lion or bobcat in the immediate vicinity of threatened livestock.

    a. Any report of livestock depredation received by the Department of Wildlife shall be forwarded immediately to the permittee for action in accordance with subsection (b) of this section.

    b. Upon receipt of a report from a livestock owner or the Department indicating that a mountain lion or bobcat is causing or about to cause damage to livestock, the permittee shall conduct an on-site investigation. If the results of the investigation support the complaint, the permittee may take the animal. If the permittee cannot determine if the complaint is valid, he shall notify a representative of the Department, who shall conduct a joint investigation to make the final determination.

    c. During November through April, the permittee shall slavage and give the hide and skull of depredating mountain lion or bobcat to the Department within 72 hours. During May through October, the permittee shall completely destroy the animal, except the skull which shall be delivered to the Department.

2. An annual wildlife permit may be issued to State Supervisor, U.S. Fish and Wildlife Service, to take the minimum number of mountain lions, bobcats, foxes, cottontail rabbits, pigmy rabbits, white-tailed jack rabbits, bears and squirrels as necessary to control damage to persons and property.

3. Upon receipt of a valid mountain lion or bobcat complaint from an individual livestock owner, the Department may issue a limited permit to the owner to take an animal that is in the act of killing his livestock.

    a. The permittee shall notify a Department representative within 72 hours after taking a mountain lion and arrangements will be made for examining the skull and sealing the hide.

b. Mountain lion or bobcat hides, after being properly sealed, may be retained by the permittee to defray the cost of handling the depredation complaint.

4. The Department may issue permits authorizing the hunting or killing of coyotes or bobcats from an aircraft.

5. Fur-bearing animals injuring any property may be taken or killed at any time in any manner, provided a permit is first obtained from the Department. The Department is authorized to enter upon the lands of a landowner and remove beaver or otter for the relief of other landowners and the protection of the public welfare.

6. The Department may issue permits consistent with Federal law to take bald eagles or golden eagles whenever it determines that they have become seriously injurious to wildlife or agriculture or other interests that the injury can only be abated by taking some of the offending birds.

7. The State Predatory Animal and Rodent Committee shall enter into agreements with the U.S. Fish and Wildlife Service covering cooperative control of crop-destroying birds in addition to predatory animals and rodents to assure maximum protection against losses of livestock, poultry, game birds, animals and crops on a statewide basis. The State Department of Agriculture in accordance with NRS 555.010 and 555.021 responds to complaints involving vertebrate pests (excluding predators) that are injurious to agriculture or public health.

8. The Department may issue a wildlife depredation permit to a landowner if needed for the prevention or alleviation of damage to standing or stored agricultural crops.

This policy shall remain in effect until amended, repealed or superseded by the Board of Wildlife Commissioners.

BY ORDER OF THE BOARD OF WILDLIFE COMMISSIONERS IN REGULAR SESSION, APRIL 17, 1981.

Marvin A. Einerwold, Chairman
Board of Wildlife Commissioners

APPENDIX B

MOUNTAIN LION HUNTING SEASONS 1965-1982

1965-1966

Type of Season: Either sex, statewide.
Season Length: Open year-round.
Limit or Quota: None.
License and Tag Requirement: Hunting license only.
Special Regulations: Unlawful to hunt with revolver or by use of artificial light.

1967

Type of Season: Either sex, statewide.
Season Length: Open year-round.
Limit or Quota: None.
License and Tag Requirement: Hunting license only.
Special Regulations:

1. Unlawful to use a revolver.
2. Unlawful to use artificial light.
3. Unlawful to trap lions.

1968

Type of Season: Either sex, statewide.
Season Length: Open year-round.
Limit or Quota: None.
License and Tag Requirements: Hunting license and tag.
Special Regulations:

1. Unlawful to use revolver.
2. Unlawful to use artificial light.
3. Livestock operator can take lions with proper permit.

1969

Type of Season: Either sex, statewide.
Season Length: Open year-round.
Limit or Quota: None.
License and Tag Requirement: Hunting license and tag.
Special Regulations:

1. May be hunted anytime day or night.
2. Lawful to use any weapon except crossbow.
3. Livestock operator can take depredating lions at any time.

1970

Type of Season: Either sex, statewide.
Season Length: October 10, 1970 - March 31, 1971 (171 days).
Limit or Quota: 1 per person.
License and Tag Requirement: Hunting license and tag.
Special Regulations:

1. Mandatory check-in of lion hide, skull and stomach contents within 5 days of harvest.
2. Hide must be sealed by a Department representative within 5 days of harvest.
3. Lions may be hunted anytime day or night.
4. Lawful to use any weapon except crossbow.
5. Livestock operator can take depredating lions at any time after issuance of a permit.

1971-1975

Type of Season: Either sex, statewide.
Season Length: Open year-round (1974 & 1975, 6 month season).
Limit or Quota: 1 per person.
License and Tag Requirement: Hunting license and tag.
Special Regulations:

1. Mandatory check-in of lion hide and skull within 48 hours of harvest (1973, 72 hours of harvest).
2. Hide must be sealed by a Department representative within 48 hours of harvest.
3. Lions may be hunted anytime day or night.
4. Lawful to use any weapon except crossbow.
5. Livestock operator can take depredating lions at any time after issuance of a permit.

1976-1978

Type of Season: Either sex, statewide.
Season Length: 1976 - October 1, 1976 - March 31, 1977 (6 months).
1977,1978 - October 1, 1977 - April 30, 1978 (7 months).
Limit or Quota:

1. One lion per person.
2. Resident and nonresident quotas by management area and through application only.

License and Tag Requirement: Hunting license and tag.
Special Regulations:

1. Mandatory check-in of lion hide and skull within 72 hours of harvest.
2. Hide must be sealed within 72 hours of harvest.
3. Lions may be hunted any time day or night.
4. Lawful to use any weapon except crossbow.
5. Livestock operator can take depredating lions any time after issuance of a permit.
6. Accidentally trapped lions are the property of the State of Nevada and shall be reported within 48 hours of capture.

1979-1980

Type of Season: Either sex, statewide.
Season Length: October 1, 1979 - April 30, 1980 (7 months).
Limit or Quota:

1. One lion per person.
2. Resident and nonresident "Trophy General Hunt" with quotas by management area, application only.
3. Resident and nonresident "Controlled Trophy Hunt" with quotas (allowable harvest) by management, application only.

License and Tag Requirements: Hunting license and tag.
Special Regulations:

1. Any person holding a valid tag for lion in management area 7, 8, 9, 10, 19, 20 or 21 (1980) obtain a 15-day controlled hunt permit at no cost before hunting.
2. Permit will be valid in a specified management area for 15 days. Unsuccessful hunters may reapply for the same or another management area if the harvest quota has not been filled. Hunters holding a 15-day permit will be notified by the Department when the harvest quota is filled for that area. The hunter may then reapply for another open area.
3. Mandatory 72 hour check-in and hide sealing required.
4. Accidentally trapped lions are the property of the State of Nevada and shall be reported within 48 hours of capture.

1981

Type of Season: Either sex, statewide.
Season Length: October 1, 1981 - April 30, 1982 (7 months).
Limit or Quota:

1. One lion per person.
2. Unlimited tag quota by application only.
3. Harvest quota by management area.

License and Tag Requirement:

1. Hunting license and tag.
2. 15-day permit.

Special Regulations:

1. Hunting permit reservations may be made by mail, telephone or appearing in person at the designated Department offices.
2. Hunting permits will be valid in a specified management area for a period of 15 days from the date of issue. If a hunter fails to harvest a lion in the specified period and management area, he may reapply as many times as he desires for a permit to hunt in any of the open management areas as long as the harvest quotas remain unfilled.
3. When the harvest quota is filled in any of the management areas, either by sport hunting or by depredation harvest, that area will be closed to mountain lion hunting, and no further permits will be issued for that area. Hunters holding a valid permit for a management area at the time that the harvest quota is filled will be notified by the Department that the area is closed, and that their permit is no longer valid. Hunters may then reapply for any other management area where the harvest quota has not been filled.

4. Department representatives will retain final judgement on issuance of permits and distribution of hunters in order to preclude a harvest quota or the over-loading of hunters in any one management area.
5. Unless otherwise specified by regulation of the Commission or Title 45 of NRS, any resident of Nevada, nonresident or alien is eligible to apply once for a mountain lion tag in any year.
6. A person who harvests a mountain lion shall, within 72 hours after harvesting it, present the skull and hide to a representative of the Department of Wildlife for inspection. The representative shall affix the seal of the Department permanently to the hide. It is unlawful for any person to transport such a hide from this state without a seal permanently affixed to the hide.
7. Except as provided in subsection 2, it is unlawful to possess the hide of a mountain lion without a seal permanently attached to it.
8. If a mountain lion is accidentally trapped or killed, the person trapping or killing it shall report the trapping or killing within 48 hours to a representative of the Department of Wildlife. The animal must be disposed of in accordance with the instructions of the representative.

1982

Limit: One.
Sex/Age Class: Either sex.
Hunting Hours: Any time of the day or night.
Season Dates:
October 1, 1982 through September 30, 1983, except as provided in sections 5 and 6 of this regulation.
Tag Quota: Unlimited.
Harvest Quota:
The harvest quota is the allowable harvest for each listed management area. When the harvest quota has been filled in any management area that area will be closed to hunting.

Area	Objective	Area	Objective
1	0	14	6
2	0	15	5
3	3	16	6
4	5	17	3
5	3	18	9
6	6	19	6
7	8	20	10
8	13	21	6
9	7	22	3
10	8	23	3
11	6	24	3
12	6	25	3
13	5	26	2
Total			135

Special Regulations

1. There is no quota on the number of tags that will be issued for the mountain lion management areas.

2. Tags will be available to residents and nonresidents by application only.

3. Hunters who are awarded tags for this mountain lion hunt must secure a hunting permit before they can hunt under the authority of this tag in any single management area. A valid lion hunting permit and tag must be in possession while hunting mountain lion.

4. Hunting permits will be authorized by mail, telephone, or by appearing in person only at the following department offices:

   For Management Areas 3, 4, 12, 13, 14 and 15:
   Region I Office, 380 W. "B" Street, Fallon, Nevada 89406
   (702) 423-3171

   For Management Areas 5, 6, 7, 8, 9, 10, 11, 19 and 20:
   Region II Office, 1375 Mountain City Highway, Elko, Nevada 89801
   (702) 738-5332

   For Management Areas 16, 17, 18, 21, 22, 23, 24, 25 and 26:
   Region III Office, 4747 Vegas Drive, Las Vegas, Nevada 89109
   (702) 385-0285

5. Hunting permits will be valid in the specified management area until the harvest objective for that management area is reached, or the general season closure, whichever is first. Upon attainment of the harvest objective, the management area will be closed to lion hunting.

6. Hunters holding a valid permit for a management area at the time that the harvest objective is filled will be notified by the Department that the area is closed and that their permit is no longer valid. Hunters may then reapply for any other management area where the harvest objective has not been filled.

7. Department representatives in the Fallon, Elko and Las Vegas Offices will retain final judgement on issuance of permits and distribution of hunters.

8. A hunting permit may be invalidated by the Department and reissued for another mountain lion management area.

Research to Regulation: Cougar Social Behavior as a Guide for Management

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In My Opinion

Research to Regulation: Cougar Social Behavior as a Guide for Management

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ABSTRACT Cougar (*Puma concolor*) populations are a challenge to estimate because of low densities and the difficulty marking and monitoring individuals. As a result, their management is often based on imperfect data. Current strategies rely on a source–sink concept, which tends to result in spatially clumped harvest within management zones that are typically approximately 10,000 km^2. Agencies often implement quotas within these zones and designate management objectives to reduce or maintain cougar populations. We propose an approach for cougar management founded on their behavior and social organization, designed to maintain an older age structure that should promote population stability. To achieve these objectives, hunter harvest would be administered within zones approximately 1,000 km^2 in size to distribute harvest more evenly across the landscape. We also propose replacing the term "quota" with "harvest threshold" because quotas often connote a harvest target or goal rather than a threshold not to exceed. In Washington, USA, where the source–sink concept is implemented, research shows that high harvest rates may not accomplish the intended population reduction objectives due to immigration, resulting in an altered population age structure and social organization. We recommend a harvest strategy based on a population growth rate of 14% and a resident adult density of 1.7 cougars/100 km^2 that represent probable average values for western populations of cougars. Our proposal offers managers an opportunity to preserve behavioral and demographic attributes of cougar populations, provide recreational harvest, and accomplish a variety of management objectives. We believe this science-based approach to cougar management is easy to implement, incurs few if any added costs, satisfies agency and stakeholder interests, assures professional credibility, and may be applied throughout their range in western North America.

KEY WORDS cougar, harvest management, harvest quota, intrinsic growth rate, management zone, *Puma concolor*, regulation, social structure, source–sink, Washington.

The history of cougar (*Puma concolor*) management in Washington and for the western United States as a whole has been dominated by political and special interest agendas creating a challenge for wildlife managers (Kertson 2005, Beausoleil and Martorello 2008, Mattson and Clark 2010, Jenks 2011, Peek et al. 2012). This is magnified by the lack of reliable information on cougar population size, density, and outcomes of management strategies (Cougar Management Guidelines Working Group 2005). In recent decades, satellite and Global Positioning System telemetry and long-term field investigations in 6 different areas in Washington (Lambert et al. 2006; Robinson et al. 2008; Cooley et al. 2008, 2009*a*, *b*; Maletzke 2010; Kertson et al. 2011*a*, *b*; R. A. Beausoleil, unpublished data), and throughout the West (Logan and Sweanor 2001, Cougar Management Guidelines Working Group 2005, Stoner et al. 2006, Hornocker and Negri 2010, Robinson and DeSimone 2011) have elucidated cougar ecology, providing managers a new scientific basis to help guide management.

Behavior and social organization are important aspects of many species' biology and should be considered for management, particularly for low-density territorial carnivores occupying the apex of the trophic hierarchy (Wielgus and Bunnell 1994, Caro et al. 2009, Packer et al. 2009, Treves 2009, Estes et al. 2011). Maintaining mature cougars is important because they influence rates of immigration and emigration, spatial distribution, reproduction, and kitten survival (Cougar Management Guidelines Working Group 2005, Hornocker and Negri 2010; Cooley et al. 2009*a*, *b*).

We propose a science-based approach to regulated harvest management founded on cougar behavior and social organization, in which harvest is regulated to maintain an older age structure to promote population and social stability. This model for cougar management addresses concerns of various constituencies to 1) provide a sustainable harvest, 2) provide quality recreational experience to the hunting public, 3) maintain viable cougar populations, and 4) more explicitly

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recognize the values of the non-consumptive public by maintaining the behavioral integrity of cougar populations.

We base our recommendations on research from Washington demonstrating that a high harvest rate may not accomplish local population reductions and may result in altering the age structure and social organization of the population. This may have unplanned consequences for cougar–prey dynamics and cougar–human conflict (Knopff et al. 2010, White et al. 2011, Kertson et al. 2013). More than US$ 5 million and >13 years (1998–2011) have been invested in cougar research in Washington at 6 study sites across a diverse landscape (Fig. 1). We distill findings from these investigations and propose strategies to help managers navigate the myriad of agendas that encompass carnivore management for a more predictable management outcome, especially in the unpredictable atmosphere of politics and advocacy. Our objective for this review is to provide a data-driven management system that can be applied consistently among management units that incorporates both species behavior and human interests.

CURRENT COUGAR MANAGEMENT STRATEGIES

Management agencies throughout the west use a variety of strategies and techniques to regulate cougar harvest, including general-season hunts with no harvest limit or season restrictions, limiting the number of hunters through permits, and limiting harvest through quotas or bag limits. The use of trailing hounds to hunt cougars is permitted in the majority of states and provinces (Beausoleil et al. 2008). In this manuscript, we propose replacing the term "quota" with "harvest threshold" because quotas often connote a harvest target or goal rather than a threshold not to exceed, and we propose that harvest should not exceed the intrinsic rate of population growth.

Current management strategies rely on a source–sink concept (Laundré and Clark 2003) and are administered within cougar management zones (CMZs), that are typically about 10,000 km^2 and often have management objectives to reduce or maintain cougar populations (Logan and Sweanor 2001). However, dispersal by cougars from adjacent areas may thwart efforts to locally reduce cougar populations (Lambert et al. 2006, Robinson et al. 2008; Cooley et al. 2009*a*). Conversely, where managers want to maintain cougar populations and apply harvest thresholds to zones, harvest may still be locally excessive when CMZs are >1,000 km^2 and the majority of the harvest occurs in clusters where hunter accessibility is relatively great (Ross et al. 1996). Although local population sinks may be re-populated by immigration of subadults, disruption may occur to the intrinsic social and spatial organization of the population, which may result in a demographic composition dominated by subadults (Lambert et al. 2006; Robinson et al. 2008; Cooley et al. 2009*b*). This situation may create unanticipated consequences, including an increase in the use of residential areas by cougars and in human–cougar complaints (Maletzke 2010, Kertson et al. 2011*b*).

HISTORY OF COUGAR MANAGEMENT IN WASHINGTON

Cougar management in Washington began in 1966 when their status changed from a bounty animal to a big-game species with hunting seasons and harvest limits (Washington

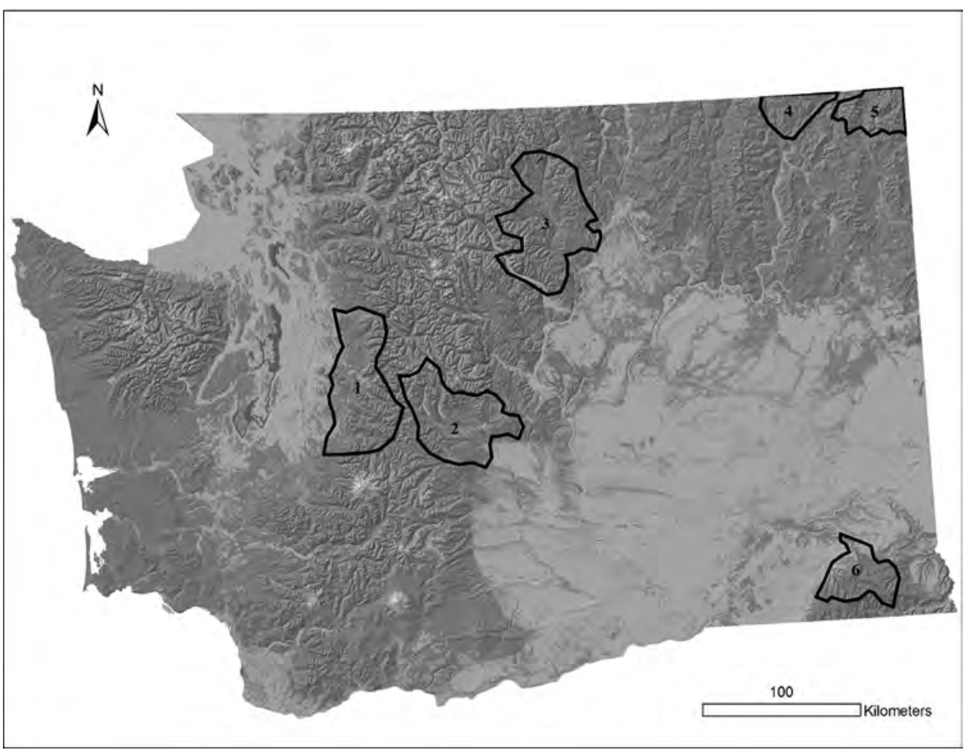

Figure 1. Six cougar research areas in Washington, USA, 2001–2012: (1) western WA; (2) central WA; (3) north-central WA; (4 and 5) northeast WA; (6) southeast WA.

Department of Fish and Wildlife [WDFW] 2008). This change came with a series of regulations, including mandatory reporting (1970), inspection and sealing of cougar pelts for demographic data (1979), and submitting a tooth from harvested animals for age analysis (mid-1980s). From 1980 to 1995, cougar harvest seasons remained static with a 6–8-week season.

Politics began to direct cougar management in 1996 when Washington voters approved Initiative 655 (I-655). Initiative 655 banned the use of dogs for hunting cougar and has been pivotal in framing the debate over cougar management in Washington since then (Kertson 2005, Beausoleil and Martorello 2008). With the use of dogs banned and anticipated decrease in cougar harvest, WDFW 1) replaced limited permit-only seasons with general seasons, 2) increased season length from 7.5 weeks to 7.5 months, 3) increased bag limits from 1 to 2 cougar/year, and 4) decreased the price of transport tags from US$ 24 to $ 5. The response to these changes resulted in increased tag sales from an annual average of 1,000 prior to I-655 to approximately 59,000/year since 1996, and this action increased harvest from an average of 121 (SD = 54, 1980–1995) to an average of 160 (SD = 44, 1996–2011)/year. Hunting opportunities and harvest were not evenly distributed, primarily increasing in areas where social tolerance for cougars was low, deer hunter density was high, and human access was high; during this time, cougar densities were unknown but assumed to be increasing (Jenks 2011, Lambert et al. 2006).

Since I-655 was approved, 16 legislative bills addressing cougar management have been introduced into the Washington legislature (http://apps.leg.wa.gov/billinfo). In 2000, Washington instituted a management concept to reduce cougar numbers in areas where complaints were high (Engrossed Substitute Senate Bill 5001-ESSB 5001). This bill and 3 others since 2003 (Substitute Senate Bill 6118-SSB 6118, Engrossed Substitute House Bill 2438-HB 2438, and Engrossed Substitute House Bill 1756-HB 1756) permitted the use of dogs in 6 counties, effectively overturning I-655 in many areas throughout Washington. In 2011, House Bill 1124 was introduced to continue hunting with hounds but failed to pass, and since the use of dogs has been prohibited statewide. However, ESSB 5001 allows the WDFW to authorize a hunt with the use of dogs when reports of conflicts with humans or their livestock exceed the previous 3-year running average.

In the midst of the political activity between 1996 and 2010, which included legislative mandates, WDFW began integrating insights from harvest monitoring (Martorello and Beausoleil 2003), and research projects (Robinson et al. 2008; Lambert et al. 2006; Cooley et al. 2009*a*, *b*; Kertson 2010; Maletzke 2010). In 2003, harvest thresholds in conjunction with a 24-hour hunter reporting hotline allowed for prompt closure of zones where the use of dogs was permitted. In 2009, the WDFW reduced the bag limit to 1 cougar/hunter/year, shortened season length to avoid some overlap with deer and elk seasons, and restricted harvest with female- and total-harvest thresholds. In 2011, WDFW managers and researchers compiled research findings and began drafting a new management strategy, an aspect of which was publicly reviewed and ultimately adopted by the Washington Fish and Wildlife Commission in spring 2012. Here, we present a synthesis of this research and develop these concepts into a management strategy.

COUGAR ABUNDANCE AND DENSITY: BEHAVIORAL CONSIDERATIONS

Estimating cougar abundance and density, as with most species, represents one of the most challenging aspects of their management. Currently, reliable estimation of cougar abundance requires expensive, field-intensive, long-term research (Hornocker and Negri 2010). Consequently, agencies use numbers of cougar complaints, cougar–human conflicts, and harvest as proxies for population size and trend (Martorello et al. 2006). However, cougar complaint reports can be unreliable (Kertson et al. 2013), and it has been shown that increasing numbers of complaints and increasing predation on mule deer (*Odocoileus hemionus*), and endangered mountain caribou (*Rangifer tarandus caribou*) in a large (10,000-km^2) heavily hunted CMZ in the Selkirk Mountains Ecosystem in northeastern Washington, northern Idaho, and southern British Columbia did not correspond to increasing densities of cougars (Katnik 2002, Robinson et al. 2002, Lambert et al. 2006). Thus, the indirect proxies of population size appeared to be plausible but were inaccurate in that heavily hunted CMZ that had approximately 38% annual removal rate of cougars.

Subsequent research in Washington was designed to examine the previous hypothesis (Lambert et al. 2006) of no direct positive correlation between harvest numbers and complaints and population densities of cougars. Working in the heavily hunted (24% of population harvested/yr), area of Kettle Falls in northern Washington, a declining female cougar population was documented as the male segment increased due to compensatory juvenile male immigration (Robinson et al. 2008). In another study area in central Washington, (Cle Elum), an opposite scenario was confirmed in that relatively low hunting mortality (11%/yr) resulted in a net emigration of younger males (Cooley et al. 2009*a*). In all cases, the population densities were remarkably similar, ranging from 1.5 to 1.7 adult (>2-yr-old), cougars/100 km^2 with total densities of about 3.5 cougars/100 km^2, including kittens and subadults. Details on estimating population densities and immigration–emigration rates have been described (Robinson et al. 2008; Cooley et al. 2009*a*, *b*; Robinson and DeSimone 2011). Additional research on 2 other study areas in western and north-central Washington showed an average resident adult density of about 1.6/100 km^2 and a total density of about 3.4/100 km^2 (R. A. Beausoleil and B. N. Kertson, unpublished data). In 3 separate study areas in Washington and Montana, increased hunting (11–38% population harvest rates) did not result in compensatory increases in cub production, cub survival, or adult survival (Robinson et al. 2008; Cooley et al. 2009*a*, *b*; Robinson and DeSimone 2011). However, variation in hunting mortality did result in compensatory immigration–emigration by primarily young males, with no net differences in total cougar numbers. Such compensatory immigration has been observed in many other highly mobile species as well (Beecham and Rohlman 1994, Merrill et al. 2006, Turgeon and Kramer 2012, Mills 2013). Therefore, increased hunting may not always result in reduced local densities of cougars, but not due to traditional density-dependent effects such as compensatory reproduction and survival; instead, increased hunting may result in compensatory immigration by mainly young males (Cooley et al. 2009*b*).

Presenting and comparing density estimates between studies is challenging because standardization is lacking (Quigley and Hornocker 2010). For example, whereas total density could temporarily fluctuate in response to immigration and emigration of subadults, density of resident breeding adults tends toward stability over time. Density estimates can also be misinterpreted from incomplete data due to differences in seasonal spatial use patterns where individuals concentrate on low-elevation ungulate winter ranges, often comprising only a portion of the population's annual distribution (Maletzke 2010). When annual boundaries of individual cougar territories are unknown, density estimates may result in inflated values and substantial overestimation of population size (Maletzke 2010). However, there is remarkable consistency in the western United States and Canada where long-term research has been conducted; resident adult densities average 1.6 cougar/100 km^2, while total densities including kittens and subadults average 2.6 cougar/100 km^2 (Quigley and Hornocker 2010). Our research in Washington corroborates these findings because adult densities averaged 1.7/100 km^2 (Cooley et al. 2009*b*; R. A. Beausoleil and B. N. Kertson, unpublished data). Therefore we encourage a more explicit, standardized approach of using estimates of adult densities for population management objectives and caution against using total densities, because they do not provide for reliable estimation of population parameters and harvest impacts (Robinson et al. 2008; Cooley et al. 2009*b*).

In Washington, where prey biomass was consistent and cougar harvest ranged from 11% to 38% of the cougar population per year, the age structure, survival, sex ratio, reproductive rate, and spatial use patterns of cougars differed (Lambert et al. 2006; Cooley et al. 2009*b*; Maletzke 2010). Where annual harvest was 24%, mean age at harvest was 27 months compared with 38 months where annual harvest was 11%. In addition, in areas of greater relative harvest, male home-range sizes were larger (753 km^2 vs. 348 km^2), and home-range overlap between males was greater (41% vs. 17%). Cougars, especially males, evolved with a social dynamic to patrol and defend a territory regardless of whether their home-range size is determined by prey density or social tolerance (Hornocker 1969, Pierce et al. 2000, Logan and Sweanor 2010). As adult mortality increases, territorial boundaries diminish. Immigrating subadults may establish home ranges readily, and their home ranges may overlap significantly, which may influence rates of predation and the distribution of prey and potentially increase probabilities for interactions with humans (K. A. Peebles, Washington State University, unpublished data).

The social system and territoriality observed for cougars is similar among many species of solitary felids, although it may manifest itself differently for males and females (Sunquist and Sunquist 2002). Although the role of social ecology for cougars will continue to be debated in the future, it is important to acknowledge that harvest intensity can affect spatial use patterns of cougars as well as their population demographics, as demonstrated for other hunted carnivore populations (Packer et al. 2009).

HARVEST MORTALITY VERSUS TOTAL MORTALITY

Although knowledge of population abundance and density is critical for sound management of cougars, it is also important that managers be aware that harvest mortality can be additive to natural mortality (Robinson et al. 2008; Cooley et al. 2009*b*; Robinson and DeSimone 2011). Failing to account for and include all mortality sources may obscure estimates of population trajectory and underestimate the impact of harvest on demographics and cougar social structure (Cooley et al. 2009*b*; Morrison 2010; Robinson and DeSimone 2011). Unfortunately, reliable knowledge of non-harvest mortality is difficult to quantify (Cougar Management Guidelines Working Group 2005), because harvest may not necessarily be representative of age structure of the population (R. A. Beausoleil, B. N. Kertson, and G. M. Koehler, unpublished data).

To illustrate the importance of considering non-harvest mortality, we documented 79 mortalities of radiomarked cougars during 4 concurrent research efforts in Washington. Of these, 49% were non-hunter harvest mortalities; 14% from agency control, 6% from intraspecific strife, 6% due to motor-vehicle collisions, 4% from disease, 4% attributed to Native American predator-control efforts, 3% due to injuries sustained during pursuit of prey, 3% from poaching or illegal harvest, and 10% from undetermined sources. In the western Washington study area, hunter harvest mortality averaged $\leq$2 animals/year from 2003 to 2008 and annual survival rate of the study population was 55% (SD = 7.8, n = 5 yr; B. N. Kertson, unpublished data). A significant mortality factor for this population was from feline leukemia virus exposure along the wildland–urban interface, resulting in an observed average annual survival rate of 55%, less than that for a heavily hunted population in Washington with 79% annual survivorship (Cooley et al. 2009*b*). These examples demonstrate the importance that non-harvest mortality can have in cougar population dynamics.

POPULATION GROWTH AND MAXIMUM SUSTAINED YIELD

The growth rate for an unhunted population, or intrinsic rate of population growth, can be described as the rate we expect the population to grow if it did not experience additive hunting mortality. Because kitten mortality and non-harvest mortality can be additive to hunting mortality, we calculated the intrinsic growth rate by censoring all harvest mortalities. In Washington, the unhunted growth rate was 1.14 (SD = $\pm$0.023) for 3 different populations (Selkirk Mountains, Kettle Falls, and Cle Elum; Morrison 2010). The intrinsic growth rate in northwest Montana was estimated by removing hunting that resulted in a population growth rate of 1.15–1.17 (Robinson and DeSimone 2011). Although growth rate may be considered equivalent to the maximum sustainable yield, the rate of growth for an unhunted population should not be the goal for harvest but rather a maximum not to exceed if a stable population is to be achieved. Using maximum sustainable yield as a management target has been cautioned against, because it does not incorporate the uncertainty of stochastic events on population abundance and may present a potential for over-harvest (Caughley and Sinclair 1994). Setting adult harvest limits to the intrinsic rate of growth of 14% should help to balance immigration and emigration among harvest units and result in greater stability of cougar densities and age structure.

HARVEST UNITS AND HARVEST THRESHOLDS

Cougars are often managed in administrative zones (Logan and Sweanor 2001), which represent an amalgam of smaller Game Management Units (GMUs). Commonly these CMZs are designated as population "sources" and "sinks" where management objectives are to maintain or decrease population levels, respectively (Laundré and Clark 2003). In Washington, 139 GMUs are partitioned throughout the state and are used to manage harvest and habitat for a variety of game species (Fig. 2). In 2011, these GMUs were combined into 13 CMZs, each comprised from 3 to 22 GMUs and encompassing 1,873–14,947 km^2 of forested and shrub-steppe habitat (total = 90,783 km^2; Fig. 3). Five CMZs had a harvest limit of 6–20 cougars, and 8 did not have limits. Individual GMUs with high hunter access and suitable snow conditions accounted for 25–50% of the total harvest within the CMZs, which has been repeated over multiple years (WDFW 2011). This uneven distribution of harvest, or harvest clustering, may create local population sinks in areas within CMZs designated as sources and may disrupt the social organization of cougars as previously explained. Additionally, this uneven distribution of harvest may result in some GMUs with little or no harvest, creating angst among hunters who feel harvest opportunity was inequitable.

Setting harvest thresholds can help to distribute harvest, minimize risk of overharvest (Ross et al. 1996), and help maintain recreational opportunity and quality of hunter experience. However, it is important to note that harvest thresholds may become less effective for distributing harvest as CMZ size increases, and harvest may be concentrated within areas where access is high (i.e., harvest clustering). Harvest thresholds to limit harvest may be more effective where harvest is distributed evenly among GMUs rather than applied to the larger CMZs. Where GMUs are small, habitat is limited, or a quota of $\leq$1 cougar is allocated, combining adjacent GMUs to reach a size of approximately 1,000 km^2 may be recommended.

HUNTER CONSIDERATIONS

Age and sex of harvest can be an important factor influencing population dynamics of big-game species. Unlike ungulates

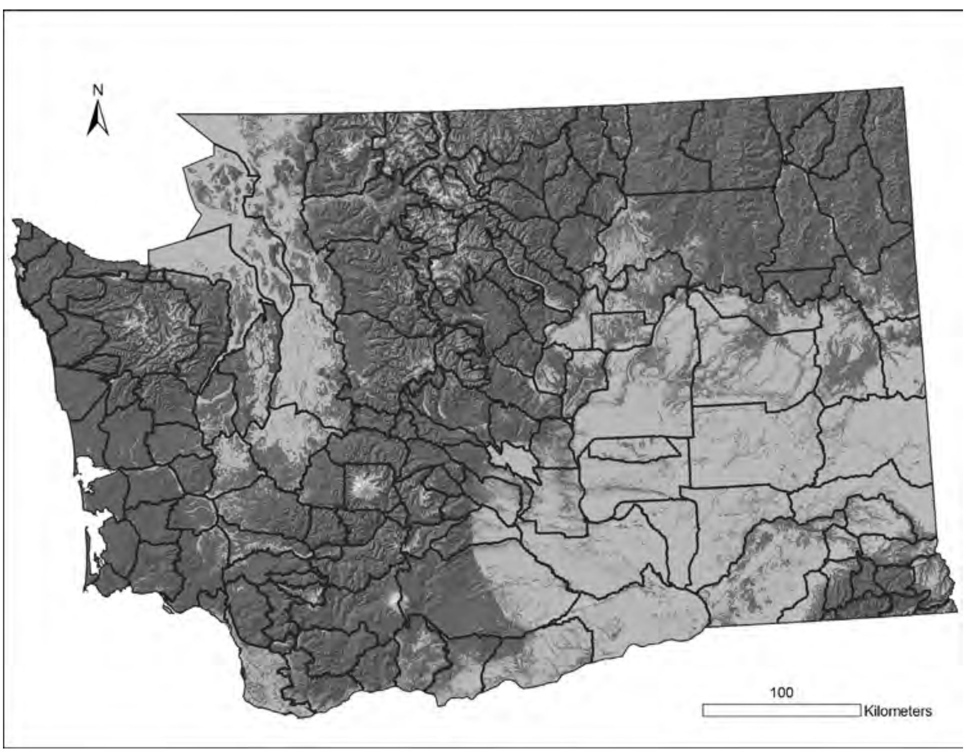

Figure 2. Distribution of cougar habitat (shaded dark) and current game-management units (outlined in black) in Washington, USA, Washington Department of Fish and Wildlife, 2012.

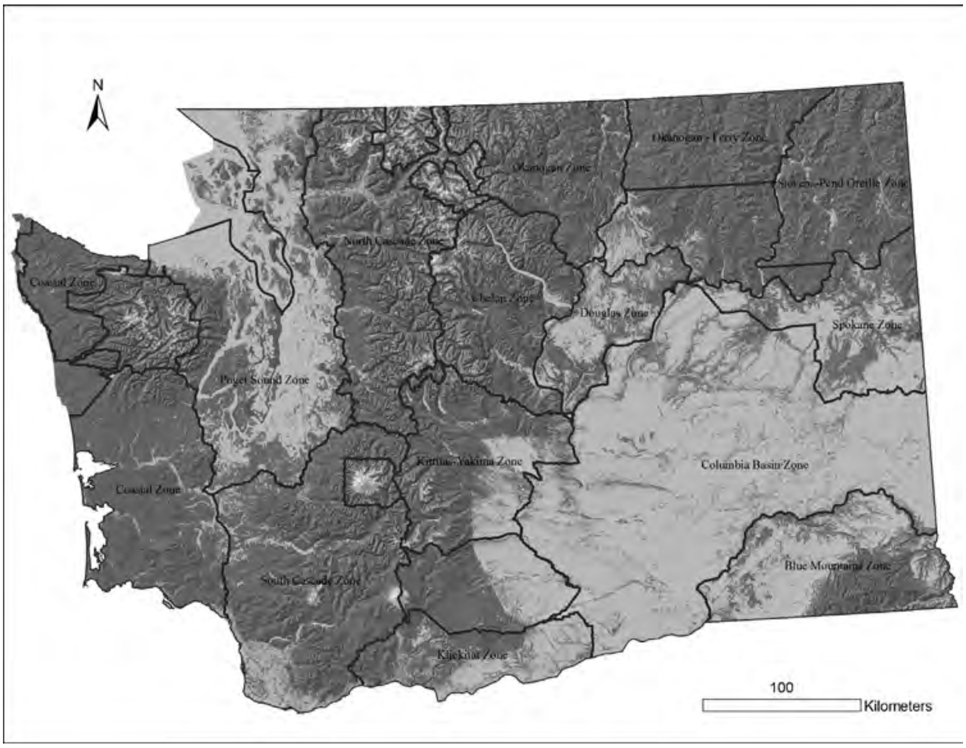

Figure 3. 2011 cougar management zones in Washington, USA, Washington Department of Fish and Wildlife, 2012.

for which juvenile status and sex are readily identifiable, most hunters are unable to distinguish female cougars from males and adults from subadults until after the animal is killed. Where the use of dogs is permitted, sex, and age determination may be more reliable but not certain due to restricted visibility of treed animals.

Many agencies employ a general open season and a permit-only season for cougar. Two concerns for hunters who participate in permit-only hunts (either limited-entry or quota hunts) are 1) when harvest threshold tallies begin during a general open season (which often overlaps with deer and elk season), and that, when filled, nullify the permit-only season; and 2) when the number of permits issued is greater than harvest threshold, thus creating a competitive atmosphere (the use it or lose it conundrum). In Washington, for example, 10–35 permits were issued for CMZs with harvest objectives for 6–20 cougars.

IMPLEMENTATION

The first step for applying our proposed management framework is to estimate the amount of cougar habitat. For Washington, we plotted 85,866 Global Positioning System and satellite telemetry locations from 117 radiocollared cougars in 5 study areas in to U.S. Fish and Wildlife Service–U.S. Geological Survey Landfire habitat coverage (LANDFIRE 2007) using ArcMap 9.3. We quantified the number of Global Positioning System locations in each habitat type, created a Geographic Information System data layer identifying habitats used by marked cougars, and extrapolated these habitats throughout the state. The result included 90,783 km^2 of the 104,000 km^2 of habitat for areas where WDFW has management authority (Fig. 1). For states and provinces lacking empirical estimation of suitable habitat for cougars, reliable and quantifiable estimates of forest cover, topographic variability, limited residential development (not to exceed exurban densities), and persistent ungulate prey may provide reasonable measure of suitable habitat for cougars (Burdett et al. 2010; Maletzke 2010; Kertson et al. 2011*b*). However, where existing Geographic Information System coverages may not reflect current landscape conditions, we advocate they be ground-truthed to avoid overestimating habitat. Including district or regional biologists and officers can also be advantageous.

We then overlaid current GMU boundaries onto this habitat coverage to calculate the available habitat within each GMU, and we applied adult densities of 1.7 cougars/100 km^2 to estimate the number of adult residents per GMU. Where GMUs were small ($<$750 km^2), or the habitat sparse, we combined adjacent GMUs; this resulted in 62 CMZs for Washington (Fig. 4). In jurisdictions where densities are not estimable, we suggest that the scientifically defensible average of 1.6 adults/100 km^2 be applied (Quigley and Hornocker 2010).

We applied a mean intrinsic rate of growth of 14% (Morrison 2010) to allocate harvest of adult cougar per unit of area (0.24 cougars/100 km^2 of habitat). For Washington, this resulted in a statewide annual harvest of 220 cougars, more than the average annual harvest from previous years. Although the proposed harvest would be greater, this harvest would be distributed more evenly across management units in the state, resulting in a more uniformly distributed hunter effort, less harvest clustering and population sinks, and

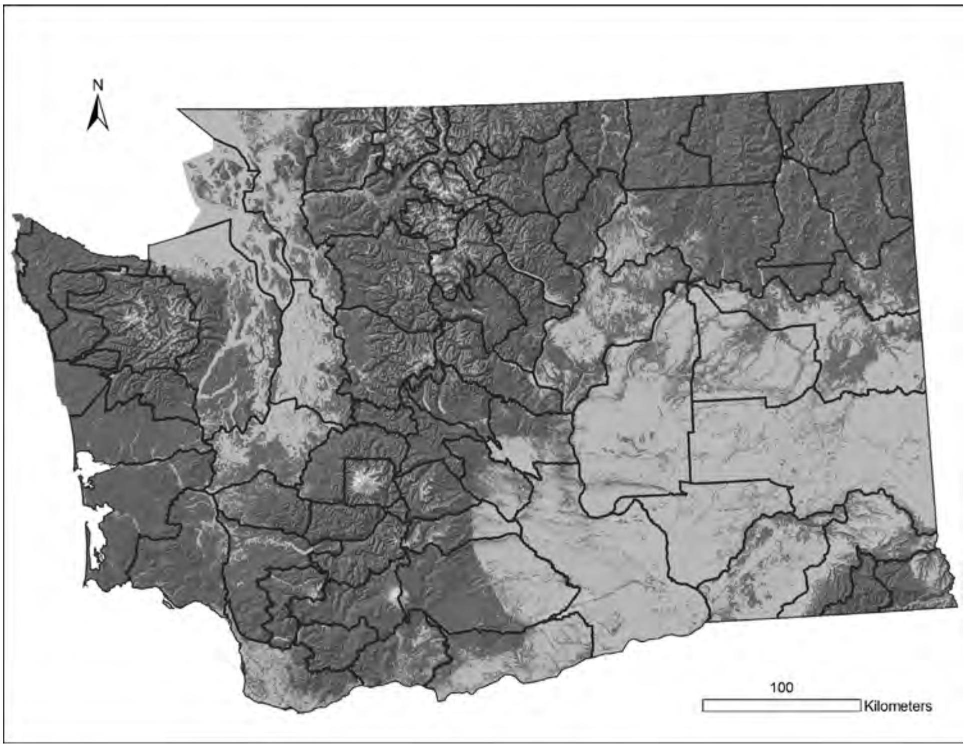

Figure 4. Proposed cougar management zones for Washington, USA, 2012.

greater stability in the cougar population. This strategy may prevent the need for harvest thresholds based on sex and could simplify harvest regulations and administration. We recommend using the harvest threshold of 14%. In addition, because subadult age classes are dynamic and difficult to estimate, and difficult to identify in the field, we recommend that harvest of this age class be counted against the allocated harvest so that recruitment is not affected in the future. Finally, we advocate administering the hunt using a 24-hour reporting and information hotline because it allows for prompt reporting of kills and CMZ closure and provides hunters the opportunity to plan hunt activity.

Administering harvest thresholds for GMUs or smaller CMZs has multiple benefits. It helps to 1) preserve the cougar's social organization by distributing harvest more evenly and avoiding creation of population sinks, 2) eliminate the need for harvest thresholds based on sex and for field identification of sex, 3) distribute hunter opportunity across the landscape, and 4) define a biological and meaningful spatial scale similar to that of their prey (ungulates), bringing management for predator and prey into alignment.

MANAGEMENT IMPLICATIONS

We acknowledge that these recommendations are based on research in Washington, but similar findings have been documented elsewhere in western North America (Quigley and Hornocker 2010). For the most part, current cougar management programs do not address the effects of harvest on social structure of cougar populations, a concept that was introduced >40 years ago (Hornocker 1969, 1970) and is supported by current research. We believe this science-based approach to cougar management is easy to implement, incurs no added costs, satisfies agency and stakeholder interests, and assures professional credibility. The current review of carnivore management has demonstrated a paradigm shift from lethal control to one of ecosystem management, and one that considers the values of multiple stakeholders and aspects of human dimensions (Treves 2009, Hornocker and Negri 2010, Van Ballenberghe 2011, Way and Bruskotter 2012, Peek et al. 2012). Our recommendations incorporating cougar behavior and social organization into a management framework addresses concerns of various constituencies, provides for quality hunter experience, and recognizes values of the non-consumptive public while maintaining viable cougar populations and the behavioral integrity of their populations.

A simple, consistent, science-based approach to cougar management can be of benefit to agencies during intervals of administrative and political uncertainty. In addition to fulfilling agency mandates for hunter opportunity, our proposal adheres to our state agency's mission to "promote development and responsible use of sound, objective science to inform decision making" (WDFW 2008). In our opinion, of equal importance is recognizing the ecological and evolutionary role of cougar in the trophic hierarchy (Estes et al. 2011); and incorporating this concept into management and education elevates the cougar's status beyond a mere predator.

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Does hunting regulate cougar populations? A test of the compensatory mortality hypothesis

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Abstract. Many wildlife species are managed based on the compensatory mortality hypothesis, which predicts that harvest mortality (especially adult male mortality) will trigger density-dependent responses in reproduction, survival, and population growth caused via reduced competition for resources. We tested the compensatory mortality hypothesis on two cougar (*Puma concolor*) populations in Washington, USA (one heavily hunted and one lightly hunted). We estimated population growth, density, survival, and reproduction to determine the effects of hunting on cougar population demography based on data collected from 2002 to 2007. In the heavily hunted population, the total hunting mortality rate (mean ± SD) was 0.24 ± 0.05 (0.35 ± 0.08 for males, 0.16 ± 0.05 for females). In the lightly hunted population, the total hunting mortality rate was 0.11 ± 0.04 (0.16 ± 0.06 for males, 0.07 ± 0.05 for females). The compensatory mortality hypothesis predicts that higher mortality will result in higher maternity, kitten survival, reproductive success, and lower natural mortality. We found no differences in rates of maternity or natural mortality between study areas, and kitten survival was lower in the heavily hunted population. We rejected the compensatory mortality hypothesis because vital rates did not compensate for hunting mortality. Heavy harvest corresponded with increased immigration, reduced kitten survival, reduced female population growth, and a younger overall age structure. Light harvest corresponded with increased emigration, higher kitten survival, increased female population growth, and an older overall age structure. Managers should not assume the existence of compensatory mortality when developing harvest prescriptions for cougars.

Key words: carnivore; compensatory mortality hypothesis; cougar; density; emigration; hunting; immigration; mortality; population growth; Puma concolor; *source–sink; survival.*

Introduction

Density-dependent population regulation has been experimentally demonstrated for a variety of animals and forms the theoretical basis for sustainable hunting of polygynous mammals (Caughley 1977, Caughley and Sinclair 1994, Ginsberg and Milner-Gulland 1994, Strickland et al. 1994). The compensatory mortality hypothesis predicts that harvest mortality, especially of adult males, triggers density-dependent responses in reproduction, offspring survival, and female population growth by reducing competition for resources (Connell 1978). In unhunted or lightly harvested populations, higher densities generate increased competition for resources, resulting in decreased reproduction, offspring survival, and female population growth. Therefore, removal of adult males in polygynous mating systems is generally considered to have benign or beneficial effects on population growth (Errington 1945, Frank and Woodroffe 2001, Johnson et al. 2001).

The compensatory mortality model has been demonstrated for a variety of ungulates (Staines 1978, Burnham and Anderson 1984, Peek 1986, Bartmann et al. 1992, White and Bartmann 1998), but little evidence suggests that the model fits carnivore populations (Franke and Woodroffe 2001, Milner et al. 2007). Because life histories of carnivores and ungulates differ, we would also expect that density dependence might operate differently. Ungulates typically have restrictive or limited dispersal movements compared to carnivores (Chepko-Sade and Halpin 1987, Howe et al. 1991, Franke and Woodroffe 2001, Zimmerman et al. 2005, Whitman et al. 2007). Therefore hunting males is likely to reduce local herbivore densities but may not have the same effect on carnivores, which display long-distance, density-independent dispersal by males. Such intrinsic emigration can depress population density, and intrinsic immigration can increase population density regardless of birth and death rates (Franke and Woodroffe 2001, Festa-Bianchet 2003). This exchange of animals via immigration and emigration may offset expected chang-

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es in density and associated effects on vital rates of resident female animals. As a result, harvest levels that are considered beneficial or benign to an ungulate population may impose additive mortality on carnivores (Franke and Woodroffe 2001, Festa-Bianchet 2003, Swenson 2003).

Cougars (*Puma concolor*) are managed for sport harvest and population control based on compensatory mortality throughout the western United States (Strickland et al. 1994, Cougar Management Guidelines Working Group 2005:71–82). Managers seeking to provide trophy-hunting opportunities often adopt strategies that seek to reduce male densities and keep female numbers high (Hemker et al. 1984, Ross and Jalkotzy 1992, Lindzey et al. 1994, Spreadbury et al. 1996, Logan and Sweanor 2001, Martorello and Beausoleil 2003). However, young male cougars often disperse long distances. Harvesting of adult males can create vacancies that attract these young dispersers to vacated territories (Hemker et al. 1984, Logan et al. 1986, Ross and Jalkotzy 1992, Logan and Sweanor 2001, Stoner et al. 2006, Robinson et al. 2008). Robinson et al. (2008) showed that heavy hunting pressure on cougars did not reduce the population in a small-scale management area because of compensatory immigration. Their results suggest that density dependence in cougar populations may act through dispersal and that models of cougar management based on the compensatory mortality hypothesis may be inappropriate.

We tested whether hunting supported the compensatory mortality hypothesis by comparing demographic parameters from two Washington State cougar populations, one heavily hunted and one lightly hunted, from 2002 to 2007. The compensatory mortality hypothesis predicts that heavy hunting of cougars will result in (1) decreased male densities, (2) increased maternity rates, (3) increased survival of young, (4) decreased natural mortality, and (5) increased female population growth; and that low levels of harvest will result in (1) increased male densities, (2) decreased maternity rates, (3) decreased survival of young, (4) higher natural mortality rates, and (5) decreased female population growth.

Study Areas

We monitored cougar population in two study areas >250 km apart and managed under different hunting strategies. Heavy hunting with the aid of hounds (hunting mortality rate = 0.24) was permitted in the Northeast Washington study area and light hunting without the use of hounds (hunting mortality rate = 0.11) was permitted in the Central Washington study area.

Heavily hunted area (HH)

The 735-km^2 study area lies north of the town of Kettle Falls, and includes a patchwork of federal, state, and privately owned lands. The study area is bounded on the southeast and southwest by the Columbia and Kettle Rivers. The Canadian–United States border forms the northern boundary. The area is part of a glacially subdued mountainous region (400–2130 m elevation) known as the Okanogan Highlands, and occupies the transition between the East-slope Cascades and Northern Rocky Mountain physiographic province (Bailey et al. 1994). Tree species include Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), ponderosa pine (*Pinus ponderosa*), western red cedar (*Thuja plicata*), and subalpine fir (*Abies lasiocarpa*). Most of the 46-cm annual precipitation falls as snow, with an average of 136 cm falling from mid-November to mid-April annually. Mean annual temperatures range from −6°C in January to 21°C in July. White-tailed deer (*Odocoileus virginianus*) are the most abundant ungulate, but mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), and moose (*Alces alces*) are also present. Common predator species besides cougar include coyotes (*Canis latrans*), black bears (*Ursus americanus*), and bobcats (*Lynx rufus*).

Lightly hunted area (LH)

The study area is located along the East-slope foothills of the North Cascades Mountains near the town of Cle Elum. The area covers 594 km^2 and includes a portion of the upper Yakima River watershed. The study area is bounded by the Cascade Mountains on the west, the Enchantment Wilderness on the north, and unforested agricultural lands of the Kittitas Valley on the south and east. Sagebrush steppe foothills (below 550 m elevation) transition upward to slopes covered with ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Psuedotsuga menziesii*). Subalpine fir (*Abies lasiocarpa*), Englemann spruce (*Picea engelmannii*), silver fir (*Abies amabilis*), and western hemlock (*Tsuga heterophylla*) dominate ridges at elevations >1550 m. Precipitation averages 56.4 cm/yr, with 160 cm of snowfall during winter. Mean annual temperature ranges from −7°C in January to 27°C in July. Elk and mule deer occur throughout the study area, and mountain goats (*Oreamnos americanus*) are present at higher elevations. Common predator species besides cougar include coyotes, black bears, and bobcats.

Methods

Captures and monitoring

We attempted to capture and mark all cougars each year, from January 2002 through December 2007, by conducting thorough and systematic searches of each study area during winter when tracks can be detected in snow. We used hounds to track and tree cougars (Hornocker 1970). We immobilized treed cougars with a mixture of ketamine hydrochloride (200 mg/mL) and xylazine hydrochloride (20 mg/mL) at a dosage of 0.4 mL/10 kg of body mass, or with Telazol at a dosage of 6 mg/kg, using a projectile dart in the hindquarter (Ross and Jalkotzy 1992, Spreadbury et al. 1996). We determined sex and classified animals as kittens (0–12 months), juveniles (13–24 months), or adults (25+ months) based on physical measurements and gum regression measurements of the canine teeth (Laundre et al. 2000).

We fitted each animal with a mortality-sensing Very High Frequency collar (VHF; Advanced Telemetry Systems, Isanti, Minnesota, USA) or Global Positioning System (GPS; Lotek Wireless, Newmarket, Ontario, Canada and Televilt, Lindesberg, Sweden). Beginning in January 2005, we investigated den sites of collared females and captured kittens by hand. We implanted kittens <6 weeks old with PIT (Passive Integrated Transponder) tags (AVID, Norco, California, USA), and collared kittens that were >6 weeks old with expandable VHF (Telonics, Mesa, Arizona, USA; T. Ruth, *personal communication*) radio collars to accommodate growth. We handled all animals in accordance with Washington State University Animal Care (IACUC Permit #3133) and Animal Welfare Assurance Committee (AWAC Permit #A3485-01). GPS collars were programmed to collect locations at 4-hour intervals (six times/day). The data were retrieved using a remote communication unit. We recorded location coordinates of VHF-collared animals at one-week intervals from ground or aerial telemetry.

Despite attempts to systematically search and mark animals, we were not able to mark the entire population. Therefore, to establish a minimum population estimate for each study area we included demographic data from collared and uncollared cougars that were harvested by hunters, killed during depredation hunts, and killed by vehicle collisions (Stoner et al. 2006, Robinson et al. 2008). Washington Department of Fish and Wildlife recorded sex and age (determined by cementum annuli) for uncollared cougars killed by hunters or killed by special harvest permits or other causes. Because measurements of gum regression and cementum annuli yield comparable ages (Robinson et al. 2008), we included all collared and uncollared animals in a linear regression analysis to examine trends in age structure over the study period.

Survival

We used radiotelemetry to monitor survival of all radio-collared cougars and assigned cause of mortality as hunting, vehicle, or natural. Natural mortalities were confirmed with necropsies. We inferred cause of kitten mortalities by examining the carcass and proximity to other collared cougars.

We used the modified Mayfield method (Heisey and Fuller 1985) to estimate survival of animals because it provides increased precision when mortality rates are high, performs well in the case of small sample size typical of large carnivore species, and can identify cause-specific mortality rates (Winterstein et al. 2001, Murray 2006). We calculated annual survival rates for male and female kittens, juveniles, and adults from January 2002 to December 2007.

To determine intervals when survival probabilities were constant, we analyzed the statistical distribution of deaths over a 365-day period (Lambert et al. 2006). This yielded two mortality seasons: a high-mortality season (LH: 1 August to 31 December, HH: 1 October to 31 January) and a low-mortality season (LH: 1 January to 31 July, HH: 2 February to September 31). Annual survival was the product of seasonal survival rates (Heisey and Fuller 1985). We chose intervals for each period based on the median date of the deaths for each period. We used the Taylor series approximation method to compute variances of class-specific survival rates, and a one-tailed z test to determine whether survival rates in LH were higher than in HH (Micromort version 1.3; Heisey and Fuller 1985).

Maternity and fecundity

We calculated maternity as the mean number of kittens observed during inspection of maternal dens and from snow tracking, divided by the number of adult females observed that year (Case 2000:183). We calculated fecundity rates, $F = S_F \times M_{x+1}$, from the female survival rate in year x multiplied by their mean maternity rate in the following year (Ebert 1999). We used two-tailed t tests assuming unequal variance to compare maternity and fecundity rates from each area (Zar 1999).

Deterministic and stochastic growth rates

We constructed a survival/fecundity dual-sex Leslie matrix (Leslie 1945) to model closed-population growth for each area using RAMAS GIS (Akçakaya 2002). We assigned female age at first reproduction as 24 months, assumed an equal sex ratio at birth, and maximum age or age at senescence of 13 years (Robinson et al. 2008).

We calculated the deterministic growth rate (λ_D) as the dominant eigenvalue of the matrix under a stable age distribution. We calculated the stochastic growth rate (λ_S) by incorporating annual environmental variability (standard deviation of annual survival and fecundity rates) and demographic stochasticity. To estimate demographic stochasticity, we sampled the number of survivors in each sex and age class from a binomial distribution, and the number of kittens born each year from a Poisson distribution using the random number generator in RAMAS GIS (Akçakaya 2002). We sampled vital rates from a lognormal distribution to avoid truncations, which can occur if standard deviations are large due to sampling and measurement error. We projected each population for six years (five transitions), and calculated λ_S as the average geometric mean growth rate from 200 simulations, the point at which rates converged (Robinson et al. 2008).

Observed growth, immigration, and emigration

We determined observed growth rates (λ_O) from annual counts of collared and unmarked cougars. Each year we tallied the number of cougars (adults, juveniles,

TABLE 1. Sources of mortality of radio-collared cougars in northeast (HH, heavily hunted) and central (LH, lightly hunted) Washington State, 2002–2007.

		HH area		
Sex and age	n	Hunting	Depredation	Natural
Female				
Kitten (0–12 months)	10		0.14 ± 0.13 (1)	0.54 ± 0.18 (4)
Juv. (13–24 months)	6			
Adult (24+ months)	19	0.22 ± 0.07 (7)		0.12 ± 0.06 (4)
Total	35	0.16 ± 0.05 (7)	0.02 ± 0.02 (1)	0.18 ± 0.06 (8)
Male				
Kitten (0–12 months)	13			0.69 ± 0.14 (6)
Juv. (13–24 months)	12	0.46 ± 0.17 (4)		
Adult (24+ months)	12	0.46 ± 0.12 (8)	0.06 ± 0.24 (1)	
Total	37	0.35 ± 0.08 (12)	0.03 ± 0.03 (1)	0.17 ± 0.06 (6)
Population totals	72	0.24 ± 0.05 (19)	0.03 ± 0.02 (2)	0.18 ± 0.04 (14)

Note: Sample sizes (n = total number of animals at risk), mortality rates (mean ± SD), and number of mortalities (in parentheses) are shown.

and kittens) in each study area and calculated λ_O as $\lambda_x = (n_t/n_0)^{1/t}$, where λ_x is the annual finite growth rate, n_0 is the starting population, n_t is the final population, and t is the number of transitions between the start and end of the population projection (Case 2000). We used a one-tailed, one-sample t test to determine whether deterministic (λ_D) and stochastic (λ_S) growth rates were higher than the average six-year observed (λ_O) growth rate for LH, and whether λ_D and λ_S were lower than λ_O for HH (Zar 1999). We estimated net immigration/emigration rate (i/e) using the equations $i/e = \lambda_D - \lambda_O$ and $e = \lambda_S - \lambda_O$ (Peery et al. 2006). We also used observations of radio-collared cougars to document net emigration and immigration in each area from 2005 through 2007, the period during which we radio-monitored kittens (radio collars enabled us to document emigrants).

Population density

We estimated mean annual densities of cougars (number of cougars/100 km^2) for each study area as the number of animals multiplied by the mean proportion of male and female locations that fell inside a mean annual 95% composite kernel home range of collared females (McLellan 1989). For unmarked cougars, we used the mean proportion of marked animals. We back-calculated the life span of each marked and unmarked cougar to the beginning of the study, its birth date (females), or immigration date (males) as described by Logan and Sweanor (2001:66), Stoner et al. (2006), and Robinson et al. (2008). We used a general linear model (GLM) to test for independent effects of study area and time on cougar density. We included study area, time, time^2, time × study area, and time^2 × study area as independent variables and then selected variables stepwise in a backward fashion, removing those that failed to be significant at the 0.10 probability level (Zar 1999).

Age structure

We calculated sex ratios (F:M) from collared cougars only to prevent bias that may result from hunters selecting for male cougars (trophies). We determined whether ratios were different from equality with a chi-square goodness-of-fit test (Zar 1999). We compared mean age of cougars in each area with a two-sample t test and examined the trend over time in age structure with simple linear regression (Zar 1999).

Confounding factors

To account for possible differences in per capita resources affecting maternity, kitten survival, and female population growth, we compared cougar densities and female predation rates in the two study areas. We compared densities with a general linear model and tested for differences in predation rates with a two-tailed t test (Zar 1999).

RESULTS

Captures and monitoring

We captured and marked 103 cougars in the two study sites (57 in HH, 46 in LH) between January 2002 and December 2007. Hunters killed 50 unmarked cougars (nine females, 13 males in HH; 14 females, 13 males, one of unknown sex in LH), and one uncollared female in LH was killed by a vehicle collision. We observed 26 unmarked kittens (six females, two males, nine of unknown sex in HH; three females, four males, two of unknown sex in LH) traveling with collared females.

Survival and mortality

Fifty-three (35 in HH, 18 in LH) radio-collared cougars died during the study (Table 1). Hunters killed 26 cougars, 22 died from natural causes, three died in vehicle collisions, and two were killed from depredation hunts. Eight juveniles (two in HH, six in LH) emigrated and were censored at the last known date of their location. An additional nine (four in HH, five in LH) animals were censored due to shed collars or lost VHF signals. Of 42 radio-collared kittens, 18 survived to one

TABLE 1. Extended.

	LH area		
n	Hunting	Vehicle	Natural
6			0.28 ± 0.24 (1)
5	0.24 ± 0.21 (1)		
12	0.04 ± 0,04 (1)		0.09 ± 0.06 (2)
23	0.07 ± 0.05 (2)		0.10 ± 0.05 (3)
13			0.47 ± 0.17 (4)
8	0.25 ± 0.22 (1)	0.25 ± 0.22 (1)	
12	0.20 ± 0.09 (4)	0.10 ± 0.07 (2)	0.05 ± 0.05 (1)
33	0.16 ± 0.06 (5)	0.09 ± 0.05 (3)	0.16 ± 0.06 (5)
56	0.11 ± 0.04 (7)	0.05 ± 0.03 (3)	0.13 ± 0.04 (8)

year of age, 16 died from natural causes, and four were censored. Six of the "natural" kitten mortalities in HH (three females, two males, one unknown sex) were presumed to have been killed by male cougars, as confirmed by canine tooth punctures in the skull and close proximity of a collared male at estimated time of death.

Average annual survival rates, including all sources of mortality, for all radio-collared cougars in HH were 0.56 ± 0.05 (mean ± SD) and 0.71 ± 0.06 in LH, but survival varied with age and sex classes (Table 2). Overall survival and survival of adults was higher in LH than in HH (overall: $Z = 1.98$, $P = 0.02$; adults: $Z = 1.75$, $P = 0.04$). Survival of adult females and survival of kittens was also higher in LH (adult females: $Z = 1.88$, $P = 0.03$; kittens: $Z = 1.49$, $P = 0.07$). We did not detect differences among other sex or age comparisons. Overall mortality rate from hunting was higher ($Z = 2.02$, $P = 0.04$) in HH (0.24 ± 0.05) than in LH (0.11 ± 0.04). We found no differences in natural mortality rates (HH = 0.18 ± 0.04, LH = 0.13 ± 0.04; $Z = 0.77$, $P = 0.44$). The standard deviation of annual survival rates, including all sources of mortality for all cougars, was 0.09 in HH and 0.06 in LH. These values were used in the standard deviation matrix of RAMAS. We removed the six kittens from the analysis that were killed by male cougars in HH, recalculated survival rates, and found that kitten survival was not different ($Z = 0.96$, $P = 0.96$) in HH (0.59 ± 0.02) and LH (0.58 ± 0.02).

Maternity and fecundity

Mean litter size was 2.63 ± 0.80 ($n = 18$ litters) in HH and 2.47 ± 0.83 ($n = 15$ litters) in LH, and did not differ between study areas ($t = 2.04$, df =30, $P = 0.94$). Proportions of females producing newborns (0.44 in HH and 0.51 in LH) were not different ($Z = -0.41$, $P = 0.68$), and proportions of females with dependent kittens (0.58 in HH and 0.75 in LH) were also not different ($Z = 1.15$, $P = 0.25$). Mean maternity in HH did not differ from that in LH (HH: 1.15 kittens/female/year vs. LH: 1.12 kittens/female/year; $t = 2.26$, df = 9, $P = 0.94$). Fecundity rates in HH and LH also did not differ (HH, 0.76 ± 0.63; LH, 0.97 ± 0.38; $t = 2.31$, df = 8, $P = 0.49$). The standard deviation of annual fecundity rates was 0.25 in HH and 0.27 in LH. These values were used in the standard deviation matrix of RAMAS.

Population growth

The deterministic annual female growth rate (λ_D) based on survival and fecundity models was 0.80 in HH and 1.13 in LH. The stochastic growth rate (mean λ_S ± SD) for HH (0.78 ± 0.19) was lower than in LH (1.10 ± 0.12; $t = 21.09$, $P < 0.01$). The observed growth rates (λ_O) based on the actual number of cougars in the study area were 0.91 (female $\lambda_O = 0.86$, male $\lambda_O = 1.02$) for HH and 0.98 (female $\lambda_O = 0.97$, male $\lambda_O = 0.96$) for LH, and were not different ($t = 0.86$, $P = 0.42$). Modeled growth rates were significantly higher than λ_O in LH (for λ_D, $t = 2.09$, $P = 0.05$; for λ_S, $t = 1.68$, $P = 0.09$) and lower than λ_O in HH (for λ_D, $t = 2.10$, $P = 0.07$; for λ_S, $t = 2.46$, $P = 0.05$. The HH population had net immigration rates of 0.11 ($\lambda_O - \lambda_D$) and 0.13 ($\lambda_O - \lambda s$), and the LH population had net emigration rates of 0.12 ($\lambda_O - \lambda s$)

TABLE 2. Radio-days and survival rates (mean ± SD) by sex and age class for radio-collared cougars in northeast (HH, heavily hunted) and central (LH, lightly hunted) Washington State, 2002–2007.

	HH area			LH area		
Sex and age	Radio-days	n	Survival rate	Radio-days	n	Survival rate
Female						
Kitten (0–12 months)	1611	5 (10)	0.32 ± 0.16	1094	1 (6)	0.72 ± 0.24
Juvenile (13–24 months)	1871	0 (6)	1.00 ± 0.00	1310	1 (5)	0.76 ± 0.21
Adult (24+ months)	9645	11 (19)	0.66 ± 0.08	7601	3 (12)	0.87 ± 0.07
Total	13 126	16 (35)	0.64 ± 0.07	10,005	5 (23)	0.83 ± 0.07
Male						
Kitten (0–12 months)	1885	6 (13)	0.31 ± 0.15	2295	4 (13)	0.53 ± 0.17
Juvenile (13–24 months)	2392	4 (12)	0.54 ± 0.52	1084	2 (8)	0.51 ± 0.24
Adult (24+ months)	4470	9 (12)	0.48 ± 0.12	5851	7 (12)	0.65 ± 0.11
Total	8746	19 (37)	0.45 ± 0.08	9230	13 (33)	0.60 ± 0.08
Population totals	21 872	35 (72)	0.56 ± 0.05	19,235	18 (56)	0.71 ± 0.06

Note: Sample size n is the number of mortalities, with the total number of monitored animals in parentheses.

TABLE 3. Densities and ages (mean ± SD) for monitored cougars in northeast (HH, heavily hunted) and central (LH, lightly hunted) Washington State, 2002–2007.

	HH area		LH area	
Age and sex	Density (cougars/100 km^2)	Age (months)	Density (cougars/100 km^2)	Age (months)
Adults (>24 months)				
Female	1.35 ± 0.12	51 ± 7	1.07 ± 0.38	68 ± 13
Male	0.23 ± 0.10	42 ± 5	0.80 ± 0.05	59 ± 5
Total	1.58 ± 0.17	48 ± 5	1.87 ± 0.42	61 ± 3
All ages				
Female	2.83 ± 0.76	33 ± 7	2.32 ± 0.44	40 ± 6
Male	0.63 ± 0.12	24 ± 5	1.30 ± 0.15	41 ± 5
Total	3.46 ± 0.69	27 ± 4	3.62 ± 0.58	39 ± 4

and 0.15 ($\lambda_O - \lambda_D$). Observations of radio-collared cougars supported these trends; we documented five emigrants and three immigrants in LH, and four immigrants and zero emigrants in HH from 2005 through 2007.

Population density

The mean 95% composite range of females was 772 km^2 (95% CI = 316–1228) for HH and 655 km^2 (95% CI = 425–885) for LH. The annual proportion (mean ± SD) of male GPS points within the composite range of females was 0.32 ± 0.08 in HH and 0.43 ± 0.16 in LH.

Time and time × area explained significant variation in cougar density ($P < 0.10$). The final model included: area, time, and time × area. Mean annual densities of all cougars were 3.46 ± 0.69/100 km^2 in HH and 3.62 ± 0.58/100 km^2 in LH, and were not different ($P = 0.26$) (Tables 3 and 4). Compared to LH, mean densities of males were lower in HH (0.63 ± 0.12 vs. 1.30 ± 0.15/100 km^2; $P < 0.01$) and mean densities of females were higher (2.83 ± 0.76 vs. 2.32 ± 0.44; $P = 0.02$). Within HH, densities of all cougars and females declined over the study period, whereas we detected no change in male densities. In LH, we did not detect a change in density for any sex and age class (all $P > 0.05$; Table 4).

Sex and age structure

Mean age of the cougar population was 27 months (2.3 years) in HH and 38 months (3.2 years) in LH (Table 3). Most mean ages of cougars were higher in the LH than in HH for all age and sex classes (all $P < 0.05$), with one exception being mean age of females, which was actually higher in the HH ($P = 0.10$) (Table 3). Mean age of female cougars in HH increased ($P = 0.03$) over time and mean age of males decreased ($P = 0.07$). We detected no changes in age for LH ($P > 0.10$) across the study period.

Confounding factors

We detected no differences in mean maternity rates ($t = 2.26$, df = 9, $P = 0.94$), predation rates ($t = 0.79$, df = 34, $P = 0.44$), or population density ($t = 1.47$, df = 1, $P = 0.26$) between areas. The female predation rate in HH was 6.68 days/kill (Cooley et al. 2008) and 7.04 days/kill in LH (K. White, *unpublished data*).

DISCUSSION

Data comparing demographics of two Washington cougar populations suggest that hunting does not act in a compensatory manner in cougar populations. The compensatory mortality hypothesis predicts that increased harvest mortality of males will reduce population density, resulting in lower competition for resources, reduced natural mortality, and increased reproduction and survival of young. The compensatory mortality hypothesis predicted that low levels of harvest will result in increased densities and rates of natural mortality, and decreased reproduction and survival.

In the heavily hunted area, female densities declined and male densities remained unchanged, whereas we

TABLE 4. Effects of study area (hunting level) and time (2002–2007) on density estimates of cougars (cougars/100 km^2) using a general linear model.

Parameter	Estimate	SE	t	P
Total cougars				
Intercept	4.05	0.38	10.71	<0.01
HH area	0.65	0.54	1.21	0.26
LH area	0.00			
Time	−0.15	0.10	−1.53	0.17
Time × area HH	−0.27	0.14	−1.94	0.09
Time × area LH	0.00			
Male cougars				
Intercept	1.41	0.14	10.17	<0.01
HH area	−0.78	0.20	−3.97	<0.01
LH area	0.00			
Time	−0.04	0.04	−1.04	0.33
Time × area HH	0.02	0.05	0.47	0.65
Time × area LH	0.00			
Female cougars				
Intercept	2.64	0.33	7.92	<0.01
HH area	1.43	0.47	3.02	0.02
LH area	0.00			
Time	−0.11	0.09	−1.30	0.23
Time × area HH	−0.29	0.12	−2.38	0.04
Time × area LH	0.00			

observed no change in male or female densities in the lightly hunted area. We found no differences in rates of natural mortality (0.18 in the heavily hunted area and 0.13 in lightly hunted area) or maternity rates (1.15 in the heavily hunted area vs. 1.12 in lightly hunted area). Kitten survival was lower in the heavily hunted area (0.32 in the heavily hunted area and 0.58 in the lightly hunted area), with none of the kitten mortalities resulting from hunting or death of the mother. Our findings reject the compensatory mortality hypothesis because vital rates did not compensate for hunting mortality.

Resource availability could have influenced vital rates; however, both populations were at similar densities (3.46 cougars/100 km^2 in the heavily hunted area and 3.62 cougars/100 km^2 in the lightly hunted area) and female predation rates were not different, suggesting that resources were similar between areas. Densities were maintained via a net immigration into the heavily hunted area and a net emigration out of the lightly hunted area. The net emigration could indicate poorer resources; however, kitten survival and female population growth were higher there, suggesting that this is not the case. The net immigration rate in the heavily hunted area could suggest better resources, but kitten survival and female population growth were lower there, also contrary to the compensatory mortality hypothesis.

Instead of hunting influencing survival and reproduction, hunting was compensated by immigration and emigration in both cougar populations. The stochastic population model, based on the compensatory mortality hypothesis, predicted a 27% population decline, whereas we observed a 9% decline in overall numbers and no decline in the male population. The difference in growth rates resulted from immigration. The stochastic model assumed a closed population structure and did not account for immigration, whereas the observed growth rate accounted for the open nature of cougar populations by including immigration. Many of the mortalities resulting from hunting were replaced by animals immigrating from surrounding areas.

In the lightly hunted population, the stochastic model predicted a 10% increase in population growth, yet cougar numbers remained stable. The projected population increase was compensated by emigration rather than by decreased vital rates. Therefore, neither total population density nor competition among cougars appeared to be influenced by hunting, with immigration and emigration counteracting the effects predicted by the compensatory mortality hypothesis

Long-distance dispersal is common in cougars (Sweanor et al. 2000, Logan and Sweanor 2001, Stoner et al. 2006) and can help to maintain overall numbers by replacing harvest mortalities with animals dispersing from neighboring areas (Hanski 2001). Rebound from heavy hunter harvest by immigration has been documented in cougar populations elsewhere (Ross and Jalkotzy 1992, Logan et al. 1986, Logan and Sweanor 2001, Anderson and Lindzey 2005, Stoner et al. 2006, Robinson et al. 2008). As a consequence, harvest models based on compensatory mortality hypothesis are unable to accurately predict the responses of cougar populations to hunting.

The heavily hunted population compensated for heavy harvest in overall numbers of cougars through male immigration. However, the female population declined ($\lambda_O' = 0.86$). Although male cougars commonly disperse long distances, females are usually philopatric (Sweanor et al. 2000). As a result, fewer female immigrants are available to immigrate and replace those that are harvested, resulting in decreased numbers of females. Adult female survival is therefore vital for population growth and recovery from harvest (Martorello and Beausoleil 2003).

Harvesting adult males may increase incidences of infanticide by allowing immigration of new, unrelated males (Ross and Jalkotzy 1992, Whitman and Packer 1997, Murphy et al. 1999, Logan and Sweanor 2001). Lower kitten survival in the heavily hunted area may be a result of high male turnover from hunting. Male carnivores are known to kill unrelated young in order to induce estrous and gain breeding opportunities (Packer and Pusey 1983, Smith and McDougal 1991, Wielgus and Bunell 1995, Swenson et al. 1997, Logan and Sweanor 2001). Our observations suggest that six kittens of three litters in the heavily hunted area may have been killed by unrelated male cougars. When we removed those six kittens from the survival analysis, we found no difference in survival rates of kittens between areas, suggesting that infanticide may have been responsible for lower kitten survival in the heavily hunted area. High rates of immigration following heavy male harvest were also documented for brown bears *Ursus arctos* (Wielgus and Bunnell 1994) and black bears *Ursus americanus* (Sargeant and Ruff 2001). Female population growth declined because of sexually selected infanticide in brown bears (Wielgus and Bunnell 1994, Swenson et al. 1997). This may indicate that the compensatory mortality hypothesis may not be appropriate for many solitary, territorial, or quasi-territorial carnivores.

It is unlikely that age structure ever stabilizes in long-lived species such as cougars, which may bias our estimates of deterministic growth. Because this lack of variability assumes a stable age distribution, we have little confidence that differences between deterministic growth rates and observed growth rates act as predictors of actual population growth and believe that differences between stochastic growth rates and observed growth rates more accurately project growth rates. Additionally, despite intense trapping efforts conducted each winter, we may have missed some cougars that were present on the landscape during the study, resulting in biased estimates of observed growth and subsequent net immigration and emigration rates. The addition of the same number of cougars each year would increase density estimates, but would not change the observed growth and emigration rates. A temporal bias, such as missing cougars only early in the study (most likely error), would yield an even lower true observed growth rate, whereas missing cougars only later in the study (least likely error) would yield a higher true observed growth rate. For example, a count of 10 cougars in 2002 and 11 cougars in 2003 would yield an observed growth rate of 1.10. If we missed three cougars in 2002, the true growth rate would have been 11/13, or 0.85. We have neither reason nor evidence to suspect that we missed more cougars as the study progressed, therefore any bias in our observed population growth rates is conservative.

Conservation Implications

Harvest models that are based on the compensatory mortality hypothesis rely on the assumption that density reductions result in reduced competition for resources, thereby increasing survival and reproduction of remaining animals. However, our results suggest that dispersal movements may mitigate for mortalities resulting from hunting and negate compensation by other vital rates. These findings have two management implications. (1) Recovery from harvest relies on nearby source populations; therefore, cougar harvest should be managed at the metapopulation scale (Cougar Management Guidelines Working Group 2005:73–74). (2) Even when healthy source populations exist, prolonged harvest will cause female population declines via direct harvest of adult males and increased kitten mortality caused by immigration of potentially infanticidal males (Ross and Jalkotzy 1992, Logan and Sweanor 2001), and kitten abandonment from harvest of mothers (R. Beausoleil, *personal communication*). The compensatory mortality hypothesis may not be appropriate for modeling hunter harvest for cougars and other large carnivores that exhibit long-distance dispersal. Assumptions of closed populations are not appropriate for solitary carnivore species.

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APPENDIX

Comparison of seasonal survival by year for radio-collared cougars in central (LH, lightly hunted) and northeast (HH, heavily hunted) Washington State, USA, 2002–2007 (*Ecological Archives* E090-207-A1).

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Improving estimation of puma (*Puma concolor*) population density: clustered camera-trapping, telemetry data, and generalized spatial mark-resight models

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Obtaining reliable population density estimates for pumas (*Puma concolor*) and other cryptic, wide-ranging large carnivores is challenging. Recent advancements in spatially explicit capture-recapture models have facilitated development of novel survey approaches, such as clustered sampling designs, which can provide reliable density estimation for expansive areas with reduced effort. We applied clustered sampling to camera-traps to detect marked (collared) and unmarked pumas, and used generalized spatial mark-resight (SMR) models to estimate puma population density across 15,314 km^2 in the southwestern USA. Generalized SMR models outperformed conventional SMR models. Integrating telemetry data from collars on marked pumas with detection data from camera-traps substantially improved density estimates by informing cryptic activity (home range) center transiency and improving estimation of the SMR home range parameter. Modeling sex of unmarked pumas as a partially identifying categorical covariate further improved estimates. Our density estimates (0.84–1.65 puma/100 km^2) were generally more precise (CV = 0.24–0.31) than spatially explicit estimates produced from other puma sampling methods, including biopsy darting, scat detection dogs, and regular camera-trapping. This study provides an illustrative example of the effectiveness and flexibility of our combined sampling and analytical approach for reliably estimating density of pumas and other wildlife across geographically expansive areas.

Pumas (cougars or mountain lions; *Puma concolor*) are the most widely distributed large carnivore in the western hemisphere[1]. Similar to other large carnivores, pumas have considerable resource requirements and provide important ecological benefits over expansive areas[1–3]. Their presence sometimes results in confli ts with humans, however, and predation by pumas can influence vital rates of terrestrial ungulate populations[4,5]. Although some puma populations have recently expanded range and present novel management challenges[6,7], other populations are small, isolated, or otherwise imperiled and might necessitate conservation intervention[8,9]. Conservation and management of pumas are often contentious issues that are influenced by multiple political, social, and economic interest groups, and resolving disputes has increasingly hinged on managing authorities possessing reliable and contemporary estimates of puma population density and abundance[10–12]. However, pumas are wide-ranging, cryptic, and notoriously difficult to detect; consequently, few jurisdictions within the species' occupied range have reliable estimates of those demographic parameters. Most puma populations are instead managed based on population indices, such as hunter effort, mortality trends, or expert opinion, extrapolation of densities from

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small study areas and other jurisdictions, or a combination thereof[10,13–15], all of which may be unreliable and could result in flawed conservation and management[16,17].

Spatially explicit capture-recapture models integrate a detection process model with an ecological process model that describes the spatial distribution of animal activity centers, or home range centers, across a study area, and can produce unbiased estimates of population density[18,19]. Recent studies have applied spatially explicit models to multiple types of detection data to estimate puma population density; for example, tissue samples collected by biopsy darting pumas that were treed using hounds[20–22], puma scat collected via area searches by scat detection dogs[23], and photographs of pumas collected from regular or contiguous arrays of remote camera-traps[24–27]. However, biopsy darting and scat detection dog sampling necessitate often expensive laboratory genetic analyses to produce individual identities from detection data[28]. Additionally, treeing pumas with hounds for biopsy darting is likely most effici t during winter and in locales with suffici t snow cover that improves tracking[20,22], and because of high DNA degradation rates in scat that can reduce sample sizes, optimal effectiveness of scat detection dog sampling is generally limited to locales with cool and dry climates[29,30]. In contrast, remote camera-trapping can be a cost-effici t and logistically feasible approach for effectively detecting pumas and other large carnivores across habitats, ecosystems, and climatic conditions[31,32].

A critical assumption of most capture-recapture models is that all detected animals are individually identifiable[19]. Th s can be difficult to achieve if camera-traps are used to detect pumas or other wildlife that lack visible, individually unique natural markings, such as the rosettes on jaguars (*Panthera onca*)[24,33]. To overcome this issue, mark-resight models and their spatially explicit analogues, spatial mark-resight (SMR) models, were developed to estimate the density of populations in which only a portion of animals are individually identifiable[26,34–37]. Attempting to assign individual identities to pumas *ad hoc* based on perceived natural marks, such as scars, ear nicks, body shapes, or carriages[25,27], can result in biased and unreliable density estimates, however, because multiple individuals may have similar physical features, causing observers to agree on incorrect identity assignments or disagree on correct identity assignments[24]. Furthermore, given the ambiguity, it is not always possible to identify a suffici t number of individually unique pumas based solely on natural marks to estimate population density[24,38].

For pumas and other species that lack unambiguous natural markings, physically capturing and applying artific al marks, such as radiocollars or ear tags, to a portion of animals in a population is likely necessary for accurate density estimation when using camera-traps for detection[26,32,34–37]. Such mark-resight methods can be viable, cost-effective alternatives to capture-recapture methods, because only a single marking event of a portion of a population is required and camera-trapping to collect resighting data is effici t. Using Global Positioning Systems (GPS) collars as marks can permit unambiguous individual identifi ation for nearly all camera-trap detections of marked individuals, assist with determining whether an animal is marked or unmarked, and also provide telemetry location data that can be integrated in spatially explicit models to improve estimation of individual activity centers, the detection function spatial scale (home range) parameter (σ), and ultimately, population density[26,36,37,39].

One challenge associated with using researcher-applied artificial marks is that in SMR models, the spatial distributions of marked and unmarked individuals across the landscape are informed by the capture and marking process; therefore, correctly specifying those distributions in the process model is critical for accurately estimating population density[35,37]. Conventional spatial mark-resight (conSMR) models assume that marked and unmarked individuals have the same spatial distribution, typically uniformity or that the two distributions can be specifi d correctly with parametric distributions[26,34,36]. Although the assumption of spatial uniformity may be valid for jaguars and other species that are identifiable by their individually unique natural markings, it is likely inappropriate if animals are physically captured and artific ally marked, because of the juxtaposition between marking and resighting locations[35,37]. If the marking and resighting detector arrays overlap, animals that are captured for marking are located on average closer to the resighting array than unmarked individuals and, therefore, likely will have higher detection rates than unmarked individuals. Consequently, if researcher-applied artific al marks are used for individual identifi ation, conSMR models, which do not account for the capture and marking process, may underestimate the numbers of both unmarked and undetected individuals and thus, population density[35,37].

A generalized spatial mark-resight model (genSMR) was recently developed that resolves this problem by including sub-models for both the marking and resighting processes[37]. Th s allows the differing spatial distributions of marked and unmarked individuals to be determined by the marking process, and simulations have demonstrated that the genSMR model produces unbiased estimates of population density when marking is not random across a study area[37]. The parameters of the genSMR model developed by Whittington *et al*.[37] are estimated via Bayesian methods using Markov chain Monte Carlo (MCMC) algorithms. In contrast, Efford and Hunter[35] developed a pseudolikelihood-based model and estimation procedure that is analogous to genSMR, which they refer to as spatial capture-mark-resight. A primary limitation of this pseudolikelihood estimation procedure is that it ignores information contained in the spatial distribution of detections of unmarked individuals. Efford and Hunter[35] argued that the information lost by discarding these data is minimal; however, the magnitude of information in the spatial locations of detections of unmarked animals can be increased through the use of partial identity covariates[34,39].

A key source of uncertainty in SMR models stems from the need to probabilistically resolve the individual identities for detections of unmarked animals, as well as detections of marked but unidentifiable animals and animals with unknown mark status, if available[34,39]. Reducing uncertainty in the individual identity assignments can reduce the uncertainty in population density estimates, which can be accomplished with partial identity covariates[39,40]. The use of categorical partial identity covariates in the form of microsatellite loci genotypes has been demonstrated[39,40], but the utility of partially identifying information in camera-trap studies, where animal sex and other potential covariates are fewer in number and less reliably determined from photographs, has not been explored. Such covariates are typically either not recorded or are discarded from camera-trap detection data, so evaluating their effectiveness for improving the precision of parameter estimates from spatially explicit models could result in improved density estimation in camera-trapping studies.

Because of the logistical and financial constraints associated with currently available puma sampling methods and survey designs, researchers are often forced to estimate puma population density for areas that are smaller than the geographical extent of populations or the scale at which conservation and management occur[10,15]. Population density estimates are then extrapolated to larger areas, typically with considerable uncertainty and unverified assumptions[10,13–15]. By incorporating spatial information about when and where individual animals are detected, spatially explicit models are robust to irregular sampling designs, such as clusters of detectors with gaps between clusters, which can permit efficient surveying of large geographical areas[18,41–45]. Recent studies evaluated clustered sampling designs of noninvasive genetic hair-traps in the spatially explicit framework for estimating American black bear (*Ursus americanus*) population density, which demonstrated that density estimates were improved, largely because more individuals were exposed to detectors and spatial recaptures were obtained over expansive areas[41,43–45]. Remote camera-trapping is arguably the most widely used and practical noninvasive method for surveying wildlife populations globally[31,32]; therefore, considerable potential exists for using clustered sampling designs in camera-trap studies to estimate population density over spatially extensive areas, which could have widespread practical utility across terrestrial wildlife species and geographical locales.

Herein, we apply clustered sampling to camera-traps in the spatially explicit framework to demonstrate the potential for this approach to survey pumas over expansive areas with reduced effort. We then apply recently developed genSMR models to the obtained camera-trap detection data to estimate puma population density and abundance. In addition, we evaluate the influence on parameter estimates of integrating telemetry data from GPS collars on marked pumas, incorporating sex as a categorical identity covariate for unmarked pumas, and accommodating activity center transiency. Our results demonstrate the flexibility of genSMR models and provide an illustrative example of the effectiveness of this combined sampling and analytical approach to produce precise and reliable population density estimates over large geographical areas.

Materials and Methods

Study area. Our study occurred during 2017 in the Southern Rocky Mountains ecoregion in north-central New Mexico, USA (Fig. 1). The area was rugged, with steep mountains, deep canyons, and expansive mesas, and elevations ranging from 1,540 to 3,524 m a.s.l. The climate was semi-arid, with average annual rainfall ranging from 22.58 to 57.63 cm and average annual snowfall ranging from 18.03 to 305.31 cm, depending on elevation; average annual high temperatures ranged from 13.72 to 22.05 °C and average annual low temperatures ranged from −4.17 to 3.00 °C, depending on elevation[46]. The majority of lands (63%) were under federal management by the U.S. Forest Service, National Park Service, or Bureau of Land Management; tribal lands (29%) and a combination of state government, local government, and privately owned lands (8%) accounted for the remainder of land area.

Live-capture and marking. To apply artificial marks to a portion of individuals, we live-captured pumas throughout our study area using Aldrich spring-activated foothold cable restraints, foothold traps, and to a lesser extent, treeing with a team of trained hounds[47,48]. We chemically immobilized captured pumas using one of the following drug combinations[49]: (1) tiletamine and zolazepam (Telazol®; Zoetis Services LLC, Parsippany, USA) at a dosage of 5.0 mg/kg combined with 1.0 mg/kg of xylazine (AnaSed®, LLOYD Inc., Shenandoah, USA), the latter of which was antagonized using 0.12 mg/kg of yohimbine (ZooPharm, Windsor, USA); or (2) 2.0 mg/kg of ketamine combined with 0.07 mg/kg of medetomidine, the latter of which was antagonized using 0.30 mg/kg of atipamezole (ZooPharm). During immobilization, we monitored the respiratory rate, heart rate, and body temperature of each puma at five-minute intervals to ensure maintenance of bodily function. We outfitted captured pumas that were field-aged based on gum recession measurements[50] as being ≥ two years-old (i.e., subadults and adults)[48] with a uniquely numbered ear tag and an Iridium GPS collar (Advanced Telemetry Systems [Isanti, USA] or Vectronic Aerospace [Berlin, Germany]). We programmed collars to acquire location fixes every one to three hours (i.e., 8–24 fixes per calendar day) and we remotely downloaded location data every three to seven days. All pumas were released at the location where captured.

Clustered camera-trap resighting. We created a survey design comprised of nine total clusters of 3×3 sampling cells in each cluster (Fig. 1). Cell spacing within a cluster was 3.5×3.5 km, or 12.25-km^2 coverage per cell and 110.25-km^2 coverage per cluster; this spacing corresponded to the recommended ≥two detectors within the smallest female home range size[43,45] reported for pumas in New Mexico (30.10 km^2)[51]. Clusters were staggered with 28-km longitudinal spacing and 36–45-km latitudinal spacing between the centers of clusters, or 4.5–7× the diameter of said smallest female home range size, assuming a bivariate normal distribution (i.e., circular home range)[19]. Prior to deploying camera-traps, we used simulation to evaluate the performance of this clustered survey design for estimating population density, given pessimistic parameter estimates and various numbers of sampling occasions[19,41,45]. For a simulated hypothetical population with low density (1.0 puma/100 km^2), low baseline detection rate ($\lambda_0 = 0.05$), and large spatial scale of the detection function ($\sigma = 5.0$ km)[20,25], results from a fitted null spatial capture-recapture model indicated that surveying this design for 17 consecutive occasions would likely estimate population density with high precision and accuracy (CV = 0.18; RMSE = 0.19), negligible bias (+0.05, 95% CI = 0.00–0.09), and nominal coverage (0.97, 95% CI = 0.94–1.00; see Supplementary Table S1). These simulations assumed that all individuals had unambiguous identities, which deviates from the mark-resight framework, but the effectiveness of survey designs for spatial capture-recapture and SMR models are similar[19].

We attempted to establish a single camera-trap within each sampling cell along canyon rims, ridges, saddles, drainages, trails, and other terrain features that could be likely travel routes for pumas; we did not place camera-traps on roads. Because of restricted property access, we were unable to establish camera-traps in some cells; thus, our final array was comprised of 68 total camera-traps (range: 3–9 camera-traps/cluster). Each camera-trap consisted of two cameras with passive infrared motion-activated sensors (Reconyx® HyperFire PC800; Holmen, USA), which we placed four to six m apart, facing each other, and mounted to trees

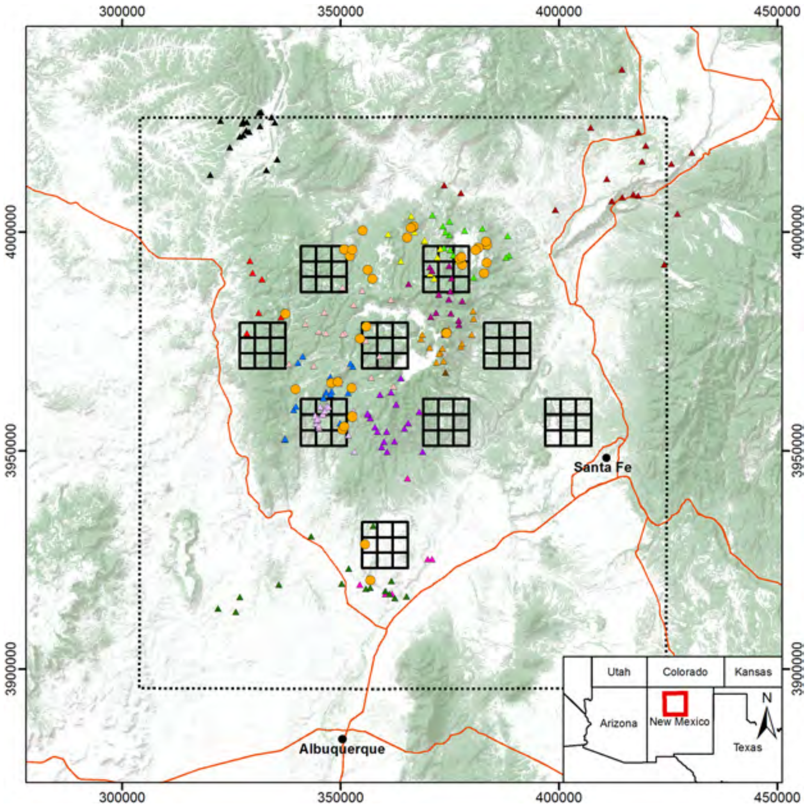

Figure 1. Study area in New Mexico, USA, where pumas were live-captured and marked with GPS collars, and camera-traps were deployed in a systematic cluster design for resighting of marked and unmarked pumas to estimate population density with generalized spatial mark-resight models. The spatial locations of live-traps (orange circles), camera-trap sampling cells (solid black outline squares), thinned telemetry locations collected during the resighting period (triangles with discrete colors corresponding to individual), and parameter estimation area (state space; dashed black line) are presented. Image created by S.M.M. with ESRI® ArcMap™ 10.4.1 software (http://desktop.arcgis.com/en/) under license (https://technology.ky.gov/gis/Pages/PostSecondarySiteLicense.aspx), with forest-shrub land cover data (green shaded areas) from the U.S. Government (https://www.mrlc.gov/data/nlcd-2011-land-cover-conus)[79]; topography data (background) from ESRI, U.S. Geological Survey, and National Oceanic and Atmospheric Administration (https://server.arcgisonline.com/ArcGIS/rest/services/World_Terrain_Base/MapServer); and major highways data (red lines) from New Mexico Department of Transportation (http://services.arcgis.com/hOpd7wfnKm16p9D9/arcgis/rest/services/NMDOT_Functional_Class/FeatureServer).

or shrubs ~one m above the ground[52]. We set cameras to medium sensitivity with bursts of five photos per detection and 30-s delays between bursts. We placed ~1.0 mL of bobcat (*Lynx rufus*) gland-based or rub-eliciting scent lure on the ground in the center of each camera-trap. These lures provided no caloric reward, and felids do not have the extraordinary olfactory capabilities that canids and ursids do[53]; neither pumas, jaguars, nor leopards (*Panthera pardus*) have exhibited a behavioral response (i.e., trap-happy or trap-shy) to detection when bobcat lure was applied[54–56]. If a camera-trap is visited, however, bobcat lure can entice pumas to linger for a slightly extended period of time, thereby affording researchers the opportunity to identify the sex and marked status of an individual from photographs[24,57,58].

We operated camera-traps for 17 consecutive seven-day occasions from July to November 2017, and we visited each camera-trap every 21–28 days to retrieve photographs, check battery levels, and reapply lure. We considered individual photographs of pumas that were acquired ≥one hr apart as unique detections[24,25]. We excluded dependent kittens, which are not reproductively mature, from the detection history to prevent inflation of density estimates[13,20]; therefore, our results represent subadult and adult pumas only. We first classified photographs by the mark status of each puma based on the presence or absence of a GPS-collar: (1) marked and identifiable, (2) marked but unidentifiable, (3) unmarked, or (4) unknown. We then identified marked pumas to the individual level based on a combination of ear tag, collar type, sex, and telemetry locations from GPS collars[26,37]. We did not attempt to assign individual identities to any non-collared pumas based on perceived natural marks, because of the inherent uncertainty that could bias density estimates[24]. We reclassified all pumas that we initially assigned unknown mark status as unmarked if photograph date and time did not align with telemetry location data for GPS-collared individuals. Similarly, we resolved all cases of marked but unidentifiable individuals by comparing telemetry locations with photograph date and time. We identified the sex of unmarked pumas when possible; for photographs from which puma sex was inconclusive, we assigned individuals unknown sex.

Spatial mark-resight analysis. We estimated puma population density using the live-capture history (marking), the camera-trap detection history (resighting), and the telemetry locations from GPS-collared pumas. Because only two pumas were captured and marked via treeing with hounds, we did not explicitly model a separate hound capture process; however, we retained hound-captured pumas in our data as marked individuals that were exposed to both the marking and resighting processes, and they also provided telemetry data that informed their activity center locations and contributed to estimation of the detection function spatial scale parameter. To jointly use all of those sources of information and account for dependency among data types, we used a Bayesian genSMR model[37] that specifi d a spatial capture-recapture density and activity center process model that was observed in three ways: (1) through the marking process in which all individual identities were known; (2) through the resighting process in which only the individual identities of marked pumas were known and unmarked identities could be partially known if sex was observed; and (3) through the telemetry process for the marked individuals with known identity. To reduce the uncertainty in probabilistically resolving the latent identities of unmarked individuals[34], we used sex as a categorical identity covariate to exclude particular combinations of detections[39,40]; for example, an unmarked male detection could not be from the same individual as an unmarked female detection. Th s assumed that the sex of individual i, sex_i ~ Bernoulli(p^{sex}), where p^{sex} is the probability that an individual is female, which must be estimated. Using this assumption, sex can be probabilistically resolved for detections of individuals whose sex was not identifi d from photographs[22], and the individual identities of unmarked pumas can be probabilistically resolved using the algorithms developed by Chandler and Royle[34], excluding identity matches between detections of different sexes. We also fit conSMR models, which ignore the marking process[26,34,36], to permit comparisons with genSMR models. We accommodated all of the aforementioned features using MCMC algorithms that are maintained in the R statistical software package SPIM[59,60].

We considered the following two process models for activity centers ($\boldsymbol{s}$). First, we used a typical spatial capture-recapture point process model in which individual i had a single $\boldsymbol{s}_i$ for the entirety of the study (marking and resighting combined), and all $\boldsymbol{s}_i$ were uniformly distributed across space ($\boldsymbol{s}_i$ ~ Uniform($\boldsymbol{S}$) for $i = 1, \ldots, N$, where $\boldsymbol{S}$ denotes the two-dimensional state space [parameter estimation area])[19]. To defi e the state space for genSMR models, we buffered the minimum and maximum longitude and latitude extents of the combined live-trap and camera-trap locations by 25 km, or ~3× the maximum estimated spatial scale of the detection function parameter that was pooled between marking and resighting processes (σ^d)[19], resulting in $\boldsymbol{S}^G = 15{,}314\,\text{km}^2$. In contrast, because conSMR models do not incorporate the marking process, the 25-km buffer was applied only to the camera-trap locations to defi e a state space for conSMR models of $\boldsymbol{S}^C = 14{,}707\,\text{km}^2$. Second, GPS-collar telemetry data indicated that the activity centers for four marked pumas may have spatially shifted large distances between the marking and resighting processes, and one marked puma died prior to the onset of resighting (see Results). Therefore, we also specifi d a spatial point process model for activity center transiency, which estimated the locations of individuals' activity centers separately for each the marking and resighting processes[61,62]. Th s process model accommodated activity center relocations between marking and resighting, including if individuals relocated to fill the territorial vacancy that resulted from the death of one marked puma[63,64]. An individual's activity centers were connected by a spatially constrained relocation event (described in detail below), which entailed that resighting activity centers must be spatially linked to the location where each marked puma was live-captured, thereby constituting an activity center model that was intermediate between conSMR and genSMR models[61,62].

We defi ed data for the marking and resighting processes using the M and R superscripts, respectively. The previously mentioned two-step process model for genSMR models required us to specify two sets of activity centers, s_i^M and s_i^R, for $i = 1, \ldots, N$. We assumed spatial uniformity of activity centers for the marking process, s_i^M ~ Uniform($\boldsymbol{S}^G$). For the resighting process, we assumed s_i^R ~ Bivariate Normal(s_i^M, Σ)[($x_{\min}$, $y_{\min}$), ($x_{\max}$, $y_{\max}$)], where $\Sigma = \sigma^t \boldsymbol{I}$, and σ^t is the spatial scale parameter for activity center transiency; the bivariate normal redistribution kernel was truncated by the extent of $\boldsymbol{S}^G$ to prevent σ^t underestimation[62]. Th s model for redistribution (i.e., spatial shift) has been used in both open and closed population spatial capture-recapture models[62,65], the latter of which allowed fully transient activity centers and was recently applied to conSMR models[61]. In contrast to those implementations, we only allowed one spatial redistribution of activity centers, because that was all that was necessary to accommodate the spatial dynamics that we observed, and fewer activity center shifts should maintain greater precision and better MCMC mixing, which is typically poor for spatially explicit models that accommodate transient activity centers[61,62].

Conditional on the aforementioned process models, the population was observed via three processes. For the marking and resighting processes, observations were made at the $J^M \times 2$ live-trap locations X^M and the $J^R \times 2$ camera-trap locations X^R, where J^M and J^R are the number of live-trap and camera-trap locations, respectively. We assumed a hazard half-normal detection function with binomial detections for the marking process, producing individual by live-trap detections summed across occasions, Y_{ij}^M ~ Binomial(p_{ij}^M, K^M), where K^M is the number of marking occasions. For the resighting process, we assumed a Poisson detection function, producing individual by camera-trap counts that were summed across occasions; specifi ally, Y_{ij}^R ~ Poisson($K^R \times p_{ij}^R$), where K^R is the number of resighting occasions. These observation models had σ^d and baseline detection rate parameters that varied by process (λ_0^M and λ_0^R). Telemetry locations from GPS collars could be recorded anywhere within the extent of $\boldsymbol{S}$. We used only the telemetry locations that were collected during the resighting period, which we thinned to one randomly selected location per survey occasion for each marked puma (i.e., one location/week). We applied this thinning to decrease temporal dependence among telemetry locations for each puma, because temporal dependence could cause underestimation of the variance of σ^d and σ^t, activity centers, and population density[26,36,37]. Telemetry locations informed the estimation of σ^d and $\boldsymbol{s}_i$, or σ^d, s_i^R, and σ^t for models that included activity center transiency.

We accounted for unequal live-trap and camera-trap operation (effort) across time, and also a puma that died prior to initiation of resighting, using individual by trap exposure matrices. These matrices are similar to a trap operation file[19], except that the exposure of each puma to each trap and trap type could differ; this allowed for known entries and exits into and out of the population, but did not account for unknown violations of the population closure assumption[37,39]. For the marking process, the $A \times J^M$ exposure matrix E^M contained the number of occasions that individual i was exposed to detection at a live-trap j, where A indicates the level of data augmentation[66]. For the resighting process, the $A \times J^R$ exposure matrix E^R contained the number of occasions that individual i was exposed to detection at camera-trap j. These exposure matrices were substituted into the binomial and Poisson observation models for K^M and K^R, respectively. To correctly allocate latent identity samples for two pumas that were live-captured and marked during the resighting period and one marked puma that died prior to resighting, we used an $n^M \times K^M$ matrix m, where n^M is the number of marked pumas, to denote the marked status of each GPS-collared puma during each resighting occasion (0 = unmarked, 1 = marked, and 2 = dead)[37]. Thus, if a puma was unmarked on occasion k, it could be allocated latent identity unmarked detections. If a puma was marked on occasion k, it could be allocated latent identity marked detections. If a puma was dead on occasion k, it could not be allocated any latent identity detections.

Several process and observation models were described, so we detail below exactly which combinations we fit. Our model specifi ations were designed to test the relative importance of four items: (1) telemetry data from marked pumas, (2) sex as a categorical identity covariate for unmarked pumas, (3) activity center transiency for marked pumas between the marking and resighting processes, and (4) conSMR versus genSMR models. The influence of telemetry data was of particular interest, because the activity centers for four marked pumas likely relocated between marking and resighting, and we also had limited prior home range size data to inform camera-trap and cluster spacing. Therefore, we fit two genSMR models that included sex identity constraints for the resighting process, but differed as to whether telemetry data were incorporated or not (models 1 and 2). We extended models 1 and 2 to accommodate activity center transiency between the marking and resighting processes for marked pumas (models 3 and 4). Because models 3 and 4 best described the observed spatial dynamics of pumas during our study, we tested the importance of sex identity constraints by fitting these models without sex identity constraints (models 5 and 6). To test the importance of using genSMR over conSMR models, we fit models 1 and 2 excluding the marking process (models 7 and 8). Finally, to investigate if sex-specific detection function parameters were necessary to estimate puma density and the sex ratio, we fit a version of model 1 that included sex-specific detection function parameters (model 9).

We ran each genSMR model for 5×10^5 iterations, thinned by 75 iterations, and we discarded the fi st 5×10^3 iterations as burn-in. The large number of iterations was more than required for the models that excluded activity center transiency, but for models that included activity center transiency, σ^t mixed poorly and required many iterations to accurately characterize this posterior distribution. In contrast, we ran each conSMR model for 4×10^4 iterations and discarded the fi st 5×10^3 iterations as burn-in. We used data augmentation to augment the sample of marked pumas with up to $A = 250$, 325–375, and 600 hypothetical individuals that had all-zero detection histories for conSMR models, genSMR models that included telemetry data, and genSMR models that excluded telemetry data, respectively[26,36,37,66]. We used the posterior modes for parameter point estimates, and we used the 95% highest posterior density intervals (HPDI) for interval estimates. We assessed precision of density estimates using the widths of 95% HPDIs and the posterior coeffici ts of variation (CV), or the posterior standard deviation divided by the posterior mode.

Ethics statement. Experimental protocols were approved by New Mexico Department of Game & Fish (per NMAC 19.35.6), Pueblo of Santa Ana Tribal Council, and a U.S. National Park Service Institutional Animal Care and Use Committee (IMR-VALL-Cain-LargeMammals-2015.A2). Data collection methods were carried out in accordance with standardized guidelines for humane wild mammal handling and welfare[67], scientifi research permits (VALL-2017-SCI-0002 and VALL-2017-SCI-0049), and with explicit permission from relevant authorities.

Results

Marking and resighting. We deployed 30 live-traps, each for an average of 22 days (range: 2–64 days). We live-captured and marked 15 pumas (12 males:3 females); one marked female died of starvation prior to initiation of camera-trapping. We used a total of 190 telemetry locations ($n_{\text{males}} = 156$; $n_{\text{females}} = 34$) collected from GPS collars during the resighting period (mean = 14 locations/puma; range = 3–17). We acquired 68 unique detections of subadult and adult pumas at 31 camera-traps (46% of traps); the average number of detections per occasion was four (range: 1–7). Twenty (29%) camera-trap detections were of eight marked pumas (6 males:2 females); 17 spatial recaptures of marked pumas were obtained during the marking and resighting processes combined ($n_{\text{males}} = 15$; $n_{\text{females}} = 2$). Among the 48 detections of unmarked pumas, sex was defin tively identifi d for 25 detections (52%; 10 male:15 female).

Population density and abundance. Puma population density point estimates ranged from 0.66 to 1.65 pumas/100 km^2, with the lowest estimates produced by conSMR models and the highest estimates produced by genSMR models that excluded telemetry data (Table 1). Integrating telemetry data approximately doubled σ^d estimates and decreased estimates of puma density in the genSMR models, whereas estimated puma density from conSMR models were similar regardless of whether telemetry data were used or not (0.66 versus 0.70 puma/100 km^2, respectively). The estimated number of unmarked pumas that were detected during resighting (n^{UM}) was between 18 and 26 individuals, with the smallest estimates from conSMR models (18–20 pumas) and the genSMR models that excluded telemetry data (20–22 pumas). The genSMR model that included telemetry data, activity center transiency, and sex as a partially identifying categorical covariate (model 3), which best explained the observed spatial dynamics of pumas during our study, estimated population density to be 0.84 puma/100 km^2 (95% HPDI: 0.50–1.28) with a CV of 0.24. Th s corresponded to an estimated population size

Model	Type	Specifications	λ_0^M	λ_0^R	σ^d	σ^t	n^{UM}	*D* (95% HPDI)	Width	CV	*N* (95% HPDI)
1	Gen	Sex + Tel	0.004	0.016	7.54	—	25	0.94 (0.59–1.48)	0.89	0.25	144 (91–227)
2	Gen	Sex	0.016	0.061	2.85	—	22	1.54 (0.96–2.75)	1.79	0.31	236 (147–421)
3	Gen	Sex + Tel + Trans	0.007	0.019	6.51	17.40	26	0.84 (0.50–1.28)	0.78	0.24	129 (74–193)
4	Gen	Sex + Trans	0.018	0.064	2.89	0.35	22	1.57 (0.93–2.65)	1.72	0.29	240 (142–406)
5	Gen	Tel + Trans	0.008	0.020	6.54	17.02	26	0.84 (0.54–1.34)	0.81	0.26	129 (82–206)
6	Gen	Trans	0.021	0.068	2.63	2.71	20	1.65 (0.95–2.72)	1.77	0.29	252 (145–417)
7	Con	Sex + Tel	—	0.025	6.64	—	20	0.66 (0.37–1.03)	0.66	0.26	97 (55–151)
8	Con	Sex	—	0.082	3.62	—	18	0.70 (0.33–1.27)	0.94	0.37	102 (49–187)
9	Gen-SS	Males + Tel	0.005	0.015	8.10	—	24	0.95 (0.59–1.43)	0.84	0.24	145 (90–219)
		Females + Tel	0.005	0.042	4.22	—					

Table 1. Parameter estimates from generalized (Gen) and conventional (Con) spatial mark-resight models. Models with and without a categorical identity constraint for puma sex (Sex), telemetry data from GPS collars (Tel), activity center transiency between marking and resighting processes (Trans), and sex-specific detection functions (SS) were considered. Baseline detection rates for the marking (λ_0^M) and resighting (λ_0^R) processes, spatial scale of the detection function (σ^d; km), spatial scale of activity center transiency (σ^t; km), the number of unmarked pumas detected during resighting (n^{UM}), population density (D = puma/100 km^2), and population size (N) were estimated. The 95% highest posterior density intervals (HPDI) are presented for D and N, as well as 95% HPDI width and coeffici t of variation (CV = SD/D) for D. See Supplementary Table S2 for further details, including 95% HPDIs for all parameter estimates.

of 129 pumas (95% HPDI: 74–193) across the 15,314 km^2 estimation area, of which an estimated 26 unmarked pumas (95% HPDI: 18–32) were detected by camera-traps. Given those point estimates, 11.63% of pumas were marked and 22.81% of unmarked pumas were detected by camera-traps, indicating that we acquired spatial detection information for a combined 34.44% of pumas within $\boldsymbol{S}^G$.

Density estimate precision. Modeling sex as a partially identifying categorical covariate for the detections of unmarked pumas improved precision of estimated density by 8%, reducing CV from 0.26 to 0.24 (model 5 versus model 3). Allowing activity center transiency for marked pumas between the marking and resighting processes improved precision of estimated puma density by 4% (based on CV), despite introducing more uncertainty into the process model via more complex model structure. Integrating telemetry data from GPS collars on marked pumas improved precision of estimated density by 17%, reducing CV from 0.29 to 0.24 (model 4 versus model 3); although, determining how much of the CV reduction resulted from a lower point estimate instead of a decrease in variance is difficult to disentangle.

Spatial scale of detection and activity center transiency. Estimates of σ^d from models that incorporated telemetry data ranged from 6.51 to 7.54 km, whereas estimates from models that excluded telemetry data ranged from 2.63 to 3.62 km. The smallest estimated σ^d was from the genSMR model that only included activity center transiency (model 6), whereas the largest σ^d was from the genSMR model that excluded activity center transiency but incorporated sex identity constraints and telemetry data (model 1). Estimated σ^t was 17.40 and 17.02 km from genSMR models that included both activity center transiency and telemetry data (models 3 and 5, respectively), but was just 0.35 and 2.71 km from genSMR models that excluded telemetry data (models 4 and 6, respectively). In models 4 and 6, σ^t was either not identifiable or was barely identifiable, so these considerably lower estimates are likely unreliable. Importantly, telemetry data from the GPS-collared pumas were critical to estimating σ^t, because the four individuals whose activity centers relocated between the marking and resighting processes were never detected by the camera-traps (Fig. 2).

Sex ratio. The genSMR model that included sex-specific detection functions (model 9) produced a similar population density estimate as the comparable genSMR model that had a pooled detection function (model 1). The estimated female and male σ^d from model 9 was 4.22 km (95% HPDI: 3.65–5.10) and 8.10 km (95% HPDI: 7.57–8.61), respectively, compared to the pooled estimate from model 1 of 7.54 km (95% HPDI: 7.06–8.12). The probability that a puma was female was 0.33 (95% HPDI: 0.16–0.49) and 0.34 (95% HPDI: 0.19–0.52) from models 3 and 9, respectively, which supports that sex-specific ty of detection function parameters was unnecessary for accurately estimating the population sex ratio. The fact that the density and sex ratio estimates were nearly identical between models with and without sex-specific ty suggests close to perfect compensation between λ_0^R and σ^d on the total exposure to detection[68]. We note that with just two spatial recaptures for marked females, our female density and sex ratio estimates are largely dependent on how representative the telemetry data (i.e., movements) for the two marked females were of the entire female cohort within $\boldsymbol{S}^G$.

Discussion

Previous puma mark-resight studies in the spatially explicit framework used conSMR models to estimate population density[25–27]. If individual animals are live-captured to apply artific al marks, and this process occurs across the same area in which resighting will occur, marked individuals will on average likely reside closer to the resighting array than unmarked individuals[37]. Modeling the marking process via genSMR models accounts for

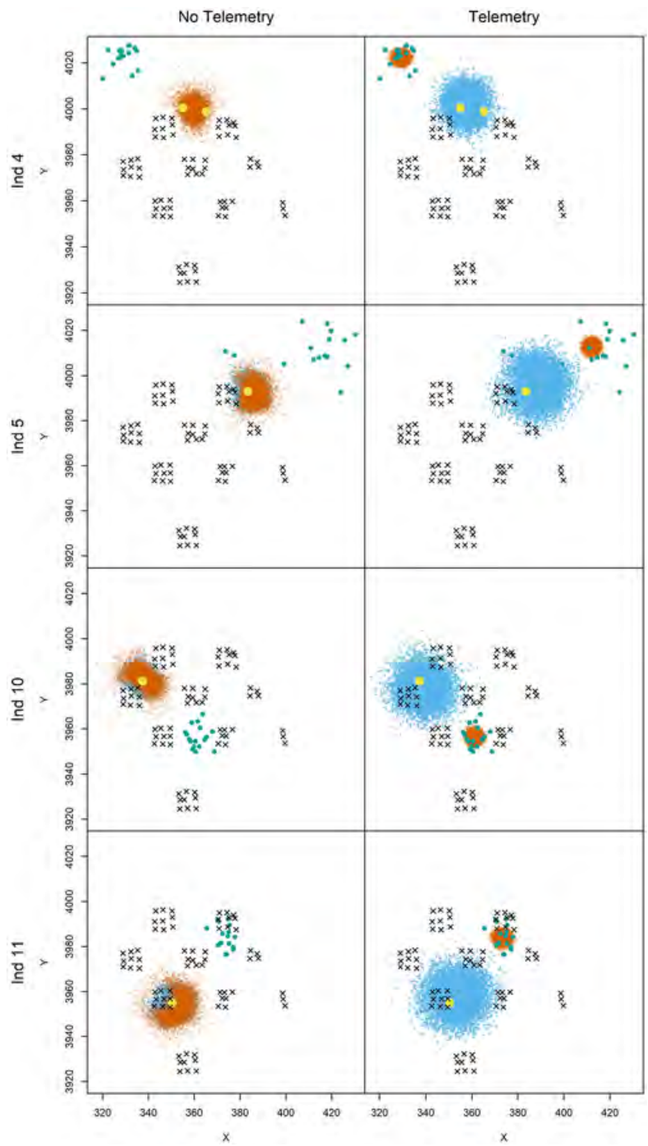

Figure 2. Estimated activity center locations for four marked pumas from generalized spatial mark-resight models that accommodated activity center transiency between marking and resighting processes, and excluded or included telemetry location data from GPS collars. The estimated posterior densities of individual activity centers for the marking and resighting processes are denoted by blue and orange, respectively. The spatial locations where each puma was live-captured, the locations of camera-traps, and thinned telemetry locations from the resighting period are denoted by yellow circles, black ×, and green circles, respectively. Image created by B.C.A. with the R statistical software[60].

these spatial patterns in activity centers, but conSMR models exclude the marking process and consequently may produce negatively biased density estimates[37,39]. Indeed, our puma density estimates from conSMR models were ~17% lower than density estimated by our best genSMR model (model 3), chosen because of its most accurate characterization of the observed puma spatial dynamics (e.g., activity center transiency [through telemetry data] and spatial information about sex of unmarked pumas). Thus, our results support that genSMR models are preferable to conSMR models when the marking process involves live-capture and the marking and resighting arrays spatially overlap; particularly if researchers cannot assume that marked animals are uniformly distributed across the landscape, or the spatial distribution of marked animals is unknown and cannot be correctly specifi d.

Integrating telemetry data from GPS collars on marked pumas substantially improved parameter estimate precision and was critical for accurately estimating population density. First, the telemetry data allowed us to defin tively determine individual identities from photograph detections. Th s was arguably more reliable than attempting to assign identities *ad hoc* based on researcher-perceived natural marks for a species that generally does not have unambiguous, individually unique physical features[24–27]. Although researchers may be tempted to treat all pumas detected by camera-traps as unmarked and apply the 'unmarked' spatial capture-recapture model[34] to estimate population density, the large home ranges and generally low detection rates of pumas, regardless of sampling method, will likely result in biased, imprecise, and unreliable density estimates from this model[39,40]. Applying artific al marks to even a small portion of a population and using SMR models can greatly improve estimation of detection function parameters and population density[26,34,36,37,39].

Telemetry data also facilitated accurate estimation of σ^d, which our results suggest was substantially underestimated by the models that relied solely on camera-trap detection data (models 2, 4, and 6). To establish our clustered camera-trap design, we based simulations on parameter estimates from previously published spatially explicit puma density studies. Based on the σ that we used in simulations (5.0 km), we presumed that our camera-trap and cluster spacing were 0.70σ and 5.60–7.20σ, respectively; however, based on the σ^d estimated by our best model (model 3), camera-trap and cluster spacing turned out to be 30% smaller (0.54σ^d and 4.30–5.53σ^d, respectively). If home ranges are large and detection rates are low ($\lambda_0 < 0.10$), detector spacing as small as 0.5σ may be too close to accurately characterize the true scale of animal movement within a single cluster[43,45]. Estimated λ_0^R was <0.10 among all of our considered models, and each of the nine clusters of camera-traps was considerably smaller than the average puma home range size derived from estimated σ^d, assuming a bivariate normal distribution[19] (110.25-km^2 cluster size versus 799.23-km^2 home range size, based on model 3). Consequently, the full extent of individual puma space use likely could not be captured within a single cluster[45], which resulted in underestimation of σ^d and overestimation of puma density by the models that excluded telemetry data. Employing a wider camera-trap spacing of 1–2σ^d (6.51–13.02 km) within each cluster likely would have resulted in detections via the camera-traps alone that more accurately reflected the larger than expected puma space use[45]. Although our spacing between clusters was well within the movement capabilities of pumas in the study area (based on estimated σ^d), a wider camera-trap spacing within clusters would also decrease the distance between clusters, which might have the added benefit of increasing the number of spatial recaptures[43,45].

An alternative but unlikely explanation for the smaller σ^d and higher puma density estimates from models that excluded telemetry data could be that the marked pumas were not a random sample of the population, but were instead representative of a cohort of pumas that had larger than average home ranges[36]. Subadult male pumas are generally transient and typically have the largest home ranges among all sex-specific cohorts of puma populations[69]. We live-captured and marked both subadults and adults and both males and females, however, and although just 20% of our marked pumas were females, genSMR model results suggested that only 33–34% of the population was female. Furthermore, the point and interval estimates of puma density from the genSMR model with sex-specific detection function parameters (model 9) were nearly identical to the analogous model with detection function parameters pooled between sexes (model 1). Th s strongly supports that a sex imbalance among marked individuals was not a source of incongruous σ^d estimates between models that included and excluded telemetry data, thereby indicating that density estimates from the genSMR models that integrated telemetry data more accurately refl cted puma space use during our study.

A third reason supporting the importance of telemetry data, and a primary reason why the transient activity center model improved density estimation, was to accurately estimate activity center locations for the pumas who relocated considerable distances between the marking and resighting processes. Efford and Hunter[35] raised concerns about the potential for such activity center transiency between observation processes to influence SMR model parameter estimates, but those authors had no independent data to test for this. In contrast, the telemetry data that we had from marked pumas allowed us to document and model large activity center relocations between processes. Because the four marked pumas who relocated were not detected by camera-traps, the resighting data provided little information about whether or not those individuals' activity center locations moved, and if so, how far. Although two pumas (individuals 10 and 11) moved to areas of the camera-trap array where they likely had similar detectability as the locations at which they were live-captured and marked, two other pumas (individuals 4 and 5) moved to areas where they were effectively undetectable by all camera-traps (Fig. 2). In model 1, which did not accommodate activity center transiency, the distances between live-capture locations and the estimated activity center locations, which were primarily informed by the telemetry data, were larger than reality. Th s inflated the σ^d estimate (7.54 versus 6.51 km from models 1 and 3, respectively), which in turn decreased the λ_0^R and λ_0^M estimates. These differences in detection function parameters corresponded to a ~12% difference in puma density point estimates (0.94 versus 0.84 puma/100 km^2), suggesting that accommodating activity center transiency may be important for reliably estimating population density in SMR studies. Additionally, σ^t was substantially underestimated without the telemetry data, because all four major movements were not discernable from the camera-trap data; this caused poor estimation of those pumas' activity center locations and introduced bias into detection function and density parameter estimates. Thus, having considerable telemetry data likely will lead to a more robust application of SMR models, informing if activity center transiency needs to be accommodated in the model structure to improve parameter estimation.

Fully transient activity centers have been considered in conSMR models[61], but our study is the fi st application of a single activity center transition that was used to explain observed animal movement dynamics. The base genSMR model provides an adequate description of the distribution of marked and unmarked individuals if they do not relocate between the marking and resighting processes; if individuals randomly relocate between processes, which is unlikely, the spatial uniformity activity center model may be appropriate. Accommodating activity center transiency as we did results in an intermediate activity center model in which individuals are not at exactly the same spatial location between processes and the similarity of locations is determined by the σ^t parameter. However, if individual animals exhibit multiple substantial movements during observation processes, an activity center model that accommodates fully transient activity centers might be more appropriate[61,62]. Nevertheless, distinguishing between a process model with stationary activity centers and a large σ^d value and a model with transient activity centers and a small σ^d value will be difficult without considerable telemetry data, given the sparsity of typical capture-recapture and mark-resight detection data.

Despite the relatively small improvement in density estimate precision from using sex as a categorical identity covariate compared to the substantial improvement from incorporating telemetry data, using categorical identity covariate data that is available from camera-trap detections has considerable promise. The 8% precision improvement that we observed by using sex of unmarked pumas comes from data that has not been used in SMR models to date, but ecologists and managers should be interested in extracting as much precision out of detection data as possible. Additionally, sex was a single categorical identity covariate that we confi med for only approximately half of the detections of unmarked pumas. Other populations of pumas or other wildlife species may provide more categorical identity covariate information from photographs; for example, the natural marks used by previous studies to attempt to assign individual identities for estimating population density[24,25,27,61,70] could instead be treated as categorical identity covariates, allowing for the possibility that more than one individual in a population has a similar physical feature. Th s would obviate the requirement that potentially erroneous individual identities are assigned, but it may also reduce the precision of density estimates, perhaps appropriately, depending on the accuracy of categorical identities assigned by observers.

We acknowledge that using GPS collars as the primary mark can be expensive, but our results indicate that the realized and potential benefits of marking a portion of a population with GPS collars outweigh the costs. Clearly, integrating telemetry data in spatially explicit analyses can substantially improve estimation of the spatial scale parameter, activity center locations, and population density, as also noted by previous studies[26,36,37,39]. Furthermore, by marking a portion of animals with GPS collars, which are typically functional for multiple years, additional demographic and ecological information that are important to conservation and management can be obtained, effectively constituting SMR as a population ecology research approach. Th s includes data on survival and cause-specific mortality, home range size, and resource selection[71,72], as well as seasonal and annual variation in population density if camera-traps are active across seasons and years, respectively. Additionally, if population genetics are of interest, genetic samples can be collected when animals are captured for marking. If study budgets are limited, a cheaper alternative may be to mark some animals with GPS collars and others with only ear tags or non-GPS collars that have visually unique numbers or patterns that can be identifi d from photographs. For example, Whittington *et al.*[37] GPS-collared some individuals, only ear-tagged others, and used camera-traps and genSMR models to precisely estimate brown bear (*Ursus arctos*) population density.

Pumas occupy tens to hundreds of thousands of square kilometers within most jurisdictions across their extant range[1,69,73]. In general, precision and accuracy of spatially explicit population density estimates for wide-ranging large carnivores improve with increasing study area size[44,45,74]. By deploying camera-traps in a systematic cluster design with gaps between clusters where no cameras existed, we were able to use a small number of camera-traps to estimate puma density for a 15,317-km^2 area. This area was five-fold larger than the average spatial extent among all previous puma density studies that also used spatially explicit models (mean = 2,849 km^2; range: 215–8,800 km^2), and our density estimates were among the most precise estimates that have been produced for pumas to date ($CV_{[genSMR]} = 0.24–0.31$; Table 2). Therefore, clustered camera-trapping in an SMR framework can facilitate efficient and reliable estimation of puma population density at the broad regional scales that conservation and management typically occur. For example, endangered Florida panthers (*P. c. coryi*) reside within a ~16,000-km^2 area that encompasses multiple patches of suitable habitat[75], and a portion of panthers are annually captured and collared[26,76]. Applying clustered camera-trapping across that entire area and using genSMR models to analyze detection data could result in the fi st range-wide spatially explicit estimates of Florida panther population density and abundance, with little additional effort compared to other available puma sampling approaches in the spatially explicit framework. Our sampling and analytical combination is likely also applicable to other terrestrial mammals that similarly lack individually unique natural markings. For instance, obtaining reliable population density and abundance estimates for imperiled Mexican gray wolves (*Canis lupus baileyi*) and red wolves (*C. rufus*) is important to their recovery, and individual wolves in those populations are routinely monitored via radiocollars that could serve as effective marks. Nevertheless, we agree with other studies that suggested researchers should use simulation to develop study area- and species-specifi survey designs prior to deploying camera-traps[43,45,74]. Having home range size data beforehand to inform camera-trap and cluster spacing would be ideal[45], but if such data are unavailable, our results support that marking a portion of animals with GPS collars and integrating their telemetry location data in spatially explicit models can serve as insurance if detector spacing turns out to be insuffici t[36].

Our study provides the fi st spatially explicit population density estimates for pumas in the semi-arid to arid southwestern United States, where hot summer temperatures, high ultraviolet radiation, and generally limited winter snow cover may impede effectiveness of, or preclude, scat detection dog and biopsy dart sampling of pumas. Regardless of model specification, all of our puma density estimates were within the range of reported spatially explicit estimates for the species, but density estimated by our best model (0.84 puma/100 km^2) was towards the lower bound of that range (Table 2). Estimates acquired using the biopsy dart and scat detection dog methods may not be directly comparable to our estimates, however, because estimates from those techniques might be inflated as a result of including dependent juveniles in the detection histories[20,23], whereas our estimates pertain solely to independent pumas. Nonetheless, the majority of our study area was characterized as high quality puma habitat relative to elsewhere in the Southwest[73]; thus, our estimates suggest that the Southwest might commonly support pumas at lower densities than ecosystems in the Northwest and Northern Rockies regions[20–24,51]. Additional research is needed to evaluate the influence that legal harvest of pumas and prey availability and distribution may have on seasonal and annual variation of puma population density in our study area and across the Southwest in general.

Study	Location	Methods	Models	Area	Densities	Widths	CVs
Th s study	New Mexico, USA	CC + TL	genSMR	15,314	0.84–1.65	0.8–1.8	0.24–0.31
Sollmann *et al.*[26]	Florida, USA	RC + TL	conSMR	1,719	1.46–1.51	1.9–2.2	0.33–0.38
Rich *et al.*[25]	Belize, Bolivia, Argentina	RC	conSMR	4,329*	0.30–6.50	0.5–8.1	0.26–0.38
Zanón-Martinez *et al.*[27]	Argentina	RC	conSMR	1,179*	1.38–4.90	3.3–5.9	0.31–0.66
Quiroga *et al.*[77]	Argentina	RC	SCR	1,882*	0.08–1.26	0.2–1.0	—
Noss *et al.*[78]	Bolivia	RC	SCR	215*	0.36–7.99	0.7–9.9	0.20–0.85
Alexander and Gese[24]	Wyoming, USA	RC	SCR	1,287	0.39–4.04†	0.6–9.9	—
Proffitt *et al.*[21]	Montana, USA	BD + SB + DR	SCR	5,912	3.20–5.60	2.9–14.0	—
Russell *et al.*[22]	Montana, USA	BD + SB	SCR	8,800	3.70–6.70	1.5–7.9	0.24–0.46
Beausoleil *et al.*[20]	Washington, USA	BD	SCR	7,939	1.90–2.40	3.2–3.9	—
Davidson *et al.*[23]	Oregon, USA	SD	SCR	1,225	2.31–5.50	1.2–5.8	—

Table 2. Study locations, sampling methods, model types, and parameter estimation areas (km^2) for studies that used spatial capture-recapture (SCR), conventional spatial mark-resight (conSMR), or generalized spatial mark-resight (genSMR) models to estimate puma population density (puma/100 km^2), ordered by sampling methods and model types. Methods included biopsy darting (BD), snow-backtracking (SB), scat detection dogs (SD), regular camera-trapping (RC), clustered camera-trapping (CC), dead recoveries (DR), and telemetry locations from GPS collars (TL). Coeffici t of variation (CV), standard errors, or standard deviations were not reported by multiple studies (—), so we also present 95% interval widths for comparing precision of density estimates. Densities are presented as the ranges of point estimates. *Average among multiple study areas; †excludes one density estimate for which variance of the corresponding spatial scale parameter (σ) was inestimable.

Data Availability

All data generated for analysis and all R code of MCMC algorithms for reproducing the analysis are available from the PANGAEA® digital repository, https://doi.org/10.1594/PANGAEA.897113. Data were made available under provisions of the State of New Mexico Inspection of Public Records Act (1978 NMSA 14.2).

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Author Contributions

S.M.M. conceived the idea and led manuscript writing; S.M.M. and D.T.W. designed the study; S.M.M., D.T.W., M.A.P. and G.C.H. collected the data; S.M.M. and B.C.A. analyzed the data. All authors contributed to writing, reviewed drafts, and gave fi al approval for publication.

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A Test of the Compensatory Mortality Hypothesis in Mountain Lions: A Management Experiment in West-Central Montana

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Research Article

A Test of the Compensatory Mortality Hypothesis in Mountain Lions: A Management Experiment in West-Central Montana

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ABSTRACT Mountain lions (*Puma concolor*) are widely hunted for recreation, population control, and to reduce conflict with humans, but much is still unknown regarding the effects of harvest on mountain lion population dynamics. Whether human hunting mortality on mountain lions is additive or compensatory is debated. Our primary objective was to investigate population effects of harvest on mountain lions. We addressed this objective with a management experiment of 3 years of intensive harvest followed by a 6-year recovery period. In December 2000, after 3 years of hunting, approximately 66% of a single game management unit within the Blackfoot River watershed in Montana was closed to lion hunting, effectively creating a refuge representing approximately 12% (915 km^2) of the total study area (7,908 km^2). Hunting continued in the remainder of the study area, but harvest levels declined from approximately 9/1,000 km^2 in 2001 to 2/1,000 km^2 in 2006 as a result of the protected area and reduced quotas outside. We radiocollared 117 mountain lions from 1998 to 2006. We recorded known fates for 63 animals, and right-censored the remainder. Although hunting directly reduced survival, parameters such as litter size, birth interval, maternity, age at dispersal, and age of first reproduction were not significantly affected. Sensitivity analysis showed that female survival and maternity were most influential on population growth. Life-stage simulation analysis (LSA) demonstrated the effect of hunting on the population dynamics of mountain lions. In our non-hunted population, reproduction (kitten survival and maternity) accounted for approximately 62% of the variation in growth rate, whereas adult female survival accounted for 30%. Hunting reversed this, increasing the reliance of population growth on adult female survival (45% of the variation in population growth), and away from reproduction (12%). Our research showed that harvest at the levels implemented in this study did not affect population productivity (i.e., maternity), but had an additive effect on mountain lion mortality, and therefore population growth. Through harvest, wildlife managers have the ability to control mountain lion populations. Published 2014. This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS additive mortality, carnivore, compensatory mortality, cougar, hunting, life-stage simulation analysis, Montana, population dynamics, *Puma concolor*, survival.

Errington (1956) coined the term "doomed surplus" to describe animals that would die by other natural causes if not killed by predators. Many hunting programs assume a similar relationship to human harvest, namely, density-dependent compensatory mortality. Modern wildlife management and hunting programs are premised on the idea of sustainable yield, and the concept of a harvestable surplus due to compensatory mortality (Larkin 1977). Under the compensatory mortality hypothesis, harvest mortalities are compensated by reductions in non-harvest mortality (compensatory mortality), increases in reproduction (compensatory natality), or immigration (Boyce et al. 1999, Williams et al. 2002, Turgeon and Kramer 2012). Evidence of compensation has been shown in a variety of species including game birds (Burnham and Anderson 1984, Sandercock et al. 2011), ungulates (Bartmann et al. 1992, Simard et al. 2013), and carnivores (Sterling et al. 1983, Sparkman et al. 2011). All mortality is not compensatory, however, as evidenced by the numerous populations that

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have been threatened or driven to extinction by overharvest (e.g., Baker and Clapham 2004, McGlone 2012). Managers would benefit from a better understanding of the life-history traits and harvest levels where mortality moves from compensatory to additive in many exploited populations (Sandercock et al. 2011, Peron 2013).

Carnivores are hunted for both sport, where population stability is desired, and population control, where mortality must be additive to achieve reduced population levels. In North America, perhaps because of their conflict with humans, a great deal of early research into the effect of harvest on a carnivore species focused on coyotes (*Canis latrans*). This work suggested that harvest mortality was largely compensatory through immigration and density-dependent or compensatory natality (Knowlton 1972, Todd and Keith 1983, Knowlton et al. 1999). These early findings, combined with a reluctance to study other disturbed or hunted populations of large carnivores, shaped management perceptions through the 1970s and 1980s (Frank and Woodroffe 2001). Recent research has suggested that hunting mortality in other carnivores may be almost perfectly additive (Creel and Rotella 2010, Murray et al. 2010).

Evidence of the additive nature of hunting to mountain lion mortality and population growth has been shown in past studies where populations were reduced through hunting, and/or increased once harvest level was reduced (Lindzey et al. 1992, Ross and Jalkotzy 1992, Lambert et al. 2006). Conversely, non-hunted populations often show high levels of intraspecific strife and mortality, leading some to speculate that hunting may be compensatory (Quigley and Hornocker 2010). The effect of harvest on a population is dependent on total harvest rate, age, and sex classes being harvested, and compensation for harvest by increases in survival or other vital rates such as maternity and immigration (Mills 2007).

The combined effects of harvest and dispersal include changes to age and social structure that may cascade through a hunted population, magnifying or reducing the effects of harvest. Mountain lions display high levels of juvenile dispersal (Chepko-Sade et al. 1987, Sweanor et al. 2000, Zimmermann et al. 2005). Males disperse to avoid inbreeding regardless of population density (intrinsic dispersal), whereas females disperse, albeit at much lower levels than males, to avoid intraspecific competition (Greenwood 1980, Logan and Sweanor 2001). Hunting can therefore skew the sex and age ratio of a population towards younger males as harvested males are quickly replaced through juvenile immigration (Robinson et al. 2008). Vertebrate species have adapted to specific age and sex population structures. Males, in general, reach sexual maturity more quickly than females because of reduced life spans (Jones et al. 2008, Ricklefs 2008). Deviations from "natural" population age and demographic structure could reduce productivity (Nussey et al. 2009). Reproductive senescence is common in mammalian females as they age (Packer et al. 1998, Berube et al. 1999). Hostetler et al. (2012) found reduced litter production in female mountain lions (Florida panthers) >9 years. Maternity of mountain lions may be reduced in hunted populations if younger males do not breed successfully, or if female recruitment is restricted and kitten production is reduced as females senesce (Berube et al. 1999), both additive effects. Conversely, harvest may reduce direct resource competition among females, resulting in increased litter sizes or maternity rates (Ordiz et al. 2008), a compensatory effect.

Logan et al. (1986) and Logan and Sweanor (2001) suggested that removal of male mountain lions from a population may decrease survival of remaining resident males by disrupting social organization and increasing direct or exploitative competition for mates and territory. Also, the loss of dominant, territorial males may increase instances of infanticide, an unexpected additive form of mortality (Logan and Sweanor 2001). Male mountain lions may kill kittens to induce their mothers into estrous, thus increasing breeding opportunities (Packer et al. 2009). However, the role played by infanticide in shaping kitten survival remains unclear. Harvest programs can induce immigration of new males, thereby increasing infanticide rates and limiting population growth (Swenson et al. 1997). A high level of male turnover resulted in increased levels of infanticide in African felids (Whitman et al. 2004, Balme et al. 2010).

Unlike ungulate species that give birth in a single "birth pulse" in early spring, mountain lions give birth year-round. In the United States, mountain lions are most heavily hunted from September to March (Cooley et al. 2011), which exposes dependent kittens to the risk of starvation due to abandonment following harvest of their mothers, perhaps increasing their naturally high mortality (Logan and Sweanor 2001). Similar to the effects of hunting on adult mortality, however, how this source of mortality is compensated for by decreases in other natural mortality is not well understood.

Ultimately, the compensatory or additive effects of harvest are best measured at the population level in terms of population growth. Matrix population models are a widely used tool for exploring the relationship of various population parameters, or vital rates, on population growth (Getz and Haight 1989, Caswell 2001). Ecologists have used matrix models and the quantifiable properties of sensitivity and elasticity to mathematically describe the consequences of varying vital rates of several species with differing life strategies. Evolutionary theory suggests that natural selection will favor low levels of variation in population parameters that contribute most to population growth (Pfister 1998). In long-lived vertebrates, and other K-selected species, adult female survival normally has the highest demographic elasticity (Gaillard et al. 1998, 2000); that is, small changes in female survival will result in the largest proportional changes in population growth rate.

Although sensitivity analysis will reveal which vital rates have the greatest effect on population growth, those same vital rates may have such low natural variability that they functionally account for little variation in population growth between years. If K-selected species have adapted life strategies where the most important vital rates have the lowest degree of variability, hunting may disrupt this adaptive

Table 1. Predictions of how mountain lion population vital rates should respond to harvest under the compensatory and additive mortality hypothesis.

Vital rate	Compensatory mortality hypothesis	Additive mortality hypothesis
Reproduction		
Litter size	Increase	No effect or reduce
Maternity	Increase	No effect or reduce
Survival	No effect	Reduce
Dispersal		
Male emigration	Reduce	No effect
Female emigration	Reduce	No effect
Male immigration	Increase	No effect
Female immigration	Increase	No effect
Population growth	No effect	Reduce

strategy by increasing their variance. Wisdom et al. (2000) developed an extension of elasticity analysis called life-stage simulation analysis (LSA), which measures the direct effects of annual variance in vital rates on population growth.

We used temporal and spatial variation in harvest structure to test the compensatory mortality hypothesis by directly comparing population parameters (i.e., survival, maternity, etc.), population structure (i.e., mean age of independent males), and population growth between hunted and non-hunted segments of a mountain lion population. Specifically, if harvest mortality was compensatory, we expected population growth to tend toward stability regardless of harvest level because of compensatory reductions in other mortality sources, or through increases in reproduction and recruitment (Table 1). If harvest mortality was additive, we expected population growth to decline with increased harvest because of reduced survival accompanied by no change in reproduction or recruitment (Table 1). We also used matrix population modeling, sensitivity analysis, and LSA to quantify how harvest affects the natural variability of vital rates, and how those changes are reflected in annual population growth.

STUDY AREA

We conducted the study in the Blackfoot River watershed (7,908 km^2) in Powell, Granite, Lewis and Clark, and Missoula counties in West-Central Montana. Hunting district 292 served as our refuge area, hereafter referred to as the Garnet study area (915 km^2). This area was protected from hunting for 6 years of the 9-year study (Fig. 1). The entire watershed is characterized by relatively moderate rolling topography, with gentle to moderate slopes dissected by steep limestone canyon areas along drainages (Brainerd 1985). This area is representative of much of western Montana, a mountainous mix of private (i.e., Plum Creek Timber Company and private land owners) and public lands (i.e., Bureau of Land Management, Helena and Lolo National Forests) with elevations ranging from 1,160 m to 2,156 m (Montana Department of Fish, Wildlife and Parks 2004). Daily mean temperatures range from −8.7°C in January to 16.5°C in July with annual precipitation ranging from 19 cm to 33 cm, occurring primarily from December to June (Western Regional Climate Center, Ovando, MT).

Dominant land cover varies from high-elevation mixed lodgepole pine (*Pinus contorta*)-subalpine fir (*Abies lasiocarpa*)

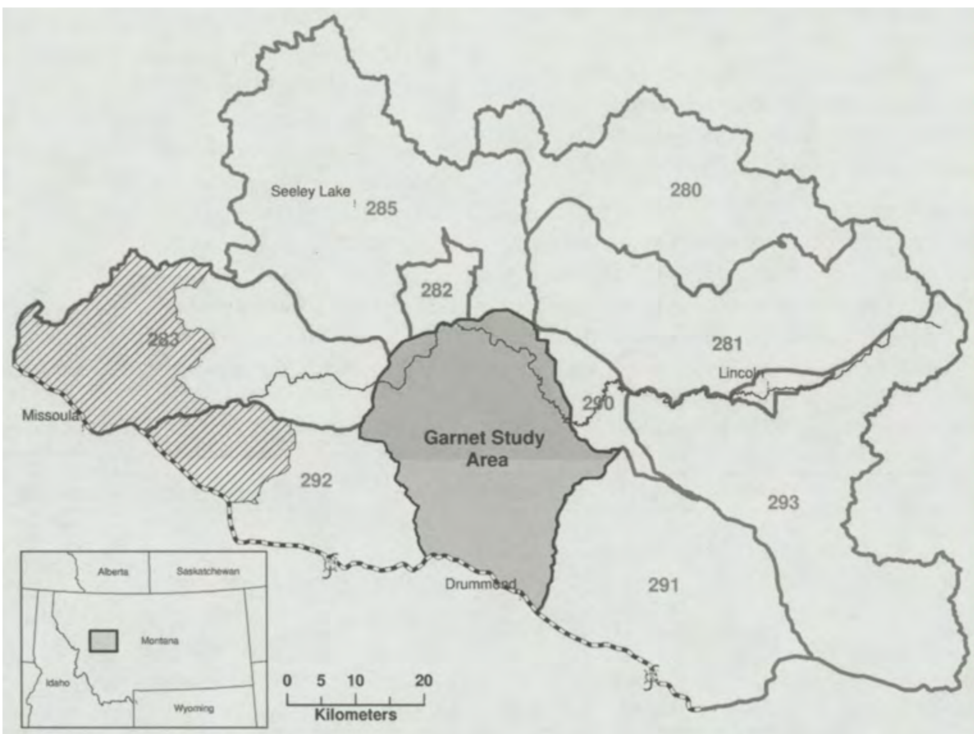

Figure 1. The Garnet study area (915 km^2), and greater Blackfoot River watershed (7,908 km^2) in western Montana. Numbers (i.e., 292) represent Montana Fish, Wildlife and Parks regional mountain lion management unit designations.

stands, to more mesic Douglas-fir (*Pseudotsuga menziesii*)-western larch (*Larix occidentalis*) stands at mid-elevations, and Douglas fir, ponderosa pine (*P. ponderosa*), and aspen (*Populus tremuloides*) at low elevations. Valley bottoms consist of a mixture of irrigated and dry land agriculture, cattle rangelands, and native bunchgrass-sagebrush (*Artemisia* spp.)-juniper (*Juniperus scopulorum*) communities (Lehmkuhl 1981). The majority of the low to mid-elevation forests have been logged in the past 50 years (Raithel 2005).

Ungulate prey species present in the area included elk (*Cervus elaphus*), white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), and moose (*Alces alces*). Elk populations were stable over the course of the study (Montana Department of Fish, Wildlife and Parks 2004), whereas deer populations may have been recovering from the El Nino-induced severe winter of 1996–1997 (Montana Department of Fish, Wildlife and Parks 2006). Cattle grazing occurred on private and public lands, however, cattle and other livestock depredations by mountain lions were rare. Carnivores besides mountain lions included black bear (*Ursus americanus*) and grizzly bear (*Ursus arctos*). Smaller predators included bobcat (*Lynx rufus*), Canada lynx (*Lynx canadensis*), coyote (*C. latrans*), wolverine (*Gulo gulo*), pine marten (*Martes americana*), and long-tailed weasel (*Mustela frenata*). Wolf (*Canis lupus*) had not recovered during the study period; the first confirmed pack established in 2006, the last year of our study (Montana Department of Fish, Wildlife and Parks 2006).

METHODS

In December 2000, following 3 years of heavy harvest, approximately 66% of a single hunting district was closed to mountain lion hunting, effectively creating a refuge representing approximately 12% (915 km^2) of the greater Blackfoot watershed (7,908 km^2) in West-Central Montana (Fig. 1). Hunting continued in the remainder of the watershed, but harvest levels declined between 2001 and 2006 as quotas were reduced (Table 2).

Capture and Monitoring

From 1997 to 2000, we applied capture efforts approximately equally across the entire watershed (Fig. 1). Following protection of the Garnet study area, we focused most capture efforts there, towards the goal of capturing all resident individuals (i.e., census). In the remainder of the Blackfoot, we continued to monitor radioed lions marked during the first 3 years of the study including re-instrumenting individuals when their radiocollar's battery life was spent. In addition, we monitored animals that either dispersed from the Garnet or had home ranges overlapping the boundary between the 2 areas.

We used trained hounds to tree mountain lions when we located fresh tracks in the snow. We darted treed animals and drugged them with a 0.06 ml/kg estimated weight mixture of ketamine hydrochloride and xylazine hydrochloride (1.45 ml xylazine to 10 ml ketamine) delivered using a Pneu-Dart Model 193SS cartridge fired rifle with disposable darts (Pneu-Dart, Inc., Williamsport, PA). We gave animals the antagonist yohimbine hydrochloride to counteract the xylazine before release.

We estimated age of captured mountain lions by tooth replacement, wear, gum recession, and cementum age analysis (Ashman et al. 1983, Laundre et al. 2000). We fitted radiocollars (Telonics, Mesa, AZ) depending on the size and age of the individual: an expandable (20–34 cm) kitten collar equipped with either a Mod-073 or Mod-305 transmitter, or an adult collar equipped with a Mod-500 transmitter. We located collared animals from fixed-wing aircraft approximately twice per week. Beginning in 2001, we fitted Telonics global positioning system (GPS) collars programmed to acquire a location every 5 hours to newly collared animals and replaced very high frequency (VHF) collars on already marked animals as opportunity allowed.

We collared both newborn kittens at the den, and those traveling with newly collared adult females. We collared newborn kittens without chemical immobilization approximately 1 month from the time the mother localized at a den site. When we located kittens outside the den (from 3 to 12 months) we treed and immobilized them as with adults. Expandable Mod-073 collars remained on kittens up to 7 months of age; mod-305 collars remained on kittens up to 10 months of age; and a mod-500 adult collar was worn by the animal through adulthood. Capture and handling protocols were approved by Montana Fish, Wildlife and Parks and conducted by their staff (Montana Department of Fish, Wildlife and Parks 2007).

Population Characteristics

Sex and age structure.—We calculated a minimum population for the Garnet study area each year by back-

Table 2. Mountain lion harvest, quotas (harvest/quota), and harvest density (animals/1,000 km^2) for the Blackfoot River watershed in West-Central Montana, 1998–2006. Beginning in December 2000, the Garnet was managed separately from the remainder of the Blackfoot watershed.

Area	Sex	1998	1999	2000	2001	2002	2003	2004	2005	2006
Garnet	Female	8[a]	8[a]	8[a]	0	0	0	0/1[b]	0	0
	Harvest density	8.74	8.74	8.74						
	Male	5[a]	6[a]	6[a]	0	0	0	1/1[b]	1/1	1/1
	Harvest density	5.46	6.55	6.55				1.09	1.09	1.09
Black-foot	Female	35/30	42/41	30/30	15/15	10/9	4/3	4/3	0/0	1/0
	Harvest density	4.42	5.31	3.79	1.89	1.26	0.5	0.5	0	0.12
	Male	41/40	30/33	27/29	19/21	12/9	8/7	7/7	6/7	8/7
	Harvest density	9.61	9.10	7.20	4.29	2.78	1.51	1.39	0.75	1.13

[a] Garnet managed as part of the Blackfoot watershed.
[b] One either-sex permit issued in 2004.

calculating the lifespan of all mountain lions known to have been present in the study area including collared and harvested animals (Logan and Sweanor 2001, Stoner et al. 2006, Robinson et al. 2008). This technique assumes that animals collared or harvested without being collared at time t were present within the watershed but undetected at time $t-1$ (specific to each animal's age and sex); as such, this method may underestimate population levels towards the end of the study period because of fewer sampling occasions. We assumed that all males were immigrants, whereas all females were recruited from within the population. Therefore, we backdated males to 24 months of age, immigrating into the population after their second birthday. We assumed females were philopatric and were likely born inside the Blackfoot watershed; however, we could not be sure if they were born inside or outside the protected Garnet study area. Therefore, we backdated females to 12 months, accounting for our philopatric assumption without biasing further any total population estimate of the Garnet study area. We used a Z-test to compare mean ages and proportion of the population consisting of adults of each sex between the hunted and non-hunted populations (Zar 1999). We hypothesized that harvest would reduce the mean age of males while increasing their proportion in the population because of a compensatory immigration response to harvest, whereas harvest would increase the mean age of adult females in the population while reducing their proportion in the population because of reduced recruitment (i.e., high juvenile mortality and/or low immigration) as resident animals aged.

Reproduction.—We estimated maternity, the mean number of young born per reproductive female per year (Caswell 2001), and its component, litter size, based on females of reproductive age within the Garnet study area only. We felt monitoring effort was sufficient within the Garnet that no litters born to, or traveling with, collared females would be missed, but logistical constraints prevented this level of monitoring in the larger watershed. We estimated average litter size based on kittens observed at den sites (i.e., <7 weeks), which assumes no kitten mortality had occurred prior to observation. The compensatory mortality hypothesis predicts that litter size will increase in a hunted population because of increased available resources (Table 1). The additive mortality hypothesis predicts that litter size will be unaffected or decline with harvest because of the age structure of females (Table 1). We tested the effect of harvest on litter size (as observed at den sites when kittens were <7 weeks) using a repeated-measures analysis of variance (ANOVA) comparing litter size within the Garnet study area during hunting and non-hunting periods. We used a repeated-measures ANOVA as the sample consisted of females with multiple litters (Zar 1999).

We observed age at dispersal and, for animals that did not leave the study area, first reproduction by radiocollaring dependent kittens and juveniles. As some hunted populations have a population skewed towards older females, we also tested how or if female age affected litter size. Using a repeated-measures ANOVA, we tested for an age effect on litter size in the females that we monitored (Zar 1999). Reduced fertility in older females could be an additive effect of harvest (Table 1).

Some researchers have used litter size, mean birth interval, and proportion of females traveling with young as surrogate measures of maternity (e.g., Lambert et al. 2006); however, these measures may introduce a bias by excluding females that fail to reproduce. We estimated maternity rate based on the total number of kittens born to all radiocollared females of reproductive age (>24 months) monitored, thus including the proportion of non-reproductive females in the population. As with litter size, the compensatory mortality hypothesis predicts that maternity rate will increase in the hunted population because of reduced competition and increased resource availability, whereas the additive mortality hypothesis predicts that maternity will be reduced or unchanged between hunted and non-hunted periods (Table 1). We tested for a hunting effect on maternity rate using a Z-test to compare the mean annual maternity rate within the Garnet study area during hunting and following protection (Zar 1999).

Dispersal.—We defined dispersal as a juvenile establishing a home range with <5% overlap of its natal home range, whereas we considered juveniles establishing home ranges with >5% overlap to be philopatric (Logan and Sweanor 2001). Dispersal rate was based on the number of independent juveniles in each year that moved outside their natal home range compared to the number monitored. We modeled juvenile dispersal as a binomial function of the estimated total population size for males and females separately (i.e., we used a generalized linear model specifying a logit link and binomial family; Hardin and Hilbe 2007). The additive mortality hypothesis predicts density-independent dispersal, whereas the compensatory mortality hypothesis suggests reduced dispersal of both sexes in the hunted population (Table 1).

Survival and Mortality

We examined mountain lion mortality in 3 ways: survival modeling, survival rate analysis, and cause-specific mortality analysis. We used survival modeling to examine the effect of independent variables (i.e., sex, age, geographic location, and hunting pressure as dictated by quota levels) on mountain lion survival and to objectively determine the best method of breaking the population into segments or cohorts with similar survival experiences. We used survival analysis to calculate and compare the survival probabilities of animals within those cohorts. Finally, we calculated and compared cause-specific mortality rates.

We derived a spatially explicit encounter history from telemetry data for each individual mountain lion to estimate survival rates and test hypotheses about factors influencing survival. We removed duplicate same-day locations from GPS collar data and combined them with VHF data to create a continuous record based on calendar time for each animal (Fieberg and DelGiudice 2009). We censored (interval truncated) animals not located for >61 days until relocated (Winterstein et al. 2001). During the first 4 years of the study, before we began to deploy GPS collars, we scheduled telemetry flights twice a week. During some periods, most notably the winter and spring of 2001, we could conduct flights only once a month because of weather, financial, and logistical constraints. We began deploying GPS collars in October 2001 and aerial telemetry flights were again limited during short periods for the remainder of the study. The 61-day period allowed some animals to be missed on 2 consecutive flights during these times of infrequent aerial telemetry. If not located after 61 days, we right-censored animals at the date of their last location in the study area.

We modeled factors influencing mountain lion survival using a combination of manual backward stepwise and best-subsets model selection (Hosmer et al. 2008). First, we conducted a univariate analysis using Cox regression (Cox 1972) to test the significance of sex, age, and hunting quota on mountain lion survival. We coded sex as an indicator variable with females coded as 1 and males coded as 0. We coded age and quota level as continuous variables, with age estimated in months and quota based on the annual-, sex-, and location-specific quotas as set by Montana Fish, Wildlife and Parks (Table 2).

We modeled mountain lion survival on the landscape by constructing 12 spatiotemporal a priori models, each suggesting a different hypothesized response in survival of the population to our experimental harvest design. We discuss 4 of these models in detail here (see online Supplementary Material for graphical depiction and explanation of all 12). For instance, the single-population (1-segment) model tested the hypothesis of total compensatory mortality by modeling survival as constant across the landscape and study period; equivalent to a null model relative to management (Fig. S1). The other 3 models represented different ways in which hunting mortality might be manifest. The management model tested the hypothesis that survival responded to small incremental changes in management or quota level, thus dividing the population into 6 segments, equivalent to a global model relative to management (Fig. S2, see also Table 2). The 3-segment population model grouped animals across the drainage between 1998 and 2000 (segment 1), then divided the population into 2 segments (segments 2 and 3) based on the protection of the Garnet study area following 2000, while hunting continued in the remainder of the Blackfoot drainage (Fig. S3). Under the compensatory mortality hypothesis, hunting replaces other forms of mortality, causing survival to remain relatively constant. Therefore, this model would not be supported if the compensatory hypothesis were true because survival between segments 2 and 3 would not differ. The 4-segment model (Fig. S4) tested the hypothesis that survival before protection of the Garnet study area differed between the watershed and the Garnet although management was the same for both areas, and that survival increased significantly outside the protected area once female quotas were set to 0. We used Akaike's Information Criterion for small sample sizes (AIC_c) to select among competing models to evaluate the strength of evidence for each hypothesis regarding the relationship of survival to temporal and geographical quota levels, as well as age and sex (Burnham and Anderson 1998, Hosmer et al. 2008).

We modeled survival time using a parametric Weibull distribution (Hosmer et al. 2008):

$$\ln(T) = \beta_0 + \beta_1 x + \sigma \times \varepsilon \quad (1)$$

where T is survival time, β_0 the model intercept, β_1 the covariate, σ a parameter estimating the shape of the hazard function based on the data, and ε the error term. We checked model specification using a link test (Cleves et al. 2004).

We calculated annual survival rates for 3 age classes of mountain lions: kitten (1–12 months), juvenile (13–24 months), and adult (>25 months) for each population model segment (as delineated by our a priori model selection, see above) using the Nelson–Aalen estimator (Nelson 1972, Aalen 1978). Because kittens were first collared at a range of ages (1–12 months) rather than only at the den (i.e., within the first 7 weeks), our estimate of kitten survival is biased high. We based survival rates on a biological year (1 Dec–30 Nov) reflecting the start of the hound-hunting season on 1 December. We raised the cumulative hazard estimate for each segment to the power of $1/t$, where t represents the length of that period in years, to calculate a mean annual survival rate across that period. To test for differences in survival between the various segments of the population, we used a Peto–Prentice test (Peto and Peto 1972, Prentice 1978, Hosmer et al. 2008). The compensatory mortality hypothesis predicts no difference in survival between hunted and non-hunted segments of the population. Conversely, reduced survival in the hunted population would indicate additive mortality.

We calculated cause-specific mortality rates using cumulative incidence functions (CIFs; Kalbfleisch and Prentice 1980, Heisey and Patterson 2006). These functions allow the estimation of mortality rates in the presence of competing risks, which are defined as >1 mutually exclusive, cause of death (Pintilie 2006). Unlike the modified Mayfield or Heisey–Fuller (Mayfield 1961, Heisey and Fuller 1985) methods of mortality estimation, which assume a normal or constant distribution of mortality risk, CIFs are non-parametric and make no assumption regarding the underlying hazard distribution.

We grouped mortalities by 6 causes. We classified animals that were harvested as part of a legal hunt, or kittens that were orphaned and starved after their mothers were shot as hunting mortality. Illegal mortality included animals killed in snares or otherwise killed out of season. We classified animals that died naturally because of starvation, disease, or intraspecific strife (including cases of infanticide) as natural mortalities. The category depredation included animals shot because of conflict with humans (i.e., livestock depredation permits, and self-defense). The final 2 categories were vehicle collisions and unknown, where a clear cause of death could not be determined.

We used cause-specific mortality rates to test the compensatory mortality hypothesis in 2 ways. First, we regressed survival of juvenile and adult mountain lions against hunting mortality. We omitted kittens because of their non-independence from adult females. We included juveniles because they spend approximately half of their juvenile year independent of their mothers and, unlike kittens, no juveniles starved after being orphaned by hunting. If hunting were compensatory, we would expect survival to remain constant as hunting mortality increased (Table 1). Conversely if hunting mortality were additive, we would expect a monotonic decrease in survival with an increase in hunting mortality (Williams et al. 2002). This regression used survival and hunting mortality probabilities based on the management model population structure (i.e., 6 population segments based on varying hunting quota levels, see Fig. S2). A similar analysis could have been conducted on annual survival and mortality values (e.g., Murray et al. 2010). However, because the management goal during the first 3 years of the study was to reduce the population, almost ensuring additive mortality, using annual rates may have biased our analysis towards inferring additivity of hunting mortality. We assumed this structure was less biased than an annual model towards an additive finding because the first 3 years of mortality are captured in a single data point and the model contains both hunting and natural mortality based on the protected and hunted portions of the Blackfoot watershed following December 2000.

We also tested the compensatory mortality hypothesis in adult and kitten survival by comparing the CIF for hunting and all other mortality sources between the hunted and non-hunted periods. Pepe and Mori (1993) provided a method for comparing the CIF of a main mortality source and competing risks simultaneously between 2 groups. This method tests the hypothesis of equality in the CIF of a main event (i.e., hunting mortality) while also testing for equality in the remaining competing risks (Pintilie 2006). If hunting mortality were additive, we would expect an increase in the hunting mortality rate, whereas the CIF for competing risks would be constant (i.e., no compensatory decrease in other mortality sources in the presence of hunting). Conversely, if hunting mortality were compensatory, we would expect an increase in the hunting CIF, with a concurrent reduction in the CIF for competing risks in the hunted population.

Population Modeling and Growth

Methods described thus far examined how harvest affected individual population parameters (i.e., survival, maternity, etc.). Ultimately, we were interested in how changes in these parameters combined to affect population growth. To quantify the population effects of harvest, we constructed a stage-based, 2-site, dual-sex Leslie matrix model (Leslie 1945) in MATLAB ® (The MathWorks, Natick, MA). The model consisted of 2 transition matrices joined by juvenile dispersal terms and was based on the 2 top survival models using the estimated survival and fecundity parameters described below. We calculated stochastic growth rates and associated standard deviations by running 10,000 2- to 6-year iterations (dependent on population segment, see Supplementary Material).

Vital rates.—We used age- and sex-specific survival rates previously discussed, estimated using the Nelson–Aalen estimator. We estimated variance of the Nelson–Aalen survival estimator following Anderson et al. (1997):

$$\mathrm{Var}(\hat{S}(t)) = (\hat{S}(t))^2 V^2(t) \tag{2}$$

and

$$V^2(t) = \sum_{(i:t_i<t)} \frac{d_i(r_i - d_i)}{r_i^3} \tag{3}$$

where $\hat{S}(t)$ is the survival estimate to time t, d_i is the number of deaths at time t_i, and r is the number at risk at time t_i. We then used White's method to remove sampling variance from annual estimations of survival variance, and included this value of process variance in a beta-distributed variance vector in each matrix model (White 2000).

We assumed that females did not breed until becoming adults (>24 months; Root 2004, Robinson et al. 2008, Treves 2009). We also assumed an equal ratio of male and female kittens (total fecundity divided equally between sexes; Logan and Sweanor 2001). We modeled variance in maternity using a stretched beta distribution with a maximum value of 2.5 annually, or maximum litter size of 5 every 2 years (Morris and Doak 2002). We modeled fecundity as a birth-pulse post-breeding process. Kittens entered the matrix as newborns and fecundity was the product of adult female survival (S_a) and average annual maternity (M_a; Morris and Doak 2002):

$$F = S_a \times M_a \tag{4}$$

We calculated a dispersal rate based on the number of independent juveniles in each year that moved between the Garnet study area and the remainder of the Blackfoot drainage compared to the number monitored. In this sense, our modeling definition of dispersal does not match the more traditional definition (reported above), where juveniles that establish home ranges with >5% overlap of their maternal home range are considered to be philopatric rather than dispersers (Logan and Sweanor 2001). Our model assumed a closed system consisting only of 2 populations, the Garnet study area and the remainder of the Blackfoot watershed. Therefore, for parameterization of our population models, an animal could have established a home range adjacent or overlapping with its mother's (philopatry) but still be classified as a disperser if its new home range was primarily (>50%) outside its maternal area (the Garnet area or the remainder of the drainage). We did not consider juveniles that dispersed out of the Blackfoot watershed completely to be dispersers because they were effectively lost to this system and population model and we therefore censored them.

Initial abundance and density dependence.—We set initial 1998 abundances at 37 total animals (i.e., kittens, juveniles, and adults) for the Garnet study area based on a minimum population back-calculated using known-aged animals, and 283 total individuals in the remainder of the Blackfoot drainage, extrapolating a similar total density (4.0 mountain lions/100 km^2) to the remainder of the watershed. We started all models in 1998 at a stable age distribution, then the mean modeled age distribution for further projections.

For instance, we started the 3-segment population model in 1998 with a stable age distribution and projected for 3 years, when survival rates changed or diverged between the Garnet and remainder of the Blackfoot. We projected a second period from 2001 to 2007 based on the age distribution outputs from the 1998 to 2000 model.

We applied a ceiling density dependence to stochastic models that affected survival of adults only (>24 months; Root 2004). We set a ceiling density of 27 adults for the Garnet study area and 210 adults for the remainder of the Blackfoot drainage based on an average density of 3 adults per 100 km^2. This liberal estimate of maximum adult density was commensurate with observed levels of 2.92 mountain lions/100 km^2 in Wyoming (Anderson and Lindzey 2005) and 2.58 mountain lions/100 km^2 in northeastern Washington (Robinson et al. 2008) both hunted populations.

Sensitivity and life-stage simulation analysis.—If harvest is additive, its effect on total population growth should vary based on which population parameter is affected in an additive manner and how reliant population growth is on that parameter. We tested the effect of each population parameter on population growth rate through perturbation. The sensitivity of lambda to each vital rate (i.e., survival, maternity, and dispersal) was calculated by individually reducing each rate by 0.10 and recalculating lambda for each population as well as the total population combined (Caswell 2001). The inclusion of lower-level parameters (maternity and female survival combined to calculate fecundity) in our matrix model negated the use of elasticities (Caswell 2001). We conducted an LSA to quantify the effects of variance on population growth within the Garnet study area separately during the hunted period (1998–2000), and the non-hunted period (2001–2006), comparing the r^2 values for each vital rate, for each period (Wisdom et al. 2000). We conducted sensitivity analysis using the 3-segment population model. Because we were only interested in the effect of harvest on vital rate variability and population growth, we conducted LSA on only the Garnet portion of the 3-segment population model pre- and post-harvest (i.e., segment 1 vs. segment 2, see Fig. S3).

Finally, given the results of our sensitivity and LSA analysis, we constructed a deterministic population model to quantify how varying levels of maternity, female kitten survival, and adult female survival combine to affect population growth. In this model, we fixed all male survival rates as well as juvenile female survival at the average levels observed for the entire study population, but ran successive simulations in which we incrementally increased kitten and adult female survival from 0.01 to 1.0, at 3 levels of maternity (1.08, 1.29, and 1.40; maternity during the hunting period, mean maternity across the study period, and maternity during the non-hunting period, respectively). We used standard matrix analysis techniques (Caswell 2001) to calculate the projected long-term population growth rate (λ) for each possible parameter combination. The probability of a kitten surviving to become a juvenile was the combined function of kitten and adult survival (i.e., kitten survival × adult survival) to mimic the effect of kitten abandonment following an adult's death. We modeled fecundity levels as in the other population models.

RESULTS

Harvest, Capture, and Monitoring

From 1998 to 2006, 299 mountain lions (158 M and 141 F) were harvested from the Blackfoot watershed, with 41 (18 M, 23 F) harvested from the Garnet study area. Mean age of harvested animals was 2.88 years (M $\bar{x} = 2.64$ yr and F $\bar{x} = 3.16$ yr). A female quota existed in all but the last 2 years of the study in the Blackfoot watershed. This quota was filled or exceeded in each year (i.e., 100–133% quota), and females composed 37% of the animals harvested (Table 2).

We captured 121 individual mountain lions 152 times between January 1998 and December 2006, including 82 kittens, 8 juveniles, and 31 adults. Of these, we collared 117 individuals and monitored them for habitat use and survival. We monitored animals for an average of 502 days (range: 7–3,231 days) with males remaining on the air for shorter periods ($\bar{x} = 284$ days) than females ($\bar{x} = 658$ days). We recorded known fates for 63 animals, and right-censored the remainder. We used right-censored animals in analysis until loss due to collar failure ($n = 16$), dispersal from the Blackfoot River drainage ($n = 7$), or survival to the end of the study ($n = 31$).

Population Characteristics

Sex and age structure.—The minimum total population count for the Garnet study area ranged from 37 mountain lions (4.0/100 km^2) in 1997 to a low of 20 (2.2/100 km^2) in 1999, before recovering to 33 (3.6/100 km^2) in 2006 (Table 3). The average age of adult females increased from 3.53 years during the hunted period to 4.83 in the non-hunted population, although this difference was not significant ($Z = -1.47$, $P = 0.14$). Similarly, the average age of adult males increased from 2.73 to 3.53, also a non-significant increase ($Z = -1.46$, $P = 0.14$). The oldest radiocollared female monitored during the study was 10 years old and the oldest male was 6 years old.

From 1997 to 2006, the Garnet population averaged 37% adult females, 15% adult males, 17% juveniles, and 30% kittens. Although the proportion of adult females in the population remained relatively constant between the hunted and non-hunted phases ($Z = 1.20$, $P = 0.22$), the proportion of adult males in the hunted population was higher (21%) than in the non-hunted (10%; $Z = 2.87$, $P < 0.01$; Table 3.).

Reproduction.—Mean total litter size of litters visited early in the den (<7 weeks) was 2.92 ($n = 24$, 95% CI: 2.70–3.13). Litter size was not affected by hunting ($F_{1,11} = 0.27$, $P = 0.61$). Of 32 litters where birth month could be confirmed, mountain lions gave birth in all months but December, February, and March. Most litters were produced from July to October. The mean age of sires in our population was 35 months (Onorato et al. 2011). Fourteen known-aged females gave birth to their first litter at a mean age of 31.4 months (range: 23–37 months). We found no effect of female age on litter size ($F_{6,6} = 1.39$, $P = 0.35$). Average birth interval was 602.6 days (95% CI: 503–702

Table 3. Minimum total mountain lion population (including kittens, juveniles, and adults), mean adult age, and proportion of total population consisting of adult male and female mountain lions censused on 1 December, 1997–2006, Garnet study area, western Montana.

		Mean adult age (yr)		Adult proportion of total population	
Year	**Minimum total population**	**Male**	**Female**	**Male**	**Female**
1997	37	2.29	3.79	0.189	0.378
1998	27	2.83	3.91	0.222	0.407
1999	20	2.8	3.7	0.25	0.5
2000	21	3	2.75	0.19	0.381
Hunted mean		2.73	3.53	0.21	0.42
2001	25	3.67	3.75	0.12	0.32
2002	24	3	4.44	0.125	0.375
2003	30	4	4.82	0.1	0.367
2004	32	3	4.91	0.094	0.344
2005	33	3.5	5.27	0.121	0.333
2006	33	4	5.8	0.061	0.303
Non-hunted mean		3.53	4.83	0.10	0.34

days) or 19.8 months. Approximately 58% of females ≥24 months gave birth each year, and 89% of females were traveling with dependent young.

The mean maternity rate across the study period was 1.29 ($n=9$, 95% CI: 0.84–1.76) kittens per female per year. Although maternity was lower during the hunting period ($\bar{x}=1.08$, $n=3$, 95% CI: 0–3.59) compared to the protected population ($\bar{x}=1.40$, $n=6$, 95% CI: 1.02–1.78), this difference was not significant ($Z=-0.53$, $P=0.59$). In 1999, we documented no litters born to collared females; however, because of heavy harvest pressure, we monitored only 2 adult females.

Dispersal.—We monitored 66 mountain lions (39 F and 27 M) during their juvenile year (13–24 months of age) during 1998–2006. Of these 66 individuals, 47 survived to independence. Mean age of dispersal was 15 months ($n=33$, range: 11–23 months). Dispersal was severely constrained in the hunted population before 2001. During the first 3 years of study when harvest level was high, only 2 of 12 juvenile females survived to independence. One dispersed out of the Blackfoot drainage, and 1 established a philopatric home range inside the Garnet study area. Between 2001 and 2006, during protection of the Garnet from hunting, we monitored 54 juvenile mountain lions, 45 of which survived to independence. In total, female juveniles showed essentially equal levels of dispersal ($n=12$) and philopatric behavior ($n=14$). We found no relationship between population level and dispersal rate of juvenile females ($Z_5=0.60$, $P=0.55$). We did not document any philopatric behavior in radiocollared juvenile males ($n=19$; 100% dispersal).

Survival and Mortality

We recorded mortalities in every month but October, with the majority coinciding with the start of the hound-hunting season in December (Fig. 2). Sex was the best predictor of mountain lion survival followed by quota and age. Females were 73% less likely than males to die (hazard ratio [HR] $=0.27$, $Z=-4.79$, $P<0.01$), with risk of mortality increasing 10% with each numerical increase in quotas (HR $=1.10$, $Z=2.77$, $P<0.01$). Risk of mortality was highest for kittens, declining by 1% for each month survived (HR $=0.99$, $Z=-1.52$, $P=0.11$). Although age was not a significant model covariate at the 0.05 level, Hosmer and Lemeshow (2000) recommend retaining variables with a probability of significance of 20% ($P=0.2$) for inclusion in further modeling following univariate analysis. This recommendation, coupled with our desire to create age-based population models as the next phase of our research, led to inclusion of all 3 variables in our subset models, with age broken into 3 categories.

Two models, 3-segment and 4-segment, including 3 age classes and sex, were the top models (Table 4; Figs. S3 and S4). The management model, which we thought best fit the actual quota levels, was the seventh ranked model (Table 4). A linktest showed that both the 3-segment ($Z=-0.51$, $P=0.61$) and the 4-segment ($Z=-0.58$, $P=0.56$) models were properly parameterized.

Mean annual survival, pooling all individuals across all years, was 0.651 (SD $=0.03$). Survival of kittens ($\bar{x}=0.785$, SD $=0.05$) and juveniles ($\bar{x}=0.592$, SD $=0.09$) did not vary by sex (kitten: $\chi^2_1=0.14$, $P=0.70$; juvenile: $\chi^2_1=0.18$, $P=0.66$). Among adults, female survival ($\bar{x}=0.786$,

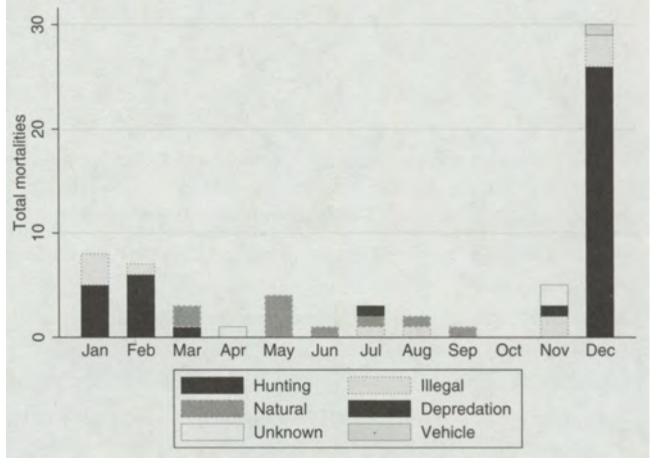

Figure 2. Timing and cause of 63 radiocollared mountain lion mortalities, 1998–2006, in the Blackfoot River watershed, Montana.

Table 4. Top models in best-fit analysis of mountain lion survival patterns in Blackfoot watershed Montana, 1998–2006. Null model log likelihood (LL) was −54.2168 (8 remaining models in Table S1).

Rank	Model	LL	df	AIC_c	ΔAIC_c
1	3-Segment	−36.1078	7	87.1115	0
2	4-Segment	−35.5328	8	88.2269	1.1154
–					
7	Management	−35.4528	10	92.7088	5.5973
–					
10	1-Segment	−44.1786	5	98.8296	11.7181

SD = 0.05) was higher than males ($\bar{x}$ = 0.515, SD = 0.12; $\chi^2_1 = 5.04$, $P = 0.02$).

Adult survival (F: $n = 13$, M: $n = 3$) was similar between the Garnet study area and the remainder of the Blackfoot drainage before December 2000 ($\chi^2_1 = 0.45$, $P = 0.50$), but differed once hunting was halted in the Garnet ($\chi^2_1 = 17.62$, $P < 0.01$; F: $n = 38$, M: $n = 17$; Table 5), consistent with the additive mortality hypothesis. Once adult female quotas were reduced to 0 outside the Garnet study area (segment 4 of the 4-segment population model, see Fig. S4), adult survival increased from 0.60 to 0.87 ($\chi^2_1 = 3.08$, $P = 0.08$) compared to survival before quota reduction (population segment 2). The marginal significance in total adult survival is explained by an increase in adult female survival while adult male survival remained relatively constant (Table 5).

Hunting was the main cause of mortality for all age and sex classes across the study period, accounting for 36 of 63 mortalities documented. Additional factors were illegal mortalities, natural, unknown, depredation, and vehicle collision (Table 6). Across the study period, mountain lions in the Blackfoot watershed had a 22% annual probability of mortality due to hunting. Regression analysis of hunting-caused mortality and survival of juveniles and adults showed a significant negative slope of −0.97 ($F_{1,4} = 21.97$, $P = 0.01$), consistent with the additive-hunting mortality hypothesis and suggesting hunting mortality is completely additive (Fig. 3). For adults and juveniles, PepeMori tests of equality in cause-specific mortality rates were significant (hunting mortality $\chi^2 = 31.18$, $P < 0.01$; all other mortality $\chi^2 = 3.58$, $P = 0.06$). The difference in other mortality sources between hunted and non-hunted populations was due to higher mortality in the hunted populations, supporting the additive-hunting mortality hypothesis.

During the heavy hunting period before closure of the Garnet study area, 6 kittens died of starvation following the harvest of their mothers, leading to a kitten cause-specific mortality rate of 0.41 (SE = 0.14). During the same period, no kittens died of natural mortality; however, following closure of the Garnet study area, 6 kittens died of natural causes including cannibalism or infanticide, a cause-specific mortality rate of 0.16 (SE = 0.06). Kitten mortality

Table 5. Mean annual survival rates of radiocollared mountain lions broken into population segments according to our 3- and 4-segment model structures 1998–2006, western Montana. Sample sizes (*n*) include animals that were counted in the risk pool of more than 1 model segment. The 3-segment model assumes that survival was similar across the watershed prior to protection of the Garnet (combined hunted), but differed after December 2000 when hunting ceased in the Garnet (Garnet protected and Blackfoot hunted). The 4-segment model assumes survival differed among 4 groups: 1) Garnet study area before December 2000 (Garnet hunted), 2) Garnet study area after hunting ceased in the area (Garnet protected), 3) Blackfoot watershed before 2005 (Blackfoot hunted), and 4) Blackfoot watershed during the last 2 years of the study when female quotas were reduced to 0 (Blackfoot hunted reduced). Survival of kittens and juveniles did not vary by sex; therefore, we present pooled estimates.

Model and segment	Area (yr)	Age and sex	*n*	Mean survival	SD
3-segment 1	Combined hunted (1998–2000)	Kitten	24	0.6566	0.09
		Juvenile	12	0.3117	0.12
		Female adult	13	0.6737	0.09
		Male adult	3	0.7167	0.21
3-Segment 2	Garnet protected (2001–2006)	Kitten	60	0.8505	0.06
		Juvenile	43	1.0	
		Female adult	25	0.9654	0.03
		Male adult	10	0.7788	0.15
3-Segment 3	Blackfoot hunted (2001–2006)	Kitten	29	0.9672	0.05
		Juvenile	44	0.6920	0.08
		Female adult	31	0.7130	0.08
		Male adult	16	0.4699	0.13
4-Segment 1	Garnet hunted (1998–2000)	Kitten	16	0.7281	0.11
		Juvenile	10	0.2326	0.13
		Female adult	9	0.5740	0.13
		Male adult	3	1.0	
4-Segment 2	Blackfoot hunted (1998–2004)	Kitten	34	0.5352	0.15
		Juvenile	32	0.2735	0.13
		Female adult	29	0.5985	0.11
		Male adult	7	0.5387	0.13
4-Segment 3	Garnet protected (2001–2006)	Kitten	60	0.6151	0.12
		Juvenile	43	1.0	
		Female adult	25	0.9654	0.03
		Male adult	10	0.7788	0.15
4-Segment 4	Blackfoot hunted reduced (2005–2006)	Kitten	9	0.9048	0.12
		Juvenile	21	0.6218	0.14
		Female adult	17	0.8746	0.09
		Male adult	10	0.5488	0.21

Table 6. Number of cause-specific mortalities and associated mortality rates (cumulative incidence function, CIF) of radiocollared mountain lions in 1998–2006 in western Montana.

Age class	Sex	Hunting	Illegal	Natural	Depredation	Unknown	Vehicle
Kitten	Male	2		5	1		1
	Female	4		2			
Juvenile	Male	9	2		1		
	Female	4	1			1	
Adult	Male	8	2				
	Female	9	6	3		2	
Total		36	11	10	2	3	1
CIFs		0.221	0.055	0.038	0.007	0.011	0.006
SE		0.03	0.01	0.01	0.006	0.006	0.006

attributed to hunting was higher during the 3-year period of heavy hunting than in the 6 years following protection of the Garnet study area ($\chi^2 = 7.58$, $P = 0.01$). However, we found no change in all other sources of mortality between the 2 periods ($\chi^2 = 0.49$, $P = 0.48$), supporting the additive mortality hypothesis.

Population Modeling and Growth

We monitored 47 kittens until independence from their mothers. One female and 6 males dispersed out of the watershed completely and were censored from dispersal rate calculations. Dispersal rates of juveniles from the Garnet study area to the Blackfoot was 0 prior to the cessation of hunting, but increased to 0.82 ± 0.19 per year for females and 0.71 ± 0.39 per year for males once the Garnet was closed to hunting. No radiocollared juveniles immigrated into the Garnet study area from the remainder of the Blackfoot watershed, where hunting was allowed, although low juvenile survival reduced the number of independent juveniles in our Blackfoot sample to 4 (3 F and 1 M), all of which remained in the hunted area.

Our population models indicted that the mountain lion population in the Blackfoot watershed declined by approximately 11–12% per year between 1998 and 2000 (Table 7). With cessation of hunting in the Garnet study area in 2001, the 3-segment model predicted recovery beginning immediately, with the watershed population growing at approximately 3% annually (Table 7). The 4-segment model indicated that mountain lion numbers in the watershed were still slightly declining between 2001 and 2004, before climbing rapidly following reductions in quotas outside the Garnet in 2005 (Table 7). Both models predicted a watershed-wide population level in January 2007 slightly below 1998 levels (Fig. 4). Both models also predicted final abundances in the Garnet study area of approximately 28 individuals, 9 fewer than at the start of the study. The trend in watershed-wide estimates from both modeled populations matches the minimum count for the Garnet based on backdating (Fig. 4); however, both models predicted a slower recovery within the Garnet study area than the minimum count for the number of animals based on backdating (Fig. 4).

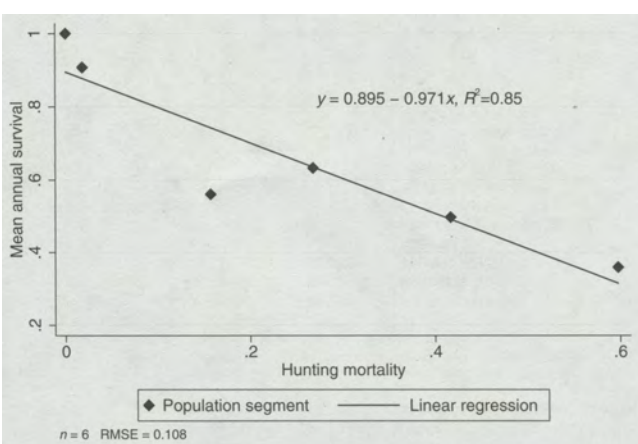

Figure 3. Regression of the relationship of hunting mortality and survival of independent mountain lions, 1998–2006, in the Blackfoot River watershed, Montana based on the management model population breakdown (see also Fig. S2).

The growth rate of the watershed-wide, mountain lion population was most sensitive to changes in adult female survival followed by juvenile and kitten female survival and maternity (Fig. 5). Negative sensitivities of dispersal from the Garnet to the hunted area of the watershed following 2001 attest to the lower survival probability of adults in the hunted area compared to the protected Garnet. LSA showed that hunting increased the importance of adult female survival to population growth by 50%, while reducing the significance of kitten survival and maternity (Fig. 6). The sum of adult female survival, female kitten survival, and maternity accounted for 92% and 57% of the variability in annual population growth of non-hunted and hunted populations, respectively. In general, adult female survival levels below 0.80 should lead to declining population levels (Fig. 7).

DISCUSSION

Population Characteristics

Hunting directly reduced population size from 37 to 20 animals between 1997 and 2000, but population parameters such as litter size, birth interval, maternity, age at dispersal, and age at first breeding were not significantly affected. Increased harvest increased the proportion of adult males in the population, while reducing the average age of both adult males and females, likely because of a compensatory immigration response into vacated home ranges (Cooley et al. 2009). We had hypothesized that female recruitment would be reduced by harvest, perhaps more greatly than

Table 7. Modeled population growth rate (λ; ±SD) based on the 3- and 4-segment population models in western Montana, 1998–2006.

Study area	Model	1998–2000 (λ)	2001–2004 (λ)	2005–2006 (λ)
Garnet	3-Segment	0.8686 (0.08)	1.024 (0.06)	1.024 (0.06)
	4-Segment	0.9352 (0.11)	0.9855 (0.05)	1.016 (0.09)
Blackfoot	3-Segment	0.8797 (0.08)	1.033 (0.06)	1.033 (0.06)
	4-Segment	0.8829 (0.12)	0.9375 (0.11)	1.176 (0.10)
Combined	3-Segment	0.8795 (0.08)	1.034 (0.05)	1.034 (0.05)
	4-Segment	0.8928 (0.11)	0.9475 (0.09)	1.155 (0.09)

males because of shorter female dispersal distance and reduced juvenile survival, resulting in an increased adult female age structure. Both female and male immigration were likely occurring during the heavy harvest period despite very low juvenile survival in the study area. The change in age structure of the population to a greater proportion of males did not affect productivity.

We estimated a mean litter size of 2.92 (measured at the den <7 weeks); however, this did not differ between hunted and unhunted periods. Estimates of litter size have ranged from a low of 1.9 in Florida (Maehr and Caddick 1995) to a high of 3.1 in southeastern British Columbia (Spreadbury et al. 1996), with most averaging around 2.5 (Logan and Sweanor 2001). Logan and Sweanor (2001), Cooley et al. (2009), and most recently Hostetler et al. (2012) have likely produced the least biased estimates of litter size by visiting den sites within the first month of birth, producing means of 3.0 ($n = 53$), 2.55 ($n = 33$), and 2.6 ($n = 94$), respectively. Similarly, our estimated birth interval of 19.8 months closely matched others in the literature, including 17.4 in New Mexico (Logan and Sweanor 2001), 19.7 in Alberta (Ross and Jalkotzy 1992), and 24.3 in Utah (Lindzey et al. 1994).

We found no effect of hunting on maternity rates, and the mean maternity rate of 1.29 was also similar to other published rates (e.g., New Mexico ranged from 1.3 to 1.6 kittens/F/yr [Logan and Sweanor 2001], whereas Robinson et al. [2008] and Cooley et al. [2009] reported maternity rates in hunted populations of 1.2 and 1.1 kittens/F/yr). Onorato et al. (2011) found the mean age of sires in our population, 35 months (range: 15–57 months), was younger than reported elsewhere. For instance, Logan and Sweanor (2001) found that 71% of litters in their non-hunted population were sired by males 35–88 months of age. However, as indicated above, the younger age structure of the male population during the hunted period did not affect kitten production.

Mean age at dispersal in our study population was similar to other mountain lion studies, where dispersal occurred between 10 and 33 months (Sweanor et al. 2000). Levels of philopatry were also similar to non-hunted populations. Sweanor et al. (2000) found that 68% of female recruits came from the local population, compared to a 50% philopatry rate in juvenile females in our work. We documented 100% male juvenile dispersal following protection from hunting.

Perhaps our most striking finding of the effects of hunting on the characteristics of this mountain lion population was the elimination of emigration during the heavy harvest period. Although this result may suggest a compensatory response (i.e., increased philopatry) of juveniles to reduced conspecific densities, juvenile survival was reduced to a level such that only 2 females and no males survived to dispersal

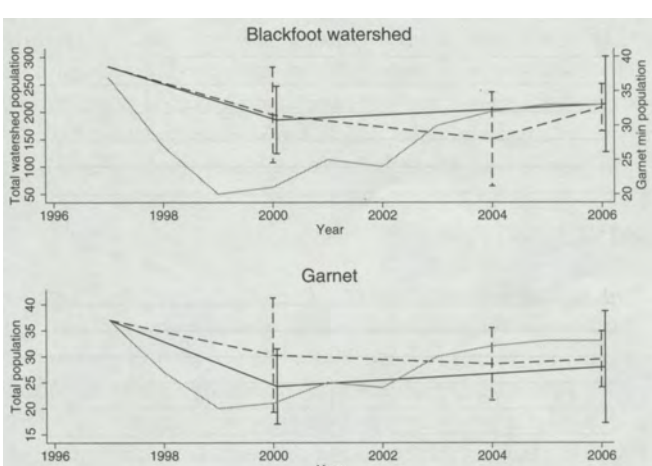

Figure 4. Projected population levels (±1 SD) for the entire Blackfoot watershed and Garnet study area based on the top population models: 3-segment model (solid black line) and 4-segment model (dashed line). The minimum population for the Garnet study area, based on backdating known-aged animals, is included for comparison (solid gray line).

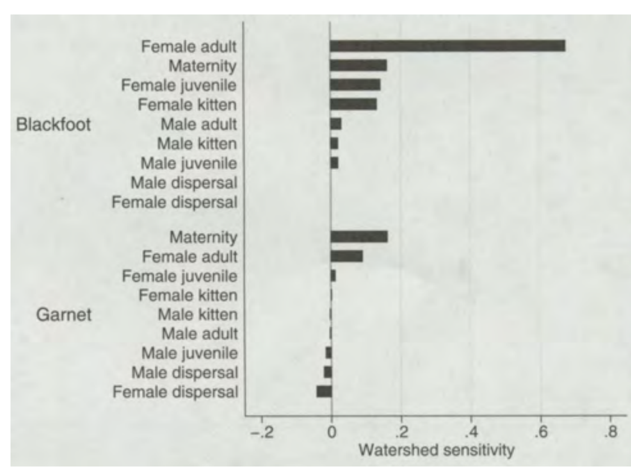

Figure 5. Sensitivities of mountain lion population growth to matrix vital rates of the 3-segment population model, 2001–2006. Maternity sensitivity is for both the Garnet and Blackfoot hunted area subpopulations in western Montana. For ease of interpretation, we present only sensitivities of the entire watershed population based on the 3-segment model 2001–2006; the sensitivities for all population segments from other population models were similar.

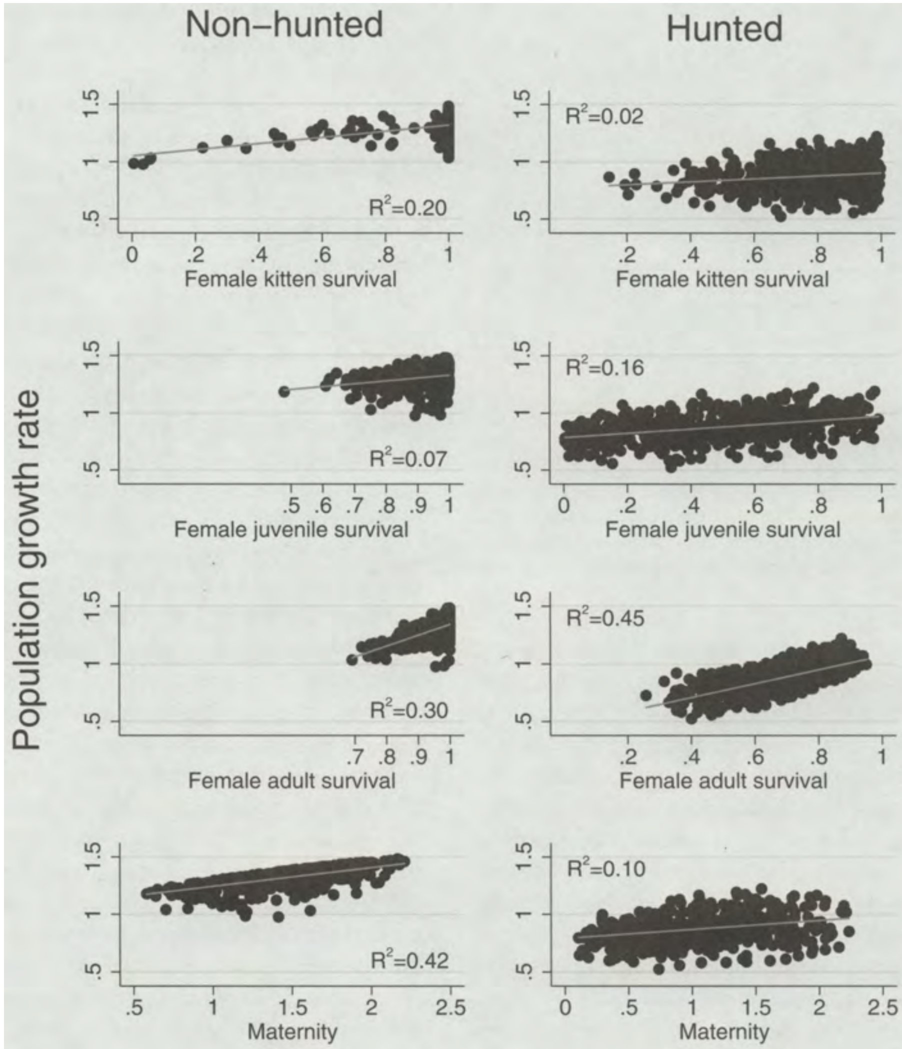

Figure 6. Life-stage simulation analysis (LSA) for mountain lions in the Garnet study area in West-Central Montana during the hunted and protected periods from 1998–2006. The R^2 value describes the proportion of the variation in population growth explained by variation in the vital rate. We omitted values for males because their survival rates and associated variances had little effect on population growth.

age (Table 5). Metapopulation dynamics are an increasingly important focus of mountain lion management and immigration, and emigration can play a major role in balancing hunted and non-hunted mountain lion populations (Beier 1993, Robinson et al. 2008, Cooley et al. 2009). Harvest levels equivalent to those recorded during the first 3 years of our study may severely reduce a population's ability to act as a source of immigration to other areas, affecting not only the focal population level, but also those populations surrounding it (Liu et al. 2011).

Survival and Mortality

Human-caused mortality shaped the survival of mountain lions in our study area, with hunting being the leading cause of mortality. The compensatory mortality hypothesis posits that harvest reduces the probability of animals experiencing other sources of mortality, thus allowing survival rates to remain relatively constant. We found an almost perfectly linear decrease in total survival of adults and juveniles with increased hunting mortality. We also found that mortality due to all other causes (i.e., illegal, natural, depredation, vehicle, and unknown) was actually lower in the non-hunted population when compared to the hunted population. Both of these findings support the additive mortality hypothesis. The 3-segment model demonstrated the distinct difference between harvest pressures and resultant survival within the Garnet study area and remainder of the Blackfoot following the restriction of hunting in 2001. We interpret the relatively poor performance of the management model as evidence that the small incremental reductions in quotas following 2000 (Table 1) did not result in significant differences in population-level survival rates.

We believe an important mechanism rendering the effects of harvest as additive is kitten mortality due to starvation following harvest of adult females. We found an essentially equal number of kitten mortalities due to the direct effects of hunting through abandonment and natural mortality following closure of the Garnet to hunting. However, because of the timing of hunting mortalities (early in the biological yr), and the longer period of monitoring and

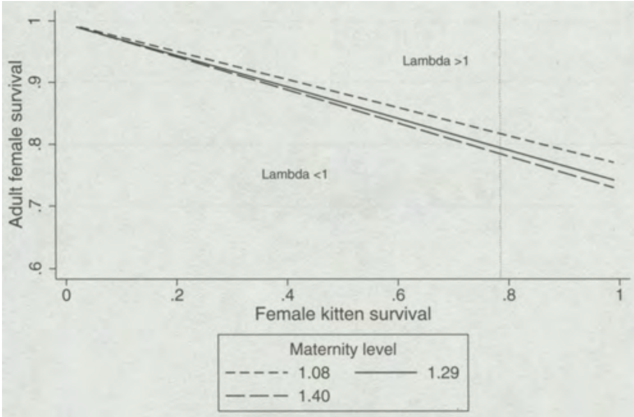

Figure 7. The relationship between mountain lion female kitten survival, adult female survival, and population growth at maternity rates of 1.08, 1.29, and 1.4. Areas above the lines represent possible lambda values greater than 1.0 and areas below represent survival levels that may lead to a decline in population. The dotted reference line represents our kitten survival estimate of 0.785 from 1998 to 2006 in the Blackfoot River watershed, Montana.

sample size following closure of the Garnet to hunting, estimated mortality rates due to hunting were significantly higher. The main influence of hunting on kitten survival may be starvation due to abandonment, not infanticide, and reductions in natural mortality do not compensate for hunting losses of kittens. Our results regarding the additive nature of hunting mortality in mountain lion populations build on Cooley et al. (2009). The additive effects of harvest, not only on adults but also through the orphaning of kittens, suggests that hunting, especially of adult females, shapes survival in hunted populations and has the potential to quickly reduce population levels.

Logan and Sweanor (2001) described the "sledgehammer approach," where hunting quotas are set mainly by the previous season's hunter success rate. As success rates decline, quotas may be reduced. However, because of a lack of inexpensive and reliable methods for tracking populations, even reduced quotas may not match existing population levels leading to further declines (Fryxell et al. 2010). Our survival modeling suggested that incremental reductions in quotas outside the protected Garnet study area did not result in significant increases in adult survival until female quotas were reduced to 0, possibly because of a mismatch between quota levels and existing population levels.

Population Modeling and Growth

Matrix population models based on the structure of our 2 top survival models resulted in similar predicted population-level outcomes. They suggested that the mountain lion population in the greater Blackfoot watershed was declining annually between 11% and 12% before protection of the Garnet study area in 2001, but recovered to levels slightly below 1998 by the end of the study in 2007. This was due to protection of the Garnet area, dispersal out of the protected Garnet, and reduced quotas in the remainder of the watershed beginning in 2004. Differences in the predicted level of decline, and the speed and level of the recovery is the result of slightly different estimated survival rates for the various survival model segments. Our estimates of kitten survival were biased high because of inclusion of kittens first marked as late as 12 months. However, even with this optimistic estimate of kitten survival, both population models predict declining populations in response to the heaviest harvest levels. If our kitten sample was based purely on animals marked at the den, our estimate of survival would most certainly be lower as would our estimate of population growth, thus strengthening our conclusion of harvest being additive.

Our sensitivity analyses showed that maternity was second in importance to female survival rates in influencing population growth rates. Sensitivity analysis does not account for annual variability, as the LSA does. Although maternity rate was held constant for all models at 1.29 kittens per female per year, fecundity is a function of maternity and adult female survival. Differences in fecundity also partially explain the different performance of each model segment.

Sensitivity analysis also showed that dispersal of both juvenile males and females from the protected Garnet into the hunted Blackfoot watershed had a strong negative effect on Garnet population growth and a weak negative effect on growth in the watershed as a whole. The population demonstrated a negative sensitivity of dispersal from the Garnet to the Blackfoot (Fig. 5), which is due to the lower survival rates in the unprotected portion of the Watershed. The matrix model suggested that juveniles would be better off remaining where their probability of survival and reproduction were higher (i.e., inside the Garnet).

Our LSA clearly demonstrated the effect of hunting on the normal population dynamics of mountain lions. In the non-hunted population, adult female survival accounted for approximately 30% of the variation in population growth between years, whereas reproduction (kitten survival and maternity) accounted for approximately 62%. Hunting reversed this balance, shifting the reliance of population growth towards adult survival (45% of the variation in growth), and away from reproduction (12%). In general, we found little effect of male survival on population growth. In the non-hunted segment of our population, male survival accounted for less than 1% of the variability in annual population growth; this level increased to 5% in the hunted population.

By varying 3 important vital rates to population growth (adult female survival, female kitten survival, and maternity) in a deterministic matrix model, we showed that adult female survival rates >0.80 (depending on kitten survival) are required for population growth (Fig. 7). However, kitten survival estimated with minimal bias due to delayed marking (e.g., Cooley et al. 2009, Hostetler et al. 2010) suggests that rates may rarely be >0.50 (see also Logan and Sweanor 2001). At that level, adult female survival <0.85 will likely result in population reduction (Fig. 7). Consistent with these results, Lambert et al. (2006) modeled broad mountain lion population declines in British Columbia, Washington, and Idaho with adult female survival rates of 0.77. Our estimates of mean kitten survival may have been biased high as the average age of a kitten when first marked was 4.7 months. As a result, our population models may slightly overestimate true growth. However, the predictions of our deterministic model regarding the relationship of kitten survival, adult female survival, maternity, and population growth (Fig. 7) are not affected by our measure of kitten survival.

Immigration and emigration have dramatic effects on real population growth rates when compared to modeled rates that do not account for dispersal. Our population models assumed a closed system consisting of only 2 populations, the Garnet and the remainder of the Blackfoot drainage. We found no juvenile dispersal from the Blackfoot back into the Garnet and therefore could not model the effect of immigration into the Garnet. We found a difference of approximately 8 animals between our modeled population estimates, and our minimum count for the Garnet. This small difference over a 9-year period could be explained by as few as 3 litters that were born inside the Garnet and were not accounted by our estimate of mean maternity rates. However, immigration into the Garnet was likely occurring, but from outside the Blackfoot watershed. Accounting for immigration and emigration, Cooley et al. (2009) showed real population decline ($\lambda = 0.91$) in a heavily hunted area with adult female survival estimated at 0.66. Without immigration, population growth would have been significantly lower, that is, $\lambda = 0.78$. That same study found an essentially stable real population growth rate ($\lambda = 0.98$) in a lightly hunted population with adult female survival of 0.87, with emigration reducing modeled growth from 1.10.

MANAGEMENT IMPLICATIONS

Our research indicates that mountain lion populations are affected by human harvest through additive effects on survival of all age classes and a resultant disruption of juvenile dispersal. We found no effect of harvest on reproductive parameters (i.e., litter size, birth interval, maternity, age at dispersal, and age at first breeding). The consistency in litter size and associated birth interval and maternity rate observed by several studies with varying levels of protection suggests that mountain lions do not possess the ability to respond to harvest through increased reproduction. This lack of elasticity in reproduction and therefore recruitment increases the need for connectivity to facilitate immigration into hunted populations. The high reliance on adult female survival for population growth should dictate very conservative female harvest unless population reduction is the stated management goal. Our results show the strong effect of harvest on targeted populations through shaping survival, and perhaps on neighboring untargeted populations by affecting dispersal patterns. Given the limitations of techniques of abundance estimation currently available and the effect of harvest on mountain lion populations, we recommend lion population objectives and harvest strategies that account for this lack of precision. A source-sink or zone management strategy, as proposed by Logan and Sweanor (2001) would protect the biological integrity of mountain lion populations, while providing public harvest opportunity and flexibility to managers in addressing management concerns.

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Special Section on Mountain Sheep Management

The Gordian Knot of Mountain Lion Predation and Bighorn Sheep

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ABSTRACT The objective of this review is to generate a synthesis of research conducted on predation of bighorn sheep (*Ovis canadensis*) and to suggest directions for future research relative to current knowledge gaps and a novel hypothesis. This review is primarily based on literature from the last 60 years on desert bighorn sheep (*O. c. nelsoni*), Rocky Mountain bighorn sheep (*O. c. canadensis*), and mountain lion (*Puma concolor*) predation. Although, many predators kill bighorn sheep, only mountain lions are currently considered to be the primary proximate cause of mortality for many bighorn sheep populations. The ultimate cause of this phenomenon has vexed wildlife managers for >40 years. There are 3 primary reasons for increased predation on bighorn sheep by mountain lions. First, there is an increased presence of mountain lions in habitats where they were historically absent or rare because of the expansion of mule deer (*Odocoileus hemionus*) following the extensive conversion of fire-maintained grasslands to shrublands in the late-1800s. Second, is the extirpation of the 2 dominant apex carnivores (wolves [*Canis lupus*] and grizzly bears [*Ursus arctos*]) during this same time period and a hypothesized numerical response of mountain lions to those extirpations. Finally, the response of mountain lions to the cessation of >70 years of intensive predator control has often resulted in unsustainable mountain lion-bighorn sheep ratios, especially for desert bighorn sheep. Additionally, the effect of mountain lion predation is exacerbated by declines in bighorn sheep that do not result in declines in mountain lions because of their ability to prey switch to mule deer, elk (*Cervus canadensis*), or domestic cattle; kleptoparasitism of mountain lions kills, by ursids and canids, resulting in higher kill rates for mountain lions; and a possible ecological trap where adaptations derived over evolutionary time are no longer adaptive because of human-induced changes in the sympatric apex predator guild. Control of mountain lions, when mountain lion-ungulate ratios are high, might be required to protect small or endangered bighorn sheep populations, and to produce bighorn sheep for restoration efforts.

KEY WORDS apparent competition, bighorn sheep, ecological trap, kleptoparasitism, mountain lion, Native American fire, predation, predator control, predator-prey ratio.

Predation on bighorn sheep (*Ovis canadensis*), specifically mountain lion (*Puma concolor*) predation on isolated populations of bighorn sheep, has hindered restoration efforts for bighorn sheep in western North America. This review paper synthesizes our current knowledge and includes a novel hypothesis for the ultimate cause of high mountain lion predation that has confounded wildlife managers for >4 decades. This review is derived primarily from historical literature published in the last 60 years on desert bighorn sheep (*O. c. nelsoni*), Rocky Mountain bighorn sheep (*O. c. canadensis*), and mountain lion predation.

Predation has a profound influence on prey population dynamics in many ecosystems. Laboratory, mesocosm, or natural experiments have assessed the role of predation on non-ungulate prey including relationships between starfish (*Pisaster* spp.) and tidal pool prey (Paine 1969), mites (*Typhlodromus occidentalis*) and mite prey (*Tarsonemus pallidus* and *Eotetranychus sexmaculatus*; Huffaker 1958), mesocarnivores and waterfowl (Garrettson and Rohwer 2001), weasels (*Mustela nivalis*) and voles (*Microtis agrestis*; Graham and Lambin 2002), mountain lions and porcupines (*Erethizon dorsatum*; Sweitzer et al. 1997), lynx (*Lynx canadensis*) and snowshoe hares (*Lepus americanus*; Krebs et al. 1995), and numerous other species. Hairston et al. (1960:424) noted "herbivores are seldom food-limited and appear most often to be predator-limited." Excluding anthropogenic associated mortality, only disease has the potential for greater population-level consequences on prey populations (Pedersen et al. 2007).

The scientific literature on predation and ungulates is replete with evidence of the depressive effects that carnivores can have on ungulate populations (Gasaway et al. 1992, Harrington et al. 1999, Hayes et al. 2003, Wittmer et al. 2005, Bergerud et al. 2007). For example, some species of African ungulates increased ≥7 times following the removal

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of apex carnivores and all prey species <150 kg declined to near pre-removal densities after those predators were reestablished (Sinclair et al. 2003).

Asymptotic densities of ungulate populations, including bighorn sheep, on predator-free islands and in predator-free enclosures are examples of the profound influence the absence of predation can have on prey density. In North America, maximum ungulate densities in those settings are remarkably similar across an array of ecosystems and study area sizes ranging from 2.5–8,000 km^2 (McCullough 1979, Bowyer et al. 1999, Bergerud et al. 2007, Simard et al. 2010, Rominger 2015). In predator-free environments the median maximum density of deer-size ungulates is approximately 35 individuals/km^2 and compared to adjacent mainland areas with predators, ungulate densities are generally an order of magnitude, or more, greater (Rominger 2015).

High ungulate densities in the absence of predation have been documented in many cases for decades (Matthews 1973, New Mexico Department of Game and Fish [NMDGF], unpublished data) and for 80–130 years in the case of the Slate Islands, Ontario, Canada, Anticosti Island, Quebec, Canada, and Antelope Island, Utah, USA (Wolfe and Kimball 1989, Potvin et al. 2003, Bergerud et al. 2007) despite dramatic changes in vegetation composition. In other northern hemisphere predator-free islands, the non-irruptive mean ungulate density is like that reported on North American islands (Kaji et al. 2004). Density of tropical fauna is also 10 to 100 times greater on tropical predator-free islands compared with adjacent mainland densities, which mirrors the ratio of ungulate densities on temperate islands to adjacent mainlands (Terborgh et al. 2001).

The predator evasion strategy of bighorn sheep relies on the combination of keen eyesight to detect predators at distance and the ability to navigate steep terrain and outmaneuver predators following visual detection (Geist 1999). Sexual segregation of female and juvenile bighorn sheep, from male bighorn sheep, is hypothesized to be related to anti-predator behavior that includes proximity to steep escape terrain (Bleich et al. 1997). Both strategies are more effective, and therefore likely to have evolved, in response to coursing predators (e.g., wolves [*Canis lupus*]; Festa-Bianchet 1991). These strategies are less effective against a stalking predator (e.g., mountain lions).

Bighorn sheep-predator relationships are associated with potential proximate and ultimate causes. High mountain lion predation on bighorn sheep, particularly desert bighorn sheep and Sierra Nevada bighorn sheep (*O. c. sierrae*) has been the proximate factor hindering restoration in many historical ranges (Wehausen 1996, Hayes et al. 2000, Kamler et al. 2002, Rominger et al. 2004). High mountain lion predation on bighorn sheep, seen since the 1970s, appears to be related to the cessation of intensive predator control used during much of the twentieth century. This release of mountain lions from predator control has resulted in increased mountain lion-bighorn ratios that can be unsustainable based on native ungulate density, especially for desert bighorn sheep (Rominger 2013).

The ultimate cause of high mountain lion predation on bighorn sheep appears to be related to a restructuring of the apex predator guild following the extirpation of wolves and grizzly bears (*Ursus arctos*; Young and Goldman 1944, Brown 1985), major shifts in biotic communities (Berger and Wehausen 1991, McPherson 1995), and the associated restructuring of the ungulate guild across much of western North America. This restructuring has been primarily influenced by the cessation of widespread Native American burning and hunting (Turner 1991, Kay 1995, Stewart 2002), the introduction of livestock and feral equids (Berger and Wehausen 1991, Brown 1994), and the resulting expansion of mule deer (*Odocoileus hemionus*) and mule deer habitats.

Other ecological factors affecting predation and bighorn sheep include apparent competition (Rominger et al. 2004, Johnson et al. 2013), specialist predators (Ross et al. 1997, Logan and Sweanor 2001, Knopff and Boyce 2007, Knopff et al. 2010), kleptoparasitism (Elbroch et al. 2015), vulnerability of small populations (Berger 1990), subsidized predators (Rominger et al. 2004), indirect effects of predation (Bourbeau-Lemieux et al. 2011), and declining native prey (Unsworth et al. 1999). The extirpation of wolves and grizzly bears from the predator guild associated with bighorn sheep resulted in mountain lions becoming the primary bighorn sheep predator. This human-induced change might have resulted in an ecological trap (Dwernychuk and Boag 1972, Schlaepfer et al. 2002). Continued restoration of wolf and grizzly bear populations throughout Rocky Mountain and desert bighorn sheep habitat will add complexity associated with multi-predator, multi-prey systems (Knopff and Boyce 2007, Kortello et al. 2007, Knopff et al. 2010, Ruth et al. 2011) compared to many systems that only have had mountain lions as a resident apex carnivore for most of the last century.

Virtually all predators, sympatric with bighorn sheep, ranging in size from gray fox (*Urocyon cinereoargenteus*) to grizzly bear, have been documented to prey upon bighorn sheep (Sawyer and Lindzey 2002) and except for foxes, have been documented to prey on adults and juveniles. Although smaller predators (e.g., coyotes [*Canis latrans*], bobcats [*Lynx rufus*], and golden eagles [(*Aquila chrysaetos*]), and less cursorial predators (e.g., black bear [*U. americanus*] and grizzly bear) are likely more effective predators of neonates, mountain lions have been documented as the primary predator of lambs (Parsons 2007, Smith et al. 2014, Karsch et al. 2016).

The consensus in the earliest review of the effects of predation on desert bighorn sheep was that no predators had population-level consequences (Desert Bighorn Council [DBC] 1957). At the inaugural DBC meeting, a special session on predation concluded that bobcats and golden eagles were the primary predators of desert bighorn sheep but that neither species limited population demographics (DBC 1957). Most biologists working on desert bighorn sheep thought that mountain lion numbers were so low, and the predator-control programs so strict (private and government year-round trapping and hunting, bounties, poisons), that mountain lions simply could not induce population declines. The first monograph and 2 of the earliest books on Rocky Mountain and desert bighorn sheep ecology (Buechner 1960, Geist 1971, Monson and Sumner 1980) were written during a period when mountain lions were unprotected, or just recently protected by law, and wolves had been extirpated from all bighorn sheep habitats in the conterminous United States (Young and Goldman 1944). Mountain lion predation was not considered to be an important influence on bighorn sheep population dynamics.

In contrast, 5–6 decades later, a different predator-management paradigm, with mountain lions protected throughout the United States (except TX) and Canadian provinces, has shifted our interpretation of the consequences of predation. The demographic recovery of mountain lions in virtually all bighorn sheep ranges, and the advent and use of radio-telemetry to assess mortality causes, has resulted in multiple examples of population-level effects of mountain lion predation on bighorn sheep (Harrison and Hebert 1988, Wehausen 1996, Hayes et al. 2000, Rominger et al. 2004, Festa-Bianchet et al. 2006). In a recent review, Sawyer and Lindzey (2002) determined that mountain lions were capable of depressing bighorn sheep populations and numerous publications have corroborated that conclusion (Kamler et al. 2002, McKinney et al. 2006, Foster and Whittaker 2010, Brewer et al. 2013, Johnson et al. 2013).

CHANGES IN THE PREDATOR-PREY COMMUNITY

Predation on bighorn sheep hypothetically has been influenced by a change in the apex predator guild following the extirpation of wolves and grizzly bears and a change in the ungulate guild following the conversion of much of western North America from a grassland ecosystem maintained with fire by Native Americans to a shrub-dominated ecosystem. Changes in the ungulate guild are primarily related to the extensive range expansion of mule deer throughout large portions of bighorn sheep range (Berger and Wehausen 1991, Turner 1991, McPherson 1995, Kay 1995, Stewart 2002).

Changes in Predator Guild

Grizzly bear and wolf distribution overlapped nearly all Rocky Mountain bighorn sheep range and some desert bighorn ranges (Young and Goldman 1944, Lamb et al. 2017). These 2 predators were absent only from the most xeric parts of Mexico, western Arizona, California, and Nevada (Young and Goldman 1944, Lamb et al. 2017). The extirpation of wolves (Young and Goldman 1944) and near extirpation of grizzly bears (Brown 1985, Lamb et al. 2017) is well documented. Mountain lions are subordinate to wolves and bears (Boyd and Neale 1992, Kortello et al. 2007, Ruth et al. 2011, Elbroch et al. 2015) and much like the well documented response of subordinate coyotes to the absence of wolves (Berger and Gese 2007, Merkle et al. 2009), mountain lions almost certainly have responded numerically to competitive release from these 2 dominate carnivores. Evidence of this subordination is the observation that when pursued by hounds, mountain lions in North America will climb trees. In South America, where mountain lions did not evolve with a large canid predator, they do not climb trees when pursued by hounds (B. M. Jansen, Arizona Game and Fish Department [AZGFD], personal communication.). Although the total cost to mountain lions of sympatry with wolves has not been assessed, it is hypothesized that interactions could affect reproduction, survival rates, habitat selection, and home range size (Kortello et al. 2007, Ruth et al. 2011). Mountain lion survival was negatively affected by increasing annual wolf use, wolves were responsible for 15% of adult mountain lion deaths, and wolf predation decreased annual kitten production 10–39% (Ruth et al. 2011).

Anecdotal evidence suggests that mountain lions and coyotes were rare or absent where grizzly bears and wolves occurred in New Mexico (Barker 1953, Stevens 2002). Stevens (2002) hunted grizzly bears, black bears, and mountain lions with dogs throughout the late 1800s, in the portion of New Mexico that is now the Gila Wilderness, but only mentioned 2 mountain lions in his book. In 1882, a Professor Dyche from the University of Kansas came to New Mexico to collect grizzly bears in what is now the Pecos Wilderness. Using a tree blind and a deer for bait, Dyche reported bobcats and foxes but not a single coyote in his diary, although they became common after the turn of the century following the extirpation of wolves (Barker 1953).

Extirpation of wolves and grizzly bears was facilitated by intensive predator control. Private predator control efforts began in the western United States soon after livestock was introduced following the end of warfare with Native Americans. In 1914, following a Congressional appropriation, federal agencies employed 300 predator control agents to protect livestock and remnant wild ungulate populations (Brown 1992). Control efforts included year-round trapping, poisoning, hunting with hounds, denning, and bounties paid from private and government sources (Buechner 1960, Brown 1992).

Xeric ecoregions with sufficient numbers of deer to maintain resident mountain lions, but without wolves or grizzly bears, presumably functioned much like systems where high mountain lion predation on bighorn occurs today. Historical accounts suggest that native ungulate densities may have been low in multi-prey ecosystems with sympatric mountain lions as the primary apex predator. As Charles Sheldon embarked on a bighorn sheep hunt into Mexico in 1915, his guide remarked that he had recently been to the Sierra Pintas in Arizona and "lions are numerous there but sheep are scarce" (Sheldon 1979:66). During the 1907 William Hornaday expedition from Tucson, Arizona to the Pinacate Mountains in Sonora, Mexico, a single adult deer was seen in a trip that lasted more than 30 days (Hornaday 1908).

Mountain lions may have been less common historically because of interspecific competitors (Stevens 2002, Riley et al. 2004, Wittmer et al. 2005) and a much more limited distribution of mule deer (Berger and Wehausen 1991, Potter 1995, Heffelfinger and Messmer 2003). Although mountain lion abundance might have been briefly released following the extirpation of wolves, >70 years of intensive predator control kept numbers low. Quantifying abundance of mountain lions is difficult (Logan and Sweanor 2001) and there are no reliable estimates from periods of intensive predator control. Bounty records from 1902–1906 in Montana indicate that bounties paid for wolves outnumbered those paid for mountain lions by >30:1. By region, there was an inverse relationship between the number of wolves and mountain lions for which a bounty was paid suggesting that in areas where wolves were prevalent, mountain lions were rare (Riley et al. 2004).

Changes in Prey Guild

Grasslands were maintained across western North America with fire by Native Americans for millennia (Turner 1991, Kay 1995, McPherson 1995, Stewart 2002). Shrubs, which are the primary forage of mule deer, were an inconspicuous component of desert grasslands prior to 1880 (McPherson 1995). Reports of mule deer were rare in the diaries of early travelers and were reported to be a minor component of Native American diets (Berger and Wehausen 1991, Potter 1995, Heffelfinger and Messmer 2003, Kay 2007). The landscape conversion, of historical grasslands to shrub or chaparral, was influenced by grazing of excessive numbers of livestock and feral equids (Berger and Wehausen 1991). This conversion resulted in range expansion of mule deer and concomitantly the presence of mountain lions (Berger and Wehausen 1991). This conversion of grasslands to chaparral and shrublands occurred throughout bighorn sheep ranges in western North America. Range expansion of mountain lions following invasion by white-tailed deer (*Odocoileus virginianus*) into areas of clear-cut old-growth forests converted to shrub-dominated habitats also has been documented (Compton et al. 1995, Wittmer et al. 2005).

The 500,000-km^2 Great Basin ecoregion is hypothesized to have been void of deer and mountain lions because grass-dominated basin and range habitats, maintained by burning by Native Americans, did not support deer (Berger and Wehausen 1991). The Great Basin contains extensive bighorn sheep habitat and pronghorn (*Antilocapra americana*) and bighorn sheep were likely the primary ungulates present in this vast landscape. Therefore, bighorn sheep in the Great Basin may have encountered little predation by mountain lions just 125 years ago. Niche separation between pronghorn and bighorn sheep would have resulted in this ecosystem functioning much like a single-prey system. Analysis of Native American diets at 2 pueblo sites in New Mexico reported the ratio of pronghorn specimens to deer specimens was 25:1 and 79:1, respectively (Potter 1995).

Mountain lions are most effective at limiting bighorn sheep populations when they are able to prey switch onto deer, elk, or cattle and there is little evidence that mountain lions can limit bighorn sheep populations without alternative prey (Berger and Wehausen 1991, Wehausen 1996). Resident mountain lions were undocumented in bighorn sheep habitat of the Providence and New York Mountains, California, United States, until the introduction of mule deer (R. A. Weaver, California Department of Fish and Wildlife, personal communication). Mountain lion predation is rare in the most xeric mountain ranges without sympatric deer or livestock (Berger and Wehausen 1991, Cronin and Bleich 1995).

THE PARADOX OF MOUNTAIN LION DENSITY

Regardless of the mechanisms that have resulted in the predator-prey guilds present today, it is the current ratio of mountain lions to native ungulate populations that appears to influence the primary proximate cause of mortality for bighorn sheep. Following decades of intensive predator control, mountain lions have increased numerically and in distribution (Fecske et al. 2011, Knopff et al. 2014). Predator control across North America was initially directed primarily toward wolves; however, the emphasis switched to mountain lions, black bears, and coyotes following the near-extirpation of wolves. Some states paid higher bounties for female mountain lions to incentivize population reduction (Buechner 1960). Until the cessation of large-scale predator control, mountain lion predation on bighorn sheep populations was insignificant (DBC 1957).

In a review of 12 studies assessing the effects of sport hunting on mountain lions, the range of densities was 1.1–7.1 mountain lions/100 km^2, although the low density does not include subadults or kittens (Cooley et al. 2011). A density of 1–3 mountain lions/100 km^2 when coupled with a standard ungulate kill rate (Wilckins et al. 2016) may have a profound influence on ungulate population dynamics (Table 1).

Global positioning system (GPS) collaring of mountain lions has allowed for a refinement of kill rates by visiting waypoint clusters associated with kills and most studies have confirmed that mountain lions kill about 1 ungulate/week (Anderson and Lindzey 2003, Knopff et al. 2009, Wilckins et al. 2016). This value is used as the mean for calculating the number of ungulate kills/100 km^2 with the 95% confidence interval for a high and low kill rate (Table 1; Wilckins et al. 2016). At a high density of 3 mountain lions/100 km^2 and a high kill rate of 1.1 ungulate/week, there would be a predicted 172 kills/100 km^2 annually (Table 1). Most small desert bighorn sheep populations in New Mexico were predicted to go extinct with 5% additive mountain lion mortality (Fisher et al. 1999). For 172 kills to be 5% of a wild ungulate population, the density required would be 3,440 ungulates/100 km^2. At a low density of 1 mountain lion/100 km^2 and a low kill rate of 0.9 ungulate/week there would be 47 kills annually (Table 1). For 47 kills to be 5% of a wild ungulate population, the density required would be 940 ungulates/100 km^2. Both numbers are essentially 1–2 orders of magnitude greater than currently estimated ungulate densities in desert bighorn sheep ranges in New Mexico (Bender et al. 2012, Rominger 2013). This is the paradox that influences high mountain lion predation in desert bighorn sheep ranges. Cunningham et al. (1999) estimated that 44% of mountain lion dietary biomass was comprised of livestock at an Arizona study area. The fact that mountain lions are a subsidized predator (Soule et al. 1988) is a partial explanation for their ability to persist despite low native

Table 1. Kills as a percentage of 3 hypothetical deer-size ungulate-prey population densities using 3 values of mountain lion density and 3 values of kill rates (e.g., low lion density [1.0] × low kill rate [0.9] × 52 weeks = 47 kills/annually). The final column is number of deer-size ungulates/100 km^2 required for the number of kills to be a 5% mortality rate (e.g., 47 kills/5 × 100) = 940.

Mountain lion density/ 100 km^2[a]	Mountain lion weekly kill rates[b] (no. prey)	No. annual kills	Annual % mortality[c] at 50 prey/100 km^2	Annual % mortality[c] at 100 prey/100 km^2	Annual % mortality at 200 prey/100 km^2	No./100 km^2 if % mortality = 5%
1	0.9	47	94	47	24	940
1	1.0	52	>100	52	25	1,040
1	1.1	57	>100	57	28	1,140
2	0.9	94	>100	94	47	1,880
2	1.0	104	>100	>100	52	2,080
2	1.1	114	>100	>100	57	2,280
3	0.9	140	>100	>100	70	2,800
3	1.0	156	>100	>100	78	3,120
3	1.1	172	>100	>100	86	3,440

[a] These values lower than most values in Cooley et al. (2011).
[b] Mean kill rate ±95% confidence intervals from Wilckins et al. (2016).
[c] >100 indicates the estimated annual kill exceeds population size.

ungulate densities (Cunningham et al. 1999, Rominger et al. 2004).

In the Fra Cristobal Mountains, New Mexico, mountain lion control conducted from 1999 until 2013 resulted in the highest estimated ungulate density of any desert mountain range in the state (New Mexico Department of Game and Fish [NMDGF], unpublished data). The combined bighorn sheep and mule deer density is approximately 400/100 km^2 (NMDGF, unpublished data). From 2003 to 2013, an average of 3.3 mountain lions were killed annually on the 107-km^2 mountain range (NMDGF, unpublished data). However, even at this high ungulate density, 2 resident mountain lions could potentially kill nearly 25% of the resident ungulates annually.

A long-term mountain lion study on the San Andres Mountains, New Mexico documented 1.72–4.25 mountain lions/100 km^2 including adults, subadults, and cubs. This study was completed in 1995 just as high mountain lion predation adversely affected mule deer density and was also the predominant mortality cause associated with the biological extinction of desert bighorn sheep (Logan and Sweanor 2001, Rominger and Weisenberger 2000). Following this study, mule deer density declined to one of the lowest ungulate densities reported in North America with an estimated 10–12 deer/100 km^2 (Bender et al. 2012, Rominger 2013). Although mountain lion density in the San Andres Mountains is currently unknown, they persist in this habitat despite a very low deer density. There has been no discernable recovery of mule deer in >20 years.

DIRECT PREDATION

Although predation by mountain lions had been anecdotally noted by several authors (Leopold 1933, DBC 1957, Blaisdell 1961), it was not until the earliest stages of the restoration of desert bighorn sheep in Texas that high mountain lion predation was documented to cause population declines (Kilpatric 1976). In rapid succession, other western states and provinces began documenting instances of high mountain lion predation (Table 2). Most early data are reported as a percentage of radio-collared bighorn sheep killed annually (Muñoz 1982, Harrison and Hebert 1988, Creeden and Graham 1997, Ross et al. 1997).

Table 2. Examples of high mountain lion predation on bighorn sheep (bhs) in western North America.

Location	Year	Citation	Specifics
TX	1975	Kilpatric (1976, 1982)	21 bhs killed inside captive breeding facility by mountain lions at Black Gap State Wildlife Area; the wild population estimated to have declined from 20 to <10
NM	1979	Muñoz (1982)	9 of 25 (36%) bhs killed by mountain lions in 14 months
NM	1980–1989	Hoban (1990)	22 of 43 bhs mortalities attributed to mountain lion predation
NM	1996–1997	Rominger and Weisenberger (2000)	Bhs decline from ~25 to 1 resulting in biological extinction. Mountain lion predation the primary cause of death
BC	1986–1988	Harrison and Hebert (1988)	2 female mountain lions kill a minimum of 21 bhs in 14 months
CO	1995	Creeden and Graham (1997)	5 of 14 (36%) radio-collared bhs killed by mountain lions within 12 months
AB	1985–1994	Ross et al. (1997)	13% of winter bhs population killed; 1 female mountain lion killed 9% of total population and 26% of lambs in 1 winter
OR	1995–2002	Foster and Whittaker (2010)	Hart Mountain bhs herd declined from 600 to 125 with mountain lion predation the primary cause of mortality
CA	1997–1999	Schaefer et al. (2000)	Mountain lion predation cause of 75% of bhs mortality
CA	1976–1988	Wehausen (1996)	49 bhs documented killed by mountain lions without telemetry
AZ	1979–1997	Kamler et al. (2002)	In meta-analysis of 365 translocated bhs, 66% of mortality was mountain predation

Table 3. Cause-specific mortality rates (CSMR) on bighorn sheep (bhs) attributed to mountain lion predation in western North America.

Location	Year	Citation	Mortality rates
CA	1988–1995	Wehausen (1996)	CSMR due to mountain lions was 0.38
AZ	1979–1997	Kamler et al. (2002)	In meta-analysis of 365 translocated bhs, the highest CSMR due to mountain lions was 0.29
AZ	1993–1996	Bristow and Olding (1998)	CSMR due to mountain lions was 0.12 for females and 0.15 for males
NM	1992–2000	Rominger et al. (2004)	CSMR due to mountain lions was 0.13 for males and 0.09 for females in desert habitat
OR	2004	Foster and Whittaker (2010)	CSMR due to mountain lions for 44 radio-collared bhs was 0.17 for males and 0.10 for females
AB/MT	1983–2003	Festa-Bianchet et al. (2006)	During years of high mountain lion predation, the CSMR due to mountain lions was 0.26 for males and 0.32 for females
CA	1992–1998	Hayes et al. (2000)	CSMR due to mountain lions for 113 radio-collared bhs ranged between 0.08 and 0.26

The development of survival models (Heisey and Fuller 1985, White and Burnham 1999) that incorporate data from telemetrically monitored bighorn sheep, allow researchers to calculate cause-specific mortality rates (CSMR; Table 3). Mountain lion-specific mortality rates of adult bighorn sheep have been as high as 0.26 (Hayes et al. 2000), 0.29 (Kamler et al. 2002), and 0.31 (Goldstein and Rominger 2012) in some ranges. Statewide lion-specific mortality rates for desert bighorn sheep in New Mexico between 1992 and 2002 were 0.16 (Goldstein and Rominger 2012) and 88% of New Mexico desert bighorn sheep populations went extinct or declined to <10 females during this period.

The high mortality rates on state-endangered desert bighorn, attributed to mountain lion predation, in New Mexico during the 1990s were unsustainable and caused populations to decline rapidly (Goldstein and Rominger 2012). However, substantially lower mountain lion mortality rates are projected to be detrimental to the persistence of small populations of bighorn sheep. A Vortex model for state-endangered desert bighorn sheep in New Mexico predicted that all extant populations had a 100% probability of extinction with just 10% mountain lion predation added to baseline non-predation demographic parameters (Fisher et al. 1999). Initial population sizes of these small herds ranged from 10–120 and just a 5% mountain lion predation rate induced an extinction probability of 0.82–1.0 for 6 extant herds (Fisher et al. 1999).

Following the initiation of mountain lion control in desert bighorn sheep ranges in New Mexico, numbers increased from <170 in 2001 to >1,100 in 2016 (Fig. 1; Ruhl and Rominger 2015). After 31 years on the New Mexico threatened and endangered species list, desert bighorn sheep were delisted in 2012 and returned to a state-protected game species (Rominger et al. 2009, Goldstein and Rominger 2013).

Predation is the dominant cause of mortality for ungulate neonates (Smith et al. 1986, Scotton 1998, Gustine et al. 2006, Quintana et al. 2016). Predation caused 82% and 86% of mortality of desert bighorn sheep lambs in 2 studies in New Mexico (Parsons 2007, Karsch et al. 2016). In both studies, mountain lions were the apex predator.

Although wolves are currently considered to be a predator of minor consequence, as mountain lions were in 1957, wolves are still recolonizing many Rocky Mountain bighorn sheep ranges and have just begun to re-occupy historical desert bighorn sheep ranges in Arizona and New Mexico. The ecological relationship between wolves and mountain lions is not well understood (Husseman et al. 2003, Kortello et al. 2007, Ruth et al. 2011, Krawchuck 2014) and research has been primarily conducted in ecosystems recently recolonized by one or both predators, or where both carnivores have responded to less intensive predator control (Knopff and Boyce 2007, Kortello et al. 2007, Ruth et al. 2011). Most of these studies have reported mountain lions to be subordinate to wolves resulting in usurpation of kills, direct mortality of adult and juveniles, and constriction of home ranges (Boyd and Neale 1992, Kortello et al. 2007, Ruth et al. 2011).

In North American ecosystems occupied by Dall's sheep (*O. dalli dalli*), the primary predator is the wolf and there is little evidence of consistent population-level consequences of predation (Barichello and Carey 1988, Hayes et al. 2003), although Bergerud and Elliot (1998) reported improved recruitment of Stone's sheep (*O. d. stonei*) following the reduction of wolf numbers in British Columbia. Barichello and Carey (1988) reported no evidence that a substantial reduction in wolf density influenced demographics of Dall's sheep. However, Arthur and Prugh (2010) reported high

Figure 1. Desert bighorn sheep population estimates, New Mexico, 1980–2016. From 1979–1999, there were 253 desert bighorn sheep released into wild populations. From 2000–2016, there were 274 desert bighorn sheep released into wild populations. Mountain lion control began in 1999 in all endangered desert bighorn sheep herds when statewide population estimates declined to <170 in 6 herds.

levels of Dall's sheep lamb mortality by coyotes, which are hypothesized to have increased because of wolf control.

Coyotes are reported to kill adult and juvenile ungulates (Hass 1989, Kelley 1980) and were the second-most important predator of juvenile desert bighorn sheep after mountain lions in the Peloncillo Mountains, New Mexico (Karsch et al. 2016). Coyotes may be more effective predators than wolves on wild sheep neonates (Arthur and Prugh 2010) and the extirpation of wolves has resulted in a competitive release of coyotes (Berger and Gese 2007). Hebert and Harrison (1988) reported coyote predation as a major source of lamb mortality in British Columbia, Canada, and that predator control targeting coyotes was responsible for a 2–2.5-fold increase in lamb:female ratios. Bobcats are reported to kill adult and juvenile ungulates (Kelley 1980, DeForge 2002); however, there is little evidence that they have population-level effects on bighorn sheep populations. Bobcats were not confirmed to have killed desert bighorn sheep lambs in the 2 New Mexico studies (Parsons 2007, Karsch et al. 2016).

Most bighorn sheep herds are comprised of <100 individuals (Berger 1990) and therefore may be more vulnerable to extinction (Berger 1990, Fisher et al. 1999), although Wehausen (1999) found less support for a strong population size effect on extinction probability. High levels of predation can cause the extirpation of small isolated populations of bighorn sheep (Rominger and Weisenberger 2000), woodland caribou (*Rangifer tarandus*; Kinley and Apps 2001), and other species (Williams et al. 2004). However, bighorn sheep populations >100 also have been documented to decline substantially, with mountain lion predation the primary cause of mortality (Wehausen 1996, Hayes et al. 2000, Foster and Whittaker 2010).

Bighorn sheep populations with sympatric deer have been documented to decline to low density, with mountain lion predation the primary mortality factor (Wehausen 1996, Foster and Whittaker 2010, Rominger 2013). This apparent competition in multiple-prey systems was first described by Holt (1977) and has been documented in bighorn sheep populations (Rominger et al. 2004, Johnson et al. 2013) and other ungulates (Bergerud and Elliot 1986, Harrington et al. 1999, McLellan et al. 2010, Wittmer et al. 2014). For Sierra Nevada bighorn sheep, the more common prey species is mule deer (Johnson et al. 2013); however, in most desert bighorn sheep habitats in Arizona and New Mexico, domestic cattle, usually juveniles, are also alternative prey (Cunningham et al. 1999, Rominger et al. 2004).

The usurpation of mountain lion kills by interspecific competitors, primarily bears or wolves, can influence predation dynamics. In Colorado and California, mountain lion kill rates increased 48% in the presence of sympatric black bears because of kleptoparasitism, with bears detected at 48–77% of mountain lion kills (Elbroch et al. 2015). Although mountain lions may occasionally kill small black bears at cache sites, it appears that mountain lions generally depart permanently following the arrival of larger black bears (Elbroch et al. 2015). Wolves were documented to usurp 12% and scavenge 28% of mountain lion kills during a 4-year period (Kortello et al. 2007). In southern British Columbia, where wolves and grizzly bears were extirpated, or greatly reduced, mountain lions are the dominant predator of woodland caribou (Compton et al. 1995, Kinley and Apps 2001, Wittmer et al. 2005). However, in north-central British Columbia, where wolves and grizzly bears persist, mountain lions are not the dominant predator (Wittmer et al. 2005).

After work by Ross et al. (1997) that documented high mortality on a wintering bighorn sheep herd by an individual mountain lion, it has been debated whether most predation on bighorn sheep is a function of specialist mountain lions. Although, specialist predators exist (Ross et al. 1997, Logan and Sweanor 2001, Knopff and Boyce 2007), other data suggest that most sympatric mountain lions will kill bighorn sheep. In the Peninsular Ranges of California, 18 of 23 individually identified mountain lions were associated with bighorn sheep kills (Ernest et al. 2002) and in the Fra Cristobal Mountains, New Mexico 16 of 18 radio-collared mountain lions either killed or attempted to kill desert bighorn sheep (NMDGF, unpublished data).

The predator-evasion strategy of bighorn sheep is far more effective against a coursing predator than a stalking predator (Festa-Bianchet 1991) and the abrupt removal of wolves and widespread replacement by mountain lions may have resulted in an evolutionary trap where past selection pressures shaped cue-response systems that were adaptive but no longer are in the face of human-induced changes. Additionally, the sexual segregation behavior of bighorn sheep might be associated with the potential for an ecological trap. Mortality rates for female bighorn sheep, attributed to mountain lion predation can be as high or higher than those for males, suggesting the benefit of this sexual segregation strategy is not particularly effective against mountain lion predation (Krausman et al. 1989, Hayes et al. 2000, Kamler et al. 2002, Festa-Bianchet et al. 2006).

DISCUSSION

Recent studies throughout western North America provide evidence that direct predation by mountain lions is a primary proximate mortality factor of bighorn sheep. The increase in mountain lion predation on bighorn sheep has followed the demographic recovery of mountain lion populations following the cessation of intensive predator control efforts. The recovery of mountain lions was preceded by expansion of their primary prey, mule deer, following the vast conversion of grasslands that had been maintained with fire by Native Americans. This shift in the mountain lion prey guild allowed for range expansion of mountain lions into habitats where wolves and grizzly bears have been extirpated. The combination of restructured predator-prey guilds and elimination of Native American fire and hunting has resulted in bighorn sheep with sympatric mountain lion densities unlikely to have occurred previously.

Additionally, livestock and feral equids responsible for conversion of grasslands contribute to the alternative prey-base for mountain lions. In ecosystems with low densities of native prey, cattle subsidize mountain lion populations and may comprise >40% of the biomass in mountain lion diets, precluding a decline in mountain lion numbers despite declining native ungulate populations (Cunningham et al. 1999, Rominger et al. 2004). Feral equids are also reported to subsidize mountain lion populations, although they are much less numerous than cattle (Berger 1986, Turner et al. 1992, Knopff and Boyce 2007). Low densities of native ungulates are correlated with increased depredation of livestock by felids and canids (Brown 1992, Khorozyan et al. 2015).

The intensity of mountain lion predation has been reported to be nearly continuous in some ecosystems and more pulse-like in other ecosystems (Ross et al. 1997, Rominger et al. 2004). Because bighorn sheep density is rarely but a fraction of that observed on predator-free islands and predator-free enclosures, most predation is considered additive mortality, especially at low bighorn sheep densities. The stalking hunting style of mountain lions is hypothesized to result in more prime-age bighorn sheep kills compared to the effect of a coursing hunting style (e.g., wolves), which exposes compromised individuals. Additionally, the encroachment of woody vegetation due to the exclusion of fire for more than a century has enhanced stalking cover for mountain lions (Wakelyn 1987).

Increased mountain lion predation and related declines in New Mexico desert bighorn sheep populations have been correlated with declines in sympatric mule deer. These populations declined sharply in the mid-1990s and there has been no discernable recovery in the last 20 years (Rominger and Weisenberger 2000, Bender et al. 2012, NMDGF, unpublished data). Observations of deer during helicopter surveys in the San Andres Mountains were as high as 150 deer/hour and have declined to <5.5 deer/hour for all bighorn sheep surveys flown since 1996 (NMDGF, unpublished data). The estimated deer density in the San Andres has declined to 0.08–0.11 mule deer/km^2, making this one of the lowest densities of North American ungulates ever reported (Bender et al. 2012, Rominger 2013). Because of this low density, there has been no deer hunting on the entire 8,300-km^2 White Sands Missile Range, New Mexico since 1999. Similarly, low mule deer observation rates have been recorded in all other desert bighorn sheep surveys in New Mexico for the last 20 years (NMDGF, unpublished data). However, it was the ratio of mountain lions to these very low-density ungulates that precluded recovery and has required mountain lion control to increase desert bighorn sheep numbers.

Declines in bighorn sheep populations, due to mountain lion predation, have been reported for nearly every state and province where this species occurs. There is little evidence that these populations recover in the absence of predator control. One exception appears to be the federally endangered Peninsular bighorn sheep population. Although this herd is still listed as endangered, it has increased from approximately 275 (Rubin et al. 1998) to approximately 980 (Botta 2011) without mountain lion control. Peninsular bighorn sheep have an elevational niche separation from mule deer that use habitat at higher elevations in the Peninsular Ranges (Hayes et al. 2000), much like the niche separation of pronghorn and bighorn sheep in the Great Basin (Berger and Wehausen 1991). Thus, mountain lions hunting in low-elevation desert bighorn habitat have virtually no opportunity to prey switch onto deer without vacating bighorn sheep habitat.

Management of predation deemed excessive relative to bighorn sheep population objectives generally involves lethal predator control. Controlling apex carnivores is much more controversial than culling mesocarnivores (Reiter et al. 1999, Rominger 2007) despite documented success in the protection and recovery of endangered species (Hecht and Nickerson 1999, Rominger et al. 2009, Johnson et al. 2013, Hervieux et al. 2014).

Predator control is used by most western state and provincial wildlife agencies to protect endangered ungulate species (Hervieux et al. 2014) and big game populations (Rominger 2007). Predator control to protect translocated desert bighorn was first advocated by Wilson et al. (1973) and has been used to aid the restoration of bighorn sheep in New Mexico, California, Texas, Arizona, Utah, and elsewhere (Rominger 2007). High levels of mountain lion predation associated with desert bighorn sheep translocations and some Rocky Mountain bighorn sheep translocations (Krausman et al. 1999, Rominger et al. 2004, McKinney et al. 2006) can be reduced by removing resident mountain lions prior to translocation. After multiple failed translocations due to mountain lion predation, NMDGF no longer translocates desert bighorn sheep without a pre-treatment mountain lion control program to reduce the density of resident mountain lions, usually beginning 3–4 months prior to translocation.

Following the extirpation of desert bighorn sheep in the Catalina Mountains, Arizona in the 1980s, desert bighorn sheep were released into historical habitat in 2013 (Krausman 2017). The initial translocation, done without a pre-treatment removal of resident mountain lions, had high mortality with mountain lions killing 15 of 30 radio-marked bighorn sheep within 4 months. Post-release control of offending mountain lions resulted in the lethal removal of 7 mountain lions. To date, mountain lions have killed a minimum of 27 of 86 radio-marked bighorn sheep from 3 releases. In the absence of mountain lion control, this attempted restoration of a native faunal component would have almost certainly failed.

Ernest et al. (2002) modeled predator control management options to mitigate mountain lion predation and determined that for populations or subpopulations with <15 females, range-wide control (habitat control) of mountain lions was the most effective paradigm. At higher female numbers, less strict take of mountain lions was recommended (e.g., only remove offending mountain lions [kill-site removal]). However, this model assumes that a documented offending mountain lion will be removed prior to making additional kills. A large data set from NMDGF suggests this is unlikely and offending mountain lions were taken at <20% of bighorn sheep kills (Rominger et al. 2011). During a period of range-wide mountain lion control, 68 mountain lion-killed bighorn sheep with very high frequency (VHF) radio-collars were documented. However, only 13 (19%) offending mountain lions were culled.

The 2 primary reasons mountain lions were not culled were the bighorn sheep kill was not detected and located prior to the mountain lion departing (59% of all kills) and the mountain lion was present but missed at the kill site (54% of attempted removals were unsuccessful because the mountain lion did not step into snare, substrate was not conducive to snare placement, hounds were unable to tree or bay mountain lion). Although sample sizes were substantially reduced, the data set was partitioned between attempts to snare offending mountain lions and attempts to hound-hunt offending mountain lions. Use of hounds was successful in 5 of 14 attempts, whereas use of snares was successful in 8 of 14 attempts (Rominger et al. 2011). Culling offending mountain lions in the Catalina Mountains, Arizona restoration project has been successful in 6 of 15 attempts and this higher success rate is attributed to the use of GPS collars that alerted managers to mountain lion kills more quickly than VHF radio-collars (B. D. Brochu, AZGFD, personal communication).

Trapping and translocation is the primary management tool used to reestablish bighorn sheep populations into unoccupied habitats (Foster 2004). Currently, most bighorn sheep used for translocation come from mountain lion-free islands (e.g., Tiburon Island, Sonora, Carmen Island, Baja California Sur, MX; Wild Horse Island, MT, USA, Antelope Island) or predator-free enclosures (e.g., Red Rock, NM, USA and Pilares, Coahuila, MX). Very few desert bighorn sheep populations with uncontrolled sympatric mountain lions produce surplus bighorn sheep for translocations.

Restoration of natural grasslands, maintained by frequent fires, at scales that would substantially reduce deer numbers is unlikely to be a near-term management option. However, most state and provincial agencies have developed habitat management plans to reduce woody vegetation to increase bighorn habitat, and potentially reduce stalking habitat for mountain lions. Although, mountain lion predation seems to be lowest in single-prey systems in the most xeric habitats, most bighorn sheep currently occur in habitats with multiple sympatric ungulates. It is hypothesized that high levels of alternative buffer prey are preferable to low-density buffer prey when habitats have high mountain lion density.

Kill rates may increase substantially in ecosystems with high levels of kleptoparasitism and if deemed excessive, population reduction of kleptoparasites, specifically bears, would be a novel management action. The cumulative effects of predation on all sex and age classes of a bighorn sheep population must be recognized. Total predation in ecosystems with a diverse predator guild may have a much more profound influence on bighorn sheep demography; therefore, wildlife managers must decide on the appropriate response relative to management needs (Griffin et al. 2011). Small, isolated bighorn sheep herds, reduced to very low numbers by predation, will require human-mediated translocations to mitigate genetic loss and demographic declines.

Factors that influence rates of mountain lion predation should be examined experimentally to enable managers to better understand this complex system that appears to be substantially altered by anthropogenic causes. Experiments should be designed and conducted in bighorn sheep herds that are large enough to sustain high levels of predation without the need to manipulate mountain lion numbers during the experiment. Understanding the role of alternative prey, including livestock, will be a potential research direction. Understanding the influence of wolf restoration on bighorn sheep and mountain lions, particularly the effect on recruitment of adult female mountains lions, will be important. Because mountain lions are relatively long-lived, this research should be conducted over long periods following the reestablishment of wolves.

MANAGEMENT IMPLICATIONS

Productive bighorn sheep populations are required for restoration via translocation, sport hunting, and endangered species recovery. Management practices to decrease mountain lion densities that adversely affect bighorn sheep populations can be ideally addressed via sport harvest levels regulated by state wildlife agencies. In habitats or states (e.g., CA) where sport harvest does not meet management objectives, facilitated mountain lion control may be required to prevent population declines of bighorn sheep. Removal of resident mountain lions, prior to translocation of desert bighorn sheep, has increased the probability of successful restoration (Rominger et al. 2009).

There is still the potential that bighorn sheep can remain a viable faunal component in the North American west. If the public and wildlife managers are interested in keeping and restoring bighorn to their native ranges for viewing, hunting, and as source populations for recovery in landscapes that have been anthropogenically altered, difficult decisions will have to be made. Continued research on predation and other ecological factors will aid in the conservation of this species.

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Using multiple data sources provides density estimates for endangered Florida panther

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Summary

1. To assess recovery of endangered species, reliable information on the size and density of the target population is required. In practice, however, this information has proved hard to acquire, especially for large carnivores that exist at low densities, are cryptic and range widely. Many large carnivore species such as the endangered Florida panther *Puma concolor coryi* lack clear visual features for individual identification; thus, using standard approaches for estimating population size, such as camera-trapping and capture–recapture modelling, has so far not been possible.
2. We developed a spatial capture–recapture model that requires only a portion of the individuals in the population to be identifiable, using data from two 9-month camera-trapping surveys conducted within the core range of panthers in southwestern Florida. Identity of three radio-collared individuals was known, and we incorporated their telemetry location data into the model to improve parameter estimates.
3. The resulting density estimates of 1·51 (±0·81) and 1·46 (±0·76) Florida panthers per 100 km^2 for each year are the first estimates for this endangered subspecies and are consistent with estimates for other puma subspecies.
4. A simulation study showed that estimates of density may exhibit some positive bias but coverage of the true values by 95% credible intervals was nominal.
5. *Synthesis and applications*. This approach provides a framework for monitoring the Florida panther – and other species without conspicuous markings – while fully accounting for imperfect detection and varying sampling effort, issues of fundamental importance in the monitoring of wildlife populations.

Key-words: camera-trapping, mark–resight, population estimation, *Puma concolor coryi*, spatial capture–recapture, telemetry, unmarked populations

Introduction

An accurate understanding of population status is fundamental for the management and recovery of endangered species (Campbell *et al*. 2002; Hoekstra *et al*. 2002). However, estimates of population size and density are lacking for many of the world's most endangered species. As a result, it has been difficult to quantify extinction risk and monitor the effects of conservation actions.

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The Florida panther *Puma concolor coryi* is the last remaining puma subspecies in eastern North America. Originally occurring from Arkansas and Louisiana to South Carolina and Florida (Young & Goldman 1946), the current distribution is restricted to about 10 000 km^2 in southern Florida (Kautz *et al*. 2006). Due to unregulated hunting in the 19th century and large-scale loss of habitat during the 20th century (Onorato *et al*. 2010), Florida panthers were listed as endangered in 1967 (US Federal Register 1967) and subsequently protected under the Endangered Species Act of 1973 (Public Law 93-205).

Nevertheless, by the early 1990s, their population had dwindled to 20–30 individuals (McBride *et al.* 2008). Intensive population management, including introduction of wild-caught pumas from Texas to alleviate effects of inbreeding (Seal 1994; USFWS 1994), legal protection (O'Brien & Mayr 1991; Janis & Clark 2002), efforts to reduce road mortality (Foster & Humphrey 1995), and habitat and prey conservation (Janis & Clark 2002) have led to an increase in panther abundance (McBride *et al.* 2008) and genetic diversity (Johnson *et al.* 2010). Still, the Florida panther remains one of the most endangered felids world-wide (Onorato *et al.* 2010).

The Florida Fish and Wildlife Conservation Commission (FWC), with assistance from the federal government (e.g. National Park Service – NPS, U.S. Fish and Wildlife Service – USFWS), commenced research on the Florida panther in 1981, resulting in publications covering a variety of topics including: estimates of demographic parameters, habitat selection, assessment of genetic restoration and documentation of biomedical issues (Beier *et al.* 2003; Onorato *et al.* 2010). Despite the intensive research effort, producing rigorous estimates of population size for the Florida panther has eluded scientists for decades (Beier *et al.* 2003), yet abundance remains a central tenet of the USFWS recovery plan objectives (USFWS 2008).

Large, elusive carnivores such as pumas are typically difficult to sample, and accurate estimates of population-related parameters are often challenging to obtain. Obstacles include low sample sizes due to rarity, wide-ranging behaviour and concerns about invasive sampling methods. Mark–recapture techniques are generally considered the gold standard for generating robust estimates of population parameters. For many felid species, camera-trapping is increasingly used for abundance estimates because the technique is non-invasive and efficient. The resulting data, in combination with traditional capture–recapture (CR) models (e.g. Otis *et al.* 1978) or spatial capture–recapture (SCR) models (e.g. Efford 2004; Royle & Young 2008), have largely facilitated the estimation of demographic parameters of many felid species with unique pelage patterns (e.g. Karanth & Nichols 1998; Karanth *et al.* 2006; Royle *et al.* 2009). Although some puma studies use this combination of methods (Kelly *et al.* 2008; Negrões *et al.* 2010), the species generally lacks clear features for individual identification from photographs, seemingly rendering camera-trapping an unfeasible option for capture–recapture modelling of Florida panthers.

Alternatively, scat sampling in combination with genetic analyses can provide capture–recapture data (Royle, Kéry & Guélat 2011). Although this sampling technique has been applied in the study of felid populations (e.g. Ruell *et al.* 2009; Gopalaswamy *et al.* 2012), it would be difficult to implement for the Florida panther due to the subspecies' low genetic diversity (Roelke, Martenson & O'Brien 1993) and the fast decay of DNA in Florida's warm and moist climate (Farrell, Roman & Sunquist 2000; Lucchini *et al.* 2002).

Given the obstacle of individual identification, collecting capture–recapture data would require that animals be physically marked and recaptured. The high cost and safety issues to both animal and handler make such approaches impractical for elusive and potentially dangerous animals like large carnivores. This risk is compounded when dealing with the small populations of endangered species. Thus, non-invasive sampling techniques are preferable whenever possible (Long *et al.* 2008).

Florida panthers have been extensively studied using traditional very high frequency (VHF) and Global Positioning System (GPS) telemetry (e.g. Land *et al.* 2008; Onorato *et al.* 2011). Potentially, telemetry collars permit individual identification based on collar characteristics (e.g. different brands on different individuals or modifying collars with unique marks) observable in photographs. Under these circumstances, camera-trap surveys concurrent with existing telemetry studies can provide data suitable for population estimation in the framework of mark–resight models (e.g. Rice & Harder 1977; McClintock *et al.* 2009; McClintock & White 2010), which do not require that individuals be physically captured multiple times. Rather, a sample of individuals is captured and marked during a single marking event that occurs prior to resighting surveys, and a non-invasive technique such as camera-trapping or visual resighting can be used to collect 'recapture' data on these individuals. While mark–resight models provide robust estimates of abundance, they suffer from the same shortcomings as traditional capture–recapture models when it comes to estimating population density. To estimate density, we need to define the area sampled. This generally relies on ad-hoc approaches, which renders density estimates somewhat arbitrary.

Our objective was to provide a rigorous and statistically sound density estimate for Florida panthers in the Picayune Strand Restoration Project area (PSRP). We used data collected during a 21-month camera-trapping study (Shindle & Kelly 2007) and telemetry data simultaneously collected by the FWC in a new modelling framework that, analogous to traditional mark–resight, allows for only a portion of the population to be identified (Chandler & Royle In Press; Sollmann *et al.* 2013). Further, analogous to SCR models, this new framework explicitly links abundance to a clearly defined area, thus providing unambiguous density estimates. To improve the estimation of model parameters associated with individual location and movement, and to produce more precise estimates of density, we extend the model by also incorporating telemetry location data. We confirm the reliability of model results using a simulation study. Providing a rigorous estimate of Florida panther density, this modelling approach has wide application for animal conservation and endangered species management.

Materials and methods

STUDY AREA

The study was conducted in PSRP, an area that encompasses the former Southern Golden Gate Estates subdivision development, covering approximately 241 km^2 in Collier County, Florida. Originally slated for housing development, the area is currently undergoing vegetative and hydrological restoration (U.S. Army Corps of Engineers 2004). Together with two neighbouring reserves, the PSRP forms a large block of panther habitat in the core of the subspecies' range. The climate of the study area is that of a tropical savannah with distinct wet (May–October) and dry (November–April) seasons (Duever *et al.* 1985).

CAMERA-TRAPPING AND RADIOTELEMETRY

From 2005 to 2007, 98 camera traps (Digital CamTrakkerTM, CamTrak South Inc., Watkinsville, GA, USA) with passive infrared heat-in-motion detectors were deployed in PSRP for 21 consecutive months as part of a pre-restoration baseline survey for panther and white-tailed deer *Odocoileus virginianus* (Shindle & Kelly 2007). A grid with 2-km^2 cells was overlaid on the study area, and one camera was placed within each grid cell (Fig. 1). Most cameras were deployed along roads or trails and secured to trees approximately 45 cm above ground. Cameras operated 24 h per day with a minimum 20-s delay between sequential photographs. Camera traps were checked every 21–28 days to retrieve images and ensure units were functioning.

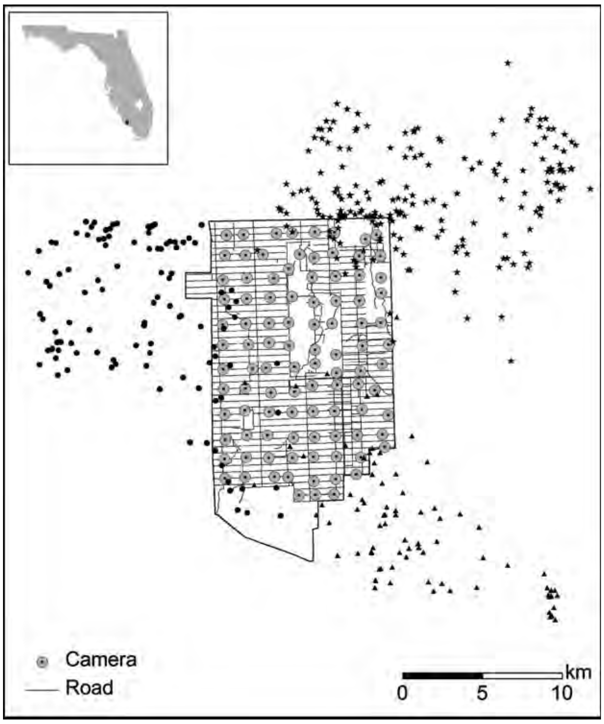

Fig. 1. Picayune Strand Restoration Project area, Southern Florida, with camera-trapping grid used to survey Florida panthers between 2005 and 2007, and radiotelemetry locations for three collared panthers (stars, circles and triangles) used in the spatial mark–resight model as the marked portion of the population.

The FWC monitors Florida panthers in the PSRP and neighbouring areas using radiotelemetry. Locations were collected via aerial telemetry three times per week (see Land *et al.* (2008) for methods). Manufacturers of radiocollars included Telonics (Mesa, Arizona, USA), Advanced Telemetry Systems (Isanti, MN, USA) and Followit (Lindesberg, Sweden). Collars from different manufacturers have distinct physical features and therefore provided a visual means of individual identification of collared panthers from camera-trap pictures.

Mark–resight models require that all marking takes place before resighting. Here, we regard those panthers as the marked part of our population that wore radiocollars throughout one or both primary camera-trapping occasions (see below) and used the PSRP as part of their home range. Panthers that were collared during the course of a primary occasion were regarded as 'unmarked'. Although some photographs of uncollared panthers could be attributed to individuals based on natural marks, many photographs of uncollared panthers were ambiguous. Since mark–resight models require that individuals can always correctly be identified as marked or unmarked, we treated all photographs of uncollared individuals as unmarked. For photographic records of uncollared individuals, we treated subsequent pictures at a given camera trap as independent if they were separated by at least an hour. Photographs that showed two (three, etc.) individuals were treated as two (three, etc.) independent records. We discarded pictures that we were unable to verify whether the individual was collared or not. We further excluded dependent kittens and juveniles from our analysis.

DATA ANALYSIS

Spatial capture–recapture models

We analysed concurrent photographic and telemetry data, building on the SCR model for partially marked populations described by Chandler & Royle (In press). Generally, SCR combines a model for individual location and movement with a model describing detection by traps, using individual and site specific detection data (Borchers & Efford 2008; Royle & Young 2008; Gardner, Royle & Wegan 2009; Borchers 2012). In SCR models, we assume that each individual i has an activity centre, $\mathbf{s}_i$, and that all $\mathbf{s}_i$ are distributed uniformly across the state space S, an area including the trapping grid, chosen large enough to include all animals potentially exposed to sampling. We assume that the number of records of individual i at trap j and occasion k, y_{ijk}, is a Poisson random variable with mean encounter rate λ_{ij}, which is a decreasing function of the distance, d_{ij}, from trap j to the individual's activity centre $\mathbf{s}_i$. Under a half-normal encounter rate model,

$$\lambda_{ij} = \lambda_0 * \exp(-d_{ij}^2/2\sigma^2),$$

λ_0 is the baseline trap encounter rate at $d_{ij} = 0$ and σ is the scale parameter of the half-normal function.

To estimate N, the number of activity centres in S, we employ data augmentation (Royle, Dorazio & Link 2007). Let n be the number of observed individuals. Then this approach is equivalent to augmenting the observed data set with $M - n$ 'all-zero' encounter histories or 'hypothetical individuals' that were never observed. N is estimated as the sum of an individual auxiliary variable, z_i,

$z_i \sim \text{Bernoulli}(\Psi)$

where $i = 1,2,3\ldots M$ and $z_i = 1$ if the animal is part of the population and 0 otherwise. The prior probability of Ψ is uniform (0,1), which corresponds to a discrete uniform (0,M) prior probability for N. M is an arbitrary value set sufficiently large as to not truncate estimates of N. Density, D, can be derived by dividing N by the area of S.

Extension of the SCR model to a mark–resight situation

Chandler & Royle (In press) extended this model to a mark–resight situation, where only part of the population can be individually identified. Under these circumstances, the individual encounter histories y_{ijk} are partially latent – only y_{ijk} for the m marked animals are observed. For the unmarked individuals, we observe only the accumulated counts $n_{jk} = \sum \mathbf{y}_{\text{ujk}},$ where $\mathbf{u} = \{m + 1,\ldots, N\}$ is an index vector of the $N - m = U$ unmarked individuals. Unobserved encounter histories are essentially missing data. Adopting a Bayesian framework and using Metropolis-within-Gibbs (MwG) Markov chain Monte Carlo (MCMC) sampling, we can update missing data using their full conditional distribution (Gelman *et al.* 2004, Ch. 11). For the y_{ijk} from unmarked animals, the full conditional is multinomial with sample size n_{jk}:

$$\mathbf{y}_{ujk} \sim \text{Multinomial}(n_{jk}, \boldsymbol{\lambda}_{uj}/\sum \boldsymbol{\lambda}_{uj})$$

The remaining model parameters are then updated conditional on the full set of encounter histories.

When the number of marked individuals, m, is known, estimating N reduces to estimating the number of unmarked individuals U. In this situation, $M - m$ = size of the hypothetical unmarked population in S. By updating the latent encounter histories (see above), we assign records of unmarked individuals to some of these hypothetical individuals, so that their encounter histories are no longer 'all-zero'.

In non-spatial mark–resight models, an important model assumption is that marked individuals represent a random subset of the population. This assumption is still required in spatial mark–resight, but additionally, the marked individuals must represent a random sample of individuals in the state space S. Here, we have only a small set of marked individuals (see results), and the telemetry information for these individuals indicates that they are distributed throughout most of S (Fig. 1).

Incorporating telemetry location data

We can relate the parameters of the half-normal encounter rate model to those of a bivariate normal movement model (Calhoun & Casby 1958), with mean = $\mathbf{s}_i$, and variance–covariance matrix $\sum$, where the variance in both dimensions is σ^2 and covariance is 0. Under this model, σ can be related to a measure of how far individuals move (Reppucci, Gardner & Lucherini 2011). Ordinarily, these parameters are estimated only from the trapping data. Telemetry data, however, provide more detailed information on individual location and movement. By assuming that the R_i locations of individual i, $\mathbf{l}_i$, are a bivariate normal (Normal_2) random variable:

$$\mathbf{l}_i \sim \text{Normal}_2(\mathbf{s}_i, \sum)$$

we can estimate σ, as well as $\mathbf{s}_i$ for the collared individuals, directly from telemetry location data using their full conditional distributions within the MwG sampler. Under this formulation, σ and $\mathbf{s}_i$ for the collared individuals are no longer conditional on the resighting data $\mathbf{y}$, but only on $\mathbf{l}$. For the unmarked individuals, $\mathbf{s}_i$ are estimated as in conventional SCR, conditional on the encounter histories. The full MwG MCMC sampler can be found in Appendix S1 (Supporting Information).

Model application to Florida panther data

To account for the lack of demographic population closure over 21 months of camera-trapping, we defined two primary occasions, from 1 July 2005 to 31 March 2006 and from 1 July 2006 to 31 March 2007. Within primary occasions, we grouped data by month and accounted for the number of days each camera trap was functional each month, t_{jk}, using $\lambda_{ij} * t_{jk}/30$. We limited telemetry data used in our model to the same time periods. To define S, we used a 15-km buffer from the outermost coordinates of the trapping grid and removed parts of the resulting rectangle that comprised ocean or islands. This resulted in an area for S of 1719·13 km^2.

We ran three chains of the MwG sampler with 200 000 iterations each, discarding 10 000 iterations as burn-in using the software R 2.13.0 (R Development Core Team 2011). To check for chain convergence, we calculated the Gelman-Rubin statistic R-hat (Gelman *et al.* 2004) using the R package coda (Plummer *et al.* 2006). Values below 1·1 indicate convergence; in our results, all model parameters had R-hat <1·1. We report the posterior mean (± standard deviation), mode, and 95% Bayesian credible intervals (95BCI) for all parameters.

Results

During the two primary occasions, we accumulated 43 890 trap days and obtained 445 photographs of Florida panthers. We discarded 137 pictures that we were unable to determine whether they belonged to a radio-collared individual or not and one picture of a collared panther that traversed the study area but was not resident (see Discussion for further treatment of this topic). Of the remaining photographs, 17 were records of identifiable radio-collared individuals and 290 pictures showed uncollared panthers (Table 1).

Three individuals met our requirements of being collared throughout one or both primary sampling occasions, with two collared individuals being present in one primary occasion only, while one was present in both occasions. For each collared individual, we accumulated an average

Table 1. Collared Florida panthers present in the Picayune Strand Restoration Project area and used as marked individuals in the spatial mark–resight model, total number of photographs and number of photographic records of these collared individuals in the two 9-month primary camera-trapping occasions

Occasion	No. collared individuals	Total number of pictures	No. pictures of collared individuals
1	2	131	2
2	2	176	15
Total*	3	307	17

*One individual from year 1 was present again in year 2.

of 99·5 (SD 10·6) telemetry locations per primary occasion (Fig. 1).

The posterior mean for the movement parameter σ was 4·45 ($\pm$0·11) km. The baseline trap encounter rate λ_0 had a posterior mean of 0·09 ($\pm$0·02) expected photographs per 30 days. The posterior mean for population density D was 1·63 ($\pm$0·50) individuals per 100 km^2 in year 1 and 1·66 ($\pm$ 0·56) individuals per 100 km^2 in year 2; for both years, the posterior mode was slightly lower, at 1·51 and 1·46 individuals per 100 km^2, respectively. Posterior summaries of parameter estimates are given in Table 2.

SIMULATION STUDY

To investigate potential bias and precision of our estimators, we generated 100 data sets consisting of both camera detection and telemetry location data under the same conditions observed for the surveyed panthers (i.e. with parameters equal to the posterior means obtained in our analyses, and the trapping grid, sampling effort, number of known individuals and telemetry locations equivalent to values in the actual field study). Across 100 data sets, parameters were estimated with low accuracy (relative root mean squared error (RMSE) 26–39%); only the RMSE of σ was low, at 3%. For N, the posterior mode presented a less biased estimator (relative bias 11–13%) than the mean (27–29%). For λ_0 and σ, relative bias of the mean was 4 and 0·3%, respectively. Coverage of the true values by 95% BCI was between 92% and 99% for all parameters (see Appendix S2, Supporting Information).

Discussion

Large felids such as the Florida panther are notoriously difficult to monitor. Low population densities and elusive behaviour often result in sparse data, requiring intensive sampling over several years. Camera traps are an ideal tool for the study of large and wide-ranging species, but inference from camera-trap data for populations that cannot be individually identified is limited. Mark–resight methods have long been used as an alternative to traditional mark–recapture studies (e.g. Rice & Harder 1977; Minta & Mangel 1989), but only recently has the concept of mark–resight modelling been extended to SCR models (Chandler & Royle In press). This development has made it possible to address a major problem facing wildlife managers who are in need of reliable density estimates for rare and elusive species without conspicuous natural marks.

Table 2. Posterior summaries of parameter estimates from a spatial mark–resight model applied to Florida panther camera-trapping and telemetry data from the Picayune Strand Restoration Project area, Florida. Density is estimated for two 9-month primary occasions (t)

Parameter	Unit	Mean (SE)	Mode	2·5%	97·5%
σ	km	4·45 (0·11)	4·46	4·24	4·68
λ_0	Pictures per 30 days	0·09 (0·02)	0·09	0·06	0·14
N (t = 1)	individuals in S	27·98 (8·54)	25	14	47
N (t = 2)	individuals in S	28·59 (9·67)	25	13	51
D (t = 1)	individuals per 100 km^2	1·63 (0·50)	1·51	0·81	2·73
D (t = 2)	individuals per 100 km^2	1·66 (0·56)	1·46	0·76	2·97

FLORIDA PANTHER DENSITY

The density estimates of approximately 1·5 individuals per 100 km^2 summarize the current state of knowledge on Florida panthers in PSRP. Historically, there have been no reliable estimates of abundance or density for the Florida panther (Beier *et al.* 2003). Although the density estimate by Maehr, Land & Roof (1991) of one individual in 110 km^2 was considered reasonable, it lacked confidence intervals and could not be applied elsewhere (Beier *et al.* 2003). Similarly, counts based on physical evidence (e.g. tracks, scats; McBride *et al.* 2008) do not account for varying sampling effort, possible double-counting of or failure to detect individuals, and they lack the potential for repeatability due to a reliance on expert observers for accurate interpretation of panther signs.

Our density estimates fall within reported densities of pumas in other parts of their geographical range. Generally, the lowest puma densities of ≤ 1 individual per 100 km^2 are found in the northern part of the species' range (e.g. Hemker, Lindzey & Ackerman 1984; Laundré & Clark 2003). Except for areas heavily impacted by poaching and logging, Central and South America generally harbour higher puma densities, ranging from just over 1 to almost 7 individuals per 100 km^2 (Kelly *et al.* 2008; Paviolo *et al.* 2009; Negrões *et al.* 2010; Soria-Diaz *et al.* 2010). Given the tropical climate and habitat of Florida, and the fact that PSRP is still recovering from heavy anthropogenic impacts, our density estimates of approximately 1·5 panthers per 100 km^2 are consistent with previous findings.

The panther population of PSRP most likely declined because of the severe habitat degradation caused by water management practices and direct human disturbance. However, PSRP has two neighbouring reserves, the Florida Panther National Wildlife Refuge (FPNWR) and the Fakahatchee Strand Preserve State Park, both of which have been protected for several decades. Compared with these reserves, PSRP probably has less suitable habitat. Indeed, until recently, the PSRP area was mainly used by dispersing male Florida panthers, and reproductive events in the area were rare (Shindle & Kelly 2007). Applying the bivariate normal model to telemetry data from VHF and GPS collared individuals in the neighbouring FPNWR showed that individuals at this site have smaller home ranges (average σ

was 3·44 km based on seven individuals), which in carnivore populations is often linked to a higher population density (e.g. Dahle & Swenson 2003; Benson, Chamberlain & Leopold 2006). Most likely, individuals from neighbouring reserves are immigrating into the PSRP area as it recovers from the severe anthropogenic impacts and as panther populations in the neighbouring areas expand.

RELIABILITY OF ESTIMATES

The precision of density estimates from spatial mark–resight models depends on the number of marked individuals (Chandler & Royle In press). In the present study, photographic data on the small number of radio-collared individuals were particularly sparse (17 pictures total), but incorporating telemetry information about individual locations and movements increased the precision of our density estimate. According to our simulation study, although we can expect some positive small-sample bias in estimates of N, we also expect the true value to fall within the 95BCI. As a result, our modelling framework represents a promising tool for population monitoring of far-ranging, elusive species. For species that are studied extensively using radiotelemetry (Land *et al.* 2008; Onorato *et al.* 2011), the combination of traditional sampling techniques such as radiotelemetry with the increasingly popular methods of camera traps and SCR modelling (Royle *et al.* 2009) is likely to replace more traditional inference methods (Nichols, O'Connell & Karanth 2011). This approach is not limited to Florida panthers, but applies to other species that are not 'naturally marked' but can be tagged or otherwise recognized, and can also be applied to other types of spatial resighting data, such as point counts for birds or amphibians. With adequate sample size, telemetry locations are not necessary to estimate population size, so tags can be anything that permits identification.

Current spatial mark–resight models assume that marked individuals are a random sample from the total population of S. This means, ideally, defining S should be part of the study design and marking efforts should be spread evenly within S. In practice, that may often not be realistic. When marked individuals are not a random sample of S, but were taken from a smaller area, density estimates are likely negatively biased. Relaxing this assumption is the focus of current SMR model development.

IMPLICATIONS FOR FUTURE FLORIDA PANTHER RESEARCH

Despite the progress made towards recovery in over 30 years of research, the Florida panther population continues to require close monitoring. Our method is an improvement over monitoring methods historically implemented for three main reasons:

1. Our model enables researchers to use camera traps, which allow for non-invasive monitoring of Florida panthers in regions where they are also monitored by telemetry.

2. The spatial mark–resight model provides a standardized analytical framework that accounts for imperfect individual detection and varying sampling effort, so that estimates of density across time and space are comparable.

3. Our modelling approach provides estimates of uncertainty about density estimates. As such, we can fully assess whether a sampling design is yielding appropriate data to monitor the Florida panther population or whether sampling has to be modified (in terms of sampling technique, design and effort).

Still, there is room for improvement. A basic assumption of any mark–resight approach is that the marked individuals are a representative sample of the population (McClintock & White 2010). This is generally accomplished by applying a technique that is different from the resighting method to mark a random sample of individuals (Bowden & Kufeld 1995). While the methods for marking and resighting were distinct in the present study, the extremely low number of collared individuals may not be representative of the entire population. Considering the difficulties, risks and costs associated with capturing large felids, tagging a larger sample of panthers may be challenging. But even adequate coordination of marking and resighting would be an improvement. In the present study, marking and resighting occurred concurrently and individuals tagged within the primary camera-trapping occasions had to be treated as 'uncollared'. By tagging animals ahead of the resight surveys, this loss of valuable data could be avoided.

Owing to the low number of collared individuals, we were unable to incorporate sex- or year-specific differences in movement and detection into our model. Differences in these parameters between males and females are known to be pronounced for large carnivores (e.g. Gardner *et al.* 2010; Sollmann *et al.* 2011). For Florida panthers, males are known to have larger home ranges than females (Onorato *et al.* 2010). Further, collared individuals were photographed more frequently during the second primary occasion, which could indicate higher trap encounter rates. Ideally, future studies should aim at collecting enough data to allow for the modelling of these effects.

The sparseness of the data also precluded any formal treatment of transiency. Transiency is a common issue in open population capture–recapture studies (e.g. Pradel *et al.* 1997). In closed population studies, formally, the presence of transient individuals violates the fundamental assumption of population closure and is therefore generally not explicitly addressed but 'assumed away'. Only because we had radiotelemetry locations, we were able to identify one of the collared panthers in our study as a transient and we decided to remove that individual from the data set. We cannot apply such a correction to the uncollared individuals. By removing transients from the collared individuals but not the uncollared, the former are arguably no longer a representative sample of the latter, which may introduce some positive bias into the estimates of density. We found, however, that retaining the transient individual resulted in unreasonable estimates of the movement parameter σ (data not shown). Given the transient's large movements this is not surprising: when applying the bivariate normal movement model to individual sets of telemetry locations, σ for the transient was 3·5 times larger than for the remaining individuals. Within the spatial mark–resight model, the estimate of σ almost doubled when retaining the transient. While it is disconcerting that a single individual impacted estimates to such a degree, this is a consequence of the small data set, where one outlier has disproportionate effects on model outcomes. With an adequate sample size (i.e. larger number of marked individuals), presence of a single outlier would have a much smaller impact. Further, the problem could be avoided or diminished by shortening the sampling time frame to better approximate a closed population. Even if a transient is present, over a short time interval, its movements are unlikely to be so pronouncedly different from resident individuals, thus diminishing its effect on parameter estimates. Alternatively, with adequate sample size, or as information on the proportion of transients in the population accumulates over time, transiency could be addressed explicitly within the model, for example, using an individual covariate describing transiency state. Regardless of the approach, future study design for Florida panther population monitoring has to both strive for larger sample sizes and consider the assumption of population closure.

Finally, identifiability of individuals on pictures could be improved, for example, by increasing camera trigger speed to allow more centred subjects and by taking multiple pictures per camera-trapping event. We discarded 137 pictures from analysis because we were unable to tell whether an animal was wearing a collar or not. If individuals can at least be identified as 'marked' (but not to individual level), their data can still be included in mark–resight models (e.g. McClintock *et al.* 2009; Sollmann *et al.* 2013).

In spite of these caveats, spatial mark–resight models allow for the development of a standardized protocol that can be applied by different investigators and at different study sites without compromising the comparability of results. As such, these models provide a valuable population monitoring tool for wildlife species that are not consistently identifiable to the individual level. For Florida panthers, spatial mark–resight models could be the cornerstone of a distribution-wide survey protocol to estimate the density or size of the Florida panther population. This is a current research priority and will be indispensable in helping quantify the level of success conservation, and management measures are having at achieving recovery objectives outlined by the USFWS.

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Supporting Information

Additional Supporting Information may be found in the online version of this article.

Appendix S1. Description of the Metropolis-within-Gibbs MCMC sampler.

Appendix S2. Simulation results.

Cougar Exploitation Levels in Utah: Implications for Demographic Structure, Population Recovery, and Metapopulation Dynamics

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Abstract

*Currently, 11 western states and 2 Canadian provinces use sport hunting as the primary mechanism for managing cougar (*Puma concolor*) populations. Yet the impacts of sustained harvest on cougar population dynamics and demographic structure are not well understood. We evaluated the effects of hunting on cougar populations by comparing the dynamics and demographic composition of 2 populations exposed to different levels of harvest. We monitored the cougar populations on Monroe Mountain in south-central Utah, USA, and in the Oquirrh Mountains of north-central Utah from 1996 to 2004. Over this interval the Monroe population was subjected to annual removals ranging from 17.6–51.5% (mean ± SE = 35.4 ± 4.3%) of the population, resulting in a >60% decline in cougar population density. Concurrently, the Oquirrh study area was closed to hunting and the population remained stationary. Mean age in the hunted population was lower than in the protected population (*$F = 9.0$*; df = 1, 60.3;* $P = 0.004$*), and in a pooled sample of all study animals, females were older than males (*$F = 13.8$*; df = 1, 60.3;* $P < 0.001$*). Females from the hunted population were significantly younger than those from the protected population (3.7 vs. 5.9 yr), whereas male ages did not differ between sites (3.1 vs. 3.4 yr), suggesting that male spatial requirements may put a lower limit on the area necessary to protect a subpopulation. Survival tracked trends in density on both sites. Levels of human-caused mortality were significantly different between sites (*$\chi^2 = 7.5$*;* $P = 0.006$*). Fecundity rates were highly variable in the protected population but appeared to track density trends with a 1-year lag on the hunted site. Results indicate that harvest exceeding 40% of the population, sustained for ≥4 years, can have significant impacts on cougar population dynamics and demographic composition. Patterns of recruitment resembled a source–sink population structure due in part to spatially variable management strategies. Based on these observations, the temporal scale of population recovery will most likely be a function of local harvest levels, the productivity of potential source populations, and the degree of landscape connectivity among demes. Under these conditions the metapopulation perspective holds promise for broad-scale management of this species.* (JOURNAL OF WILDLIFE MANAGEMENT 70(6):1588–1600; 2006)

Key words

connectivity, cougar, demographics, hunting, metapopulation, population dynamics, Puma concolor, *radiotelemetry, refuge, source–sink dynamics, Utah.*

Across western North America sport harvest is the primary mechanism for the population-scale management of *Puma concolor* (Pierce and Bleich 2003). Management regimes vary from public safety and depredation control only in California, to a year-round open season in Texas (Nowell and Jackson 1996). In order to balance hunting opportunities with protection of big game and livestock, most states manage cougar populations at some intermediate level. However, cougars are secretive, long-lived, and utilize large home ranges, making them difficult to manage with precision (Ross et al. 1996). At present, there are no widely accepted methods for the enumeration of cougars across diverse habitat types and climatic regimes (Anderson et al. 1992, Ross et al. 1996). Most techniques (e.g., track counts, scent stations, probability sampling) have limitations that render them marginally useful (Choate et al. 2006) or capable of detecting only large and rapid changes in population size (Van Sickle and Lindzey 1992, Beier and Cunningham 1996). Additionally, cougars occur at low population densities relative to their primary prey, making them sensitive both to bottom-up (e.g., prey declines; Logan and Sweanor 2001, Bowyer et al. 2005) and top-down (e.g., overexploitation; Murphy 1998) perturbations. Assessing cougar population trends is complicated by annual removals of varying intensity. Changes in population size and composition are generally indexed through harvest data and are therefore confounded by nonrandom sampling biases, further hindering reliable trend estimation (Wolfe et al. 2004).

Cougar management in Utah is spatially organized, with 4 broad ecoregions subdivided into 30 different hunting units. Each unit is managed independently in order to apply harvest pressure according to local priorities, which can include density reductions aimed at increasing survival in mule deer (*Odocoileus hemionus*) or bighorn sheep (*Ovis canadensis*) populations. Cougars are therefore managed at 2 different spatial scales. Locally, they are either managed conservatively as a trophy species or liberally as a limiting factor in the population dynamics of native ungulates. The statewide population, however, is managed for sustainable

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hunting opportunities and persistence across its currently occupied range (Mason et al. 1999).

Cougar hunting in Utah is conducted by means of pursuit with trained hounds. The hunting season extends from mid-December to early June, but approximately 75% of the kill occurs during December to March, when snow cover facilitates tracking and pursuit (Mason et al. 1999). Prior to 1998 the sport harvest of cougars occurred under a Limited Entry (i.e., lottery) system in which the number of permits for individual units is restricted. The long-term mean hunter success for this system is 64%. Beginning with the 1997–1998 season the Harvest Objective (i.e., quota) system was introduced for some units. This system employs an unlimited availability of permits to achieve a prescribed level of kill. Hunters are required to report their kill within 48 hours and the unit is closed once the quota is reached. Typically 74% of the quota is achieved, but instances of overharvest do occur. Between 1995 and 2003 legal harvest accounted for 90.0% of the total statewide cougar kill (Hill and Bunnell 2005). The remaining known mortality was distributed among animals killed in response to livestock depredation (6.2%) and other human-caused mortality, including roadkill and accidental trappings (3.8%). Additional unreported mortality such as incidental take during big game hunting seasons and illegal snaring occurs, but the magnitude of this impact is probably small relative to legal harvest. Individual cougars involved in livestock depredation are managed by the Wildlife Services Division of the United States Department of Agriculture, who may employ foothold snares as well as hounds to remove offending individuals. Nuisance cougars are defined as animals in urban settings that constitute a potential threat to human safety. These animals are generally controlled by Utah Division of Wildlife Resources (UDWR) personnel using lethal or nonlethal means, as circumstances warrant.

Little is known about both the immediate and long-term effects of sustained harvest on cougar populations (Anderson 1983, Ross et al. 1996). Numerous studies have been conducted on exploited populations (Murphy 1983, Barnhurst 1986, Logan et al. 1986, Ross and Jalkotzy 1992, Cunningham et al. 2000), including 2 removal experiments (Lindzey et al. 1992, Logan and Sweanor 2001), but few of these studies directly addressed the questions of: 1) how harvest affects the demographic structure of a population, and 2) what the long-term implications are for persistence and recovery of exploited populations within a metapopulation context. Moreover, habitat configuration and connectivity are important factors influencing cougar recruitment patterns, but with few exceptions (Beier 1993, 1995, Maehr et al. 2002) this relationship has been largely overlooked.

Recent years have seen the emergence of the idea of managing cougars as a metapopulation based on the effects of natural habitat patchiness (Sweanor et al. 2000, Laundré and Clark 2003) or anthropogenic fragmentation (Beier 1996, Ernest et al. 2003). Because metapopulations transcend administrative boundaries, understanding population response to sustained harvest is vital in order to manage for persistence across landscapes exhibiting varying degrees of natural and human-caused fragmentation.

We assessed the impacts of exploitation on cougar population dynamics by comparing demographic characteristics between an exploited and a semiprotected population. Specific objectives of this study were: 1) determine how harvest levels might influence the dynamics and demographic structure of individual populations, 2) identify the factors that may influence the rate of population recovery, and 3) assess how the distribution of harvest impacts might affect recruitment within a metapopulation context.

Study Area

Cougar habitat in Utah is geographically fragmented, being broadly associated with mesic regions between 1500 m and 3000 m. The Wasatch Mountains and associated high plateaus form the core habitat, longitudinally bisecting the state, whereas the Colorado Plateau and Great Basin ecoregions consist primarily of desert ecosystems, with suitable habitat sparsely distributed among insular mountain ranges (Fig. 1). We selected Monroe Mountain and the Oquirrh Mountains as study areas for this research (Fig. 1). Although differences existed between these sites in terms of size and plant community composition, they were located within 190 km of each other, making them climatically and ecologically similar in a broad sense, but far enough apart to be treated demographically as independent populations. The most pronounced difference between these populations was the level of exploitation to which each was subjected.

Exploited Area

Monroe Mountain comprises part of the Sevier Plateau in the Southern Mountains ecoregion of south-central Utah (38.5°N, 112°W). The site is a high volcanic plateau extending 75 km in a north–south orientation and lies within a west–east geologic transition from basin and range topography to the Colorado Plateau. Hydrologically, Monroe is part of the Great Basin, but climatically and biologically it is more closely associated with other high-elevation regions of the Colorado Plateau and southern Rocky Mountains. The study site covered approximately 1,300 km^2 and encompassed the central unit of the Fishlake National Forest, southeast of Richfield. Other landholders included the Bureau of Land Management (BLM), State of Utah, and various private interests.

The terrain is mountainous with elevations ranging from 1,600–3,400 m. Annual precipitation ranged from 15–20 cm at lower elevations to 60–120 cm on the plateaus above 2,700 m. Approximately 60% of the annual precipitation occurred as snow in January and February, with most of the remainder derived from summer thunderstorms (Ashcroft et al. 1992). Snowpack typically persisted until mid-June at elevations >3,000 m. Mean monthly temperatures ranged from −4.6° C in January to 18.7° C in July (Ashcroft et al. 1992).

Plant communities were diverse and varied with elevation and aspect (Edwards et al. 1995). Piñon-juniper woodlands

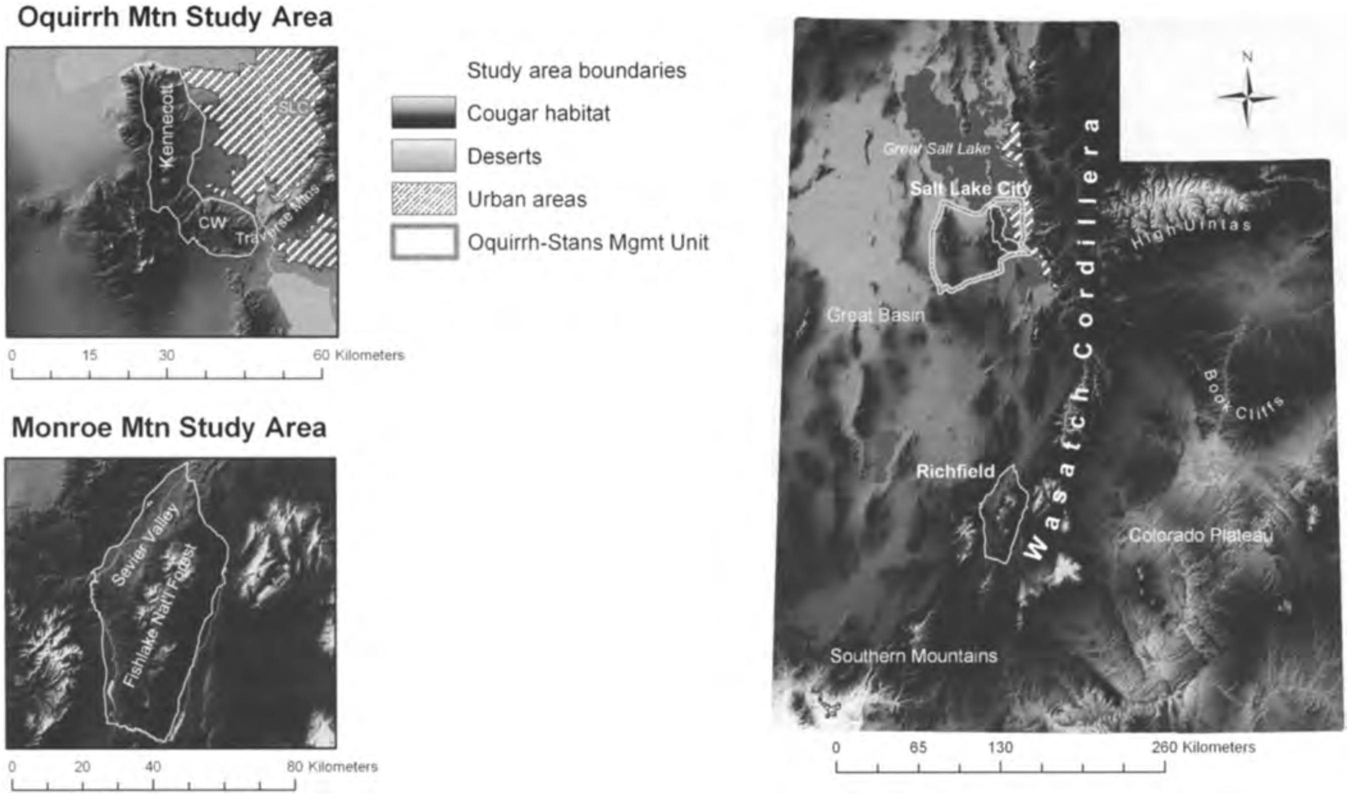

Figure 1. Study-area locations and cougar habitat across Utah, USA, 1996–2004.

(*Pinus edulis, Juniperus scopulorum, Juniperus osteosperma*) comprised the single largest vegetation type covering approximately 44% of the area. Mixed conifer and aspen (*Populus tremuloides*) stands occurred at higher elevations, with gambel oak (*Quercus gambelii*), mountain shrub (e.g., *Cercocarpus ledifolius, Rosa woodsii, Purshia tridentata*), and mixed sagebrush (*Artemisia tridentata*) –grassland meadows interspersed throughout.

Resource exploitation included livestock grazing, logging, and recreation. The UDWR classified Monroe Mountain as Cougar Management Unit 23. Mule deer and elk (*Cervus elaphus*), the primary cougar prey species on this site, were also managed for annual harvests. Human densities around the site varied from 73/100 km^2 to 382/100 km^2 (U.S. Census Bureau), with most of the population scattered among small agricultural communities in the Sevier Valley on the northwestern boundary of the study site.

Protected Area

The Oquirrh-Traverse Mountains complex (hereafter the Oquirrhs) extends 55 km in a north–south orientation on the eastern edge of the Great Basin ecoregion in north-central Utah (40.5°N, 112.2°W). The Oquirrhs are typical of other mountain ranges within this ecoregion in that they form islands of high productivity relative to the surrounding desert basins (Brown 1971) and thus represented the majority of cougar habitat in this area.

The total area of the Oquirrhs measures approximately 950 km^2, but we conducted fieldwork primarily on the northeastern slope of the range on properties owned and managed by the Utah Army National Guard (Camp Williams, Traverse Mountains, 100 km^2) and the Kennecott Utah Copper Corporation (Oquirrh Mountains, 380 km^2). The site was situated at the southern end of the Great Salt Lake, abutting the southwestern side of the greater Salt Lake metro area. Ownership on the southern and western portions of the Oquirrhs was a conglomeration of BLM, grazing associations, and small mining interests, with approximately 45% of the range residing in private ownership.

Elevations on the site vary from lake level at 1,280 m up to 3,200 m. The Traverse Mountains run perpendicular to the Oquirrhs, and range in elevation from 1,650 m to 2,100 m. Annual precipitation ranged from 30–40 cm in the Salt Lake and Tooele valleys to 100–130 cm on the highest ridges and peaks. Most precipitation fell as snow between December and April, with approximately 25% occurring in the form of summer thunderstorms. Mean monthly temperatures ranged from −2.4° C in January to 22.2° C in July (Ashcroft et al. 1992).

Gambel oak and sagebrush were the predominant vegetation on the site. Also prevalent were Utah juniper in the foothills, and canyon maple (*Acer grandidentatum*) in the drainages at low elevations, and across broader areas above 1,800 m. Mountain mahogany (*Cercocarpus spp.*) was present, but relegated to well-drained soils along ridges. North-facing slopes above 2,200 m supported localized montane communities of aspen and Douglas fir (Edwards et al. 1995).

Mining activities have dominated the Kennecott property for >100 years (Roylance 1982), and the site included 2 large open pit mines and attendant infrastructure. Camp Williams was used for military training activities, and consequently exhibited brief fire return intervals. All prominent peaks on the study site supported commercial radio and television transmitters with associated access roads. A limited amount of livestock grazing occurred seasonally. Mule deer and elk were present on this study area as well; however deer were not hunted, whereas elk were subject to intensive management through annual harvests and active translocation projects. The study site was part of the Oquirrh-Stansbury Cougar Management Unit 18, but both of these properties were closed to the public and cougar hunting was prohibited. Human density adjoining the study area varied from 232/100 km^2 in rural Tooele County to 47,259/100 km^2 in urban Salt Lake County (United States Census Bureau).

Methods

We monitored cougar populations within the 2 study areas simultaneously from early 1997 to December 2004. We estimated demographic parameters for each population based on radiotelemetry data collected between 1996 and 2004 on Monroe and from 1997 and 2004 on the Oquirrhs. We calculated estimates of life-history parameters for cougars on the Oquirrh site during 1997 and 1998 from raw data presented in Leidolf and Wolfe (Utah State University, unpublished data). We performed statistical comparisons with the use of SAS (V.8) software. We report all descriptive statistics as mean ± SE unless otherwise noted.

Radiotelemetry and Harvest

We conducted intensive capture efforts during winter (Nov–Apr) each year of the study. We captured cougars by pursuing them into trees, culverts, cliffs, or mine shafts with trained hounds (Hemker et al. 1984). We immobilized each animal with a 5:1 combination of ketamine HCl and xylazine HCl (Kreeger 1996) at a dose of 10 mg ketamine plus 2 mg xylazine/kg of body weight. We administered immobilizing drugs with a Palmer CO_2 pistol (Powder Springs, Georgia), jab stick, or hand-held syringe. We collected tooth (vestigial premolar, P2) samples for age determination by counts of cementum annulations. We sexed, aged, weighed, measured, tattooed with a unique identifier, and equipped with a radiocollar (Advanced Telemetry Solutions, Isanti, Minnesota) and a microchip (AVID Co., Norco, California) every adult animal captured. We checked adult females for evidence of lactation during handling. We tattooed, microchipped, and released all kittens too small to wear a radiocollar. We conducted all procedures in accordance with Utah State University Institutional Animal Care and Use Committee standards (Approval No. 937-R).

We relocated all radio-collared cougars with the use of aerial and ground-based telemetry techniques (Mech 1983). We conducted telemetry flights bimonthly on both sites as weather conditions permitted. We also relocated cougars opportunistically with ground-based telemetry by plotting radiotriangulated locations on United States Geological Survey 7.5′ topographic quads with the use of Universal Transverse Mercator coordinates (zone 12, North American Datum 1927). We stored all locations in a Geographic Information Systems (GIS) database (ArcView, ESRI Products, Redlands, California).

Over the course of the study, radiocollared cougars on Monroe Mountain were not protected from harvest beyond normal legal stipulations outlined in the UDWR hunting proclamations. Annual hunter-kill was regulated by apportionment of a limited number of hunter permits, issued by the UDWR on the decision of the State Wildlife Board. The Camp Williams and Kennecott properties were closed to hunting throughout the study; however, radiocollared cougars leaving those properties were considered legal take on adjacent private and public lands within Unit 18 during the 1997–2001 hunting seasons. Radiocollared cougars on that unit were protected after 2002.

Demographic Parameters

Density.—We measured cougar density as the total number of adult and subadult cougars/100 km^2 present during winter. Our a priori goal was to capture and collar as many individuals as possible. In this sense, we attempted to conduct a census of the population during winter, but during no year were we able to capture all independent cougars. To derive a conservative estimate of the number of unmarked animals on the site, we used 2 methods. First, because males and females can generally be differentiated by track size (Fjelline and Mansfield 1989), we considered multiple track sets of same-sexed animals encountered in the same watershed one individual. Given the large ranges of cougars, we felt that the primary watersheds on the site ($n = 4$; mean ± SD = 361 ± 95 km^2, range = 237–462 km^2) provided a practical threshold for differentiating individuals, as these basins approximated the size of a male home range. This does not negate the possibility that some individuals were double-counted; however, the effect of this error on the population estimate was small due to the number of animals that fell into this category annually. Second, we back-calculated birthdates of radiocollared cougars from age estimations based on tooth wear and counts of cementum annulations and used this information to assess our estimates of uncollared individuals from track evidence and hunter harvest. We excluded males backdated in this manner from the population estimate when they were <3 years old because of the likelihood that they were recent immigrants. Because females tend to be philopatric (Sweanor et al. 2000), we included them in the population estimate as resident subadults at the backcalculated age of 1–2 years. Although there are exceptions to these arbitrary dispersal rules, they provide a reasonable cutoff point for population estimates based on known cougar behavior (Beier 1995, Sweanor et al. 2000). We summed the total number of animals detected (from all means: capture, deaths, tracks) in June at the end of the capture and hunting seasons. This number most accurately represented the population during the period June to December of the preceding year (Choate et al. 2006).

Road densities were high across both study areas. In addition to using 4-wheel-drive vehicles, we conducted winter tracking efforts on horseback and snowmachine in order to reduce bias associated with different levels of access. Using multiple methods also helped to reduce bias in terms of the social classes most vulnerable to detection due to frequent road crossings or small home ranges (Barnhurst 1986). Snow conditions influenced our ability to detect tracks, and therefore dry winters may have some bias associated with population counts; however, this bias was likely consistent between sites, as both study areas are subject to similar weather patterns.

We based study-area boundaries on major roads surrounding the site; therefore we used ecologically relevant vegetative and topographic features to delineate and quantify habitat within the study-site perimeter. We used the criteria of Laing and Lindzey (1991), which excluded valley bottoms and landcover types dominated by urban and agricultural uses. Maps represent geographical area on the planar surface and do not account for slope differences in mountainous terrain where actual surface area is greater. This discrepancy in area calculation leads to an increasing overestimation of population density as the ruggedness of the terrain increases. In order to increase the accuracy of the density estimates we used GIS software (ArcView surface to area ratio extension, Jenness Enterprises, Flagstaff, Arizona) to calculate the surface areas of habitat within study-site perimeters.

Age structure.—We determined age at the time of capture by visual inspection of tooth wear and gumline recession (Ashman et al. 1983, Laundré et al. 2000). In a few cases we used counts of cementum annulations (Matson's Lab, Milltown, Montana). To test for age differences among treatment groups (site and sex combinations), we used a 2-way factorial analysis of variance in a completely randomized design with unequal variances. We adjusted significance levels for pairwise mean comparisons to control experimentwise Type I error with the Tukey-Kramer method.

Cause-specific mortality.—We determined causes of mortality through visual inspection and necropsy of carcasses. When we could not determine cause of death in the field, we submitted the carcass to the Utah State University Veterinary Diagnostics Lab for detailed analysis. We calculated mortality by tallying cause of death among radiocollared animals and unmarked animals found opportunistically during tracking sequences. We pooled all human-related causes by site and tested for proportional differences with the use of chi-square (χ^2) tests.

Survival.—We calculated survival annually for all radiocollared adult and subadult animals from each population. To account for staggered entry and censoring due to the additions and losses of radiocollared animals to the sample, we used a Kaplan-Meier product limit estimator (Kaplan and Meier 1958). We estimated annual survival by defining the start of sample intervals as 1 December of each year. By beginning the sampling interval prior to the beginning of the hunting season (15 Dec), we ensured that human-related mortality is accounted for only once during a single nonoverlapping period in each year. We calculated measures of precision for the computed survival rates from procedures described by Cox and Oakes (1984; cited in Pollock et al. 1989). We compared survival curves between sites with the use of the log-rank test (Pollock et al. 1989).

Fecundity.—We measured fecundity as the proportion of sexually mature females detected with litters-of-the-year (kittens <1 yr) on site during winter. We counted litters during snow tracking and capture efforts. We checked all females taken in the hunt for signs of lactation, which helped account for otherwise undocumented reproduction. Kittens >3 months old are only found with their mothers 20–43% of the time (Barnhurst 1986), but we tracked many female cougars on multiple occasions, thereby increasing the probability of detecting kittens, if present. We did not attempt any analyses on the actual number of kittens born per litter, because of the difficulty in determining the actual number of kittens when ≥ 2 track sets were found. There are 2 potential sources of error in this estimate. First, it is possible that some maternal females experienced whole-litter loss prior to the winter tracking season, and therefore a proportion of nonlactating females or those without kittens may actually have been reproductively active that season. Second, kittens <2 months old are not mobile, and so this cohort would also have been missed through track-based counts. Consequently, both the number of kittens per litter and the proportion of reproductively active females are biased low. The minimum percentage of females caring for young provided an annual estimate of productivity for each population (Barnhurst 1986). We used paired t-tests to detect differences in mean fecundity rates pooled over the entire study interval.

Dispersal.—We tattooed the ears of all kittens handled on the Oquirrh mountain site in the event that they were recaptured as adults. For the Oquirrh Mountain animals, we were able to calculate several crude estimates of dispersal distance and direction opportunistically based on harvest returns of animals marked as kittens. In addition, we monitored subadults captured as transients on Monroe via radiotelemetry for extrasite movements, thus providing some information on coarse-scale movement patterns. We calculated distances as a straight line between capture site and death site or the center of the home range.

Landscape Configuration

We used measures of landscape configuration to assess the overall degree of connectivity of the study sites to surrounding habitats within their respective ecoregions. Connectivity is defined here as "the degree to which the landscape facilitates or impedes [animal] movement among resource patches" (Taylor et al. 1993). We used descriptions provided by Laing and Lindzey (1991) to delineate potential connective habitats between the study areas and neighboring patches. In assessing connectivity for cougars we used only easily quantifiable landscape variables and did not consider potential psychological barriers, although there is some evidence that outdoor lighting may function as such (Beier 1995). We derived the following metrics: size (km^2), shape (perimeter–area ratios), greatest interpatch distance, percent of perimeter connected to neighboring habitat patches, width of connective habitat, and percent of perimeter impermeable to cougar movement. Impermeability refers to landscape features that prohibited, filtered, or redirected animal movement (Ernest et al. 2003, Forman et al. 2003), such as the Great Salt Lake, interstate highways, and urban areas. Some of these features may not form absolute barriers, but they can act as an impediment to animal movement. Perimeter-area ratios are a unitless metric that provided a relative measure of how circular (or how much edge) one study area had relative to the other. We derived these measures in ArcView using the spatial analyst extension and a 30-m digital elevation model of the state of Utah.

Results

Radiotelemetry and Harvest

Capture.—We captured and marked 110 individual cougars on the 2 study sites, representing 145 capture events (Table 1). In addition, we found one dead cougar opportunistically during tracking on the Oquirrh site. We conducted captures on Monroe Mountain from January 1996 to March 2004 and on the Oquirrh site from February 1997 to March 2004. Rugged terrain and frequent animal use of culverts, mine shafts, and lava tubes hindered the collection of ground-based telemetry observations. Consequently most telemetry data were derived from aerial surveys. Monitoring times for Monroe cougars averaged 758 days (range = 2–3140 days) for females, and 194 days (range = 3–662 days) for males. On the Oquirrh site we monitored females for a mean of 810 days (range = 14–2674 days) and males for 399 days (range = 76–1173 days). Differences between sexes reflected the smaller sample of males, their greater tendency to emigrate, and shorter residence times.

Monroe Mountain cougar harvest.—For the period 1990–1995, prior to initiation of this study, a mean of 15.6 (range = 14–19) hunting permits were issued annually, corresponding to a mean kill of 8.7 cougars per year (range = 6–12), and a mean hunter success of 54.0% (range = 40.7–64.9%). In 1996, the number of permits issued increased 33.7% over the 1990–1995 mean. In 1997, the number of permits increased 40% over 1996 levels and 151% over the 1990–1995 mean. Between 1999 and 2000, the number of permits issued decreased to 1990–1995 mean levels and was again decreased for the 2001 season. During the years of heavy harvest (1996–2001), mean per-capita hunting pressure (i.e., the proportion of the population that was legally harvestable) was 87% (range = 68.5–100%). During the years of reduced harvest (2002–2004) mean per-capita hunting pressure was 25.7% (range = 22.7–29.4%; Table 2). During the study 164 permits were issued, 79 cougars were killed (51 M, 28 F), and total hunter success was 48.1%, whereas mean annual hunter success was 46.5%

Table 1. Number of cougars captured according to age and sex classes, Monroe and Oquirrh Mountain study sites, Utah, USA, 1996–2004.

Age and sex	Monroe	Oquirrhs
Adults		
F	16	20
M	12	7
Subadults		
F	14	2
M	15	3
Kittens		
F	2	9
M	1	9
Totals	60	50

(1996–2001) and 73.3% (2002–2004; Hill and Bunnell 2005). The general decline in the number of hunting tags issued over time was partially in response to preliminary study results.

Oquirrh Mountain cougar harvest.—From 1996 to 2001 radiocollared animals on Unit 18 were considered legally harvestable. Cougars on the Camp Williams and Kennecott properties were protected, but these areas were surrounded by private and public lands open to hunting, making any study animal found offsite legal quarry. Beginning in 2002, all radiocollared animals on the unit were protected by law regardless of property ownership to facilitate a concurrent study. During our study 5 radiocollared cougars were killed just outside the study site boundaries (4 M, 1 F). Of these, the 4 males were legally harvested, whereas the female was taken after the 2002 moratorium on radiocollared study animals.

Demographic Parameters

Density.—Estimated high densities (cougars/100 km^2) were similar between sites (Oquirrhs, 2.9; Monroe, 3.2); however, trends in this parameter differed markedly (Fig. 2). Density on Monroe showed a consistent decline during the years of heavy harvest (1997–2001), which leveled off when permits were reduced by 80%, averaging 2.0 ± 0.3 (2002–2004). Oquirrh density showed minimal variation over the study interval averaging 2.8 ± 0.1 (Fig. 2).

Age structure.—Age estimates determined upon initial capture were pooled by sex and site for the entire study period (Table 1). Sexually mature cougars from the Monroe population ($n = 57$) averaged 3.4 ± 0.2 years (F = 3.7 ± 0.4; M = 3.1 ± 0.3). Adult cougars from the Oquirrh population ($n = 33$) averaged 4.6 ± 0.3 years (F = 5.9 ± 0.5; M = 3.4 ± 0.4; Fig. 3). Mean cougar ages differed both by study site (Monroe cougars < Oquirrh cougars; $F = 9.0$, df = 1,60.3, $P = 0.004$) and by sex (F > M; $F = 13.8$; df = 1, 60.3; $P < 0.001$). Further, we found evidence of an interaction between sex and site ($F = 5.31$; df = 1, 60.3; $P = 0.025$). Within the Monroe population male and female mean ages did not differ ($t = 1.21$; df = 54.6; $P = 0.625$), whereas Oquirrh females were significantly older than their male counterparts ($t = 3.70$; df = 30.2; $P = 0.003$). Between sites, Oquirrh females were older than Monroe females ($t =$

Table 2. Cougar harvest characteristics from Monroe Mountain (Unit 23), Utah, USA, 1996–2004.

Hunting season	Estimated population[a]	Permits issued	Cougars killed[b]	% hunter success	% F	% population Hunted[c]	% population Killed
1995–96	35	24	14	58.3	42.9	68.5	40.0
1996–97	42	40	17	42.5	47.1	95.2	40.5
1997–98	33	30	15	50.0	26.7	90.9	45.5
1998–99	26	25	7	28.0	28.6	96.1	26.9
1999–00	21	15	9	60.0	44.4	71.4	42.9
2000–01	15	15	6	40.0	33.3	100.0	40.0
2001–02	17	5	3	60.0	33.3	29.4	17.6
2002–03	20	5	4	80.0	00.0	25.0	20.0
2003–04	22	5	4	80.0	25.0	22.7	18.2
Mean	25.6	18.2	8.8	55.4	31.2	66.6	32.4
SE	3.0	4.1	1.8	17.5	5.0	10.8	3.8

[a] Estimated number of adults and independent subadults from winter capture and tracking efforts.
[b] Legal sport harvest only (Hill and Bunnell 2005).
[c] Per capita hunting pressure, i.e., the ratio of the number of permits issued to the estimated population size (column 3/column 2).

−3.53; df = 38.8; $P = 0.004$), but male ages did not differ between sites ($t = -0.54$; df = 22.5; $P = 0.949$).

Cause-specific mortality.—Mortality on the Monroe site was predominantly human caused (74%), with legal harvest accounting for 81% of human-caused ($n = 26$) and 60% of total mortality ($n = 35$) (Fig. 4). Causes of mortality on the Oquirrh site varied (Fig. 4). All human causes (including roadkill) comprised 53% of the total mortality ($n = 17$) and of this, legal harvest accounted for 44% of all human-caused mortality ($n = 9$) but only 24% of the total. Levels of human-caused mortality differed between sites ($\chi^2 = 7.5$; $P = 0.006$). Various forms of poaching (neck snares, illegal hunter-kill) occurred sporadically on both sites (Monroe, $n = 2$; Oquirrhs, $n = 1$), though alone, this did not represent a significant source of mortality for radio-collared animals.

The second leading cause of death on both sites was intraspecific predation, comprising 17% ($n = 6$) and 18% ($n = 3$) of total mortality on the Monroe and Oquirrh sites, respectively. During the years of high per-capita harvest pressure on Monroe, all victims of intraspecific aggression were resident adult females ($n = 4$), whereas during the period of light harvest all victims were subadult males ($n = 2$). On the Oquirrhs, 1 victim was a predispersal subadult male and 2 were adult females. Notably, one of these instances was an adult female cannibalizing another female with dependent young. Two years later, the survivor in this encounter was killed by an unidentified cougar. Cause of death could not be determined in three cases (2 F, 1 M), but did not appear to be human-related.

In addition to direct mortality, ≥11 kittens from 5 different litters on Monroe were orphaned when their mothers were killed during the winter hunt ($n = 10$) or during summer depredation control actions ($n = 1$). We confirmed the death of one orphaned litter (2 kittens, approx. 6 months old) due to dehydration and malnutrition. On the Oquirrhs, one male kitten was orphaned at the estimated age of 9 months when its mother was killed by an automobile. This animal survived 6 weeks before being taken in a depredation control action on a small ranch just outside of Salt Lake City. A litter of 3 4-month-old kittens died following the disease-related death of their mother. One other male kitten was marked at the age of 7 months following the poaching-related death of its mother in January 2002. It survived at least 2 months before radio contact was lost. Aside from this individual, no other orphans were detected following the deaths of their mothers or as adults on either study area in subsequent years.

Survival.—Adult survival varied between sites and among years (Fig. 5). On Monroe, survival tracked harvest

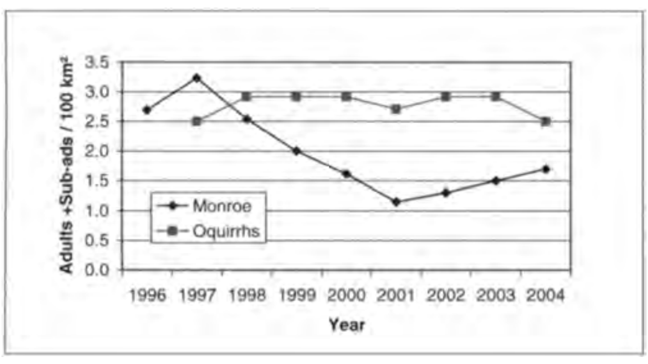

Figure 2. Annual nonjuvenile cougar density as determined from capture, tracking, and harvest, Monroe and Oquirrh Mountain study sites, Utah, USA, 1996–2004.

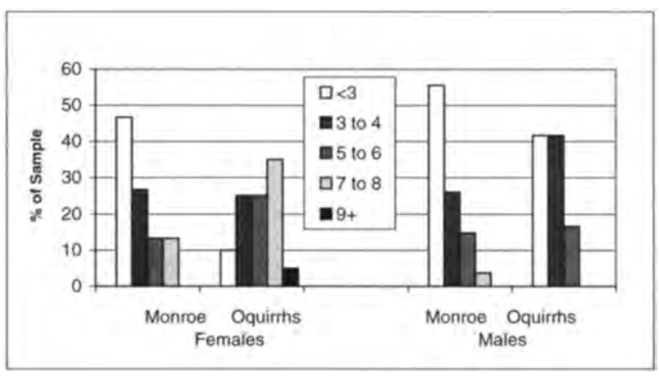

Figure 3. Age distribution of radiocollared cougars by sex, Monroe ($n = 57$) and Oquirrh ($n = 30$) Mountain study sites, Utah, USA, 1996–2004.

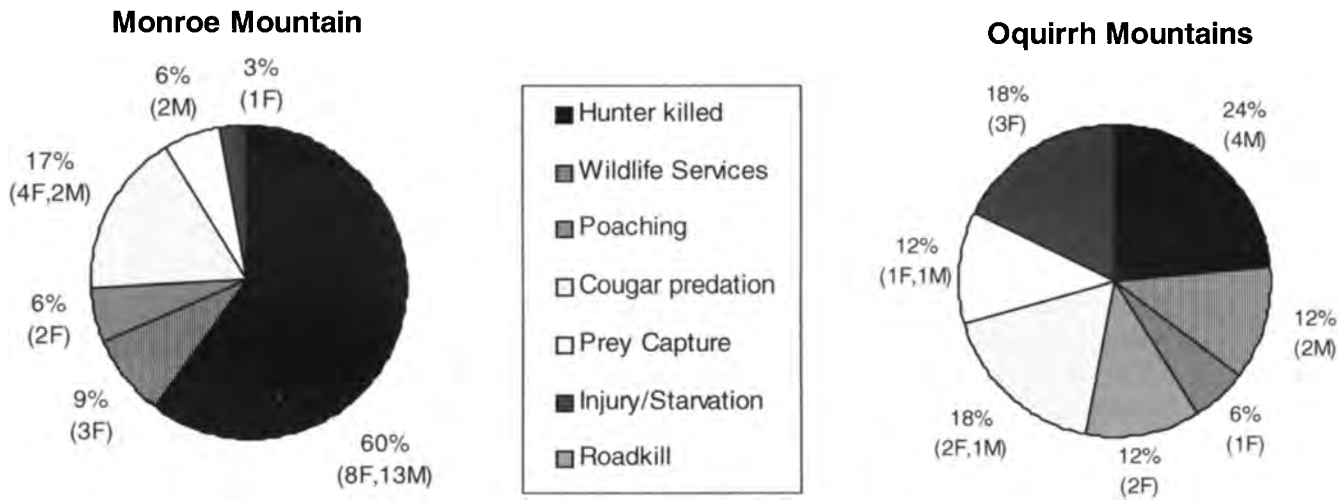

Figure 4. Cause-specific mortality among radiocollared cougars from the Monroe ($n = 35$) and Oquirrh Mountain ($n = 17$), study sites, Utah, USA, 1996–2004.

intensity, ranging from a high of 1.0 in 1996, just prior to the initiation of the treatment period, and declining to a low of 0.36 ± 0.33 (95% CI) in 2001, the end of high per-capita hunting pressure. Survival on the Oquirrhs showed moderate variation, ranging from 0.63 ± 0.28 to 0.91 ± 0.17. Trends in survival mirrored those of density on both sites, averaging 0.64 ± 0.07 (± SE) on Monroe and 0.76 ± 0.04 on the Oquirrhs. Analysis of trends over the entire interval suggested a difference in survival between sites ($\chi^2 = 3.41$; df $= 1$, $P = 0.068$).

Fecundity.—Reproduction varied between sites and years (Fig. 6). The number of litters detected annually ranged from 0–9 on Monroe and from 1–5 on the Oquirrhs, averaging 0.24 ± 0.04 (Monroe) and 0.34 ± 0.05 (Oquirrhs) litters per sexually mature female. Although rates did not differ statistically between sites ($t = -1.23$; df $=$ 7; $P = 0.258$), fecundity on Monroe tracked the population decline and included a zero detection rate in 2002, the year following the lowest population estimate. At that time there were ≥ 5 sexually mature females present. The lowest fecundity estimate for the Oquirrh population was recorded the year after a 50% reduction in elk numbers. These animals were removed for reintroductions in other states. The removal was conducted over 2 years and was comprised primarily of cows and calves, the sex and age classes most vulnerable to cougar predation (Murphy 1998). The number of resident females on the Oquirrh site was smaller ($\bar{x} = 9.6$/yr) than on Monroe ($\bar{x} = 15.7$/yr), which may have influenced the variability in fecundity. Litter sizes averaged 1.7 and 1.9 kittens per litter on Monroe and the Oquirrhs, respectively. Based exclusively on the Oquirrh site using only kittens handled and marked (4–10 months post partum), the sex ratio was even (9 F, 9 M).

Dispersal.—Several animals were captured and marked either just prior to, or during dispersal. Four cougars (1 F, 3 M) moved from Monroe to neighboring mountain ranges 19–55 km distant. Two of these (1 F, 1 M) established residency in habitat adjacent to the study area; one was recaptured and his collar removed (fate unknown); and one was harvested 42 km northeast on the Fishlake Plateau (Fig. 7).

Seven dispersals were documented on the Oquirrh site (2 F, 5 M), ranging in distance from 13 to 85 km (Fig. 7). Of these, 3 (1 F, 2 M) settled elsewhere in the Oquirrh Mountains; 1 female moved to the Simpson-Sheeprock Mountains; 2 males moved to the Stansbury Mountains where they were hunter-killed as transients; and 1 male dispersed to the Mt. Timpanogos region of the southern

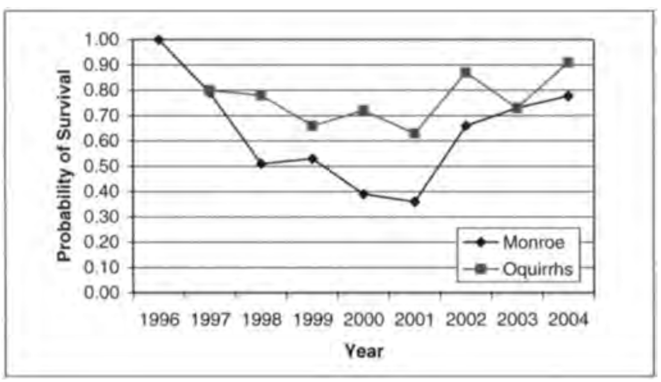

Figure 5. Estimated annual survival rates for radiocollared cougars, Monroe and Oquirrh Mountain study sites, Utah, USA, 1996–2004.

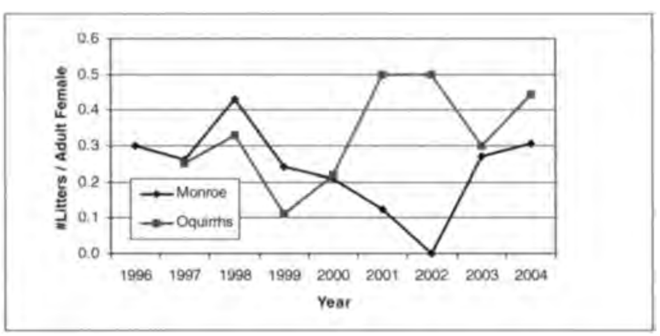

Figure 6. Annual fecundity rates for adult cougars on the Monroe and Oquirrh Mountain study sites, Utah, USA, 1996–2004.

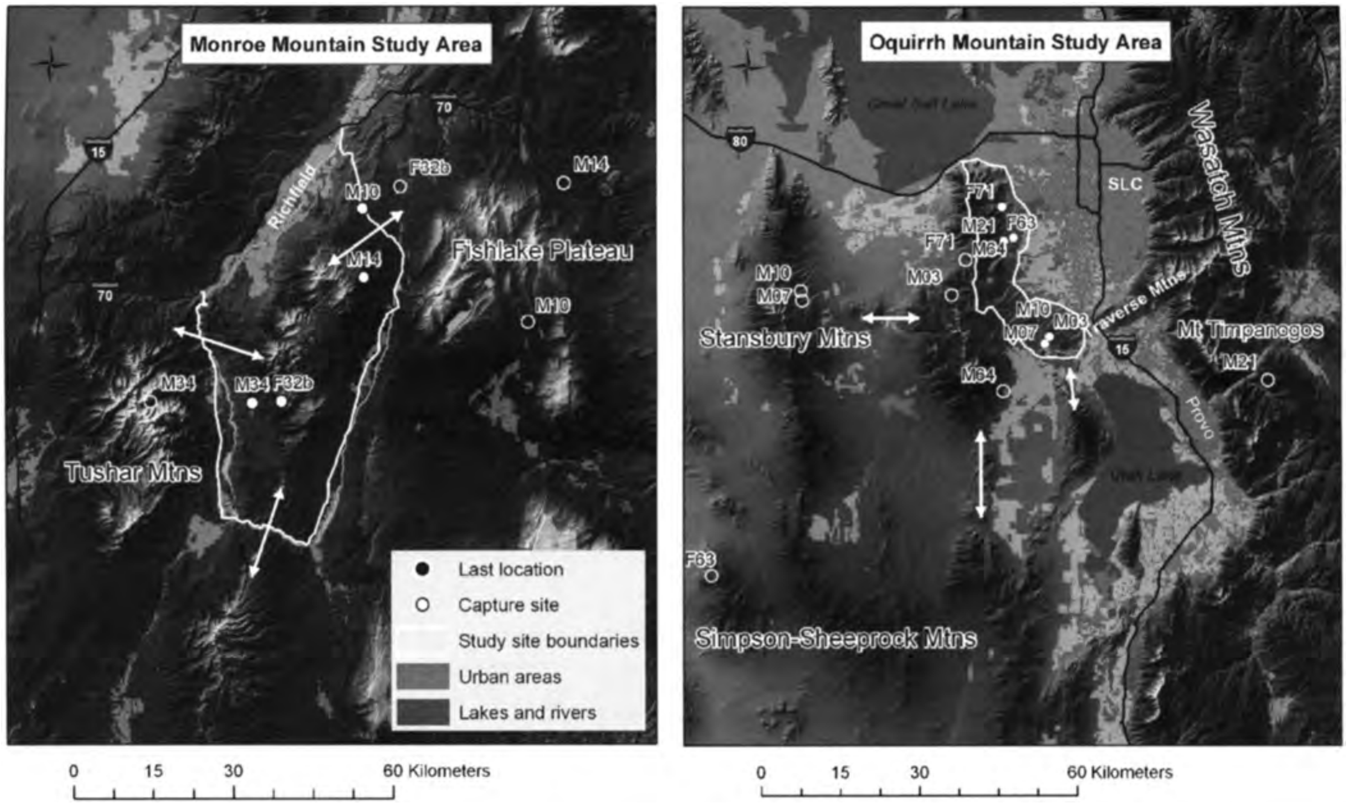

Figure 7. Dispersal patterns and landscape connectivity, Monroe and Oquirrh Mountain study sites, Utah, USA, 1996–2004. Arrows represent points of habitat connectivity.

Wasatch Mountains, crossing a 6-lane interstate and ≥5 km of city streets to get there.

Landscape Configuration

The study sites exhibited similar perimeter-area indices, but notable differences in connectivity and perimeter permeability (Table 3). During the study, no substantial movement barriers existed along the perimeter of Monroe Mountain, and in general, the unit was well connected to other habitats of similar quality within the Southern Mountains ecoregion (Fig. 7).

In contrast, only 5% of the Oquirrhs' perimeter was connected to neighboring habitat and approximately 40% was nearly impermeable to cougar movement. Movement barriers included the southern shore of the Great Salt Lake (7 km), the Salt Lake metro area (50 km), and a heavily traveled segment of Interstate 15 (2 km), which bisected the Traverse Mountains (Fig. 7). The remaining 55% graded into salt desert scrub communities offering little vegetative cover or surface water (West 1983). Additionally, residential development emanating from the Salt Lake–Provo metropolitan corridor was much greater around the Oquirrh site.

Overall, the Oquirrhs exhibited much thinner and more tenuous connectivity to neighboring patches of generally poorer quality (i.e., lower primary production), a pattern typical of basin and range topography (Fig. 1). This topographic fragmentation combined with anthropogenic fragmentation in the foothills and valleys around the site rendered this area susceptible to isolation (see Beier 1995).

Discussion

Influence of Harvest on Cougar Populations

Demographic differences between study populations reflected the prevailing management strategies. Cougar removal on Monroe Mountain ranged from 17.6–54.5% of the adult population exceeding 40% for 4 of the 5 years of high per-capita hunting pressure. Females comprised 32% of the harvest but 100% of depredation control and poaching mortality. Under this regime the population declined by >60%, whereas the Oquirrh Mountain population remained stationary. Moreover, the Oquirrh population had a significantly higher mean age among females and a smaller proportion of subadults. Age structure of males did not differ between sites, suggesting either: 1) males and females had a fundamentally different age distribution in the general population, or 2) the unhunted portion of the Oquirrhs was too small to adequately protect males. Density, survival, and fecundity were all negatively associated with sustained high per-capita hunting pressure on Monroe Mountain, whereas, with the exception of fecundity, these measures remained relatively constant over the same interval on the Oquirrh site. Though humans represented the single greatest source of mortality for animals traveling outside the Oquirrh study site, the absence of harvest within the study area suggests that the Camp Williams–Kennecott properties collectively acted as a functional refuge. Resident females were the primary beneficiaries of this protection. On the Monroe site, the prevalence

Table 3. Measures of landscape connectivity, Monroe and Oquirrh Mountain study sites, Utah, USA, 1996–2004.

Landscape metrics	Monroe	Oquirrhs
Perimeter (km)	178	150
Area (km^2)	1300	950
Perimeter:area	0.137	0.157
Greatest interpatch distance (km)	7	25
Perimeter impermeable (%)	0	40
Perimeter connected (%)	33	5
Width connective habitat (km)	7–21	2–4.5

of human-caused mortality, lack of starvation as a mortality cause, and moderately stable prey populations (UDWR, unpublished data) suggest that this level of mortality was largely additive. Annual harvests exceeding 30% of the adult population consisting of 42% females, carried out continuously for >3 years, can reduce density, fecundity, and skew age structure.

The consequences of sustained exploitation may not be limited to numeric population changes. Fecundity rates on Monroe tracked per-capita harvest pressure with a 1-year lag. We did not observe compensatory reproduction under increased harvest levels, as has been noted for some monogamous carnivores (Knowlton 1972, Frank and Woodroffe 2001). Smuts (1978), Knick (1990), and Wielgus and Bunnell (2000) reported analogous findings for hunted populations of African lions (*Panthera leo*), bobcats (*Lynx rufus*), and brown bears (*Ursus arctos*), respectively. One hypothesized function of male territoriality among polygynous carnivores is to increase offspring survival by excluding nonsire males from the natal range (Bertram 1975, Ross and Jalkotzy 1992), thereby reducing infanticide and optimizing fitness (Packer and Pusey 1984, Swenson 2003). Cougars are known to exhibit this behavior (Hornocker 1970, Hemker et al. 1986, Pierce et al. 1998) suggesting that hunted populations may experience increased levels of infanticide (Swenson 2003). On Monroe heavy harvest and subsequent social instability may have reduced the reproductive capacity of the population and therefore its ability to compensate losses.

Factors Influencing the Rate of Population Recovery

From 2002 to 2004 per capita hunting pressure on Monroe Mountain was reduced to <30%, during which survival and fecundity increased. Nevertheless, following 3 seasons of light harvest the population had only recovered to 52.4% of its 1997 levels, with nearly equal sex ratios and reproduction lagging behind resident replacement.

Lindzey et al. (1992) in Utah and Logan and Sweanor (2001) in New Mexico conducted controlled removals to examine the demographic mechanisms and time scales of population recovery. These authors noted that female recruitment was achieved via philopatric behavior or diffuse dispersal, whereas male recruitment was solely the product of immigration. Further, they suggested that recovery from 27–58% population reductions could be attained within 2–3 years under complete protection. However, those removals spanned only a single season and large sanctuaries (>1,000 km^2) buffered the treatment areas. In contrast, the Monroe population had only a 7-month annual reprieve from hunting pressure and was surrounded by units subjected to similar levels of exploitation.

The degree of landscape connectivity can mediate demographic connectivity, and is thus an important factor in population recovery or persistence (Beier 1993). Strong connectivity is the most likely reason we detected transients on Monroe each winter. These animals buffered population declines (Brown and Kodric-Brown 1977) but may have contributed to social instability. It has been hypothesized that the removal of resident males may induce a "vacuum effect" in which multiple transients vie for a vacant home range, potentially leading to an increase in population density (Shaw 1981, Logan et al. 1986). Our results lend only limited support to this argument. We observed an increase in the relative proportion of subadult males subsequent to removal of resident males, whereas the overall population declined. In general, males tend to disperse farther than females, remain transient longer, and are less tolerant of other males (Cunningham et al. 2001, Logan and Sweanor 2001, Maehr et al. 2002). Conversely, females often exhibit philopatric behavior, reproduce at an earlier age than males, and tolerate spatial overlap with other females (Murphy 1998, Pierce et al. 2000). Therefore, the transient segment of the cougar population is likely to be male biased (Hansson 1991). Removal of resident males provides territory vacancies that may be contested by multiple immigrants, thereby temporarily increasing the proportion of males in the population but not the overall density of males in the general population. Based on preliminary data from the post-treatment period, we hypothesize that following sustained disturbance, population recovery will proceed in 2 general phases: numerical and functional. Functional recovery implies not simply increases in absolute density but rather stabilization of social relationships and decreases in the variability of vital life-history rates. Female-biased sex ratios, low male turnover rates, and higher per-capita productivity may be used as relative indices of functional recovery.

Harvest Dynamics and the Regional Metapopulation

The metapopulation concept has been proposed as a framework for large-scale management of cougars (Beier 1996, Sweanor et al. 2000, Laundré and Clark 2003). In the strictest sense, a metapopulation is the composite of numerous spatially discrete subpopulations exhibiting independent behavior over time. The dynamics of the metapopulation are the net result of the shifting balance between local extinctions and recolonizations facilitated by intermittent dispersal events. The latter quality defines the classic metapopulation (Levins 1969, Hanski and Simberloff 1997).

The source–sink model provides a mechanism for metapopulation dynamics by emphasizing recruitment patterns within and among populations. The more general definition describes a sink as a net importer and a source as a net exporter of individuals over time (Pulliam 1988). Demographically, the Monroe and Oquirrh populations approximate the sink–source archetypes, respectively, albeit as a result of exploitation levels rather than habitat quality (e.g., Novaro et al. 2000). When harvest and its apparent impacts are considered, the Monroe population exhibited sink-like mortality. Notwithstanding low kitten production, each winter new animals, primarily subadult males, were captured on the site. Some of these individuals may have been resident progeny but mammalian dispersal patterns tend to be male-biased (Greenwood 1980). Low productivity and high immigration rates are the essence of a sink population.

In contrast, the Oquirrh population exhibited static density and emigration of resident progeny. No marked female kittens were detected as adults on the site. Indeed, 5 tattooed kittens (2 F, 3 M) were later killed elsewhere in the Oquirrhs or on neighboring mountain ranges up to 85 km distant. Solely based on age (4 yr) the female emigrants could have raised one litter to independence, whereas the males were killed immediately upon leaving their natal ranges, thereby subsidizing the harvest in adjacent units. On the Oquirrh site female dispersal appeared to be related to the saturation of available habitat, suggesting a source-like population structure.

When the prevailing harvest rate is considered a component of habitat quality, then a spatially clumped harvest distribution can promote source–sink dynamics. This may result in an immigration gradient directed toward patches such as Monroe Mountain, where strong connectivity coupled with low population density create an ecological trap (i.e., a productive habitat that displays sink-like mortality patterns, e.g., Bailey et al. 1986, Kokko and Sutherland 2001). These sites represent examples of populations exhibiting different dynamics simultaneously within a metapopulation. Importantly, source–sink characteristics may be dynamic and interchangeable depending on how prevailing management interacts with habitat productivity and connectivity. For example, the Monroe population illustrates the potential consequences of overharvest, yet is situated within a large semicontiguous tract of habitat spanning the state with extensions into Colorado, Idaho, and Arizona. Conversely, the Oquirrh population appears demographically stable, but lies within an ecoregion defined by weak connectivity among sparsely distributed desert ranges. Under different objectives, conservative management could render the Monroe population a source, whereas the Oquirrh population should be managed under the small population paradigm (Caughley 1994).

Management Implications

At the scale of the local population or management unit, annual harvests exceeding 40% of the nonjuvenile population for $\geq$4 years can not only reduce density but may also promote or maintain a demographic structure that is younger, less productive, and socially unstable. At an ecoregional scale the difficulties of reliably delineating discrete populations (Pierce and Bleich 2003) and their respective sizes (Choate et al. 2006) emphasize the importance of managing cougars in a metapopulation context. That said, source–sink characteristics may be more amenable to field evaluation than the extinction and recolonization events that define classic metapopulations. Numeric recovery of overexploited populations may initially depend more on immigration than in situ reproduction. Under moderate to heavy exploitation this tack may require: 1) an assessment of habitat connectivity between identified sources and sinks, and 2) the presence of truly functional source populations, most readily managed through the establishment of refugia.

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Research Article

Evaluation of Harvest Indices for Monitoring Cougar Survival and Abundance

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ABSTRACT Harvest indices are used by state wildlife management agencies to monitor population trends and set harvest quotas for furbearer species. Although harvest indices may be readily collected from hunters, the reliability of harvest indices for monitoring demography and abundance of the harvested species is rarely examined, particularly amongst large carnivores. The overall objective of this study was to assess whether cougar (*Puma concolor*) harvest statistics collected by wildlife managers were correlated with changes in cougar demography, mainly survival rates and abundance. We estimated key demographic parameters for 2 cougar populations in Utah over 17 years during which we monitored 235 radio-collared cougars. We then compared these demographic parameters to harvest statistics provided by the Utah Division of Wildlife Resources over the same time period for the Oquirrh-Stansbury (lightly harvested population) and Monroe (heavily harvested population) harvest management units. In the Oquirrh-Stansbury unit, the percent of harvested cougars >6 years old was positively correlated with annual survival, indicative of a population experiencing several years of high survival resulting in an older age structure. Percent of permits filled and cougar abundance were also significantly correlated, suggesting higher hunting success with increased density. In the Monroe management unit, the annual percent of permits filled was correlated with changes in overall annual survival and male and female annual survival. Of utmost importance, pursuit success (cougars treed/day) increased with the number of cougars on the unit suggesting that pursuit indices may be an informative metric for wildlife managers to determine cougar population trends. Because both management units were subjected to contrasting mortality regimes, results provided by this assessment could potentially be applied to additional management areas sharing similar ecological characteristics and harvest metrics. Published 2015. This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS abundance, competing risks, exploitation, harvest statistics, management, mortality, *Puma concolor*, survival.

Knowledge of the status of a carnivore population is essential for the development and implementation of an effective management plan (Ginsberg 2001, Pollock et al. 2012). Carnivores are often managed through regulated sport hunting to maintain viable populations (Sillero-Zubiri and Laurenson 2001, Keefover-Ring 2005), and reduce impacts of predation on their principal prey species and domestic livestock (Treves and Karanth 2003, Anderson et al. 2010, Loveridge et al. 2010). Management agencies often face the difficulty of opposing demands for more effective carnivore control to protect human safety, big game populations, and domestic livestock, and the demand for additional carnivore-hunting opportunities by sportsmen and outfitters and even societal demands for protection from exploitation (Sillero-Zubiri and Laurenson 2001, Anderson et al. 2010, Funston et al. 2013).

Given their large spatial requirements, low densities, and elusiveness, the management of large carnivores is often challenging because of the difficulties in estimating vital rates and population abundance (Gese 2001, Pollock et al. 2012). Cougar (*Puma concolor*) management nevertheless depends on the ability to monitor demographic responses to changing policies and management actions (Anderson et al. 2010). Unfortunately, state and provincial wildlife agencies are often required to make management decisions without the demographic information needed to monitor and maintain sustainable cougar population levels from one harvest season to the next (i.e., adaptive harvest management) because this information is often unavailable. Frequently, harvest

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composition statistics (e.g., age structure and sex composition) are used in lieu of measured demographic variables of population performance and abundance (Whittaker and Wolfe 2011). Harvest data alone is not sufficient for estimation of population size but rather should be used in conjunction with additional demographic data such as annual survival rates (Erickson 1982, Kolenosky and Strathearn 1987, Lindzey 1987, Rolley 1987, Chilelli et al. 1996). The question arises as to whether harvest statistics and harvest composition are reasonable approximations of changes in demographic performance (e.g., survival) and population abundance over time.

Of all demographic estimates, wildlife managers are most interested in monitoring animal abundance because annual changes in abundance measure the net balance among births, immigrants, deaths, and emigrants (BIDE), and indicate whether there is a surplus that can be sustainably harvested from year to year. Because a complete census is never possible, abundance must be estimated using appropriate methods that can account for imperfect detection and even multiple counting of individuals. Indeed, a number of approaches have been proposed for estimating cougar abundance and associated densities (Van Dyke et al. 1986, Smallwood and Fitzhugh 1995, Choate et al. 2006), but all have logistic limitations and statistical assumptions that are difficult to meet in a field setting.

When abundance becomes too difficult to accurately estimate, attention is sometimes transferred to the BIDE vital rates that determine abundance to monitor population trends rather than abundance per se. Immigration and emigration may play a large role in the change of male cougar abundance (Robinson et al. 2008), but in the female-limiting component of the population attention should be focused on reproductive success and survival (Lambert et al. 2006). Regardless of whether the focus is on the male or female component, cause-specific mortality analyses can provide deeper insight into the factors underlying management-relevant changes in survival and population dynamics (e.g., hunting vs. vehicle collisions).

The Utah Division of Wildlife Resources (UDWR) currently uses harvest rate, percent females in the harvest, and number of cougars treed per day to set the following years harvest quotas (Utah Cougar Advisory Group 2011). The cougars treed per day can be thought of a catch-per-unit-effort estimator (Choate et al. 2006). Although there was no significant relationship between cougars treed/day and the size of 2 cougar populations monitored for 6 years (Choate et al. 2006), the UDWR incorporates this index in their formula to determine harvest levels. We calculated estimates of key demographic parameters from 2 cougar populations that were intensively monitored in Utah for 17 years, and compared these estimates to harvest statistics provided by the UDWR over the length of the study period. Cougars in the Oquirrh-Stansbury cougar management unit (OSCMU) were primarily exposed to non-hunting anthropogenic sources of mortality and cougars in the Monroe cougar management unit (MCMU) were mostly influenced by hunting mortality. Our objective was to assess the correlations between currently used harvest statistics and independently derived population parameters within the OSCMU and MCMU.

STUDY AREA

We examined cougar populations on the OSCMU and MCMU, located in the Great Basin and Colorado Plateau ecoregions, respectively, in Utah. Mountain ranges in these ecoregions were surrounded by desert basins and formed a basin and range landscape. Annual precipitation ranged from 60 cm to 120 cm in the higher elevations to 15–20 cm in the desert basin regions with most of the precipitation arriving as snow in January and February (Moller and Gillies 2008). The Oquirrh-Traverse Mountains were dominated by Gambel oak (*Quercus gambelii*), sagebrush (*Artemisia* spp.), and Utah juniper (*Juniperus osteosperma*), whereas Monroe Mountain was dominated by pinyon (*Pinus edulis*)-juniper (*Juniperus* spp.) woodlands.

The OSCMU was located in north-central Utah on the eastern edge of the Great Basin (40.5°N, 112.2°W). The Oquirrh Mountains measured >950 km^2, but the study area was focused on a 500-km^2 area encompassing the northeastern slope on properties owned and managed by the Utah Army National Guard (Camp Williams) and the Kennecott Utah Copper Corporation. The site was bounded on the north by the Great Salt Lake and on the east by the Salt Lake Valley. Approximately, 55% of the study area was under the jurisdiction of the Bureau of Land Management (BLM), with the remainder held by individuals, grazing associations, mining companies, and the military. The study area was situated within the larger OSCMU, but both properties (Camp Williams and Kennecott) were closed to the public and cougar hunting was prohibited. Although radio-collared cougars leaving those properties were legally protected within the management unit, they were susceptible to poaching, depredation control, trapping, and road kill. Thus, this population was considered to be semi-protected.

Monroe Mountain comprised part of the Sevier Plateau in south-central Utah (38.5°N, 112°W). The study area measured approximately 1,300 km^2, and formed the central part of the Fishlake National Forest. Additional landholders included the BLM, the State, and various private interests. The study area was within the MCMU, where cougars were managed for sustainable hunting opportunities. Other carnivores present included bobcats (*Lynx rufus*) and coyotes (*Canis latrans*), which were both subject to trapping pressure. Resource use included livestock grazing (cattle, sheep), logging, fossil fuel exploration, and off highway vehicle recreation (e.g., all terrain vehicles). Stoner et al. (2006) provide a more detailed description of the study areas.

METHODS

Cougar Harvest in Utah

Nearly all cougars harvested in Utah are taken with the aid of dogs (Utah Cougar Advisory Group 2011). An individual hunter is restricted to holding either a limited entry permit or a harvest objective permit per season, and must wait 3 years to reapply once they acquire a limited-entry permit. The bag limit is 1 cougar/season, and kittens and females accompanied by young are generally protected from harvest. Currently, the cougar hunting season runs from late November through late May on both limited entry and most harvest objective units. Some units are open year-round and some have earlier or later opening dates. Pursuit (chase or no-kill) seasons provide additional recreational opportunities over most of the state. The pursuit season generally follows the hunting season, but specific units have year-round pursuit and a few units are closed to pursuit (Utah Cougar Advisory Group 2011).

We used information covering 1996–2012 that was published in the most recent Utah Cougar Annual Report (Utah Division of Wildlife Resources 2012), which collated information for a number of harvest and pursuit statistics used by UDWR managers from the OSCMU and MCMU; reporting of each cougar harvested is legally mandated. We first focused on the 3 indices used to monitor cougar population trends and guide management in Utah: percent females in harvest, number of cougars treed per day, and number of cougars harvested annually. We examined additional harvest indicators that were specific to each sex (i.e., annual no. harvested males, % of males in the harvest) and harvest indicators that pertained to age (i.e., proportion of cougars that were $\geq$6 years of age in the harvest, the mean age of harvested animals each year). Finally, we examined statistics related directly to harvest regulations (i.e., % of hunting permits filled each year, no. sport-harvested cougars, no. harvest permits allotted, including all limited entry, conservation, and conventional permits; Utah Division of Wildlife Resources 2012).

Field Methods

From January 1996 to June 2012, we conducted capture efforts during winter (Dec to Apr). We pursued cougars with trained hounds, and then immobilized each cougar with a combination of ketamine hydrochloride (10 mg/kg) and xylazine hydrochloride (2 mg/kg; Fort Dodge Animal Health, Fort Dodge, IA) following recommendations in Kreeger (1996). We sexed, weighed, measured, ear tattooed, and microchipped (AVID, Norco, CA) each individual. For aging the animal, we extracted a vestigial premolar (P2) for aging with cementum annuli, a field estimate of age using gum-line recession (Laundré et al. 2000), and tooth wear (Ashman et al. 1983). We fitted all adult (>24 months) and sub-adult (12–24 months) cougars with a very high frequency (VHF) radio-collar (Advanced Telemetry Systems, Isanti, MN) or a global positioning system (GPS) collar (i.e., Televilt Simplex, Lindesberg, Sweden; LoTek 4400S, Newmarket, Ontario, Canada). We located cougars with a VHF collar twice a month with aerial or ground telemetry (Mech 1983); we attempted to acquire locations of cougars with a GPS collar every 3 hours. We marked kittens (0–12 months) that were too small to wear a radio-collar with a microchip (AVID) and tattooed their ears with a unique identification number. We released all animals at the capture site. For each population, data collection was based on radio-telemetry information collected between 1 January 1996 and 30 June 2012. Animal capture and handling procedures were conducted in accordance with Utah State University Institutional Animal Care and Use Committee standards (approval no. 937-R).

The Utah cougar hunting season commenced in mid-November and continued to the end of May each year. However, most of the harvest occurred during a 4-month period when snow was on the ground (Dec to Mar). We used individual locations within the MCMU collected after 1 March 1996, directly after the harvest season, so we would not split a harvest season across an analysis year and to maximize use of available data (the first individuals were marked in Jan 1996); similarly, the study began in the OSCMU on the 1 March 1997.

The fate of most marked individuals was known with the exception of 11 cases for which we could not ascertain an emigration or death status. We ascertained emigration status and radio-collar failures for 35 and 47 individuals in the QSCMU and the MCMU, respectively (Table 1). Kittens that did not survive to age 1 were not included in the analyses because their fates were dependent on the fate of their mothers. However, kittens that survived to their first birthday and remained in the unit where they were initially marked were included in the analyses; through left-truncation, we included such individuals from age 1 onward in all analyses.

We determined the causes of mortality through visual inspection and necropsy of carcasses (Stoner et al. 2006). When we could not determine cause of death in the field, we submitted the carcass to the Utah Veterinary Diagnostics Lab (Logan, Utah) for a detailed necropsy. Precision of mortality dates varied: with GPS-collared and hunter-harvested animal mortality, dates were known to within 1 day, whereas we estimated dates for animals wearing conventional VHF radio-collars using the midpoint between the last live signal and the detection date of the first mortality signal (+/− 15 days).

Demographic Analyses

Classical survival models used in human demography (Kleinbaum and Klein 2005) are appropriate for estimating survival trajectories when individuals are followed from entrance into the study until death (Murray et al. 2010, Aubry et al. 2011, Sandercock et al. 2011). Various extensions to the non-parametric Kaplan–Meier (Kaplan and Meier 1958) estimator, such as the Cox Proportional Hazard model (CPH; Cox 1972), further allow identification of the measurable (i.e., observed) covariates associated with patterns in survival trajectories. We used semi-parametric CPH models because they do not require assumptions about the shape of the underlying mortality hazard (the force of mortality) over life. Rather, each covariate within the model is assumed to act multiplicatively (i.e., proportionally) on the baseline mortality hazard at each time step (Bradburn et al. 2003): $h_i(t) = h_0(t)^* \exp(\beta_i X_i)$ such as where h_0 refers to the baseline hazard (i.e., the hazard's value when all covariate values are null), X denotes a vector of

Table 1. Sex- and location-specific deaths by cause of mortality for radio-collared cougars in the Oquirrh-Stansbury Cougar Management Unit (OSCMU), 1997–2012, and in the Monroe Cougar Management Unit (MCMU), 1996–2012, Utah, USA.

	OSCMU						MCMU					
	Total		Females		Males		Total		Females		Males	
Mortality cause	*n*	% of total mortality	*n*	% of total mortality	*n*	% of total mortality	*n*	% of total mortality	*n*	% of total mortality	*n*	% of total mortality
1 Hunting	16	32.0	5	17.2	11	52.4	72	67.9	28	53.8	44	81.5
2 Poaching	1	2.0	1	3.4	0	0.0	6	5.7	4	7.7	2	3.7
3 Depredation control	1	2.0	0	0.0	1	4.8	7	6.6	5	9.6	2	3.0
4 Road kill	3	6.0	3	10.3	0	0.0	0	0.0	0	0.0	0	0.0
5 Capture mortality	1	2.0	1	3.4	0	0.0	4	3.8	3	5.8	1	1.8
6 Intra-specific strife	11	22.0	6	20.7	5	23.8	12	11.3	8	15.4	4	7.4
7 Predation attempt	5	10.0	3	10.3	2	9.5	3	2.8	2	3.8	1	1.8
8 Injury, starvation	12	24.0	10	34.5	2	9.5	2	1.9	2	3.5	0	0.0
Total mortality	50		29		21		106		52		54	
Anthropogenic (1–5)	22	44.0	10	34.5	12	57.1	89	83.9	40	76.9	49	90.7
Harvest (1)	16	32.0	5	17.2	11	52.4	72	67.9	28	53.8	44	81.5
Natural only (6–8)	28	56.0	19	65.5	9	42.9	17	16.0	12	23.1	5	9.3

covariates such as $X = (X_1, X_2, \ldots X_i)$, and t denotes time (in our case, time elapsed since marking; Murray and Patterson 2006). We conducted all analyses in R (version 2.15.0, Development Core Team 2012).

Standard survival estimators consider the elapsed time from some origin until the occurrence of death or failure. If ≥ 1 type of end point is of interest, these end points are called competing risks (Geskus 2011). With radio-telemetry data, a competing risk analysis can be used to attain unbiased estimates of cause-specific mortality, whereas standard tabular presentations of percentage representations for cause-of-death data are inherently biased (Heisey and Patterson 2006) but can nevertheless be useful to visualize the cause of death data. Because specific causes of mortality might be more reliable indicators of harvest statistics used to guide cougar management, we considered 2 dichotomies in mortality estimates. We estimated annual cause-specific mortality at each study area for human harvest versus all other causes of death, or all anthropogenic causes of mortality (i.e., harvest, poaching, depredation control, road kill, capture-related mortality) versus natural mortality agents (i.e., intra-specific strife, injury during predation attempt) using the R package wild1 (Sargeant 2011, Wolfe et al. 2015). For the purpose of this assessment, we were specifically interested in estimating annual mortality from hunting exclusively (i.e., the harvest rate $\hat{h}_t$) because it should be most closely linked to harvest statistics if such relationships exist.

We used a minimum abundance index or population estimate for each management unit that included the number of adults and independent sub-adults (i.e., no longer with their mother) based on all captures, radio-telemetry, tracking, and mortality data (Logan and Sweanor 2001, Choate et al. 2006, Cooley et al. 2009). We also calculated corresponding densities based on the size of each unit (adult and independent sub-adult cougars per 100 km^2).

We used Spearman's rank correlation coefficient (r) to examine the relationships between the harvest indices collected by the UDWR and the independently derived demographic rates (Zar 1999). Correlation coefficients range from -1 (i.e., perfect negative correlation) to $+1$ (i.e., perfect positive correlation), where a correlation of 0 indicates there is no relationship between the 2 variables. We used the standard error of a correlation coefficient to determine the confidence intervals around a true correlation of 0, and t-tests to test the null hypothesis that the true correlation was 0 (Zar 1999). For each analysis, we reported the correlation coefficient and associated P-value and considered correlation coefficients with P-values ≤ 0.10 significant.

RESULTS

Overall, demographic analyses were based on 235 marked individual cougars (MCMU: $n = 148$, 66 M and 82 F, 37 sub-adults and 111 adults; OSCMU: $n = 87$, 32 M and 55 F, 24 sub-adults and 63 adults). Seventeen individuals died of natural mortality and 89 of anthropogenic causes in MCMU. In the OSCMU, 28 individuals died of natural death versus 22 of anthropogenic causes (Table 1). In the MCMU, 72 individuals were harvested and 34 individuals died of non-harvest mortality (i.e., all other causes of death). Within the OSCMU, 16 individuals were harvested and 34 individuals died of other causes (Table 1). An additional 82 cougars were right-censored because they were still alive at the end of the study or because they emigrated from the management unit (47 in MCMU and 35 in OSCMU; i.e., the data they provided while on the study area was used until they emigrated out of the study area).

We calculated an abundance index akin to a minimum population abundance estimate for each unit (Fig. 1). In the OSCMU, this index fluctuated between 10 and 20 adults and independent subadult cougars over time, with a corresponding density that ranged from 2 to 4 adult and independent subadult cougars/100 km^2 (Fig. 1). In the MCMU, this index ranged from 10 to 40 adult and independent subadults, for a corresponding density of 1 to 3.5 adult and independent subadult cougars/100 km^2 (Fig. 1).

Unit-Specific Demographic Estimates and Harvest Statistics

Annual survival fluctuated over time in the OSCMU (Fig. 2A) and MCMU (Fig. 2B). Notably, in 1999 and 2012

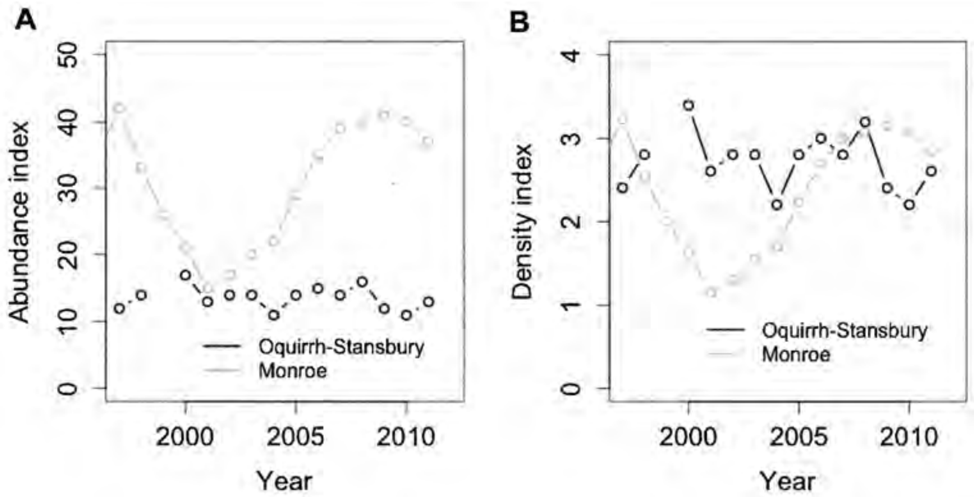

Figure 1. Changes in A) cougar abundance and B) associated density index (cougars/100 km^2), for adult and independent subadult cougars on the Oquirrh-Stansbury (1997–2012) and the Monroe (1996–2012) study areas, in Utah, USA.

annual survival in the MCMU was low (Fig. 2B). Male survival was consistently lower than female survival in both units, and survival was higher in the OSCMU compared to MCMU (Fig. 2).

In the OSCMU, the primary cause of death in males was harvest (Table 1, Fig. 3), and natural causes (injury, starvation) in females (Table 1). Intra-specific strife was also an important influence of overall mortality, equally distributed between females and males (Table 1). Individuals between ages 2 and 6 primarily died from harvest mortality or other sources of anthropogenic mortality (e.g., car collision, Wildlife Services removals). For individuals that died of non-harvest mortality, females died at a later age on average than males (Wolfe et al. 2015). Over the span of the MCMU, 67% of all individuals that died were harvested (Table 1, Fig. 3). All age-classes were subjected to harvest and non-harvest causes of mortality, and more individuals died between 2 and 4 years of age compared to any other age class.

Generally, in the OSCMU we observed a decrease in harvest indices over time. In the MCMU, however, we observed an increase in harvest indices over the last few years of the study. Specifically, increases were observed in the total harvest and in the percentage of harvest permits filled since 2006, along with an increase in the percentage of cougars harvested that were >6 years old and in the number of females harvested since 2009. The number of cougars treed/day (i.e., pursuit statistic) and mean age at harvest fluctuated over time with an increase in the pursuit statistic and harvest pressure since 2004 in the MCMU.

Correlation of Demographic Estimates and Harvest

We found significant correlations between several harvest statistics and demographic estimates for the OSCMU (Table 2) and MCMU (Table 3). In the OSCMU, we found the percent of permits filled and the minimum abundance index were positively correlated (Fig. 4A, Table 2). Further, the percent of individuals in the harvest

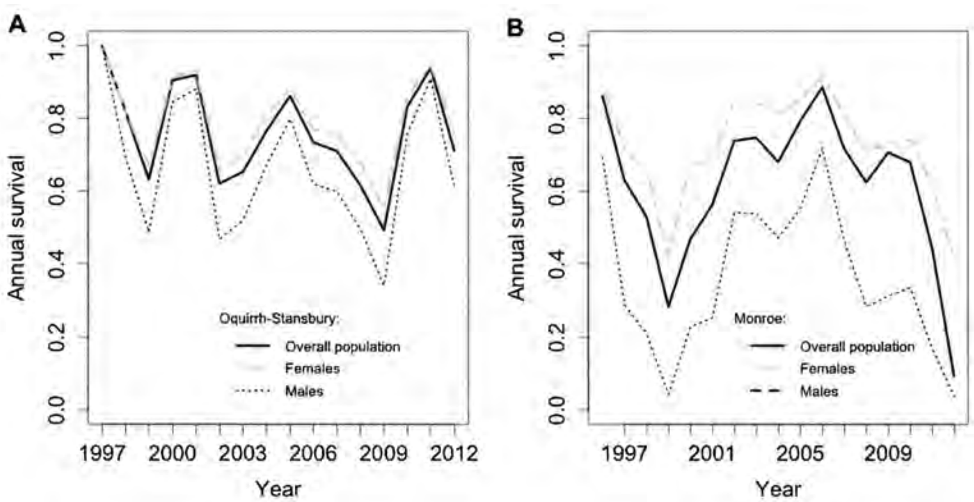

Figure 2. Changes in overall and sex-specific annual survival for radio-collared cougars in the A) Oquirrh-Stansbury and B) Monroe study areas in Utah, USA from 1997 to 2012 and 1996 to 2012, respectively.

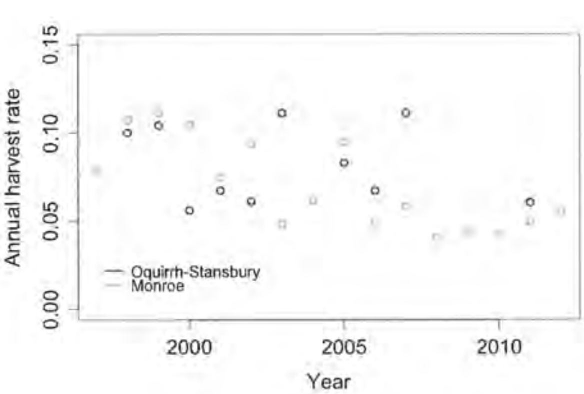

Figure 3. Changes in annual harvest mortality estimates over time in the Oquirrh-Stansbury and Monroe study areas Utah, USA from 1997 to 2012 and 1996 to 2012, respectively.

>6 years old was positively correlated with annual survival, annual male survival, and annual female survival (Fig. 4B–D, Table 2). In the MCMU, which experienced greater hunting pressure, overall annual harvest mortality was principally influenced by male annual harvest mortality (Fig. 5A, Table 3). We also observed a negative relationship between the annual number of females in the harvest and annual survival (Fig. 5B, Table 3). Additionally, we found a negative correlation between the annual proportion of females in the harvest and annual survival (Fig. 5F, Table 3). Further, percentage of permits filled each year was positively correlated with overall annual survival, annual male survival, and annual female survival (Fig. 5, Table 3). We detected a positive relationship between the number of cougars treed/day and the annual abundance index (Fig. 5G, Table 3), suggesting that pursuit success increased with the number of cougars on the unit.

DISCUSSION

Monitoring survival and determining the abundance of large carnivores is a daunting task for many wildlife agencies. Being able to use indirect measures of abundance to monitor changes in population size and survival (i.e., harvest) has routinely been used for large carnivores and cougars in particular, for several decades (Beausoleil et al. 2008, Whittaker and Wolfe 2011). However, knowing the relationships between these indirect measures or harvest indices and actual demographic parameters such as survival and population abundance requires long-term data collected with consistent field methodologies.

Even though intense harvest in the MCMU was a potential concern for sustainable management of cougars in this region, cougar densities assessed from the marked population indicated that densities rebounded and have been maintained at 3 adult cougars/100 km^2 over the last few years (Fig. 1). Immigration was a factor that we were not able to quantify, but the age structure indicated that an influx of cougars since 2006 has likely compensated for increased removal of cougar residents through hunting. Additional data on cougar movement in and out of the study area would be needed to quantify this influx, and the role immigration plays in maintaining stable dynamics (Sweanor et al. 2000, Robinson et al. 2008, Cooley et al. 2009). Abundance estimates obtained from the results of genetic mark-recapture procedures (Long et al. 2008, Kelly et al. 2012), and more sophisticated analytical methods such as dead recovery multi-state analysis (Koons et al. 2014) could help improve abundance estimates in the future. However, the question of whether a density of 3 adult cougars/100 km^2 is the target density that state wildlife agencies should manage for remains unresolved.

Densities ranged from 2 to 4 adult and independent subadult cougars/100 km^2 in the OSCMU and 1 to 3.5 adult and subadult cougars/100 km^2 in the MCMU (Fig. 1). According to the 2009–2021 Utah Cougar Management Plan (Utah Cougar Advisory Group 2011), high quality habitat was assigned a density range of 2.5–3.9 adult and subadult cougars/100 km^2, medium quality habitat was 1.7–2.5 adult and subadult cougars cougars/100 km^2, and low quality habitat was 0.26–0.52 adult and subadult cougars cougars/100 km^2. According to these standards, the OSCMU and MCMU cougar populations would be classed as high quality habitat. Because cougars have large home ranges, these numbers would be valid in locations where cougar home ranges are not constrained by human development and encroachment. This is not the case in the OSCMU, and might not hold true in the MCMU either.

Table 2. Correlations matrix between demographic parameters and harvest statistics in the Oquirrh-Stansbury Cougar Management Unit, 1997–2012, Utah, USA. Significant correlations ($P < 0.1$) are indicated with an asterisk.

		Harvest statistics							
Demographic parameter		**Sport harvest**	**Male sport harvest**	**Female sport harvest**	**% permits filled**	**% harvest >6 years**	**% females harvested**	**No. cougars treed/day**	**Mean age of harvest**
Annual survival	*r*	0.192	0.052	0.329	0.063	0.552*	0.313	−0.093	0.267
	P	0.475	0.847	0.213	0.816	0.026*	0.237	0.742	0.318
Annual male	*r*	0.131			0.013	0.546*	0.307	−0.123	0.286
survival	*P*	0.627			0.961	0.028*	0.248	0.663	0.282
Annual female	*r*	0.132			0.029	0.550*	0.293	−0.099	0.268
survival	*P*	0.625			0.913	0.027*	0.271	0.726	0.315
Annual	*r*	0.218	0.284	0.104	0.600*	−0.199	−0.337	0.260	−0.358
abundance index	*P*	0.453	0.325	0.723	0.023*	0.496	0.238	0.390	0.209
Annual harvest	*r*	−0.435	−0.393	−0.396	−0.433	−0.441	−0.002	0.062	−0.460
mortality	*P*	0.209	0.261	0.258	0.211	0.202	0.996	0.864	0.181

Table 3. Correlations matrix between demographic parameters and harvest statistics in the Monroe Cougar Management Unit, 1996–2012, Utah, USA. Significant correlations ($P < 0.1$) are indicated with an asterisk.

		Harvest statistics							
Demographic parameter		Sport harvest	Male sport harvest	Female sport harvest	% permits filled	% harvest >6 years	% females harvested	No. cougars treed/day	Mean age of harvest
Annual survival	r	−0.237	0.035	−0.419*	0.630*	0.034	−0.453*	0.058	0.056
	P	0.359	0.893	0.094*	0.009*	0.896	0.067*	0.836	0.831
Annual male survival	r	−0.275			0.659*	−0.065	−0.370	−0.193	−0.050
	P	0.275			0.050*	0.804	0.144	0.490	0.849
Annual female survival	r	−0.262			0.679*	0.030	−0.374	−0.131	0.041
	P	0.310			0.004*	0.908	0.139	0.641	0.875
Annual abundance index	r	0.308	0.249	0.248	−0.013	0.038	0.017	0.747*	0.149
	P	0.246	0.353	0.353	0.961	0.888	0.951	0.002*	0.581
Annual harvest mortality	r	0.370	0.463*	0.119	−0.393	−0.040	−0.046	−0.355	−0.289
	P	0.144	0.061*	0.648	0.132	0.880	0.861	0.193	0.260

Specifically, dispersing cougars are potentially exposed to car collisions and Wildlife Services removal. Also, demographic stochasticity alone could lead to small populations of cougars in both locations. We suggest that the UDWR consider re-examining their density and habitat quality indices for future cougar management, and the size of management units for a species whose populations are predominantly regulated by source-sink dynamics (Robinson et al. 2008, Cooley et al. 2009).

The most intuitive finding of our analysis was the positive correlation between the percentage of permits filled and the minimum abundance index in the OSCMU. This was a fairly simple relationship indicating that hunters were more successful when cougars were more abundant. The fraction of females in the harvest is arguably the statistic most widely used by managers to monitor changes in cougar populations (Cooley et al. 2011). However, our analysis revealed no significant correlation between this metric and either annual female survival or annual abundance in the OSCMU, possibly because this index combines a variable fraction of non-reproductive sub-adult females with adult females. Anderson and Lindzey (2005) noted that the sex ratio of harvested cougars alone is of limited value in identifying population change, but when combined with age structure, both provide a more reliable index to population change. This was substantiated by our findings that at least for the OSCMU population, the percent of the harvest >6 years was positively correlated with annual female survival. However, this metric generally served as a proxy for the age structure of the population and was likely indicative of a population that has experienced several years of high survival and a greater proportion of more fecund females in the population.

In the MCMU, overall annual harvest mortality was principally influenced by male annual harvest mortality, suggesting that males were more heavily targeted than females in the MCMU. We further observed a positive correlation between the percentage of permits filled and annual survival overall but also independently for both female

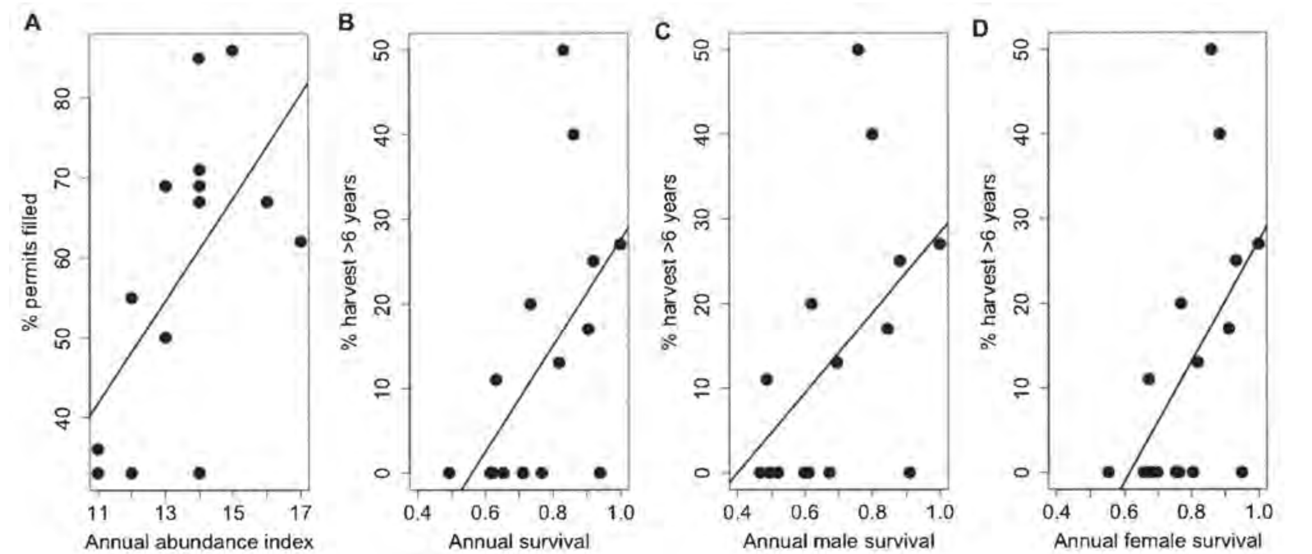

Figure 4. Significant correlations between A) % permits filled and annual abundance, B) % of harvested cougars >6 years old and overall annual survival, C) % of harvested cougars >6 years old and annual male survival, and D) % of harvested cougars >6 years old and annual female survival, for the Oquirrh-Stansbury Cougar Management Unit, 1997–2012, Utah, USA.

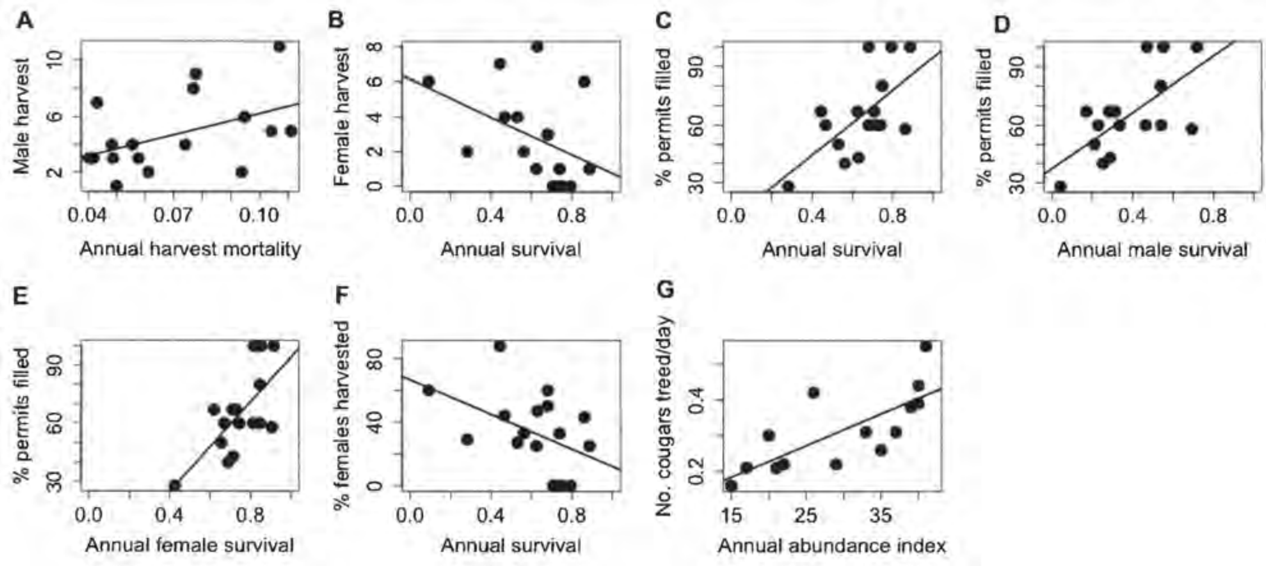

Figure 5. Significant correlations between A) male harvest rate and annual harvest mortality, B) female harvest and annual survival, C) % permits filled and overall annual survival, D) % permits filled and annual male survival, E) % permits filled and annual female survival, F) % females in the harvest and annual survival, and G) no. cougars treed/day and annual abundance for the Monroe Cougar Management Unit, 1996–2012, Utah, USA.

and male survival. This relationship indicates that hunters were more successful when annual cougar survival was high for the population as a whole, but also for females and males separately. The number of females harvested and the fraction of females in the harvest were negatively correlated with annual survival, suggesting that in this management unit, both statistics are relevant and their use is justified as the most widely used harvest index to monitor changes in cougar populations (Cooley et al. 2011). One of the more surprising results was the strong positive relationship between the number of cougars treed per day during the pursuit-season and the index of minimum annual cougar abundance on the MCMU. This index was arguably independent from harvest data because it is derived from the success of non-lethal pursuit permits. Choate et al. (2006) reported a weak ($P = 0.13$) correlation from the same unit that was derived in the same manner but for a much shorter time span (6 years). As discussed by Whittaker and Wolfe (2011), this pursuit index is a catch-per-unit-effort estimator, and although easily obtained, this index is subject to several assumptions including demographic and geographic independence and constant catchability throughout the period of data collection. The latter assumption may be unrealistic because it implies that cougars do not learn to avoid capture. Despite these limitations, the relatively low cost of obtaining this index via phone surveys of sportsmen warrants further investigation and refinement.

MANAGEMENT IMPLICATIONS

Using harvest statistics that are already commonly collected from hunters in the state of Utah to determine harvest quotas for cougars was justified by our analyses. Specifically, the total number of females harvested and the fraction of females in the harvest were negatively correlated with annual survival; managers are right to pay particular attention to these harvest statistics for monitoring cougar populations. In the MCMU, the percentage of permits filled was also a good proxy to changes in annual survival, annual female survival, and annual male survival. The highest correlation between cougars treed/day and the annual abundance of cougars suggests that pursuit indices may be an informative metric for wildlife managers to determine cougar population trends in intensely harvested management units. These harvest statistics may be suitable for cougar management units that have a similar hunting management regime as MCMU, with hunting being the predominant source of mortality.

In the OSCMU, the percentage of cougars in the harvest >6 years of age was correlated to overall annual survival, annual female, and male survival making them useful for monitoring changes in the demographics of cougar management units where harvest is not the only dominant cause of death (Wolfe et al. 2015). In such units, the percentage of permits filled tracked changes in annual cougar abundance, suggesting that this metric is a good indicator of population abundance in units that are not under intense harvest pressure.

Ideally, managers should also keep track of change in demographic rates, specifically survival and abundance, in key harvest management units that display contrasting harvest and mortality regimes. Our results illustrate the value of long-term data collection and suggest the possibility of expanding the scope of such comparisons to additional management units. Because the OSCMU and MCMU were subjected to contrasting mortality regimes (Wolfe et al. 2015), our results could be expanded to additional management units that share either the OSCMU or the MCMU characteristics. Ultimately, we suggest this analytical framework be extended to other harvested carnivore species for which harvest indices are available. When demographic information is available for certain harvest management units, correlations between harvest indices and demographic rates can be used to assess which harvest indices are better proxies to changes in survival, abundance, and population dynamics.

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ABSTRACT

We produced three, statewide, inductive habitat suitability models and population estimates for mountain lions for New Mexico. The first two models used a binary logistic regression to produce the linear combination of habitat variables that best predicted the distinction between either (1) mountain lion harvest locations and random points; or, (2) gps collared mountain lion locations and random points. The third model was produced by combining the mapped results of the first two models by adding the "excellent" and "good" habitat from the collar model to the harvest model. The models produced by binary logistic regression were entered into Raster Calculator in ArcGIS to produce maps of habitat suitability state wide. Habitat suitability was simplified to 5 categories (quintiles) using Spatial Analysis, Reclassify, in ArcGIS. Finally, the area of each habitat suitability class for each mountain lion management zone was multiplied by plausible mountain lion densities (derived from the literature) to produce an estimated range of mountain lion population sizes. The harvest, collar, and combined models predicted 8%, 16%, and 60% greater statewide mountain lion population estimates, respectively, than the current New Mexico Department of Game and Fish population estimates based on a deductive model. (Note: The higher population estimate produced by our harvest model is not uniform across mountain lion management zones. Approximately, half of the management zones were predicted to have smaller populations than previously predicted.) Our harvest model is the most conservative of the three and is in close agreement, at the state level, with the deductive model. We suggest that the harvest model be the primary source for guiding an adaptive management approach to mountain lion conservation in New Mexico.

INTRODUCTION

Information on the abundance and distribution of any species is essential for its responsible management. According to the New Mexico Department of Game and Fish Strategic Plan for 2008 through 2012, the mission of the agency is:

"To provide and maintain an adequate supply of wildlife and fish within the state of New Mexico by utilizing a flexible management system that provides for their protection, propagation, regulation, conservation, and for their use as public recreation and food supply."

Meeting these objectives for mountain lions poses significant challenges as these animals are secretive and occur at relatively low densities, making it difficult to conduct population counts. Even the result of such a census may be primarily local in application. However, the density estimates obtained from local studies is a critical starting point in understanding mountain lion population sizes and distribution.

To address these needs in mountain lion management alternative approaches to direct population counts are used. One increasingly useful approach is the use of habitat or niche modeling with GIS technology (Hirzel et al. 2006). The Cougar Management Guidelines Working Group (2005) suggests this technique as a primary means of planning statewide mountain lion management programs. This approach has been used to predict mountain lion habitat dispersal corridors and habitat patches in the Midwest (LaRue and Nielson 2005) as well as mountain lion population distribution and dispersal routes in Riverside County California, and to inform mountain lion management in New Mexico (Negri and Quigley 2010). These models have employed a deductive approach using expert opinion regarding mountain lion habitat preferences. Actual location data may be used to produce more objective, and possibly more accurate models. Location data may come from hunter harvest records or from VHF or GPS collars worn by free roaming mountain lions. The resulting models are inductive, generalizing habitat preferences from a subset of the mountain lion population across a broad geographic area. It should be noted that models built from harvest data may also be biased by hunter distribution and success. Data from collared mountain lions can address some of these biases. Perhaps the greatest utility of these models is that they represent testable hypotheses about the distribution and density of mountain lions that can inform an adaptive management approach.

Our primary goal in this project is to provide a scientifically robust estimate of mountain lion status across the state, based on actual mountain lion locations derived from harvest data and GPS collared mountain lions. Our objectives were to: (1) Identify and map habitat quality, defined by probability of mountain lion occurrence, in five quality categories, excellent, good, moderate, fair, and poor; (2) quantify the total area of each category of habitat quality in square kilometers by game management unit and mountain lion management zone; (3) map the statewide distribution of each habitat type; and, (4) project a statewide mountain lion population estimate, broken down by hunt unit and mountain lion management zone, based on the area and extent of habitat categories and reasonable mountain lion densities derived from the scientific literature.

METHODS

Statistical Approach

We used an inductive model building approach, using mountain lion locations, and their associated habitat characteristics to make generalizations about mountain lion habitat preference and suitability. Specifically, we used a binary logistic regression to produce the linear combination of habitat variables that best distinguished between random locations and mountain lion locations across the state of New Mexico. We made this approach more rigorous by building the model with a subset of locations and then testing the accuracy of the model at identifying the remaining points as either random or mountain lion based on associated habitat characteristics. This linear combination of variables (the model) was then entered into ArcGIS Raster Calculator to produce habitat suitability maps. We actually constructed three models: we used a binary logistic regression to distinguish between harvest locations and random locations to produce one model. We used the same approach to distinguish between random locations and collared mountain Lion locations to produce a separate model. Finally, we combined these models by adding the ‘excellent’ and ‘good’ habitats from the collar model to the harvest model.

Data

In initial model building, we used two sources of mountain location data, (1) harvest and (2) GPS collar, and data on several habitat variables: (3) vegetation type, (4) topographic ruggedness, (5) slope, (6) elevation, (7) snow depth, (8) distance to paved roads, (9) distance to dirt roads, (10) elk distribution, and (11) mule deer distribution.

(1) New Mexico mountain lion harvest data was provided by the New Mexico Department of Game and Fish. Approximately, 1,684 total records from 2001 to 2009 were provided. We georeferenced 1,397 of these records for the model. There are inherent, but unavoidable, biases to harvest data in the construction of harvest data. For example, proximity to roads may seem to be an important quality for suitable mountain lion habitat. When, in fact, it is hunter access that drives the importance of this variable. A second potential source of error is the accuracy of the georeferencing. Caution is warranted in the use and interpretation of models based on harvest data.

(2) We obtained GPS collar data from 10 free roaming mountain lions between 2005 and 2010. GPS locations were taken at night and reflect active habitat use. We used approximately, 13,000 GPS locations for model building. A bias inherent to the use of these data is their restricted geographic application. As all of these mountain lions were in the southcentral portion of New Mexico, below 7,000 ft, the resulting model would not predict that habitat types outside of this region would be suitable mountain lion habitat. (eg mixed coniferous forest). The advantage of these data is that they show mountain lion habitat use outside of areas frequented by hunters.

(3) We simplified vegetation classifications provided by the Southwest Regional GAP Analysis, as described in “Landcover descriptions for the Southwestern Regional GAP Analysis project” compiled by NatureServe, 2004. The relationship between the vegetation categories used for the model and the original SWReGAP categories can be found in Appendix I. For use in the raster calculator, we created a separate raster for each vegetation type, giving pixels a value of either zero (not the specified vegetation type) or one.

(4) We created an index of topographic ruggedness by using the USGS 30 meter National Elevation Dataset for New Mexico available from the RGIS website. (http://rgis.unm.edu/intro.cfm). The following equation was applied: TPI = SQR(FOCALSTD([DEM], CIRCLE, X, where X is the number of pixels in the radius of the circle. In this way we created four rasters of topographic ruggedness at four scales: 120, 240, 480, and 960 meters, respectively.

(5) Slope was derived from the USGS 30m DEM as percentage slope using ArcGIS Spatial Analyst.

(6) Elevation was taken from the USGS 30m DEM

(7) Snow depth was obtained from the National Climatic Data Center which is within the National Oceanic and Atomospheric Administration (NOAA)

(http://hurricane.ncdc.noaa.gov/cgi-bin/climaps/climaps.pl). National data representing average annual snowfall were used for this input.

(8) Distance to Paved Roads was calculated from the TIGER 2008 roads dataset. Roads were obtained from the U.S. Census 2008 TIGER shapefiles website (http://www2.census.gov/cgi-bin/shapefiles/national-files). Paved roads were extracted and distance to roads was calculated using the Euclidean Distance function in Spatial Analyst at a 30 m resolution.

(9) Distance to Dirt Roads was calculated from the TIGER 2008 roads dataset. Dirt roads were extracted and distance to roads was calculated using the Euclidean Distance function in Spatial Analyst at a 30 m resolution.

(10) We calculated a rough index of elk availability by dividing the total allowable harvest of elk for the 2010-2011 season by the area of each hunt unit.

(11) We calculated a rough index of mule deer availability by dividing the total allowable harvest of mule deer for the 2010-2011 season by the area of each hunt unit.

We entered the resulting binary logistic models (one for harvest data and one for collar data) into the ArcGIS Spatial Analyst, Raster Calculator to produce a raster in which each pixel was given a value that corresponded to the inverse odds of mountain lion occurrence. The range of pixel values in each of the resulting rasters was then simplified to 255 values using the Spatial Analysist Reclassify tool. These 255 values were then further simplified to 5 values by grouping the 255 values by quintiles and reclassifying a second time. The result, for each model, was a raster showing 5 categories of mountain lion habitat suitability (probability of mountain lion occurrence).

Next, we used Hawth's Tools, Raster Tools, Thematic Raster Summary by Polygon to calculate the area of each habitat class for each Game Management Unit (GMU). Then we multiplied each habitat type area for each GMU by a range of possible mountain lion densities, supplied by the New Mexico Department of Game and Fish (Table 1).

	Excellent	Good	Moderate	Fair
Density Range (per 100sqKm)	2-3	0.89-1.2	0.4-0.6	0.2-0.3

Table 1. Mountain lion density ranges by habitat category, provided by the New Mexico Department of Game and Fish used in the calculation of mountain lion populations.

RESULTS

In both the harvest and collar models the variables with the most significant predictive value were topographic ruggedness, at the scale of 480m, and vegetation type. The addition of other predictor variables did not significantly improve the models. In the models that follow, the lower the coefficient, the more this variable contributes to suitable mountain lion habitat. The binary logistic regression models were:

(1) for harvest data:
Puma = -.0001[TRI480] + 21.844 * [acmesq1] + 21.04 * [acpsdg2] + 21.127 * [agric3] + 22.019 * [badland4] + 21.616 * [barren5] + 22.54 * [ccreosote7] + 42.332 * [cscrub8] + 21.352 * [canyon9] +22.277 * [canmesa10] + 42.322 * [ccdunesd11] + 20.547 * [chaparral12] + 19.583 * [cliffrock13] + 0.065 * [cpshrub14] + 42.399 * [dgrasslnd15] + 22.219 * [dunes17] +21.857 * [gpmesq18] + 42.322 * [gpsndshb19] + 19.088 * [gpfpgrass20] + 42.322 * [gypgrass21] +21.907 * [imgrass22] + 21.9 * [imbshrub23] + 21.539 * [junpgrass25] + 42.332 * [lava26] + 19.9 * [madoak29] + 20.419 * [mixconifer30] + 20.261 * [mongrass32] + 19.962 * [montshrub33] + 42.337 * [water35] +19.681 * [pine36] + 20.529 * [pj37] + 20.27 * [playa38] + 19.486 * [ripwood42] + 20.381 * [sage44] + 22.459 * [sgprairie45] + 21.051 * [urban49]

Certain adjustments to coefficients were made: 0.065 coefficient for cpshrub (Colorado Plateau Shrubland) was unrealistic and resulted from small sample size. Also, the coefficients for [barren5], [playa38], and [urban49] were changed to 43 (meaning low probability of mountain lion occurrence), as breeding populations of mountain lions cannot reasonably be expected to occur in these areas.

This model correctly predicted 85% of test mountain lion harvest locations (Appendix II).

(2) for collar data:
Puma = -0.0001 * [TRI_480.img] + 19.708 * [acmesq1] + 18.739 * [acpsdg2] + 20.998 * [agric3] + 43.049 * [badland4] + 43.654 * [barren5] + 20.002 * [ccreosote7] + 19.724 * [cscrub8] + 46.082 * [canyon9] + 22.311 * [ccdunesd11] + 18.515 * [chaparral12] + 17.559 * [cliffrock13] + 19.886 * [dgrasslnd15] + 20.735 * [dunes17] + 42.769 * [gpmesq18] + 42.412 * [gpsndshb19] + 42.409 * [gypgrass21] + 20.603 * [imgrass22] + 22.279 * [imbshrub23] + 46.184 * [jungrass25] + 42.46 * [lava26] + 21.677 * [madoak29] + 25.507 * [mixconifer30] + 43.691 * [mongrass32] + 44.049 * [montshrub33] + 42.489 * [water35] + 21.742 * [pine36] + 19.870 * [pj37] + 19.231 * [playa38] + 1.215 * [ripherb39] + 15.223 * [ripwood42] + 44.265 * [sage44] + 42.479 * [sgprairie45] + 42.496 * [urban49]

This model correctly predicted 99% of test collared mountain lion locations. (Appendix III)

The three resulting models, from harvest data, collar data, and the combination of the two, predict successively larger statewide mountain lion populations respectively. The harvest data model is the most conservative, predicting a statewide population of mountain lions between 2,099 and 3,122 (Table 2, Figure 1). The collar model predicts a statewide population between 2,253 and 3,122 (Table 2, Figure 2). The combined models, in which excellent and good mountain lion habitat predicted by the collar model was added to the harvest model, predicts a statewide population between 3,197 and 4,732 (Table 2, Figure 3). The real number of mountain lions statewide likely lies between the harvest model and harvest + collar population estimates. As the harvest model is the most conservative, we suggest that it be used for management decisions.

Cougar Zone	harvest lo	harvest hi	collar lo	collar hi	harvcol lo	harvcol hi
A	139	207	117	167	169	249
B	96	142	38	56	98	146
C	193	289	58	84	195	291
D	52	76	21	31	56	82
E	168	251	120	171	187	275
F	104	156	45	65	108	161
G	166	247	155	223	209	308
H	54	78	216	318	206	302
I	123	183	146	215	198	295
J	298	445	294	429	436	646
K	151	225	177	262	232	347
L	43	64	137	203	145	216
M	98	146	362	537	376	557
N	51	76	8	12	52	78
O	70	103	51	71	75	109
P	33	49	13	19	33	49
Q	115	170	236	347	268	396
R	87	131	22	33	88	132
S	57	85	37	52	65	95
T						
Total	2099	3122	2253	3294	3197	4732

Table 2. This table compares mountain lion population estimates by mountain lion management unit across the three models, harvest, collar, and harvest and collar (Harvcol) combined. Note that mountain lion population estimates for the "T" (Tribal) areas of the state are not included in the estimate.

For detailed calculations of mountain lion population size by GMU across all three models see Appendix IV.

DISCUSSION

The harvest data model, the most conservative of the three models, predicts a statewide mountain lion population approximately 8% larger than the current NMDGF mountain lion population estimates. It is perhaps most notable, that the two estimates are so similar. The harvest model's higher statewide estimate is not the result of uniformly higher estimates across GMU's. Approximately, half of the units were predicted to have fewer mountain lions by the model than previously predicted by NMDGF. The fact that tribal areas were not included in the statewide population estimate makes the harvest model more conservative.

The accuracy of any model is only as good as the data used to construct the model. There are at least three points of potential issue with the data used for these models.

First, there are inherent biases in both harvest data and GPS collar data. Harvest data may be biased by hunter access (roads) or environmental factors that increase hunter success (snow). The result of this bias is that the model may underestimate the mountain lion population in areas where there are few roads or where there is infrequent, or no, snow fall. Likewise, favored hunting areas with high success may over-estimate mountain lion populations. The GPS collar data is biased in two ways. First, because there was not a statewide distribution of collared mountain lions, the habitat selection of collared lions was limited. For example, because all collared mountain lions were in southcentral New Mexico, below 7,000 ft, obviously suitable habitat types, such as mixed conifer, are not predicted to be suitable mountain lion habitat by this model. This also, would lead to a significant underestimate of statewide populations. Second, collared mountain lions may pass through unsuitable habitat, regularly, to access favored habitats. As a result, unfavorable habitat types, such as creosote flats, may be shown by the model to be moderately suitable to mountain lion populations, causing an overestimation of mountain lion numbers. A solution to the second bias may be addressed by using only prey cache sites from collared mountain lions. Evidence of mountain lions feeding in particular habitats is stronger evidence of habitat suitability than mere location data.

A second source of concern is the accuracy of georeferenced harvest data. Whereas collar data may be accurate to the scale of meters, harvest data may only be accurate to the scale of 100's of meters or even kilometers. The result may be that truly unfavored habitat types appear to be favored. The best remedy for these inaccuracies is sample size. With 1,400 georeferenced records, we can be relatively confident that this is not a significant source of error in these models.

A final area of potential inaccuracy, in calculating population size, is the choice of density ranges. The density of mountain lions has been accurately measured in a number of intensive field studies. However, it is difficult to compare density estimates across studies due to differences in approach. Recently, Quigley and Hornocker (2010) provided a summary of density estimates across several studies, ranging from 0.32 to 7.3 per 100 sqKm. The density estimates used in these models are conservative, ranging from 0.2 to 3 per 100sqKm. Mountain lion densities in New Mexico might exceed this top range in productive habitats. Recently, four resident adult females and two resident adult males were observed frequenting a 100 sqKm camera study area in the eastern piedmont of the Black Range.

The primary utility of population estimate models is to serve as hypotheses to guide adaptive management practices. There are at least two methods for testing the accuracy of these model predictions: (1) remote camera mark-resight population estimates in select habitats and (2) monitoring the sex and age distribution of harvested lions as per the findings of Anderson and Lindzey (2005).

ACKNOWLEDGEMENTS

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APPENDIX I

SWReGAP Original Vegetation Types	Our Model Vegetation Types
Apacherian-Chihuahuan Mesquite Upland Scrub	AC Mesquite
Apacherian-Chihuahuan Piedmont Semi-Desert Grassland and Steppe	ACPSD Grassland
Agriculture	Agriculture
Inter-Mountain Basins Shale Badland	Badland
North American Warm Desert Badland	Badland
Inter-Mountain Basins Playa	Barren
Barren Lands, Non-specific	Barren
Recently Burned	Barren
Inter-Mountain Basins Subalpine Limber-Bristlecone Pine Woodland	Bristle Cone
North American Warm Desert Pavement	C Creosote
Chihuahuan Creosotebush, Mixed Desert and Thorn Scrub	C Creosote
Chihuahuan Succulent Desert Scrub	C scrub
Chihuahuan Mixed Salt Desert Scrub	C scrub
Rocky Mountain Cliff and Canyon	Canyon
Sierra Nevada Cliff and Canyon	Canyon
Inter-Mountain Basins Cliff and Canyon	Canyon
Colorado Plateau Mixed Bedrock Canyon and Tableland	Canyon and Mesa
Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub	CC Dune Sand
Great Basin Semi-Desert Chaparral	Chaparral
Mogollon Chaparral	Chaparral
Coahuilan Chaparral	Chaparral
Rocky Mountain Alpine Bedrock and Scree	Cliff and Rock
Mediterranean California Alpine Bedrock and Scree	Cliff and Rock
Western Great Plains Cliff and Outcrop	Cliff and Rock
North American Warm Desert Bedrock Cliff and Outcrop	Cliff and Rock
Recently Mined or Quarried	Cliff and Rock
Colorado Plateau Blackbrush-Mormon-tea Shrubland	CP Shrub
Southern Colorado Plateau Sand Shrubland	CP Shrub
Chihuahuan-Sonoran Desert Bottomland and Swale Grassland	D Grassland
Chihuahuan Sandy Plains Semi-Desert Grassland	D Grassland
Disturbed, Non-specific	Disburbed
Inter-Mountain Basins Active and Stabilized Dune	Dunes
North American Warm Desert Active and Stabilized Dune	Dunes
Western Great Plains Mesquite Woodland and Shrubland	GP Mesquite
Western Great Plains Sandhill Shrubland	GP sand Shrub

SWReGAP Original Vegetation Types	Our Model Vegetation Types
Western Great Plains Foothill and Piedmont Grassland	GPFP Grassland
Chihuahuan Gypsophilous Grassland and Steppe	Gyp Grassland
Inter-Mountain Basins Semi-Desert Grassland	IM Grassland
Inter-Mountain Basins Mat Saltbush Shrubland	IMB Shrub
Inter-Mountain Basins Mixed Salt Desert Scrub	IMB Shrub
Inter-Mountain Basins Semi-Desert Shrub Steppe	IMB Shrub
Inter-Mountain Basins Greasewood Flat	IMB Shrub
Inter-Mountain Basins Wash	IMB Wash
Southern Rocky Mountain Juniper Woodland and Savanna	Juniper Grassland
Inter-Mountain Basins Juniper Savanna	Juniper Grassland
Madrean Juniper Savanna	Juniper Grassland
Inter-Mountain Basins Volcanic Rock and Cinder Land	Lava
North American Warm Desert Volcanic Rockland	Lava
	Layer border
Recently Logged Areas	Logged
Madrean Pine-Oak Forest and Woodland	Madrean Oak
Madrean Encinal	Madrean Oak
Madrean Upper Montane Conifer-Oak Forest and Woodland	Madrean Oak
Rocky Mountain Aspen Forest and Woodland	Mixed Conifer
Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland	Mixed Conifer
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Mixed Conifer
Northern Pacific Mesic Subalpine Woodland	Mixed Conifer
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	Mixed Conifer
Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland	Mixed Conifer
Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland	Mixed Conifer
Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland	Mixed Conifer
Inter-Mountain West Aspen-Mixed Conifer Forest and Woodland Complex	Mixed Conifer
Mediterranean California Red Fir Forest and Woodland	Mixed Conifer
Mojave Mid-Elevation Mixed Desert Scrub	Mojave Scrub
Rocky Mountain Alpine Fell-Field	Montane Grass
Rocky Mountain Subalpine Mesic Meadow	Montane Grass
Southern Rocky Mountain Montane-Subalpine Grassland	Montane Grass
Rocky Mountain Alpine-Montane Wet Meadow	Montane Grass

SWReGAP Original Vegetation Types	Our Model Vegetation Types
Temperate Pacific Montane Wet Meadow	Montane Grass
Mediterranean California Subalpine-Montane Fen	Montane Grass
North Pacific Montane Grassland	Montane Grass
Rocky Mountain Bigtooth Maple Ravine Woodland	Mountain Shrub
Rocky Mountain Alpine Dwarf-Shrubland	Mountain Shrub
Rocky Mountain Gambel Oak-Mixed Montane Shrubland	Mountain Shrub
Rocky Mountain Lower Montane-Foothill Shrubland	Mountain Shrub
Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland	Mountain Shrub
Central Mixedgrass Prairie	Odd grass
Invasive Perennial Grassland	Odd grass
Invasive Perennial Forbland	Odd grass
Invasive Annual Grassland	Odd grass
Invasive Annual and Biennial Forbland	Odd grass
Open Water	Open Water
Rocky Mountain Lodgepole Pine Forest	Pine forest
Rocky Mountain Ponderosa Pine Woodland	Pine forest
Sierra Nevada Subalpine Lodgepole Pine Forest and Woodland	Pine forest
Mediterranean California Ponderosa-Jeffrey Pine Forest and Woodland	Pine forest
Rocky Mountain Foothill Limber Pine-Juniper Woodland	Pine forest
Southern Rocky Mountain Pinyon-Juniper Woodland	Pinyon Juniper
Colorado Plateau Pinyon-Juniper Woodland	Pinyon Juniper
Great Basin Pinyon-Juniper Woodland	Pinyon Juniper
Colorado Plateau Pinyon-Juniper Shrubland	Pinyon Juniper
Madrean Pinyon-Juniper Woodland	Pinyon Juniper
Recently Chained Pinyon-Juniper Areas	Pinyon Juniper
North American Warm Desert Playa	Playa
North American Arid West Emergent Marsh	Riparian Herb
Western Great Plains Floodplain Herbaceous Wetland	Riparian Herb
Western Great Plains Saline Depression Wetland	Riparian salt
Rocky Mountain Subalpine-Montane Riparian Shrubland	Riparian Shrub
Rocky Mountain Subalpine-Montane Riparian Woodland	Riparian Woodland
Rocky Mountain Lower Montane Riparian Woodland and Shrubland	Riparian Woodland
North American Warm Desert Lower Montane Riparian Woodland and Shrubland	Riparian Woodland
Western Great Plains Riparian Woodland and Shrubland	Riparian

	Woodland
SWReGAP Original Vegetation Types	**Our Model Vegetation Types**
North American Warm Desert Riparian Woodland and Shrubland	Riparian Woodland
North American Warm Desert Riparian Mesquite Bosque	Riparian Woodland
Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland	Riparian Woodland
Invasive Southwest Riparian Woodland and Shrubland	Riparian Woodland
Sonoran Paloverde-Mixed Cacti Desert Scrub	S Shrub
Sonora-Mojave Creosotebush-White Bursage Desert Scrub	S Shrub
Sonora-Mojave Mixed Salt Desert Scrub	S Shrub
Sonora-Mojave-Baja Semi-Desert Chaparral	S Shrub
Sonoran Mid-Elevation Desert Scrub	S Shrub
Inter-Mountain Basins Big Sagebrush Shrubland	Sagebrush
Great Basin Xeric Mixed Sagebrush Shrubland	Sagebrush
Colorado Plateau Mixed Low Sagebrush Shrubland	Sagebrush
Inter-Mountain Basins Montane Sagebrush Steppe	Sagebrush
Inter-Mountain Basins Big Sagebrush Steppe	Sagebrush
Wyoming Basins Low Sagebrush Shrubland	Sagebrush
Western Great Plains Shortgrass Prairie	SG Prarie
Western Great Plains Sandhill Prairie	SH Prarie
Western Great Plains Tallgrass Prairie	Tallgrass
North American Alpine Ice Field	Tundra
Rocky Mountain Dry Tundra	Tundra
Developed, Open Space - Low Intensity	Urban
Developed, Medium - High Intensity	Urban
North American Warm Desert Wash	WD Wash

APPENDIX II

SPSS Harvest Model Binary Logistic Regression Output

```
LOGISTIC REGRESSION VARIABLES Class
  /SELECT=validate EQ 1
  /METHOD=FSTEP(LR) TRI480 GAP_4
  /CONTRAST (GAP_4)=Indicator
  /SAVE=PRED COOK SRESID
  /PRINT=GOODFIT
  /CRITERIA=PIN(0.05) POUT(0.10) ITERATE(20) CUT(0.5).
```

Logistic Regression

Notes

	Output Created	02-Jun-2010 17:49:27
	Comments	
Input	Data	C:\Documents and Settings\tperry\My Documents\My Dropbox\Cougar\NMDGFhabitatmodel\Data2010\modeldata2b.sav
	Active Dataset	DataSet1
	Filter	Model_ID > 4000 & Class ne 'PC' (FILTER)
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	2397
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing
	Syntax	LOGISTIC REGRESSION VARIABLES Class /SELECT=validate EQ 1 /METHOD=FSTEP(LR) TRI480 GAP_4 /CONTRAST (GAP_4)=Indicator /SAVE=PRED COOK SRESID /PRINT=GOODFIT /CRITERIA=PIN(0.05) POUT(0.10) ITERATE(20) CUT(0.5).
Resources	Processor Time	0:00:00.515
	Elapsed Time	0:00:00.517
Variables Created or Modified	PRE_1	Predicted probability
	COO_1	Analog of Cook's influence statistics
	SRE_1	Standard residual

```
[DataSet1] C:\Documents and Settings\tperry\My Documents\My Dropbox\Cougar\NMDGFhabitatmodel\Data2010\modeldata2b.sav
```

Case Processing Summary

Unweighted Cases [a]		N	Percent
Selected Cases	Included in Analysis	1684	70.3
	Missing Cases	0	.0
	Total	1684	70.3
	Unselected Cases	713	29.7
	Total	2397	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
PH	0
R	1

Categorical Variables Codings

			Parameter coding					
		Frequency	(1)	(2)	(3)	(4)	(5)	(6)
GAP_4	1	51	1.000	.000	.000	.000	.000	.000
	2	175	.000	1.000	.000	.000	.000	.000
	3	26	.000	.000	1.000	.000	.000	.000
	4	3	.000	.000	.000	1.000	.000	.000
	5	9	.000	.000	.000	.000	1.000	.000
	7	79	.000	.000	.000	.000	.000	1.000
	8	4	.000	.000	.000	.000	.000	.000
	9	4	.000	.000	.000	.000	.000	.000
	10	4	.000	.000	.000	.000	.000	.000
	11	12	.000	.000	.000	.000	.000	.000
	12	16	.000	.000	.000	.000	.000	.000
	13	7	.000	.000	.000	.000	.000	.000
	14	1	.000	.000	.000	.000	.000	.000
	15	2	.000	.000	.000	.000	.000	.000
	17	4	.000	.000	.000	.000	.000	.000
	18	9	.000	.000	.000	.000	.000	.000
	19	13	.000	.000	.000	.000	.000	.000
	20	10	.000	.000	.000	.000	.000	.000
	21	2	.000	.000	.000	.000	.000	.000
	22	52	.000	.000	.000	.000	.000	.000
	23	72	.000	.000	.000	.000	.000	.000
	25	57	.000	.000	.000	.000	.000	.000
	26	2	.000	.000	.000	.000	.000	.000
	29	53	.000	.000	.000	.000	.000	.000
	30	105	.000	.000	.000	.000	.000	.000
	32	24	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(7)	(8)	(9)	(10)	(11)	(12)	(13)
GAP_4	1	.000	.000	.000	.000	.000	.000	.000
	2	.000	.000	.000	.000	.000	.000	.000
	3	.000	.000	.000	.000	.000	.000	.000
	4	.000	.000	.000	.000	.000	.000	.000
	5	.000	.000	.000	.000	.000	.000	.000
	7	.000	.000	.000	.000	.000	.000	.000
	8	1.000	.000	.000	.000	.000	.000	.000
	9	.000	1.000	.000	.000	.000	.000	.000
	10	.000	.000	1.000	.000	.000	.000	.000
	11	.000	.000	.000	1.000	.000	.000	.000
	12	.000	.000	.000	.000	1.000	.000	.000
	13	.000	.000	.000	.000	.000	1.000	.000
	14	.000	.000	.000	.000	.000	.000	1.000
	15	.000	.000	.000	.000	.000	.000	.000
	17	.000	.000	.000	.000	.000	.000	.000
	18	.000	.000	.000	.000	.000	.000	.000
	19	.000	.000	.000	.000	.000	.000	.000
	20	.000	.000	.000	.000	.000	.000	.000
	21	.000	.000	.000	.000	.000	.000	.000
	22	.000	.000	.000	.000	.000	.000	.000
	23	.000	.000	.000	.000	.000	.000	.000
	25	.000	.000	.000	.000	.000	.000	.000
	26	.000	.000	.000	.000	.000	.000	.000
	29	.000	.000	.000	.000	.000	.000	.000
	30	.000	.000	.000	.000	.000	.000	.000
	32	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(14)	(15)	(16)	(17)	(18)	(19)	(20)
GAP_4	1	.000	.000	.000	.000	.000	.000	.000
	2	.000	.000	.000	.000	.000	.000	.000
	3	.000	.000	.000	.000	.000	.000	.000
	4	.000	.000	.000	.000	.000	.000	.000
	5	.000	.000	.000	.000	.000	.000	.000
	7	.000	.000	.000	.000	.000	.000	.000
	8	.000	.000	.000	.000	.000	.000	.000
	9	.000	.000	.000	.000	.000	.000	.000
	10	.000	.000	.000	.000	.000	.000	.000
	11	.000	.000	.000	.000	.000	.000	.000
	12	.000	.000	.000	.000	.000	.000	.000
	13	.000	.000	.000	.000	.000	.000	.000
	14	.000	.000	.000	.000	.000	.000	.000
	15	1.000	.000	.000	.000	.000	.000	.000
	17	.000	1.000	.000	.000	.000	.000	.000
	18	.000	.000	1.000	.000	.000	.000	.000
	19	.000	.000	.000	1.000	.000	.000	.000
	20	.000	.000	.000	.000	1.000	.000	.000
	21	.000	.000	.000	.000	.000	1.000	.000
	22	.000	.000	.000	.000	.000	.000	1.000
	23	.000	.000	.000	.000	.000	.000	.000
	25	.000	.000	.000	.000	.000	.000	.000
	26	.000	.000	.000	.000	.000	.000	.000
	29	.000	.000	.000	.000	.000	.000	.000
	30	.000	.000	.000	.000	.000	.000	.000
	32	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(21)	(22)	(23)	(24)	(25)	(26)	(27)
GAP_4	1	.000	.000	.000	.000	.000	.000	.000
	2	.000	.000	.000	.000	.000	.000	.000
	3	.000	.000	.000	.000	.000	.000	.000
	4	.000	.000	.000	.000	.000	.000	.000
	5	.000	.000	.000	.000	.000	.000	.000
	7	.000	.000	.000	.000	.000	.000	.000
	8	.000	.000	.000	.000	.000	.000	.000
	9	.000	.000	.000	.000	.000	.000	.000
	10	.000	.000	.000	.000	.000	.000	.000
	11	.000	.000	.000	.000	.000	.000	.000
	12	.000	.000	.000	.000	.000	.000	.000
	13	.000	.000	.000	.000	.000	.000	.000
	14	.000	.000	.000	.000	.000	.000	.000
	15	.000	.000	.000	.000	.000	.000	.000
	17	.000	.000	.000	.000	.000	.000	.000
	18	.000	.000	.000	.000	.000	.000	.000
	19	.000	.000	.000	.000	.000	.000	.000
	20	.000	.000	.000	.000	.000	.000	.000
	21	.000	.000	.000	.000	.000	.000	.000
	22	.000	.000	.000	.000	.000	.000	.000
	23	1.000	.000	.000	.000	.000	.000	.000
	25	.000	1.000	.000	.000	.000	.000	.000
	26	.000	.000	1.000	.000	.000	.000	.000
	29	.000	.000	.000	1.000	.000	.000	.000
	30	.000	.000	.000	.000	1.000	.000	.000
	32	.000	.000	.000	.000	.000	1.000	.000

Categorical Variables Codings

		Parameter coding					
		(28)	(29)	(30)	(31)	(32)	(33)
GAP_4	1	.000	.000	.000	.000	.000	.000
	2	.000	.000	.000	.000	.000	.000
	3	.000	.000	.000	.000	.000	.000
	4	.000	.000	.000	.000	.000	.000
	5	.000	.000	.000	.000	.000	.000
	7	.000	.000	.000	.000	.000	.000
	8	.000	.000	.000	.000	.000	.000
	9	.000	.000	.000	.000	.000	.000
	10	.000	.000	.000	.000	.000	.000
	11	.000	.000	.000	.000	.000	.000
	12	.000	.000	.000	.000	.000	.000
	13	.000	.000	.000	.000	.000	.000
	14	.000	.000	.000	.000	.000	.000
	15	.000	.000	.000	.000	.000	.000
	17	.000	.000	.000	.000	.000	.000
	18	.000	.000	.000	.000	.000	.000
	19	.000	.000	.000	.000	.000	.000
	20	.000	.000	.000	.000	.000	.000
	21	.000	.000	.000	.000	.000	.000
	22	.000	.000	.000	.000	.000	.000
	23	.000	.000	.000	.000	.000	.000
	25	.000	.000	.000	.000	.000	.000
	26	.000	.000	.000	.000	.000	.000
	29	.000	.000	.000	.000	.000	.000
	30	.000	.000	.000	.000	.000	.000
	32	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding	
		(34)	(35)
GAP_4	1	.000	.000
	2	.000	.000
	3	.000	.000
	4	.000	.000
	5	.000	.000
	7	.000	.000
	8	.000	.000
	9	.000	.000
	10	.000	.000
	11	.000	.000
	12	.000	.000
	13	.000	.000
	14	.000	.000
	15	.000	.000
	17	.000	.000
	18	.000	.000
	19	.000	.000
	20	.000	.000
	21	.000	.000
	22	.000	.000
	23	.000	.000
	25	.000	.000
	26	.000	.000
	29	.000	.000
	30	.000	.000
	32	.000	.000

Categorical Variables Codings

			Parameter coding					
		Frequency	(1)	(2)	(3)	(4)	(5)	(6)
GAP_4	33	35	.000	.000	.000	.000	.000	.000
	35	3	.000	.000	.000	.000	.000	.000
	36	266	.000	.000	.000	.000	.000	.000
	37	344	.000	.000	.000	.000	.000	.000
	38	4	.000	.000	.000	.000	.000	.000
	42	21	.000	.000	.000	.000	.000	.000
	44	26	.000	.000	.000	.000	.000	.000
	45	176	.000	.000	.000	.000	.000	.000
	49	11	.000	.000	.000	.000	.000	.000
	50	2	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(7)	(8)	(9)	(10)	(11)	(12)	(13)
GAP_4	33	.000	.000	.000	.000	.000	.000	.000
	35	.000	.000	.000	.000	.000	.000	.000
	36	.000	.000	.000	.000	.000	.000	.000
	37	.000	.000	.000	.000	.000	.000	.000
	38	.000	.000	.000	.000	.000	.000	.000
	42	.000	.000	.000	.000	.000	.000	.000
	44	.000	.000	.000	.000	.000	.000	.000
	45	.000	.000	.000	.000	.000	.000	.000
	49	.000	.000	.000	.000	.000	.000	.000
	50	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(14)	(15)	(16)	(17)	(18)	(19)	(20)
GAP_4	33	.000	.000	.000	.000	.000	.000	.000
	35	.000	.000	.000	.000	.000	.000	.000
	36	.000	.000	.000	.000	.000	.000	.000
	37	.000	.000	.000	.000	.000	.000	.000
	38	.000	.000	.000	.000	.000	.000	.000
	42	.000	.000	.000	.000	.000	.000	.000
	44	.000	.000	.000	.000	.000	.000	.000
	45	.000	.000	.000	.000	.000	.000	.000
	49	.000	.000	.000	.000	.000	.000	.000
	50	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(21)	(22)	(23)	(24)	(25)	(26)	(27)
GAP_4	33	.000	.000	.000	.000	.000	.000	1.000
	35	.000	.000	.000	.000	.000	.000	.000
	36	.000	.000	.000	.000	.000	.000	.000
	37	.000	.000	.000	.000	.000	.000	.000
	38	.000	.000	.000	.000	.000	.000	.000
	42	.000	.000	.000	.000	.000	.000	.000
	44	.000	.000	.000	.000	.000	.000	.000
	45	.000	.000	.000	.000	.000	.000	.000
	49	.000	.000	.000	.000	.000	.000	.000
	50	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding					
		(28)	(29)	(30)	(31)	(32)	(33)
GAP_4	33	.000	.000	.000	.000	.000	.000
	35	1.000	.000	.000	.000	.000	.000
	36	.000	1.000	.000	.000	.000	.000
	37	.000	.000	1.000	.000	.000	.000
	38	.000	.000	.000	1.000	.000	.000
	42	.000	.000	.000	.000	1.000	.000
	44	.000	.000	.000	.000	.000	1.000
	45	.000	.000	.000	.000	.000	.000
	49	.000	.000	.000	.000	.000	.000
	50	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding	
		(34)	(35)
GAP_4	33	.000	.000
	35	.000	.000
	36	.000	.000
	37	.000	.000
	38	.000	.000
	42	.000	.000
	44	.000	.000
	45	1.000	.000
	49	.000	1.000
	50	.000	.000

Block 0: Beginning Block

Classification Table[d,e]

			Predicted			
			Selected Cases [a]			Unselected Cases [b,,c]
			Class			Class
Observed			PH	R	Percentage Correct	PH
Step 0	Class	PH	977	0	100.0	420

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. Some of the unselected cases are not classified due to either missing values in the independent variables or categorical variables with values out of the range of the selected cases.

d. Constant is included in the model.

e. The cut value is .500

Classification Table[d,e]

Observed			Predicted: Unselected Cases[b,,c] Class R	Percentage Correct
Step 0	Class	PH	0	100.0

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. Some of the unselected cases are not classified due to either missing values in the independent variables or categorical variables with values out of the range of the selected cases.

d. Constant is included in the model.

e. The cut value is .500

Classification Table[d,e]

Observed			Predicted: Selected Cases[a] Class PH	R	Percentage Correct	Unselected Cases[b,,c] Class PH
Step 0	Class	R	707	0	.0	292
		Overall Percentage			58.0	

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. Some of the unselected cases are not classified due to either missing values in the independent variables or categorical variables with values out of the range of the selected cases.

d. Constant is included in the model.

e. The cut value is .500

Classification Table[d,e]

Observed			Predicted: Unselected Cases[b,,c] Class R	Percentage Correct
Step 0	Class	R	0	.0
		Overall Percentage		59.0

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. Some of the unselected cases are not classified due to either missing values in the independent variables or categorical variables with values out of the range of the selected cases.

d. Constant is included in the model.

e. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	-.323	.049	42.914	1	.000	.724

Variables not in the Equation[a]

			Score	df	Sig.
Step 0	Variables	TRI480	128.563	1	.000
		GAP_4	420.926	35	.000
		GAP_4(1)	13.155	1	.000
		GAP_4(2)	.007	1	.932
		GAP_4(3)	.697	1	.404
		GAP_4(4)	.752	1	.386
		GAP_4(5)	.684	1	.408
		GAP_4(6)	48.530	1	.000
		GAP_4(7)	5.541	1	.019
		GAP_4(8)	.106	1	.745
		GAP_4(9)	1.794	1	.180
		GAP_4(10)	16.702	1	.000
		GAP_4(11)	1.913	1	.167
		GAP_4(12)	2.214	1	.137
		GAP_4(13)	.724	1	.395
		GAP_4(14)	2.767	1	.096
		GAP_4(15)	1.794	1	.180
		GAP_4(16)	2.263	1	.132
		GAP_4(17)	18.104	1	.000
		GAP_4(18)	4.225	1	.040
		GAP_4(19)	2.767	1	.096
		GAP_4(20)	14.128	1	.000
		GAP_4(21)	20.991	1	.000
		GAP_4(22)	4.854	1	.028
		GAP_4(23)	2.767	1	.096
		GAP_4(24)	14.044	1	.000
		GAP_4(25)	18.535	1	.000
		GAP_4(26)	2.883	1	.090
		GAP_4(27)	7.092	1	.008
		GAP_4(28)	4.153	1	.042
		GAP_4(29)	99.496	1	.000
		GAP_4(30)	25.735	1	.000
		GAP_4(31)	.475	1	.491
		GAP_4(32)	6.698	1	.010
		GAP_4(33)	1.363	1	.243

a. Residual Chi-Squares are not computed because of redundancies.

Variables not in the Equation[a]

			Score	df	Sig.
Step 0	Variables	GAP_4(34)	110.429	1	.000
		GAP_4(35)	.055	1	.815

a. Residual Chi-Squares are not computed because of redundancies.

Block 1: Method = Forward Stepwise (Likelihood Ratio)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	456.703	35	.000
	Block	456.703	35	.000
	Model	456.703	35	.000
Step 2	Step	26.096	1	.000
	Block	482.799	36	.000
	Model	482.799	36	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	1834.339[a]	.238	.320
2	1808.244[a]	.249	.335

a. Estimation terminated at iteration number 20 because maximum iterations has been reached. Final solution cannot be found.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	.000	7	1.000
2	19.988	8	.010

Contingency Table for Hosmer and Lemeshow Test

		Class = PH		Class = R		
		Observed	Expected	Observed	Expected	Total
Step 1	1	264	264.000	43	43.000	307
	2	154	154.000	39	39.000	193
	3	33	33.000	11	11.000	44
	4	241	241.000	103	103.000	344
	5	119	119.000	82	82.000	201
	6	71	71.000	99	99.000	170
	7	42	42.000	90	90.000	132
	8	37	37.000	139	139.000	176
	9	16	16.000	101	101.000	117

Contingency Table for Hosmer and Lemeshow Test

		Class = PH		Class = R		
		Observed	Expected	Observed	Expected	Total
Step 2	1	143	151.599	25	16.401	168
	2	140	140.266	27	26.734	167
	3	141	135.651	27	32.349	168
	4	135	123.956	33	44.044	168
	5	116	113.046	52	54.954	168
	6	112	106.290	60	65.710	172
	7	68	83.546	100	84.454	168
	8	62	56.473	106	111.527	168
	9	41	39.734	127	128.266	168
	10	19	26.437	150	142.563	169

Classification Table[d]

			Predicted			
			Selected Cases[a]			Unselected Cases[b,,c]
			Class			Class
Observed			PH	R	Percentage Correct	PH
Step 1	Class	PH	817	160	83.6	350
		R	283	424	60.0	119
		Overall Percentage			73.7	
Step 2	Class	PH	830	147	85.0	358
		R	288	419	59.3	120
		Overall Percentage			74.2	

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. Some of the unselected cases are not classified due to either missing values in the independent variables or categorical variables with values out of the range of the selected cases.

d. The cut value is .500

Classification Table[d]

Observed			Predicted: Unselected Cases[b,,c] Class R	Percentage Correct
Step 1	Class	PH	70	83.3
		R	173	59.2
		Overall Percentage		73.5
Step 2	Class	PH	62	85.2
		R	172	58.9
		Overall Percentage		74.4

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. Some of the unselected cases are not classified due to either missing values in the independent variables or categorical variables with values out of the range of the selected cases.

d. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	GAP_4			311.527	35	.000	
	GAP_4(1)	21.899	28533.052	.000	1	.999	3.240E9
	GAP_4(2)	20.895	28533.052	.000	1	.999	1.187E9
	GAP_4(3)	21.206	28533.052	.000	1	.999	1.620E9
	GAP_4(4)	21.899	28533.052	.000	1	.999	3.240E9
	GAP_4(5)	21.429	28533.052	.000	1	.999	2.025E9
	GAP_4(6)	22.576	28533.052	.000	1	.999	6.379E9
	GAP_4(7)	42.409	34899.910	.000	1	.999	2.617E18
	GAP_4(8)	21.206	28533.052	.000	1	.999	1.620E9
	GAP_4(9)	22.304	28533.052	.000	1	.999	4.860E9
	GAP_4(10)	42.409	30801.915	.000	1	.999	2.617E18
	GAP_4(11)	20.107	28533.052	.000	1	.999	5.400E8
	GAP_4(12)	19.414	28533.052	.000	1	.999	2.700E8
	GAP_4(13)	.003	49291.073	.000	1	1.000	1.003
	GAP_4(14)	42.409	40272.478	.000	1	.999	2.617E18
	GAP_4(15)	22.304	28533.052	.000	1	.999	4.860E9
	GAP_4(16)	21.899	28533.052	.000	1	.999	3.240E9
	GAP_4(17)	42.409	30633.353	.000	1	.999	2.617E18
	GAP_4(18)	19.008	28533.052	.000	1	.999	1.800E8
	GAP_4(19)	42.409	40272.478	.000	1	.999	2.617E18
	GAP_4(20)	21.928	28533.052	.000	1	.999	3.335E9

a. Variable(s) entered on step 1: GAP_4.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	GAP_4(21)	21.962	28533.052	.000	1	.999	3.451E9
	GAP_4(22)	21.453	28533.052	.000	1	.999	2.074E9
	GAP_4(23)	42.409	40272.478	.000	1	.999	2.617E18
	GAP_4(24)	19.619	28533.052	.000	1	.999	3.314E8
	GAP_4(25)	19.934	28533.052	.000	1	.999	4.544E8
	GAP_4(26)	20.107	28533.052	.000	1	.999	5.400E8
	GAP_4(27)	19.819	28533.052	.000	1	.999	4.050E8
	GAP_4(28)	42.409	36778.073	.000	1	.999	2.617E18
	GAP_4(29)	19.414	28533.052	.000	1	.999	2.700E8
	GAP_4(30)	20.356	28533.052	.000	1	.999	6.924E8
	GAP_4(31)	20.107	28533.052	.000	1	.999	5.400E8
	GAP_4(32)	19.414	28533.052	.000	1	.999	2.700E8
	GAP_4(33)	20.395	28533.052	.000	1	.999	7.200E8
	GAP_4(34)	22.529	28533.052	.000	1	.999	6.086E9
	GAP_4(35)	21.023	28533.052	.000	1	.999	1.350E9
	Constant	-21.206	28533.052	.000	1	.999	.000

a. Variable(s) entered on step 1: GAP_4.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 2[b]	TRI480	.000	.000	20.419	1	.000	1.000
	GAP_4			213.860	35	.000	
	GAP_4(1)	21.844	28402.674	.000	1	.999	3.067E9
	GAP_4(2)	21.040	28402.674	.000	1	.999	1.373E9
	GAP_4(3)	21.127	28402.674	.000	1	.999	1.498E9
	GAP_4(4)	22.019	28402.674	.000	1	.999	3.653E9
	GAP_4(5)	21.616	28402.674	.000	1	.999	2.441E9
	GAP_4(6)	22.540	28402.674	.000	1	.999	6.154E9
	GAP_4(7)	42.332	34793.135	.000	1	.999	2.424E18
	GAP_4(8)	21.352	28402.674	.000	1	.999	1.875E9
	GAP_4(9)	22.277	28402.674	.000	1	.999	4.730E9
	GAP_4(10)	42.322	30681.180	.000	1	.999	2.400E18
	GAP_4(11)	20.547	28402.674	.000	1	.999	8.383E8
	GAP_4(12)	19.583	28402.674	.000	1	.999	3.197E8
	GAP_4(13)	.065	49215.716	.000	1	1.000	1.068
	GAP_4(14)	42.399	40171.974	.000	1	.999	2.593E18
	GAP_4(15)	22.219	28402.674	.000	1	.999	4.461E9
	GAP_4(16)	21.857	28402.674	.000	1	.999	3.107E9
	GAP_4(17)	42.322	30511.951	.000	1	.999	2.400E18
	GAP_4(18)	19.088	28402.674	.000	1	.999	1.948E8
	GAP_4(19)	42.322	40180.210	.000	1	.999	2.399E18
	GAP_4(20)	21.907	28402.674	.000	1	.999	3.267E9
	GAP_4(21)	21.900	28402.674	.000	1	.999	3.245E9
	GAP_4(22)	21.539	28402.674	.000	1	.999	2.260E9
	GAP_4(23)	42.332	40180.175	.000	1	.999	2.423E18
	GAP_4(24)	19.900	28402.674	.000	1	.999	4.389E8
	GAP_4(25)	20.419	28402.674	.000	1	.999	7.373E8
	GAP_4(26)	20.261	28402.674	.000	1	.999	6.301E8
	GAP_4(27)	19.962	28402.674	.000	1	.999	4.670E8
	GAP_4(28)	42.337	36676.628	.000	1	.999	2.435E18
	GAP_4(29)	19.681	28402.674	.000	1	.999	3.528E8
	GAP_4(30)	20.529	28402.674	.000	1	.999	8.230E8
	GAP_4(31)	20.270	28402.674	.000	1	.999	6.354E8
	GAP_4(32)	19.486	28402.674	.000	1	.999	2.902E8
	GAP_4(33)	20.381	28402.674	.000	1	.999	7.102E8
	GAP_4(34)	22.459	28402.674	.000	1	.999	5.675E9
	GAP_4(35)	21.051	28402.674	.000	1	.999	1.387E9
	Constant	-21.118	28402.674	.000	1	.999	.000

a. Variable(s) entered on step 1: GAP_4.

b. Variable(s) entered on step 2: TRI480.

Model if Term Removed

Variable		Model Log Likelihood	Change in -2 Log Likelihood	df	Sig. of the Change
Step 1	GAP_4	-1145.521	456.703	35	.000
Step 2	TRI480	-917.170	26.096	1	.000
	GAP_4	-1055.662	303.081	35	.000

Variables not in the Equation

			Score	df	Sig.
Step 1	Variables	TRI480	21.763	1	.000
		Overall Statistics	21.763	1	.000

```
COMPUTE chgdev=SRE_1 ** 2.
EXECUTE.
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=PRE_1 chgdev MISSING=LISTWISE R
EPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: PRE_1=col(source(s), name("PRE_1"))
  DATA: chgdev=col(source(s), name("chgdev"))
  GUIDE: axis(dim(1), label("Predicted probability"))
  GUIDE: axis(dim(2), label("chgdev"))
  ELEMENT: point(position(PRE_1*chgdev))
END GPL.
```

GGraph

Notes

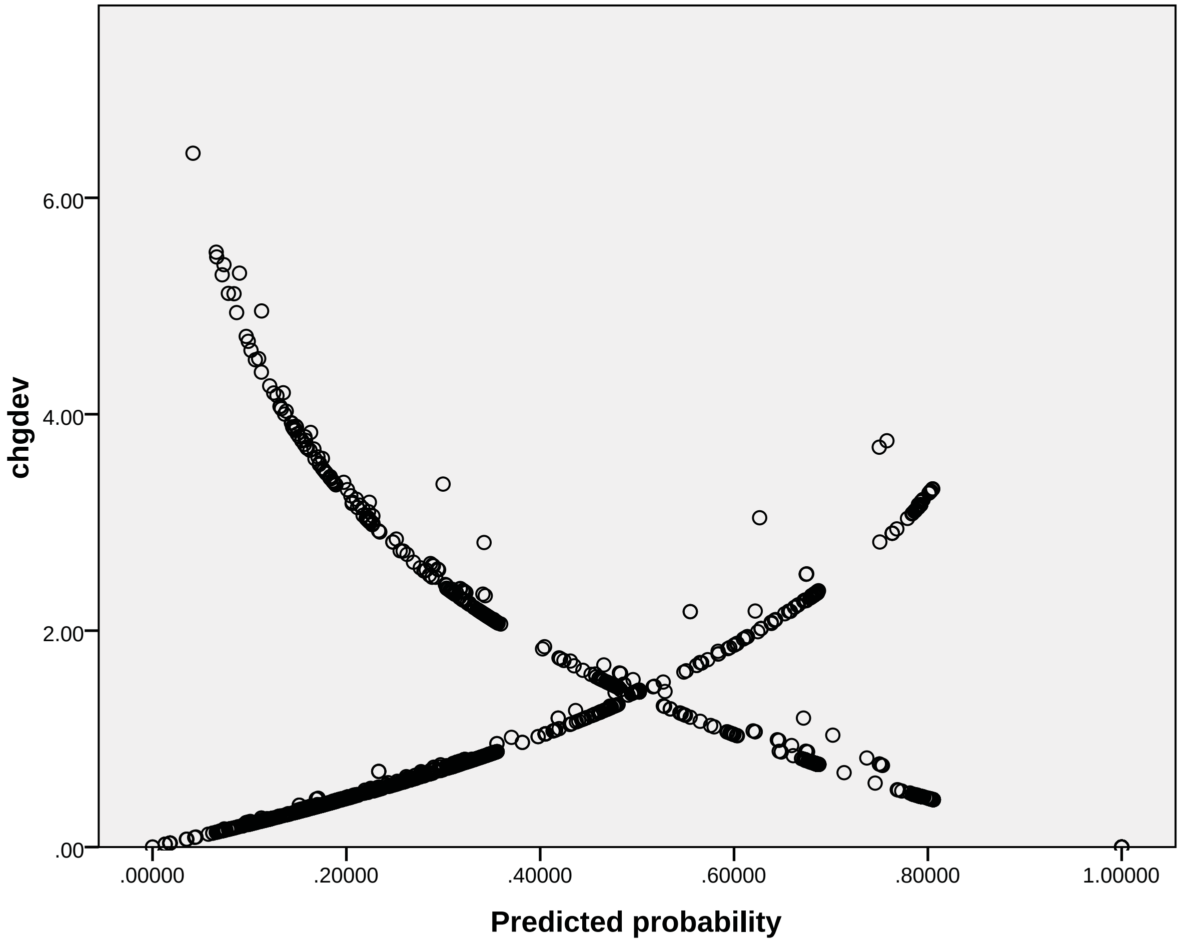
	Output Created	02-Jun-2010 17:52:24
	Comments	
Input	Data	C:\Documents and Settings\tperry\My Documents\My Dropbox\Cougar\NMDGFhabitatmodel\Data2010\modeldata2b.sav
	Active Dataset	DataSet1
	Filter	Model_ID > 4000 & Class ne 'PC' (FILTER)
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	2397

Notes

	Syntax	GGRAPH
		  /GRAPHDATASET NAME="graphdataset" VARIABLES=PRE_1 chgdev MISSING=LISTWISE REPORTMISSING=NO
		  /GRAPHSPEC SOURCE=INLINE.
		BEGIN GPL
		  SOURCE: s=userSource(id("graphdataset"))
		  DATA: PRE_1=col(source(s), name("PRE_1"))
		  DATA: chgdev=col(source(s), name("chgdev"))
		  GUIDE: axis(dim(1), label("Predicted probability"))
		  GUIDE: axis(dim(2), label("chgdev"))
		  ELEMENT: point(position(PRE_1*chgdev))
		END GPL.

Resources	Processor Time	0:00:00.266
	Elapsed Time	0:00:00.281

```
[DataSet1] C:\Documents and Settings\tperry\My Documents\My Dropbox\Cougar\NM
DGFhabitatmodel\Data2010\modeldata2b.sav
```



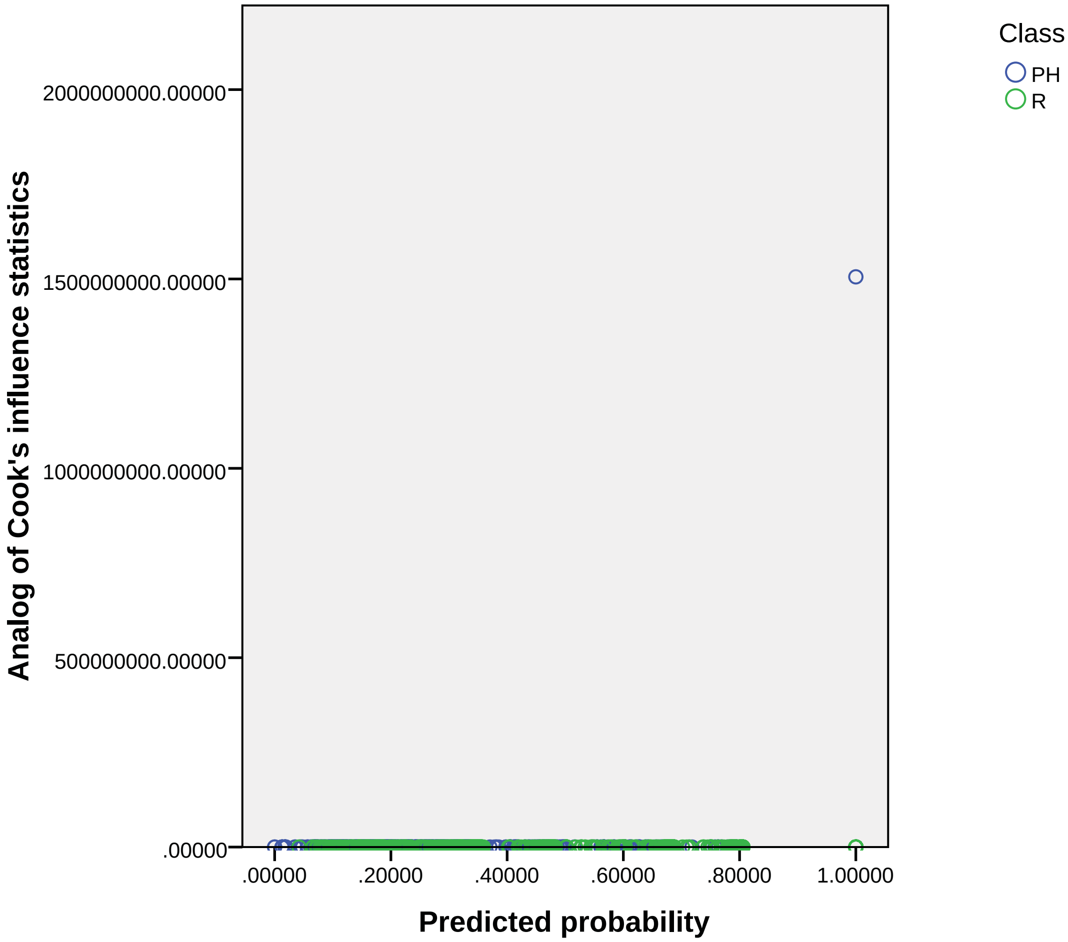

```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=PRE_1 COO_1 Class MISSING=LISTW
ISE REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: PRE_1=col(source(s), name("PRE_1"))
  DATA: COO_1=col(source(s), name("COO_1"))
  DATA: Class=col(source(s), name("Class"), unit.category())
  GUIDE: axis(dim(1), label("Predicted probability"))
  GUIDE: axis(dim(2), label("Analog of Cook's influence statistics"))
  GUIDE: legend(aesthetic(aesthetic.color.exterior), label("Class"))
  ELEMENT: point(position(PRE_1*COO_1), color.exterior(Class))
END GPL.
```

GGraph

Notes

	Output Created	02-Jun-2010 17:54:44
	Comments	
Input	Data	C:\Documents and Settings\tperry\My Documents\My Dropbox\Cougar\NMDGFhabitatmodel\Data2010\modeldata2b.sav
	Active Dataset	DataSet1
	Filter	Model_ID > 4000 & Class ne 'PC' (FILTER)
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	2397
	Syntax	GGRAPH /GRAPHDATASET NAME="graphdataset" VARIABLES=PRE_1 COO_1 Class MISSING=LISTWISE REPORTMISSING=NO /GRAPHSPEC SOURCE=INLINE. BEGIN GPL SOURCE: s=userSource(id("graphdataset")) DATA: PRE_1=col(source(s), name("PRE_1")) DATA: COO_1=col(source(s), name("COO_1")) DATA: Class=col(source(s), name("Class"), unit.category()) GUIDE: axis(dim(1), label("Predicted probability")) GUIDE: axis(dim(2), label("Analog of Cook's influence statistics")) GUIDE: legend(aesthetic(aesthetic.color.exterior), label("Class")) ELEMENT: point(position(PRE_1*COO_1), color.exterior(Class)) END GPL.
Resources	Processor Time	0:00:00.312
	Elapsed Time	0:00:00.296

```
[DataSet1] C:\Documents and Settings\tperry\My Documents\My Dropbox\Cougar\NM
DGFhabitatmodel\Data2010\modeldata2b.sav
```




```
SORT CASES BY COO_1 (D).
USE ALL.
COMPUTE filter_$=(Model_ID > 4000 & Class ne 'PC' & COO_1 < 2.0).
VARIABLE LABEL filter_$ "Model_ID > 4000 & Class ne 'PC' & COO_1 < 2.0 (FILTE
R)".
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMAT filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.
LOGISTIC REGRESSION VARIABLES Class
  /SELECT=validate EQ 1
  /METHOD=FSTEP(LR) TRI480 GAP_4
  /CONTRAST (GAP_4)=Indicator
  /SAVE=PRED COOK SRESID
  /PRINT=GOODFIT
  /CRITERIA=PIN(0.05) POUT(0.10) ITERATE(20) CUT(0.5).
```

Logistic Regression

Notes

	Output Created	02-Jun-2010 17:57:31
	Comments	
Input	Data	C:\Documents and Settings\tperry\My Documents\My Dropbox\Cougar\NMDGFhabitatmodel\Data2010\modeldata2b.sav
	Active Dataset	DataSet1
	Filter	Model_ID > 4000 & Class ne 'PC' & COO_1 < 2.0 (FILTER)
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	2394
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing
	Syntax	LOGISTIC REGRESSION VARIABLES Class /SELECT=validate EQ 1 /METHOD=FSTEP(LR) TRI480 GAP_4 /CONTRAST (GAP_4)=Indicator /SAVE=PRED COOK SRESID /PRINT=GOODFIT /CRITERIA=PIN(0.05) POUT(0.10) ITERATE(20) CUT(0.5).
Resources	Processor Time	0:00:00.453
	Elapsed Time	0:00:00.452
Variables Created or Modified	PRE_2	Predicted probability
	COO_2	Analog of Cook's influence statistics
	SRE_2	Standard residual

```
[DataSet1] C:\Documents and Settings\tperry\My Documents\My Dropbox\Cougar\NM
DGFhabitatmodel\Data2010\modeldata2b.sav
```

Case Processing Summary

Unweighted Cases [a]		N	Percent
Selected Cases	Included in Analysis	1683	70.3
	Missing Cases	0	.0
	Total	1683	70.3
	Unselected Cases	711	29.7
	Total	2394	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
PH	0
R	1

Categorical Variables Codings

			Parameter coding					
		Frequency	(1)	(2)	(3)	(4)	(5)	(6)
GAP_4	1	51	1.000	.000	.000	.000	.000	.000
	2	175	.000	1.000	.000	.000	.000	.000
	3	26	.000	.000	1.000	.000	.000	.000
	4	3	.000	.000	.000	1.000	.000	.000
	5	9	.000	.000	.000	.000	1.000	.000
	7	79	.000	.000	.000	.000	.000	1.000
	8	4	.000	.000	.000	.000	.000	.000
	9	4	.000	.000	.000	.000	.000	.000
	10	4	.000	.000	.000	.000	.000	.000
	11	12	.000	.000	.000	.000	.000	.000
	12	16	.000	.000	.000	.000	.000	.000
	13	7	.000	.000	.000	.000	.000	.000
	15	2	.000	.000	.000	.000	.000	.000
	17	4	.000	.000	.000	.000	.000	.000
	18	9	.000	.000	.000	.000	.000	.000
	19	13	.000	.000	.000	.000	.000	.000
	20	10	.000	.000	.000	.000	.000	.000
	21	2	.000	.000	.000	.000	.000	.000
	22	52	.000	.000	.000	.000	.000	.000
	23	72	.000	.000	.000	.000	.000	.000
	25	57	.000	.000	.000	.000	.000	.000
	26	2	.000	.000	.000	.000	.000	.000
	29	53	.000	.000	.000	.000	.000	.000
	30	105	.000	.000	.000	.000	.000	.000
	32	24	.000	.000	.000	.000	.000	.000
	33	35	.000	.000	.000	.000	.000	.000
	35	3	.000	.000	.000	.000	.000	.000
	36	266	.000	.000	.000	.000	.000	.000
	37	344	.000	.000	.000	.000	.000	.000
	38	4	.000	.000	.000	.000	.000	.000
	42	21	.000	.000	.000	.000	.000	.000
	44	26	.000	.000	.000	.000	.000	.000
	45	176	.000	.000	.000	.000	.000	.000
	49	11	.000	.000	.000	.000	.000	.000
	50	2	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(7)	(8)	(9)	(10)	(11)	(12)	(13)
GAP_4	1	.000	.000	.000	.000	.000	.000	.000
	2	.000	.000	.000	.000	.000	.000	.000
	3	.000	.000	.000	.000	.000	.000	.000
	4	.000	.000	.000	.000	.000	.000	.000
	5	.000	.000	.000	.000	.000	.000	.000
	7	.000	.000	.000	.000	.000	.000	.000
	8	1.000	.000	.000	.000	.000	.000	.000
	9	.000	1.000	.000	.000	.000	.000	.000
	10	.000	.000	1.000	.000	.000	.000	.000
	11	.000	.000	.000	1.000	.000	.000	.000
	12	.000	.000	.000	.000	1.000	.000	.000
	13	.000	.000	.000	.000	.000	1.000	.000
	15	.000	.000	.000	.000	.000	.000	1.000
	17	.000	.000	.000	.000	.000	.000	.000
	18	.000	.000	.000	.000	.000	.000	.000
	19	.000	.000	.000	.000	.000	.000	.000
	20	.000	.000	.000	.000	.000	.000	.000
	21	.000	.000	.000	.000	.000	.000	.000
	22	.000	.000	.000	.000	.000	.000	.000
	23	.000	.000	.000	.000	.000	.000	.000
	25	.000	.000	.000	.000	.000	.000	.000
	26	.000	.000	.000	.000	.000	.000	.000
	29	.000	.000	.000	.000	.000	.000	.000
	30	.000	.000	.000	.000	.000	.000	.000
	32	.000	.000	.000	.000	.000	.000	.000
	33	.000	.000	.000	.000	.000	.000	.000
	35	.000	.000	.000	.000	.000	.000	.000
	36	.000	.000	.000	.000	.000	.000	.000
	37	.000	.000	.000	.000	.000	.000	.000
	38	.000	.000	.000	.000	.000	.000	.000
	42	.000	.000	.000	.000	.000	.000	.000
	44	.000	.000	.000	.000	.000	.000	.000
	45	.000	.000	.000	.000	.000	.000	.000
	49	.000	.000	.000	.000	.000	.000	.000
	50	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(14)	(15)	(16)	(17)	(18)	(19)	(20)
GAP_4	1	.000	.000	.000	.000	.000	.000	.000
	2	.000	.000	.000	.000	.000	.000	.000
	3	.000	.000	.000	.000	.000	.000	.000
	4	.000	.000	.000	.000	.000	.000	.000
	5	.000	.000	.000	.000	.000	.000	.000
	7	.000	.000	.000	.000	.000	.000	.000
	8	.000	.000	.000	.000	.000	.000	.000
	9	.000	.000	.000	.000	.000	.000	.000
	10	.000	.000	.000	.000	.000	.000	.000
	11	.000	.000	.000	.000	.000	.000	.000
	12	.000	.000	.000	.000	.000	.000	.000
	13	.000	.000	.000	.000	.000	.000	.000
	15	.000	.000	.000	.000	.000	.000	.000
	17	1.000	.000	.000	.000	.000	.000	.000
	18	.000	1.000	.000	.000	.000	.000	.000
	19	.000	.000	1.000	.000	.000	.000	.000
	20	.000	.000	.000	1.000	.000	.000	.000
	21	.000	.000	.000	.000	1.000	.000	.000
	22	.000	.000	.000	.000	.000	1.000	.000
	23	.000	.000	.000	.000	.000	.000	1.000
	25	.000	.000	.000	.000	.000	.000	.000
	26	.000	.000	.000	.000	.000	.000	.000
	29	.000	.000	.000	.000	.000	.000	.000
	30	.000	.000	.000	.000	.000	.000	.000
	32	.000	.000	.000	.000	.000	.000	.000
	33	.000	.000	.000	.000	.000	.000	.000
	35	.000	.000	.000	.000	.000	.000	.000
	36	.000	.000	.000	.000	.000	.000	.000
	37	.000	.000	.000	.000	.000	.000	.000
	38	.000	.000	.000	.000	.000	.000	.000
	42	.000	.000	.000	.000	.000	.000	.000
	44	.000	.000	.000	.000	.000	.000	.000
	45	.000	.000	.000	.000	.000	.000	.000
	49	.000	.000	.000	.000	.000	.000	.000
	50	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(21)	(22)	(23)	(24)	(25)	(26)	(27)
GAP_4	1	.000	.000	.000	.000	.000	.000	.000
	2	.000	.000	.000	.000	.000	.000	.000
	3	.000	.000	.000	.000	.000	.000	.000
	4	.000	.000	.000	.000	.000	.000	.000
	5	.000	.000	.000	.000	.000	.000	.000
	7	.000	.000	.000	.000	.000	.000	.000
	8	.000	.000	.000	.000	.000	.000	.000
	9	.000	.000	.000	.000	.000	.000	.000
	10	.000	.000	.000	.000	.000	.000	.000
	11	.000	.000	.000	.000	.000	.000	.000
	12	.000	.000	.000	.000	.000	.000	.000
	13	.000	.000	.000	.000	.000	.000	.000
	15	.000	.000	.000	.000	.000	.000	.000
	17	.000	.000	.000	.000	.000	.000	.000
	18	.000	.000	.000	.000	.000	.000	.000
	19	.000	.000	.000	.000	.000	.000	.000
	20	.000	.000	.000	.000	.000	.000	.000
	21	.000	.000	.000	.000	.000	.000	.000
	22	.000	.000	.000	.000	.000	.000	.000
	23	.000	.000	.000	.000	.000	.000	.000
	25	1.000	.000	.000	.000	.000	.000	.000
	26	.000	1.000	.000	.000	.000	.000	.000
	29	.000	.000	1.000	.000	.000	.000	.000
	30	.000	.000	.000	1.000	.000	.000	.000
	32	.000	.000	.000	.000	1.000	.000	.000
	33	.000	.000	.000	.000	.000	1.000	.000
	35	.000	.000	.000	.000	.000	.000	1.000
	36	.000	.000	.000	.000	.000	.000	.000
	37	.000	.000	.000	.000	.000	.000	.000
	38	.000	.000	.000	.000	.000	.000	.000
	42	.000	.000	.000	.000	.000	.000	.000
	44	.000	.000	.000	.000	.000	.000	.000
	45	.000	.000	.000	.000	.000	.000	.000
	49	.000	.000	.000	.000	.000	.000	.000
	50	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(28)	(29)	(30)	(31)	(32)	(33)	(34)
GAP_4	1	.000	.000	.000	.000	.000	.000	.000
	2	.000	.000	.000	.000	.000	.000	.000
	3	.000	.000	.000	.000	.000	.000	.000
	4	.000	.000	.000	.000	.000	.000	.000
	5	.000	.000	.000	.000	.000	.000	.000
	7	.000	.000	.000	.000	.000	.000	.000
	8	.000	.000	.000	.000	.000	.000	.000
	9	.000	.000	.000	.000	.000	.000	.000
	10	.000	.000	.000	.000	.000	.000	.000
	11	.000	.000	.000	.000	.000	.000	.000
	12	.000	.000	.000	.000	.000	.000	.000
	13	.000	.000	.000	.000	.000	.000	.000
	15	.000	.000	.000	.000	.000	.000	.000
	17	.000	.000	.000	.000	.000	.000	.000
	18	.000	.000	.000	.000	.000	.000	.000
	19	.000	.000	.000	.000	.000	.000	.000
	20	.000	.000	.000	.000	.000	.000	.000
	21	.000	.000	.000	.000	.000	.000	.000
	22	.000	.000	.000	.000	.000	.000	.000
	23	.000	.000	.000	.000	.000	.000	.000
	25	.000	.000	.000	.000	.000	.000	.000
	26	.000	.000	.000	.000	.000	.000	.000
	29	.000	.000	.000	.000	.000	.000	.000
	30	.000	.000	.000	.000	.000	.000	.000
	32	.000	.000	.000	.000	.000	.000	.000
	33	.000	.000	.000	.000	.000	.000	.000
	35	.000	.000	.000	.000	.000	.000	.000
	36	1.000	.000	.000	.000	.000	.000	.000
	37	.000	1.000	.000	.000	.000	.000	.000
	38	.000	.000	1.000	.000	.000	.000	.000
	42	.000	.000	.000	1.000	.000	.000	.000
	44	.000	.000	.000	.000	1.000	.000	.000
	45	.000	.000	.000	.000	.000	1.000	.000
	49	.000	.000	.000	.000	.000	.000	1.000
	50	.000	.000	.000	.000	.000	.000	.000

Block 0: Beginning Block

Classification Table[c,d]

Observed			Predicted: Selected Cases[a] Class PH	Predicted: Selected Cases[a] Class R	Predicted: Selected Cases[a] Percentage Correct	Predicted: Unselected Cases[b] Class PH
Step 0	Class	PH	976	0	100.0	419
		R	707	0	.0	292
		Overall Percentage			58.0	

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. Constant is included in the model.

d. The cut value is .500

Classification Table[c,d]

Observed			Predicted: Unselected Cases[b] Class R	Predicted: Unselected Cases[b] Percentage Correct
Step 0	Class	PH	0	100.0
		R	0	.0
		Overall Percentage		58.9

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. Constant is included in the model.

d. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	-.322	.049	42.625	1	.000	.724

Variables not in the Equation[a]

			Score	df	Sig.
Step 0	Variables	TRI480	128.660	1	.000
		GAP_4	420.133	34	.000
		GAP_4(1)	13.127	1	.000
		GAP_4(2)	.006	1	.937
		GAP_4(3)	.692	1	.405
		GAP_4(4)	.750	1	.386
		GAP_4(5)	.682	1	.409

a. Residual Chi-Squares are not computed because of redundancies.

Variables not in the Equation[a]

			Score	df	Sig.
Step 0	Variables	GAP_4(6)	48.459	1	.000
		GAP_4(7)	5.535	1	.019
		GAP_4(8)	.105	1	.746
		GAP_4(9)	1.791	1	.181
		GAP_4(10)	16.685	1	.000
		GAP_4(11)	1.918	1	.166
		GAP_4(12)	2.218	1	.136
		GAP_4(13)	2.764	1	.096
		GAP_4(14)	1.791	1	.181
		GAP_4(15)	2.258	1	.133
		GAP_4(16)	18.086	1	.000
		GAP_4(17)	4.231	1	.040
		GAP_4(18)	2.764	1	.096
		GAP_4(19)	14.098	1	.000
		GAP_4(20)	20.948	1	.000
		GAP_4(21)	4.837	1	.028
		GAP_4(22)	2.764	1	.096
		GAP_4(23)	14.070	1	.000
		GAP_4(24)	18.579	1	.000
		GAP_4(25)	2.891	1	.089
		GAP_4(26)	7.107	1	.008
		GAP_4(27)	4.149	1	.042
		GAP_4(28)	99.670	1	.000
		GAP_4(29)	25.842	1	.000
		GAP_4(30)	.476	1	.490
		GAP_4(31)	6.709	1	.010
		GAP_4(32)	1.369	1	.242
		GAP_4(33)	110.270	1	.000
		GAP_4(34)	.054	1	.816

a. Residual Chi-Squares are not computed because of redundancies.

Block 1: Method = Forward Stepwise (Likelihood Ratio)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	455.614	34	.000
	Block	455.614	34	.000

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Model	455.614	34	.000
Step 2	Step	26.096	1	.000
	Block	481.710	35	.000
	Model	481.710	35	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	1834.339 [a]	.237	.319
2	1808.244 [a]	.249	.335

a. Estimation terminated at iteration number 20 because maximum iterations has been reached. Final solution cannot be found.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	.000	8	1.000
2	20.939	8	.007

Contingency Table for Hosmer and Lemeshow Test

		Class = PH		Class = R		
		Observed	Expected	Observed	Expected	Total
Step 1	1	35	35.000	5	5.000	40
	2	228	228.000	38	38.000	266
	3	154	154.000	39	39.000	193
	4	33	33.000	11	11.000	44
	5	241	241.000	103	103.000	344
	6	119	119.000	82	82.000	201
	7	71	71.000	99	99.000	170
	8	42	42.000	90	90.000	132
	9	37	37.000	139	139.000	176
	10	16	16.000	101	101.000	117
Step 2	1	143	151.457	25	16.543	168
	2	143	142.709	27	27.291	170
	3	137	135.459	31	32.541	168
	4	137	123.632	31	44.368	168
	5	115	112.883	53	55.117	168
	6	111	103.671	57	64.329	168
	7	68	83.546	100	84.454	168
	8	62	56.473	106	111.527	168
	9	41	39.734	127	128.266	168
	10	19	26.437	150	142.563	169

Classification Table[c]

Observed			Predicted: Selected Cases[a] Class PH	Selected Cases[a] Class R	Selected Cases[a] Percentage Correct	Unselected Cases[b] Class PH
Step 1	Class	PH	816	160	83.6	350
		R	283	424	60.0	119
		Overall Percentage			73.7	
Step 2	Class	PH	829	147	84.9	358
		R	288	419	59.3	120
		Overall Percentage			74.2	

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. The cut value is .500

Classification Table[c]

Observed			Predicted: Unselected Cases[b] Class R	Unselected Cases[b] Percentage Correct
Step 1	Class	PH	69	83.5
		R	173	59.2
		Overall Percentage		73.6
Step 2	Class	PH	61	85.4
		R	172	58.9
		Overall Percentage		74.5

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	GAP_4			311.527	34	.000	
	GAP_4(1)	21.899	28538.768	.000	1	.999	3.241E9
	GAP_4(2)	20.895	28538.768	.000	1	.999	1.187E9
	GAP_4(3)	21.206	28538.768	.000	1	.999	1.620E9
	GAP_4(4)	21.899	28538.768	.000	1	.999	3.241E9
	GAP_4(5)	21.429	28538.768	.000	1	.999	2.026E9

a. Variable(s) entered on step 1: GAP_4.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	GAP_4(6)	22.577	28538.768	.000	1	.999	6.381E9
	GAP_4(7)	42.409	34904.585	.000	1	.999	2.618E18
	GAP_4(8)	21.206	28538.768	.000	1	.999	1.620E9
	GAP_4(9)	22.305	28538.768	.000	1	.999	4.861E9
	GAP_4(10)	42.409	30807.210	.000	1	.999	2.618E18
	GAP_4(11)	20.107	28538.768	.000	1	.999	5.402E8
	GAP_4(12)	19.414	28538.768	.000	1	.999	2.701E8
	GAP_4(13)	42.409	40276.528	.000	1	.999	2.618E18
	GAP_4(14)	22.305	28538.768	.000	1	.999	4.861E9
	GAP_4(15)	21.899	28538.768	.000	1	.999	3.241E9
	GAP_4(16)	42.409	30638.678	.000	1	.999	2.618E18
	GAP_4(17)	19.009	28538.768	.000	1	.999	1.801E8
	GAP_4(18)	42.409	40276.528	.000	1	.999	2.618E18
	GAP_4(19)	21.928	28538.768	.000	1	.999	3.336E9
	GAP_4(20)	21.962	28538.768	.000	1	.999	3.452E9
	GAP_4(21)	21.453	28538.768	.000	1	.999	2.074E9
	GAP_4(22)	42.409	40276.528	.000	1	.999	2.618E18
	GAP_4(23)	19.619	28538.768	.000	1	.999	3.315E8
	GAP_4(24)	19.935	28538.768	.000	1	.999	4.545E8
	GAP_4(25)	20.107	28538.768	.000	1	.999	5.402E8
	GAP_4(26)	19.820	28538.768	.000	1	.999	4.051E8
	GAP_4(27)	42.409	36782.508	.000	1	.999	2.618E18
	GAP_4(28)	19.414	28538.768	.000	1	.999	2.701E8
	GAP_4(29)	20.356	28538.768	.000	1	.999	6.926E8
	GAP_4(30)	20.107	28538.768	.000	1	.999	5.402E8
	GAP_4(31)	19.414	28538.768	.000	1	.999	2.701E8
	GAP_4(32)	20.395	28538.768	.000	1	.999	7.202E8
	GAP_4(33)	22.530	28538.768	.000	1	.999	6.088E9
	GAP_4(34)	21.024	28538.768	.000	1	.999	1.350E9
	Constant	-21.206	28538.768	.000	1	.999	.000

a. Variable(s) entered on step 1: GAP_4.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 2[b]	TRI480	.000	.000	20.419	1	.000	1.000
	GAP_4			213.861	34	.000	
	GAP_4(1)	21.844	28397.882	.000	1	.999	3.066E9
	GAP_4(2)	21.040	28397.882	.000	1	.999	1.373E9
	GAP_4(3)	21.127	28397.882	.000	1	.999	1.497E9
	GAP_4(4)	22.019	28397.882	.000	1	.999	3.653E9
	GAP_4(5)	21.616	28397.882	.000	1	.999	2.441E9
	GAP_4(6)	22.540	28397.882	.000	1	.999	6.153E9
	GAP_4(7)	42.332	34789.224	.000	1	.999	2.423E18
	GAP_4(8)	21.352	28397.882	.000	1	.999	1.875E9
	GAP_4(9)	22.277	28397.882	.000	1	.999	4.729E9
	GAP_4(10)	42.322	30676.744	.000	1	.999	2.400E18
	GAP_4(11)	20.547	28397.882	.000	1	.999	8.381E8
	GAP_4(12)	19.583	28397.882	.000	1	.999	3.196E8
	GAP_4(13)	42.399	40168.587	.000	1	.999	2.592E18
	GAP_4(14)	22.218	28397.882	.000	1	.999	4.460E9
	GAP_4(15)	21.857	28397.882	.000	1	.999	3.107E9
	GAP_4(16)	42.322	30507.491	.000	1	.999	2.400E18
	GAP_4(17)	19.088	28397.882	.000	1	.999	1.948E8
	GAP_4(18)	42.321	40176.823	.000	1	.999	2.399E18
	GAP_4(19)	21.907	28397.882	.000	1	.999	3.267E9
	GAP_4(20)	21.900	28397.882	.000	1	.999	3.245E9
	GAP_4(21)	21.538	28397.882	.000	1	.999	2.260E9
	GAP_4(22)	42.331	40176.788	.000	1	.999	2.423E18
	GAP_4(23)	19.900	28397.882	.000	1	.999	4.388E8
	GAP_4(24)	20.418	28397.882	.000	1	.999	7.372E8
	GAP_4(25)	20.261	28397.882	.000	1	.999	6.300E8
	GAP_4(26)	19.962	28397.882	.000	1	.999	4.669E8
	GAP_4(27)	42.336	36672.918	.000	1	.999	2.435E18
	GAP_4(28)	19.681	28397.882	.000	1	.999	3.528E8
	GAP_4(29)	20.528	28397.882	.000	1	.999	8.229E8
	GAP_4(30)	20.270	28397.882	.000	1	.999	6.353E8
	GAP_4(31)	19.486	28397.882	.000	1	.999	2.902E8
	GAP_4(32)	20.381	28397.882	.000	1	.999	7.101E8
	GAP_4(33)	22.459	28397.882	.000	1	.999	5.674E9
	GAP_4(34)	21.050	28397.882	.000	1	.999	1.387E9
	Constant	-21.118	28397.882	.000	1	.999	.000

a. Variable(s) entered on step 1: GAP_4.

b. Variable(s) entered on step 2: TRI480.

Model if Term Removed

Variable		Model Log Likelihood	Change in -2 Log Likelihood	df	Sig. of the Change
Step 1	GAP_4	-1144.977	455.614	34	.000
Step 2	TRI480	-917.170	26.096	1	.000
	GAP_4	-1055.070	301.897	34	.000

Variables not in the Equation

			Score	df	Sig.
Step 1	Variables	TRI480	21.763	1	.000
		Overall Statistics	21.763	1	.000

APPENDIX III

SPSS Collar Model Binary Logistic Regression Output

```
LOGISTIC REGRESSION VARIABLES Class
  /SELECT=validate EQ 1
  /METHOD=FSTEP(LR) TRI480 GAP_4
  /CONTRAST (GAP_4)=Indicator
  /SAVE=PRED COOK SRESID
  /PRINT=GOODFIT
  /CRITERIA=PIN(0.05) POUT(0.10) ITERATE(20) CUT(0.5).
```

Logistic Regression

Notes

	Output Created	02-Jun-2010 17:32:46
	Comments	
Input	Data	C:\Documents and Settings\tperry\My Documents\My Dropbox\Cougar\NMDGFhabitatmodel\Data2010\modeldata2b.sav
	Active Dataset	DataSet1
	Filter	Model_ID > 4000 & Class ne 'PH' & COO_1 < 2.0 (FILTER)
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11076
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing
	Syntax	LOGISTIC REGRESSION VARIABLES Class /SELECT=validate EQ 1 /METHOD=FSTEP(LR) TRI480 GAP_4 /CONTRAST (GAP_4)=Indicator /SAVE=PRED COOK SRESID /PRINT=GOODFIT /CRITERIA=PIN(0.05) POUT(0.10) ITERATE(20) CUT(0.5).
Resources	Processor Time	0:00:01.578
	Elapsed Time	0:00:01.578
Variables Created or Modified	PRE_1	Predicted probability
	COO_1	Analog of Cook's influence statistics
	SRE_1	Standard residual

```
[DataSet1] C:\Documents and Settings\tperry\My Documents\My Dropbox\Cougar\NM
DGFhabitatmodel\Data2010\modeldata2b.sav
```

Case Processing Summary

Unweighted Cases [a]		N	Percent
Selected Cases	Included in Analysis	7684	69.4
	Missing Cases	0	.0
	Total	7684	69.4
	Unselected Cases	3392	30.6
	Total	11076	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
PC	0
R	1

Categorical Variables Codings

			Parameter coding					
		Frequency	(1)	(2)	(3)	(4)	(5)	(6)
GAP_4	1	274	1.000	.000	.000	.000	.000	.000
	2	2476	.000	1.000	.000	.000	.000	.000
	3	29	.000	.000	1.000	.000	.000	.000
	4	2	.000	.000	.000	1.000	.000	.000
	5	5	.000	.000	.000	.000	1.000	.000
	7	308	.000	.000	.000	.000	.000	1.000
	8	23	.000	.000	.000	.000	.000	.000
	9	2	.000	.000	.000	.000	.000	.000
	10	3	.000	.000	.000	.000	.000	.000
	11	16	.000	.000	.000	.000	.000	.000
	12	315	.000	.000	.000	.000	.000	.000
	13	206	.000	.000	.000	.000	.000	.000
	15	11	.000	.000	.000	.000	.000	.000
	17	8	.000	.000	.000	.000	.000	.000
	18	6	.000	.000	.000	.000	.000	.000
	19	13	.000	.000	.000	.000	.000	.000
	21	2	.000	.000	.000	.000	.000	.000
	22	191	.000	.000	.000	.000	.000	.000
	23	75	.000	.000	.000	.000	.000	.000
	25	31	.000	.000	.000	.000	.000	.000
	26	2	.000	.000	.000	.000	.000	.000
	29	67	.000	.000	.000	.000	.000	.000
	30	39	.000	.000	.000	.000	.000	.000
	32	5	.000	.000	.000	.000	.000	.000
	33	6	.000	.000	.000	.000	.000	.000
	35	3	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(7)	(8)	(9)	(10)	(11)	(12)	(13)
GAP_4	1	.000	.000	.000	.000	.000	.000	.000
	2	.000	.000	.000	.000	.000	.000	.000
	3	.000	.000	.000	.000	.000	.000	.000
	4	.000	.000	.000	.000	.000	.000	.000
	5	.000	.000	.000	.000	.000	.000	.000
	7	.000	.000	.000	.000	.000	.000	.000
	8	1.000	.000	.000	.000	.000	.000	.000
	9	.000	1.000	.000	.000	.000	.000	.000
	10	.000	.000	1.000	.000	.000	.000	.000
	11	.000	.000	.000	1.000	.000	.000	.000
	12	.000	.000	.000	.000	1.000	.000	.000
	13	.000	.000	.000	.000	.000	1.000	.000
	15	.000	.000	.000	.000	.000	.000	1.000
	17	.000	.000	.000	.000	.000	.000	.000
	18	.000	.000	.000	.000	.000	.000	.000
	19	.000	.000	.000	.000	.000	.000	.000
	21	.000	.000	.000	.000	.000	.000	.000
	22	.000	.000	.000	.000	.000	.000	.000
	23	.000	.000	.000	.000	.000	.000	.000
	25	.000	.000	.000	.000	.000	.000	.000
	26	.000	.000	.000	.000	.000	.000	.000
	29	.000	.000	.000	.000	.000	.000	.000
	30	.000	.000	.000	.000	.000	.000	.000
	32	.000	.000	.000	.000	.000	.000	.000
	33	.000	.000	.000	.000	.000	.000	.000
	35	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(14)	(15)	(16)	(17)	(18)	(19)	(20)
GAP_4	1	.000	.000	.000	.000	.000	.000	.000
	2	.000	.000	.000	.000	.000	.000	.000
	3	.000	.000	.000	.000	.000	.000	.000
	4	.000	.000	.000	.000	.000	.000	.000
	5	.000	.000	.000	.000	.000	.000	.000
	7	.000	.000	.000	.000	.000	.000	.000
	8	.000	.000	.000	.000	.000	.000	.000
	9	.000	.000	.000	.000	.000	.000	.000
	10	.000	.000	.000	.000	.000	.000	.000
	11	.000	.000	.000	.000	.000	.000	.000
	12	.000	.000	.000	.000	.000	.000	.000
	13	.000	.000	.000	.000	.000	.000	.000
	15	.000	.000	.000	.000	.000	.000	.000
	17	1.000	.000	.000	.000	.000	.000	.000
	18	.000	1.000	.000	.000	.000	.000	.000
	19	.000	.000	1.000	.000	.000	.000	.000
	21	.000	.000	.000	1.000	.000	.000	.000
	22	.000	.000	.000	.000	1.000	.000	.000
	23	.000	.000	.000	.000	.000	1.000	.000
	25	.000	.000	.000	.000	.000	.000	1.000
	26	.000	.000	.000	.000	.000	.000	.000
	29	.000	.000	.000	.000	.000	.000	.000
	30	.000	.000	.000	.000	.000	.000	.000
	32	.000	.000	.000	.000	.000	.000	.000
	33	.000	.000	.000	.000	.000	.000	.000
	35	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(21)	(22)	(23)	(24)	(25)	(26)	(27)
GAP_4	1	.000	.000	.000	.000	.000	.000	.000
	2	.000	.000	.000	.000	.000	.000	.000
	3	.000	.000	.000	.000	.000	.000	.000
	4	.000	.000	.000	.000	.000	.000	.000
	5	.000	.000	.000	.000	.000	.000	.000
	7	.000	.000	.000	.000	.000	.000	.000
	8	.000	.000	.000	.000	.000	.000	.000
	9	.000	.000	.000	.000	.000	.000	.000
	10	.000	.000	.000	.000	.000	.000	.000
	11	.000	.000	.000	.000	.000	.000	.000
	12	.000	.000	.000	.000	.000	.000	.000
	13	.000	.000	.000	.000	.000	.000	.000
	15	.000	.000	.000	.000	.000	.000	.000
	17	.000	.000	.000	.000	.000	.000	.000
	18	.000	.000	.000	.000	.000	.000	.000
	19	.000	.000	.000	.000	.000	.000	.000
	21	.000	.000	.000	.000	.000	.000	.000
	22	.000	.000	.000	.000	.000	.000	.000
	23	.000	.000	.000	.000	.000	.000	.000
	25	.000	.000	.000	.000	.000	.000	.000
	26	1.000	.000	.000	.000	.000	.000	.000
	29	.000	1.000	.000	.000	.000	.000	.000
	30	.000	.000	1.000	.000	.000	.000	.000
	32	.000	.000	.000	1.000	.000	.000	.000
	33	.000	.000	.000	.000	1.000	.000	.000
	35	.000	.000	.000	.000	.000	1.000	.000

Categorical Variables Codings

		Parameter coding						
		(28)	(29)	(30)	(31)	(32)	(33)	(34)
GAP_4	1	.000	.000	.000	.000	.000	.000	.000
	2	.000	.000	.000	.000	.000	.000	.000
	3	.000	.000	.000	.000	.000	.000	.000
	4	.000	.000	.000	.000	.000	.000	.000
	5	.000	.000	.000	.000	.000	.000	.000
	7	.000	.000	.000	.000	.000	.000	.000
	8	.000	.000	.000	.000	.000	.000	.000
	9	.000	.000	.000	.000	.000	.000	.000
	10	.000	.000	.000	.000	.000	.000	.000
	11	.000	.000	.000	.000	.000	.000	.000
	12	.000	.000	.000	.000	.000	.000	.000
	13	.000	.000	.000	.000	.000	.000	.000
	15	.000	.000	.000	.000	.000	.000	.000
	17	.000	.000	.000	.000	.000	.000	.000
	18	.000	.000	.000	.000	.000	.000	.000
	19	.000	.000	.000	.000	.000	.000	.000
	21	.000	.000	.000	.000	.000	.000	.000
	22	.000	.000	.000	.000	.000	.000	.000
	23	.000	.000	.000	.000	.000	.000	.000
	25	.000	.000	.000	.000	.000	.000	.000
	26	.000	.000	.000	.000	.000	.000	.000
	29	.000	.000	.000	.000	.000	.000	.000
	30	.000	.000	.000	.000	.000	.000	.000
	32	.000	.000	.000	.000	.000	.000	.000
	33	.000	.000	.000	.000	.000	.000	.000
	35	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

			Parameter coding					
		Frequency	(1)	(2)	(3)	(4)	(5)	(6)
GAP_4	36	231	.000	.000	.000	.000	.000	.000
	37	1562	.000	.000	.000	.000	.000	.000
	38	9	.000	.000	.000	.000	.000	.000
	39	11	.000	.000	.000	.000	.000	.000
	42	1591	.000	.000	.000	.000	.000	.000
	44	8	.000	.000	.000	.000	.000	.000
	45	139	.000	.000	.000	.000	.000	.000
	49	5	.000	.000	.000	.000	.000	.000
	50	10	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(7)	(8)	(9)	(10)	(11)	(12)	(13)
GAP_4	36	.000	.000	.000	.000	.000	.000	.000
	37	.000	.000	.000	.000	.000	.000	.000
	38	.000	.000	.000	.000	.000	.000	.000
	39	.000	.000	.000	.000	.000	.000	.000
	42	.000	.000	.000	.000	.000	.000	.000
	44	.000	.000	.000	.000	.000	.000	.000
	45	.000	.000	.000	.000	.000	.000	.000
	49	.000	.000	.000	.000	.000	.000	.000
	50	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(14)	(15)	(16)	(17)	(18)	(19)	(20)
GAP_4	36	.000	.000	.000	.000	.000	.000	.000
	37	.000	.000	.000	.000	.000	.000	.000
	38	.000	.000	.000	.000	.000	.000	.000
	39	.000	.000	.000	.000	.000	.000	.000
	42	.000	.000	.000	.000	.000	.000	.000
	44	.000	.000	.000	.000	.000	.000	.000
	45	.000	.000	.000	.000	.000	.000	.000
	49	.000	.000	.000	.000	.000	.000	.000
	50	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(21)	(22)	(23)	(24)	(25)	(26)	(27)
GAP_4	36	.000	.000	.000	.000	.000	.000	1.000
	37	.000	.000	.000	.000	.000	.000	.000
	38	.000	.000	.000	.000	.000	.000	.000
	39	.000	.000	.000	.000	.000	.000	.000
	42	.000	.000	.000	.000	.000	.000	.000
	44	.000	.000	.000	.000	.000	.000	.000
	45	.000	.000	.000	.000	.000	.000	.000
	49	.000	.000	.000	.000	.000	.000	.000
	50	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(28)	(29)	(30)	(31)	(32)	(33)	(34)
GAP_4	36	.000	.000	.000	.000	.000	.000	.000
	37	1.000	.000	.000	.000	.000	.000	.000
	38	.000	1.000	.000	.000	.000	.000	.000
	39	.000	.000	1.000	.000	.000	.000	.000
	42	.000	.000	.000	1.000	.000	.000	.000
	44	.000	.000	.000	.000	1.000	.000	.000
	45	.000	.000	.000	.000	.000	1.000	.000
	49	.000	.000	.000	.000	.000	.000	1.000
	50	.000	.000	.000	.000	.000	.000	.000

Block 0: Beginning Block

Classification Table[d,e]

Observed			Predicted			
			Selected Cases [a]			Unselected Cases [b,,c]
			Class			Class
			PC	R	Percentage Correct	PC
Step 0	Class	PC	6983	0	100.0	3105
		R	701	0	.0	286
		Overall Percentage			90.9	

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. Some of the unselected cases are not classified due to either missing values in the independent variables or categorical variables with values out of the range of the selected cases.

d. Constant is included in the model.

e. The cut value is .500

Classification Table[d,e]

Observed			Predicted: Unselected Cases[b,,c] Class R	Percentage Correct
Step 0	Class	PC	0	100.0
		R	0	.0
		Overall Percentage		91.6

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. Some of the unselected cases are not classified due to either missing values in the independent variables or categorical variables with values out of the range of the selected cases.

d. Constant is included in the model.

e. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	-2.299	.040	3366.256	1	.000	.100

Variables not in the Equation[a]

			Score	df	Sig.
Step 0	Variables	TRI480	193.467	1	.000
		GAP_4	3249.293	34	.000
		GAP_4(1)	3.700	1	.054
		GAP_4(2)	165.803	1	.000
		GAP_4(3)	44.762	1	.000
		GAP_4(4)	19.928	1	.000
		GAP_4(5)	49.840	1	.000
		GAP_4(6)	49.696	1	.000
		GAP_4(7)	1.902	1	.168
		GAP_4(8)	19.928	1	.000
		GAP_4(9)	29.896	1	.000
		GAP_4(10)	83.928	1	.000
		GAP_4(11)	24.433	1	.000
		GAP_4(12)	19.048	1	.000
		GAP_4(13)	1.090	1	.296
		GAP_4(14)	7.778	1	.005
		GAP_4(15)	59.816	1	.000
		GAP_4(16)	129.719	1	.000
		GAP_4(17)	19.928	1	.000
		GAP_4(18)	20.004	1	.000

a. Residual Chi-Squares are not computed because of redundancies.

Variables not in the Equation[a]

			Score	df	Sig.
Step 0	Variables	GAP_4(19)	288.649	1	.000
		GAP_4(20)	310.057	1	.000
		GAP_4(21)	19.928	1	.000
		GAP_4(22)	.647	1	.421
		GAP_4(23)	105.726	1	.000
		GAP_4(24)	49.840	1	.000
		GAP_4(25)	59.816	1	.000
		GAP_4(26)	29.896	1	.000
		GAP_4(27)	15.423	1	.000
		GAP_4(28)	15.122	1	.000
		GAP_4(29)	.043	1	.836
		GAP_4(30)	1.106	1	.293
		GAP_4(31)	193.180	1	.000
		GAP_4(32)	79.775	1	.000
		GAP_4(33)	1410.155	1	.000
		GAP_4(34)	49.840	1	.000

a. Residual Chi-Squares are not computed because of redundancies.

Block 1: Method = Forward Stepwise (Likelihood Ratio)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	1957.578	34	.000
	Block	1957.578	34	.000
	Model	1957.578	34	.000
Step 2	Step	248.424	1	.000
	Block	2206.003	35	.000
	Model	2206.003	35	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	2735.363[a]	.225	.492
2	2486.939[a]	.250	.546

a. Estimation terminated at iteration number 20 because maximum iterations has been reached. Final solution cannot be found.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	.000	5	1.000
2	412.175	8	.000

Contingency Table for Hosmer and Lemeshow Test

		Class = PC		Class = R		
		Observed	Expected	Observed	Expected	Total
Step 1	1	21	21.000	0	.000	21
	2	1588	1588.000	3	3.000	1591
	3	516	516.000	5	5.000	521
	4	2402	2402.000	74	74.000	2476
	5	1459	1459.000	103	103.000	1562
	6	684	684.000	122	122.000	806
	7	313	313.000	394	394.000	707
Step 2	1	759	767.789	9	.211	768
	2	766	767.508	3	1.492	769
	3	766	766.038	2	1.962	768
	4	756	762.823	12	5.177	768
	5	760	753.635	7	13.365	767
	6	759	741.582	8	25.418	767
	7	753	729.472	15	38.528	768
	8	695	707.731	74	61.269	769
	9	637	646.101	131	121.899	768
	10	332	340.319	440	431.681	772

Classification Table[d]

Observed			Predicted			
			Selected Cases [a]			Unselected Cases [b,,c]
			Class			Class
			PC	R	Percentage Correct	PC
Step 1	Class	PC	6936	47	99.3	3091
		R	386	315	44.9	171
		Overall Percentage			94.4	
Step 2	Class	PC	6957	26	99.6	3098
		R	379	322	45.9	167
		Overall Percentage			94.7	

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. Some of the unselected cases are not classified due to either missing values in the independent variables or categorical variables with values out of the range of the selected cases.

d. The cut value is .500

Classification Table[d]

Observed			Predicted: Unselected Cases[b,,c] Class R	Percentage Correct
Step 1	Class	PC	14	99.5
		R	115	40.2
		Overall Percentage		94.5
Step 2	Class	PC	7	99.8
		R	119	41.6
		Overall Percentage		94.9

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. Some of the unselected cases are not classified due to either missing values in the independent variables or categorical variables with values out of the range of the selected cases.

d. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	GAP_4			537.205	34	.000	
	GAP_4(1)	19.249	12716.568	.000	1	.999	2.290E8
	GAP_4(2)	17.724	12716.568	.000	1	.999	4.980E7
	GAP_4(3)	20.996	12716.568	.000	1	.999	1.313E9
	GAP_4(4)	42.406	31135.968	.000	1	.999	2.611E18
	GAP_4(5)	42.406	22018.312	.000	1	.998	2.611E18
	GAP_4(6)	19.845	12716.568	.000	1	.999	4.157E8
	GAP_4(7)	19.645	12716.568	.000	1	.999	3.403E8
	GAP_4(8)	42.406	31135.968	.000	1	.999	2.611E18
	GAP_4(9)	42.406	26461.344	.000	1	.999	2.611E18
	GAP_4(10)	22.302	12716.568	.000	1	.999	4.849E9
	GAP_4(11)	16.850	12716.568	.000	1	.999	2.079E7
	GAP_4(12)	15.881	12716.568	.000	1	.999	7885299.240
	GAP_4(13)	19.699	12716.568	.000	1	.999	3.592E8
	GAP_4(14)	20.693	12716.568	.000	1	.999	9.699E8
	GAP_4(15)	42.406	20759.502	.000	1	.998	2.611E18
	GAP_4(16)	42.406	16910.896	.000	1	.998	2.611E18
	GAP_4(17)	42.406	31135.968	.000	1	.999	2.611E18
	GAP_4(18)	19.709	12716.568	.000	1	.999	3.627E8
	GAP_4(19)	21.837	12716.568	.000	1	.999	3.046E9
	GAP_4(20)	42.406	14622.694	.000	1	.998	2.611E18

a. Variable(s) entered on step 1: GAP_4.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	GAP_4(21)	42.406	31135.968	.000	1	.999	2.611E18
	GAP_4(22)	19.205	12716.568	.000	1	.999	2.192E8
	GAP_4(23)	21.461	12716.568	.000	1	.999	2.092E9
	GAP_4(24)	42.406	22018.312	.000	1	.998	2.611E18
	GAP_4(25)	42.406	20759.502	.000	1	.998	2.611E18
	GAP_4(26)	42.406	26461.344	.000	1	.999	2.611E18
	GAP_4(27)	19.578	12716.568	.000	1	.999	3.183E8
	GAP_4(28)	18.553	12716.568	.000	1	.999	1.141E8
	GAP_4(29)	19.124	12716.568	.000	1	.999	2.021E8
	GAP_4(30)	.001	17566.230	.000	1	1.000	1.001
	GAP_4(31)	14.932	12716.568	.000	1	.999	3053815.512
	GAP_4(32)	42.406	19069.490	.000	1	.998	2.611E18
	GAP_4(33)	42.406	13165.607	.000	1	.997	2.611E18
	GAP_4(34)	42.406	22018.312	.000	1	.998	2.611E18
	Constant	-21.204	12716.568	.000	1	.999	.000

a. Variable(s) entered on step 1: GAP_4.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 2[b]	TRI480	-.001	.000	132.154	1	.000	.999
	GAP_4			497.452	34	.000	
	GAP_4(1)	19.708	12711.790	.000	1	.999	3.622E8
	GAP_4(2)	18.739	12711.790	.000	1	.999	1.375E8
	GAP_4(3)	20.998	12711.790	.000	1	.999	1.317E9
	GAP_4(4)	43.049	30959.496	.000	1	.999	4.964E18
	GAP_4(5)	43.654	21297.512	.000	1	.998	9.094E18
	GAP_4(6)	20.002	12711.790	.000	1	.999	4.859E8
	GAP_4(7)	19.724	12711.790	.000	1	.999	3.681E8
	GAP_4(8)	46.082	28382.916	.000	1	.999	1.030E20
	GAP_4(9)	42.803	26413.176	.000	1	.999	3.883E18
	GAP_4(10)	22.311	12711.790	.000	1	.999	4.894E9
	GAP_4(11)	18.515	12711.790	.000	1	.999	1.099E8
	GAP_4(12)	17.559	12711.790	.000	1	.999	4.223E7
	GAP_4(13)	19.886	12711.790	.000	1	.999	4.327E8
	GAP_4(14)	20.735	12711.790	.000	1	.999	1.011E9
	GAP_4(15)	42.769	20689.731	.000	1	.998	3.754E18
	GAP_4(16)	42.412	16907.280	.000	1	.998	2.625E18
	GAP_4(17)	42.409	31134.003	.000	1	.999	2.618E18
	GAP_4(18)	20.603	12711.790	.000	1	.999	8.868E8
	GAP_4(19)	22.279	12711.790	.000	1	.999	4.741E9
	GAP_4(20)	46.184	13732.247	.000	1	.997	1.142E20
	GAP_4(21)	42.460	31133.154	.000	1	.999	2.756E18
	GAP_4(22)	21.677	12711.790	.000	1	.999	2.596E9
	GAP_4(23)	25.507	12711.790	.000	1	.998	1.195E11
	GAP_4(24)	43.691	20829.787	.000	1	.998	9.436E18
	GAP_4(25)	44.049	20211.892	.000	1	.998	1.349E19
	GAP_4(26)	42.489	26448.596	.000	1	.999	2.836E18
	GAP_4(27)	21.742	12711.790	.000	1	.999	2.770E9
	GAP_4(28)	19.870	12711.790	.000	1	.999	4.262E8
	GAP_4(29)	19.231	12711.790	.000	1	.999	2.248E8
	GAP_4(30)	1.215	16833.775	.000	1	1.000	3.369
	GAP_4(31)	15.223	12711.790	.000	1	.999	4084781.105
	GAP_4(32)	44.265	17393.544	.000	1	.998	1.675E19
	GAP_4(33)	42.479	13159.203	.000	1	.997	2.807E18
	GAP_4(34)	42.496	21998.765	.000	1	.998	2.856E18
	Constant	-21.202	12711.790	.000	1	.999	.000

a. Variable(s) entered on step 1: GAP_4.

b. Variable(s) entered on step 2: TRI480.

Model if Term Removed

Variable		Model Log Likelihood	Change in -2 Log Likelihood	df	Sig. of the Change
Step 1	GAP_4	-2346.471	1957.578	34	.000
Step 2	TRI480	-1367.682	248.424	1	.000
	GAP_4	-2179.597	1872.256	34	.000

Variables not in the Equation

			Score	df	Sig.
Step 1	Variables	TRI480	133.652	1	.000
		Overall Statistics	133.652	1	.000

```
COMPUTE chgdev=SRE_1 ** 2.
EXECUTE.
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=PRE_1 chgdev MISSING=LISTWISE R
EPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: PRE_1=col(source(s), name("PRE_1"))
  DATA: chgdev=col(source(s), name("chgdev"))
  GUIDE: axis(dim(1), label("Predicted probability"))
  GUIDE: axis(dim(2), label("chgdev"))
  ELEMENT: point(position(PRE_1*chgdev))
END GPL.
```

GGraph

Notes

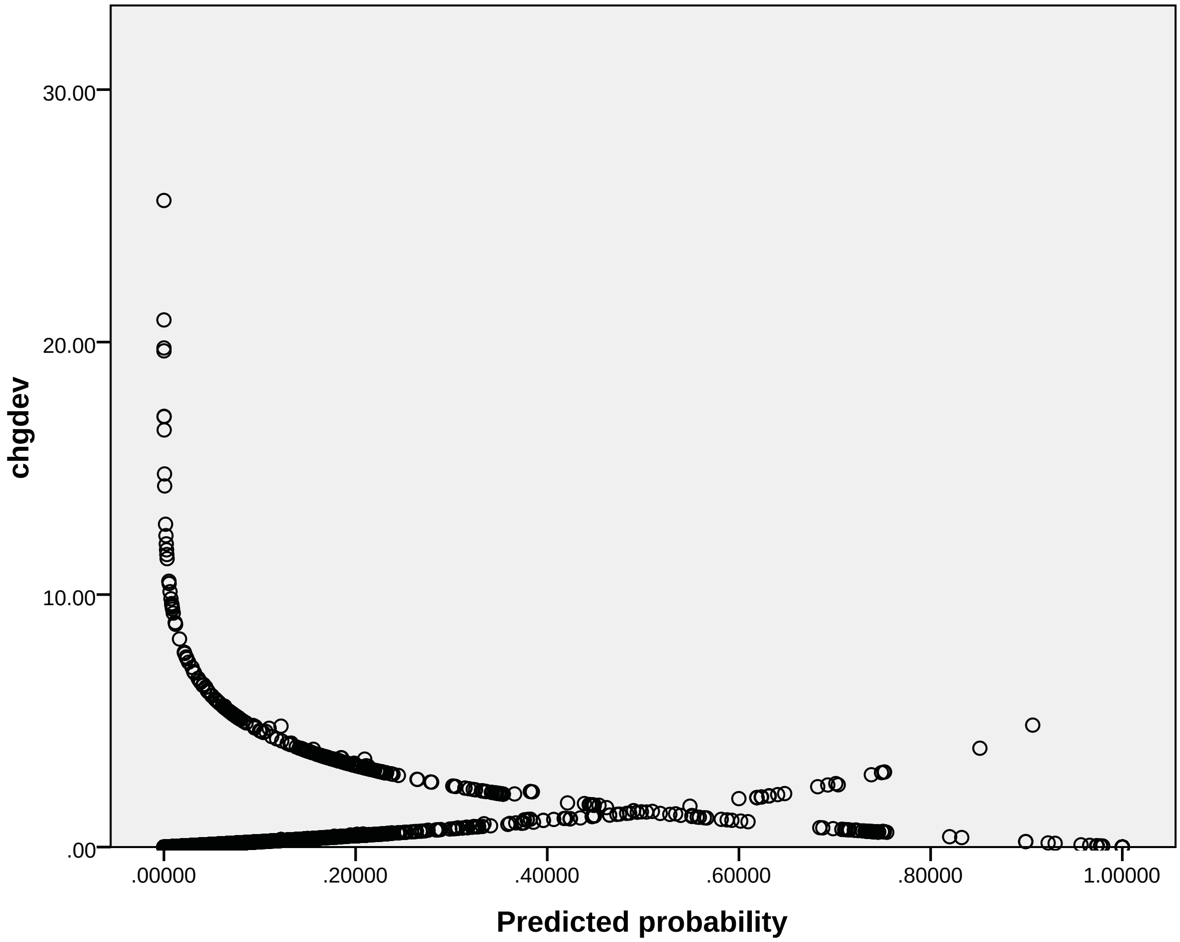
	Output Created	02-Jun-2010 17:35:29
	Comments	
Input	Data	C:\Documents and Settings\tperry\My Documents\My Dropbox\Cougar\NMDGFhabitatmodel\Data2010\modeldata2b.sav
	Active Dataset	DataSet1
	Filter	Model_ID > 4000 & Class ne 'PH' & COO_1 < 2.0 (FILTER)
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11076

Notes

	Syntax	GGRAPH
		  /GRAPHDATASET NAME="graphdataset" VARIABLES=PRE_1 chgdev MISSING=LISTWISE REPORTMISSING=NO
		  /GRAPHSPEC SOURCE=INLINE.
		BEGIN GPL
		  SOURCE: s=userSource(id("graphdataset"))
		  DATA: PRE_1=col(source(s), name("PRE_1"))
		  DATA: chgdev=col(source(s), name("chgdev"))
		  GUIDE: axis(dim(1), label("Predicted probability"))
		  GUIDE: axis(dim(2), label("chgdev"))
		  ELEMENT: point(position(PRE_1*chgdev))
		END GPL.

Resources	Processor Time	0:00:00.281
	Elapsed Time	0:00:00.296

```
[DataSet1] C:\Documents and Settings\tperry\My Documents\My Dropbox\Cougar\NM
DGFhabitatmodel\Data2010\modeldata2b.sav
```




```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=PRE_1 COO_1 Class MISSING=LISTW
ISE REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: PRE_1=col(source(s), name("PRE_1"))
  DATA: COO_1=col(source(s), name("COO_1"))
  DATA: Class=col(source(s), name("Class"), unit.category())
  GUIDE: axis(dim(1), label("Predicted probability"))
  GUIDE: axis(dim(2), label("Analog of Cook's influence statistics"))
  GUIDE: legend(aesthetic(aesthetic.color.exterior), label("Class"))
  ELEMENT: point(position(PRE_1*COO_1), color.exterior(Class))
END GPL.
```

GGraph

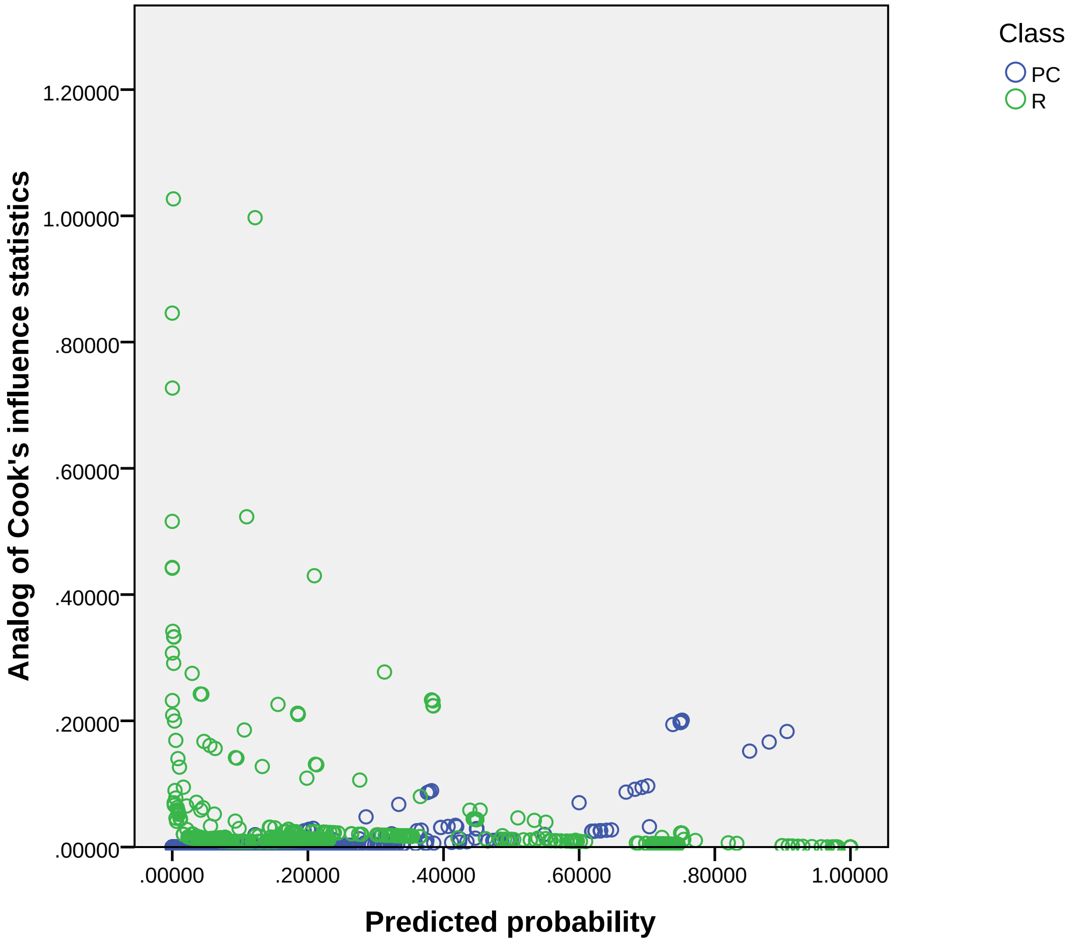
Notes

	Output Created	02-Jun-2010 17:36:13
	Comments	
Input	Data	C:\Documents and Settings\tperry\My Documents\My Dropbox\Cougar\NMDGFhabitatmodel\Data2010\modeldata2b.sav
	Active Dataset	DataSet1
	Filter	Model_ID > 4000 & Class ne 'PH' & COO_1 < 2.0 (FILTER)
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11076

	Syntax	GGRAPH
		  /GRAPHDATASET NAME="graphdataset" VARIABLES=PRE_1 COO_1 Class MISSING=LISTWISE REPORTMISSING=NO
		  /GRAPHSPEC SOURCE=INLINE.
		BEGIN GPL
		  SOURCE: s=userSource(id("graphdataset"))
		  DATA: PRE_1=col(source(s), name("PRE_1"))
		  DATA: COO_1=col(source(s), name("COO_1"))
		  DATA: Class=col(source(s), name("Class"), unit.category())
		  GUIDE: axis(dim(1), label("Predicted probability"))
		  GUIDE: axis(dim(2), label("Analog of Cook's influence statistics"))
		  GUIDE: legend(aesthetic(aesthetic.color.exterior), label("Class"))
		  ELEMENT: point(position(PRE_1*COO_1), color.exterior(Class))
		END GPL.

Resources	Processor Time	0:00:00.375
	Elapsed Time	0:00:00.390

```
[DataSet1] C:\Documents and Settings\tperry\My Documents\My Dropbox\Cougar\NMDGFhabitatmodel\Data2010\modeldata2b.sav
```




```
USE ALL.
COMPUTE filter_$=(Model_ID > 4000 & Class ne 'PH'  & COO_1  <  2.0).
VARIABLE LABEL filter_$ "Model_ID > 4000 & Class ne 'PH'  & COO_1  <  2.0 (FI
LTER)".
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMAT filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.
LOGISTIC REGRESSION VARIABLES Class
  /SELECT=validate EQ 1
  /METHOD=FSTEP(LR) TRI480 GAP_4
  /CONTRAST (GAP_4)=Indicator
  /SAVE=PRED COOK SRESID
  /PRINT=GOODFIT
  /CRITERIA=PIN(0.05) POUT(0.10) ITERATE(20) CUT(0.5).
```

Logistic Regression

Notes

	Output Created	02-Jun-2010 17:37:37
	Comments	
Input	Data	C:\Documents and Settings\tperry\My Documents\My Dropbox\Cougar\NMDGFhabitatmodel\Data2010\modeldata2b.sav
	Active Dataset	DataSet1
	Filter	Model_ID > 4000 & Class ne 'PH' & COO_1 < 2.0 (FILTER)
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11075
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing
	Syntax	LOGISTIC REGRESSION VARIABLES Class /SELECT=validate EQ 1 /METHOD=FSTEP(LR) TRI480 GAP_4 /CONTRAST (GAP_4)=Indicator /SAVE=PRED COOK SRESID /PRINT=GOODFIT /CRITERIA=PIN(0.05) POUT(0.10) ITERATE(20) CUT(0.5).
Resources	Processor Time	0:00:01.547
	Elapsed Time	0:00:01.548
Variables Created or Modified	PRE_2	Predicted probability
	COO_2	Analog of Cook's influence statistics
	SRE_2	Standard residual

[DataSet1] C:\Documents and Settings\tperry\My Documents\My Dropbox\Cougar\NMDGFhabitatmodel\Data2010\modeldata2b.sav

Case Processing Summary

Unweighted Cases [a]		N	Percent
Selected Cases	Included in Analysis	7684	69.4
	Missing Cases	0	.0
	Total	7684	69.4
	Unselected Cases	3391	30.6
	Total	11075	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
PC	0
R	1

Categorical Variables Codings

			Parameter coding					
		Frequency	(1)	(2)	(3)	(4)	(5)	(6)
GAP_4	1	274	1.000	.000	.000	.000	.000	.000
	2	2476	.000	1.000	.000	.000	.000	.000
	3	29	.000	.000	1.000	.000	.000	.000
	4	2	.000	.000	.000	1.000	.000	.000
	5	5	.000	.000	.000	.000	1.000	.000
	7	308	.000	.000	.000	.000	.000	1.000
	8	23	.000	.000	.000	.000	.000	.000
	9	2	.000	.000	.000	.000	.000	.000
	10	3	.000	.000	.000	.000	.000	.000
	11	16	.000	.000	.000	.000	.000	.000
	12	315	.000	.000	.000	.000	.000	.000
	13	206	.000	.000	.000	.000	.000	.000
	15	11	.000	.000	.000	.000	.000	.000
	17	8	.000	.000	.000	.000	.000	.000
	18	6	.000	.000	.000	.000	.000	.000
	19	13	.000	.000	.000	.000	.000	.000
	21	2	.000	.000	.000	.000	.000	.000
	22	191	.000	.000	.000	.000	.000	.000
	23	75	.000	.000	.000	.000	.000	.000
	25	31	.000	.000	.000	.000	.000	.000
	26	2	.000	.000	.000	.000	.000	.000
	29	67	.000	.000	.000	.000	.000	.000
	30	39	.000	.000	.000	.000	.000	.000
	32	5	.000	.000	.000	.000	.000	.000
	33	6	.000	.000	.000	.000	.000	.000
	35	3	.000	.000	.000	.000	.000	.000
	36	231	.000	.000	.000	.000	.000	.000
	37	1562	.000	.000	.000	.000	.000	.000
	38	9	.000	.000	.000	.000	.000	.000
	39	11	.000	.000	.000	.000	.000	.000
	42	1591	.000	.000	.000	.000	.000	.000
	44	8	.000	.000	.000	.000	.000	.000
	45	139	.000	.000	.000	.000	.000	.000
	49	5	.000	.000	.000	.000	.000	.000
	50	10	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(7)	(8)	(9)	(10)	(11)	(12)	(13)
GAP_4	1	.000	.000	.000	.000	.000	.000	.000
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	3	.000	.000	.000	.000	.000	.000	.000
	4	.000	.000	.000	.000	.000	.000	.000
	5	.000	.000	.000	.000	.000	.000	.000
	7	.000	.000	.000	.000	.000	.000	.000
	8	1.000	.000	.000	.000	.000	.000	.000
	9	.000	1.000	.000	.000	.000	.000	.000
	10	.000	.000	1.000	.000	.000	.000	.000
	11	.000	.000	.000	1.000	.000	.000	.000
	12	.000	.000	.000	.000	1.000	.000	.000
	13	.000	.000	.000	.000	.000	1.000	.000
	15	.000	.000	.000	.000	.000	.000	1.000
	17	.000	.000	.000	.000	.000	.000	.000
	18	.000	.000	.000	.000	.000	.000	.000
	19	.000	.000	.000	.000	.000	.000	.000
	21	.000	.000	.000	.000	.000	.000	.000
	22	.000	.000	.000	.000	.000	.000	.000
	23	.000	.000	.000	.000	.000	.000	.000
	25	.000	.000	.000	.000	.000	.000	.000
	26	.000	.000	.000	.000	.000	.000	.000
	29	.000	.000	.000	.000	.000	.000	.000
	30	.000	.000	.000	.000	.000	.000	.000
	32	.000	.000	.000	.000	.000	.000	.000
	33	.000	.000	.000	.000	.000	.000	.000
	35	.000	.000	.000	.000	.000	.000	.000
	36	.000	.000	.000	.000	.000	.000	.000
	37	.000	.000	.000	.000	.000	.000	.000
	38	.000	.000	.000	.000	.000	.000	.000
	39	.000	.000	.000	.000	.000	.000	.000
	42	.000	.000	.000	.000	.000	.000	.000
	44	.000	.000	.000	.000	.000	.000	.000
	45	.000	.000	.000	.000	.000	.000	.000
	49	.000	.000	.000	.000	.000	.000	.000
	50	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(14)	(15)	(16)	(17)	(18)	(19)	(20)
GAP_4	1	.000	.000	.000	.000	.000	.000	.000
	2	.000	.000	.000	.000	.000	.000	.000
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	4	.000	.000	.000	.000	.000	.000	.000
	5	.000	.000	.000	.000	.000	.000	.000
	7	.000	.000	.000	.000	.000	.000	.000
	8	.000	.000	.000	.000	.000	.000	.000
	9	.000	.000	.000	.000	.000	.000	.000
	10	.000	.000	.000	.000	.000	.000	.000
	11	.000	.000	.000	.000	.000	.000	.000
	12	.000	.000	.000	.000	.000	.000	.000
	13	.000	.000	.000	.000	.000	.000	.000
	15	.000	.000	.000	.000	.000	.000	.000
	17	1.000	.000	.000	.000	.000	.000	.000
	18	.000	1.000	.000	.000	.000	.000	.000
	19	.000	.000	1.000	.000	.000	.000	.000
	21	.000	.000	.000	1.000	.000	.000	.000
	22	.000	.000	.000	.000	1.000	.000	.000
	23	.000	.000	.000	.000	.000	1.000	.000
	25	.000	.000	.000	.000	.000	.000	1.000
	26	.000	.000	.000	.000	.000	.000	.000
	29	.000	.000	.000	.000	.000	.000	.000
	30	.000	.000	.000	.000	.000	.000	.000
	32	.000	.000	.000	.000	.000	.000	.000
	33	.000	.000	.000	.000	.000	.000	.000
	35	.000	.000	.000	.000	.000	.000	.000
	36	.000	.000	.000	.000	.000	.000	.000
	37	.000	.000	.000	.000	.000	.000	.000
	38	.000	.000	.000	.000	.000	.000	.000
	39	.000	.000	.000	.000	.000	.000	.000
	42	.000	.000	.000	.000	.000	.000	.000
	44	.000	.000	.000	.000	.000	.000	.000
	45	.000	.000	.000	.000	.000	.000	.000
	49	.000	.000	.000	.000	.000	.000	.000
	50	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(21)	(22)	(23)	(24)	(25)	(26)	(27)
GAP_4	1	.000	.000	.000	.000	.000	.000	.000
	2	.000	.000	.000	.000	.000	.000	.000
	3	.000	.000	.000	.000	.000	.000	.000
	4	.000	.000	.000	.000	.000	.000	.000
	5	.000	.000	.000	.000	.000	.000	.000
	7	.000	.000	.000	.000	.000	.000	.000
	8	.000	.000	.000	.000	.000	.000	.000
	9	.000	.000	.000	.000	.000	.000	.000
	10	.000	.000	.000	.000	.000	.000	.000
	11	.000	.000	.000	.000	.000	.000	.000
	12	.000	.000	.000	.000	.000	.000	.000
	13	.000	.000	.000	.000	.000	.000	.000
	15	.000	.000	.000	.000	.000	.000	.000
	17	.000	.000	.000	.000	.000	.000	.000
	18	.000	.000	.000	.000	.000	.000	.000
	19	.000	.000	.000	.000	.000	.000	.000
	21	.000	.000	.000	.000	.000	.000	.000
	22	.000	.000	.000	.000	.000	.000	.000
	23	.000	.000	.000	.000	.000	.000	.000
	25	.000	.000	.000	.000	.000	.000	.000
	26	1.000	.000	.000	.000	.000	.000	.000
	29	.000	1.000	.000	.000	.000	.000	.000
	30	.000	.000	1.000	.000	.000	.000	.000
	32	.000	.000	.000	1.000	.000	.000	.000
	33	.000	.000	.000	.000	1.000	.000	.000
	35	.000	.000	.000	.000	.000	1.000	.000
	36	.000	.000	.000	.000	.000	.000	1.000
	37	.000	.000	.000	.000	.000	.000	.000
	38	.000	.000	.000	.000	.000	.000	.000
	39	.000	.000	.000	.000	.000	.000	.000
	42	.000	.000	.000	.000	.000	.000	.000
	44	.000	.000	.000	.000	.000	.000	.000
	45	.000	.000	.000	.000	.000	.000	.000
	49	.000	.000	.000	.000	.000	.000	.000
	50	.000	.000	.000	.000	.000	.000	.000

Categorical Variables Codings

		Parameter coding						
		(28)	(29)	(30)	(31)	(32)	(33)	(34)
GAP_4	1	.000	.000	.000	.000	.000	.000	.000
	2	.000	.000	.000	.000	.000	.000	.000
	3	.000	.000	.000	.000	.000	.000	.000
	4	.000	.000	.000	.000	.000	.000	.000
	5	.000	.000	.000	.000	.000	.000	.000
	7	.000	.000	.000	.000	.000	.000	.000
	8	.000	.000	.000	.000	.000	.000	.000
	9	.000	.000	.000	.000	.000	.000	.000
	10	.000	.000	.000	.000	.000	.000	.000
	11	.000	.000	.000	.000	.000	.000	.000
	12	.000	.000	.000	.000	.000	.000	.000
	13	.000	.000	.000	.000	.000	.000	.000
	15	.000	.000	.000	.000	.000	.000	.000
	17	.000	.000	.000	.000	.000	.000	.000
	18	.000	.000	.000	.000	.000	.000	.000
	19	.000	.000	.000	.000	.000	.000	.000
	21	.000	.000	.000	.000	.000	.000	.000
	22	.000	.000	.000	.000	.000	.000	.000
	23	.000	.000	.000	.000	.000	.000	.000
	25	.000	.000	.000	.000	.000	.000	.000
	26	.000	.000	.000	.000	.000	.000	.000
	29	.000	.000	.000	.000	.000	.000	.000
	30	.000	.000	.000	.000	.000	.000	.000
	32	.000	.000	.000	.000	.000	.000	.000
	33	.000	.000	.000	.000	.000	.000	.000
	35	.000	.000	.000	.000	.000	.000	.000
	36	.000	.000	.000	.000	.000	.000	.000
	37	1.000	.000	.000	.000	.000	.000	.000
	38	.000	1.000	.000	.000	.000	.000	.000
	39	.000	.000	1.000	.000	.000	.000	.000
	42	.000	.000	.000	1.000	.000	.000	.000
	44	.000	.000	.000	.000	1.000	.000	.000
	45	.000	.000	.000	.000	.000	1.000	.000
	49	.000	.000	.000	.000	.000	.000	1.000
	50	.000	.000	.000	.000	.000	.000	.000

Block 0: Beginning Block

Classification Table[c,d]

Observed			Predicted: Selected Cases[a] Class PC	Selected Cases[a] Class R	Selected Cases[a] Percentage Correct	Unselected Cases[b] Class PC
Step 0	Class	PC	6983	0	100.0	3105
		R	701	0	.0	286
		Overall Percentage			90.9	

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. Constant is included in the model.

d. The cut value is .500

Classification Table[c,d]

Observed			Predicted: Unselected Cases[b] Class R	Unselected Cases[b] Percentage Correct
Step 0	Class	PC	0	100.0
		R	0	.0
		Overall Percentage		91.6

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. Constant is included in the model.

d. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	-2.299	.040	3366.256	1	.000	.100

Variables not in the Equation[a]

			Score	df	Sig.
Step 0	Variables	TRI480	193.467	1	.000
		GAP_4	3249.293	34	.000
		GAP_4(1)	3.700	1	.054
		GAP_4(2)	165.803	1	.000
		GAP_4(3)	44.762	1	.000
		GAP_4(4)	19.928	1	.000
		GAP_4(5)	49.840	1	.000

a. Residual Chi-Squares are not computed because of redundancies.

Variables not in the Equation[a]

			Score	df	Sig.
Step 0	Variables	GAP_4(6)	49.696	1	.000
		GAP_4(7)	1.902	1	.168
		GAP_4(8)	19.928	1	.000
		GAP_4(9)	29.896	1	.000
		GAP_4(10)	83.928	1	.000
		GAP_4(11)	24.433	1	.000
		GAP_4(12)	19.048	1	.000
		GAP_4(13)	1.090	1	.296
		GAP_4(14)	7.778	1	.005
		GAP_4(15)	59.816	1	.000
		GAP_4(16)	129.719	1	.000
		GAP_4(17)	19.928	1	.000
		GAP_4(18)	20.004	1	.000
		GAP_4(19)	288.649	1	.000
		GAP_4(20)	310.057	1	.000
		GAP_4(21)	19.928	1	.000
		GAP_4(22)	.647	1	.421
		GAP_4(23)	105.726	1	.000
		GAP_4(24)	49.840	1	.000
		GAP_4(25)	59.816	1	.000
		GAP_4(26)	29.896	1	.000
		GAP_4(27)	15.423	1	.000
		GAP_4(28)	15.122	1	.000
		GAP_4(29)	.043	1	.836
		GAP_4(30)	1.106	1	.293
		GAP_4(31)	193.180	1	.000
		GAP_4(32)	79.775	1	.000
		GAP_4(33)	1410.155	1	.000
		GAP_4(34)	49.840	1	.000

a. Residual Chi-Squares are not computed because of redundancies.

Block 1: Method = Forward Stepwise (Likelihood Ratio)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	1957.578	34	.000
	Block	1957.578	34	.000

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Model	1957.578	34	.000
Step 2	Step	248.424	1	.000
	Block	2206.003	35	.000
	Model	2206.003	35	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	2735.363[a]	.225	.492
2	2486.939[a]	.250	.546

a. Estimation terminated at iteration number 20 because maximum iterations has been reached. Final solution cannot be found.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	.000	5	1.000
2	412.175	8	.000

Contingency Table for Hosmer and Lemeshow Test

		Class = PC		Class = R		
		Observed	Expected	Observed	Expected	Total
Step 1	1	21	21.000	0	.000	21
	2	1588	1588.000	3	3.000	1591
	3	516	516.000	5	5.000	521
	4	2402	2402.000	74	74.000	2476
	5	1459	1459.000	103	103.000	1562
	6	684	684.000	122	122.000	806
	7	313	313.000	394	394.000	707
Step 2	1	759	767.789	9	.211	768
	2	766	767.508	3	1.492	769
	3	766	766.038	2	1.962	768
	4	756	762.823	12	5.177	768
	5	760	753.635	7	13.365	767
	6	759	741.582	8	25.418	767
	7	753	729.472	15	38.528	768
	8	695	707.731	74	61.269	769
	9	637	646.101	131	121.899	768
	10	332	340.319	440	431.681	772

Classification Table[c]

Observed			Predicted: Selected Cases[a] Class PC	R	Percentage Correct	Unselected Cases[b] Class PC
Step 1	Class	PC	6936	47	99.3	3091
		R	386	315	44.9	171
		Overall Percentage			94.4	
Step 2	Class	PC	6957	26	99.6	3098
		R	379	322	45.9	167
		Overall Percentage			94.7	

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. The cut value is .500

Classification Table[c]

Observed			Predicted: Unselected Cases[b] Class R	Percentage Correct
Step 1	Class	PC	14	99.5
		R	115	40.2
		Overall Percentage		94.5
Step 2	Class	PC	7	99.8
		R	119	41.6
		Overall Percentage		94.9

a. Selected cases validate EQ 1

b. Unselected cases validate NE 1

c. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	GAP_4			537.205	34	.000	
	GAP_4(1)	19.249	12716.568	.000	1	.999	2.290E8
	GAP_4(2)	17.724	12716.568	.000	1	.999	4.980E7
	GAP_4(3)	20.996	12716.568	.000	1	.999	1.313E9
	GAP_4(4)	42.406	31135.968	.000	1	.999	2.611E18
	GAP_4(5)	42.406	22018.312	.000	1	.998	2.611E18

a. Variable(s) entered on step 1: GAP_4.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	GAP_4(6)	19.845	12716.568	.000	1	.999	4.157E8
	GAP_4(7)	19.645	12716.568	.000	1	.999	3.403E8
	GAP_4(8)	42.406	31135.968	.000	1	.999	2.611E18
	GAP_4(9)	42.406	26461.344	.000	1	.999	2.611E18
	GAP_4(10)	22.302	12716.568	.000	1	.999	4.849E9
	GAP_4(11)	16.850	12716.568	.000	1	.999	2.079E7
	GAP_4(12)	15.881	12716.568	.000	1	.999	7885299.240
	GAP_4(13)	19.699	12716.568	.000	1	.999	3.592E8
	GAP_4(14)	20.693	12716.568	.000	1	.999	9.699E8
	GAP_4(15)	42.406	20759.502	.000	1	.998	2.611E18
	GAP_4(16)	42.406	16910.896	.000	1	.998	2.611E18
	GAP_4(17)	42.406	31135.968	.000	1	.999	2.611E18
	GAP_4(18)	19.709	12716.568	.000	1	.999	3.627E8
	GAP_4(19)	21.837	12716.568	.000	1	.999	3.046E9
	GAP_4(20)	42.406	14622.694	.000	1	.998	2.611E18
	GAP_4(21)	42.406	31135.968	.000	1	.999	2.611E18
	GAP_4(22)	19.205	12716.568	.000	1	.999	2.192E8
	GAP_4(23)	21.461	12716.568	.000	1	.999	2.092E9
	GAP_4(24)	42.406	22018.312	.000	1	.998	2.611E18
	GAP_4(25)	42.406	20759.502	.000	1	.998	2.611E18
	GAP_4(26)	42.406	26461.344	.000	1	.999	2.611E18
	GAP_4(27)	19.578	12716.568	.000	1	.999	3.183E8
	GAP_4(28)	18.553	12716.568	.000	1	.999	1.141E8
	GAP_4(29)	19.124	12716.568	.000	1	.999	2.021E8
	GAP_4(30)	.001	17566.230	.000	1	1.000	1.001
	GAP_4(31)	14.932	12716.568	.000	1	.999	3053815.512
	GAP_4(32)	42.406	19069.490	.000	1	.998	2.611E18
	GAP_4(33)	42.406	13165.607	.000	1	.997	2.611E18
	GAP_4(34)	42.406	22018.312	.000	1	.998	2.611E18
	Constant	-21.204	12716.568	.000	1	.999	.000

a. Variable(s) entered on step 1: GAP_4.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 2[b]	TRI480	-.001	.000	132.154	1	.000	.999
	GAP_4			497.452	34	.000	
	GAP_4(1)	19.708	12711.790	.000	1	.999	3.622E8
	GAP_4(2)	18.739	12711.790	.000	1	.999	1.375E8
	GAP_4(3)	20.998	12711.790	.000	1	.999	1.317E9
	GAP_4(4)	43.049	30959.496	.000	1	.999	4.964E18
	GAP_4(5)	43.654	21297.512	.000	1	.998	9.094E18
	GAP_4(6)	20.002	12711.790	.000	1	.999	4.859E8
	GAP_4(7)	19.724	12711.790	.000	1	.999	3.681E8
	GAP_4(8)	46.082	28382.916	.000	1	.999	1.030E20
	GAP_4(9)	42.803	26413.176	.000	1	.999	3.883E18
	GAP_4(10)	22.311	12711.790	.000	1	.999	4.894E9
	GAP_4(11)	18.515	12711.790	.000	1	.999	1.099E8
	GAP_4(12)	17.559	12711.790	.000	1	.999	4.223E7
	GAP_4(13)	19.886	12711.790	.000	1	.999	4.327E8
	GAP_4(14)	20.735	12711.790	.000	1	.999	1.011E9
	GAP_4(15)	42.769	20689.731	.000	1	.998	3.754E18
	GAP_4(16)	42.412	16907.280	.000	1	.998	2.625E18
	GAP_4(17)	42.409	31134.003	.000	1	.999	2.618E18
	GAP_4(18)	20.603	12711.790	.000	1	.999	8.868E8
	GAP_4(19)	22.279	12711.790	.000	1	.999	4.741E9
	GAP_4(20)	46.184	13732.247	.000	1	.997	1.142E20
	GAP_4(21)	42.460	31133.154	.000	1	.999	2.756E18
	GAP_4(22)	21.677	12711.790	.000	1	.999	2.596E9
	GAP_4(23)	25.507	12711.790	.000	1	.998	1.195E11
	GAP_4(24)	43.691	20829.787	.000	1	.998	9.436E18
	GAP_4(25)	44.049	20211.892	.000	1	.998	1.349E19
	GAP_4(26)	42.489	26448.596	.000	1	.999	2.836E18
	GAP_4(27)	21.742	12711.790	.000	1	.999	2.770E9
	GAP_4(28)	19.870	12711.790	.000	1	.999	4.262E8
	GAP_4(29)	19.231	12711.790	.000	1	.999	2.248E8
	GAP_4(30)	1.215	16833.775	.000	1	1.000	3.369
	GAP_4(31)	15.223	12711.790	.000	1	.999	4084781.105
	GAP_4(32)	44.265	17393.544	.000	1	.998	1.675E19
	GAP_4(33)	42.479	13159.203	.000	1	.997	2.807E18
	GAP_4(34)	42.496	21998.765	.000	1	.998	2.856E18
	Constant	-21.202	12711.790	.000	1	.999	.000

a. Variable(s) entered on step 1: GAP_4.

b. Variable(s) entered on step 2: TRI480.

Model if Term Removed

Variable		Model Log Likelihood	Change in -2 Log Likelihood	df	Sig. of the Change
Step 1	GAP_4	-2346.471	1957.578	34	.000
Step 2	TRI480	-1367.682	248.424	1	.000
	GAP_4	-2179.597	1872.256	34	.000

Variables not in the Equation

			Score	df	Sig.
Step 1	Variables	TRI480	133.652	1	.000
		Overall Statistics	133.652	1	.000

APPENDIX IV

Detailed calculations of mountain lion population size by GMU. H, C, and HC are abbreviations for harvest model, collar model, and harvest and collar models combined, respectively. Numbers in columns with “Excellent”, “Good”, “Moderate”, “Fair”, and “Poor” represent units of 100 sq Km area of that habitat quality category predicted by each model. These are then arranged by row for each GMU. For example, the harvest model predicts 960 sq Km of excellent mountain lion habitat in GMU 2C. The numbers in the columns with “hi” and “lo” represent the total of hi and lo density estimates for each habitat quality category multiplied by the area of that habitat quality category for each GMU. For example, the harvest model predicts between 24 and 36 resident adult mountain lions in GMU 2C.

GMU	Cougar_Zone	Havest lo	Harvest hi	Collar lo	Collar hi	Harvcol lo	Harvcol hi	H Excellent	H Good	H Moderate	H Fair	H Poor	C Excellent	C Good	C Moderate	C Fair	C Poor	HC Excellent	HC Good	HC Moderate	HC Fair	HC Poor
2C	A	24	36	20	29	28	41	9.607	2.106	6.770	0.952	1.476	5.671	7.019	6.623	0.012	1.587	11.366	3.286	5.590	0.335	0.334
7	A	56	83	58	83	75	109	11.874	7.915	62.350	0.946	5.436	5.431	35.608	39.720	0.014	7.747	15.859	31.554	38.711	0.309	2.088
2B	A	34	52	18	26	35	52	16.661	0.823	0.994	0.209	0.649	5.503	6.579	3.426	0.124	3.705	16.889	0.896	0.921	0.076	0.554
2A	A	25	37	20	28	31	46	11.101	1.237	3.531	0.204	4.240	5.013	9.339	3.086	0.014	2.860	14.076	1.931	2.837	0.021	1.447
5A	B	8	12	4	5	8	12	3.315	0.829	1.528	0.042	0.203	0.290	2.691	2.029	0.001	0.905	3.468	0.973	1.384	0.020	0.071
50	B	24	35	11	15	25	36	6.660	8.540	8.407	0.014	0.257	1.897	4.779	6.159	0.031	11.011	6.685	10.286	6.670	0.004	0.233
51	B	45	68	17	24	46	69	21.388	1.929	1.989	0.152	0.229	3.691	5.679	8.845	3.137	4.333	21.648	2.516	1.400	0.036	0.087
5B	B	18	27	7	11	19	28	8.675	0.488	1.101	0.207	0.237	1.762	1.847	5.542	0.579	0.979	8.867	0.947	0.633	0.063	0.198
48	C	8	12	2	3	8	12	3.845	0.187	0.149	0.193	5.421	0.417	0.151	2.321	0.664	6.240	3.847	0.200	0.136	0.193	5.419
49	C	21	32	4	7	21	32	10.516	0.259	0.113	0.005	0.073	0.840	0.423	3.303	5.300	1.099	10.544	0.262	0.110	0.003	0.047
53	C	29	42	6	8	29	43	12.337	3.748	1.441	0.000	0.191	1.031	1.224	3.464	6.072	5.928	12.423	3.780	1.409	0.000	0.105
43	C	30	44	16	22	31	45	10.961	4.299	9.395	0.268	24.340	2.539	10.612	2.462	0.075	33.575	11.023	6.158	7.543	0.245	24.295
46	C	36	54	11	17	36	54	17.714	0.443	1.003	0.268	13.309	2.531	2.024	10.408	2.045	15.729	17.717	0.465	0.982	0.268	13.306
45	C	70	104	19	27	70	105	33.792	1.017	2.805	0.058	1.741	3.546	5.569	8.899	15.020	6.379	33.851	2.017	1.805	0.050	1.690
42	D	33	48	13	18	36	53	8.167	10.252	17.804	3.117	71.809	3.532	4.432	3.739	0.995	98.451	8.531	12.884	17.748	2.748	69.237
47	D	9	14	3	4	9	14	2.190	3.861	3.689	0.558	20.919	0.940	0.465	1.089	0.336	28.387	2.201	3.873	3.689	0.547	20.907
41	D	4	6	4	6	6	8	0.538	0.124	7.189	0.035	39.591	0.550	1.460	4.017	0.005	41.444	0.622	1.566	7.189	0.031	38.068
59	D	5	7	2	3	5	8	0.831	2.113	3.746	0.468	41.564	0.390	0.354	1.718	0.106	46.155	0.845	2.156	3.746	0.455	41.521
9	E	80	119	69	99	96	139	27.819	6.890	45.505	0.271	5.773	12.808	38.553	22.983	0.817	11.096	29.629	32.448	19.315	0.024	4.842
10	E	88	131	50	72	91	136	39.478	4.999	11.485	0.290	1.528	9.136	27.463	18.802	0.601	1.777	40.699	6.582	9.900	0.008	0.590
6B	F	7	10	1	1	7	10	3.395	0.196	0.001	0.000	0.001	0.011	0.005	0.625	1.932	1.020	3.395	0.198	0.000	0.000	0.000
6A	F	47	70	22	31	50	74	20.854	1.989	8.910	0.127	0.619	4.982	7.359	10.153	4.930	5.074	21.447	5.239	5.367	0.056	0.390
6C	F	50	75	23	33	51	76	22.680	2.991	5.429	0.016	2.061	5.871	8.936	5.303	5.272	7.795	22.728	5.308	3.086	0.003	2.052
17	G	53	79	51	74	72	106	22.408	4.174	11.604	0.097	4.304	16.919	14.497	9.144	1.126	0.902	31.733	7.815	2.901	0.001	0.136
13	G	113	168	105	149	138	201	39.644	15.380	50.615	0.301	9.371	20.995	58.600	26.599	0.117	9.000	47.152	39.061	21.757	0.021	7.322
19	H	36	52	131	193	122	180	8.340	12.938	19.225	1.101	68.492	48.979	24.760	26.608	0.068	9.680	50.581	23.461	0.195	0.001	35.858
20	H	18	26	86	126	84	122	1.996	4.018	25.111	0.401	34.723	31.097	23.612	6.471	0.013	5.056	31.326	23.416	0.394	0.007	11.106
36	I	35	52	32	47	47	71	14.927	3.297	5.120	0.200	3.478	11.326	8.205	4.432	0.257	2.802	21.933	3.730	0.527	0.106	0.727
37	I	32	48	36	53	50	75	12.497	2.284	12.173	0.154	15.498	14.131	6.725	3.373	0.409	17.968	23.598	2.040	2.074	0.111	14.783
18	I	42	62	68	99	81	120	13.251	4.668	27.657	0.073	17.658	24.350	19.866	3.939	0.052	15.100	34.370	10.869	6.089	0.005	11.975
38	I	14	21	11	16	20	30	3.249	1.859	15.464	0.152	63.537	4.005	2.261	2.418	0.106	75.470	6.617	1.952	12.249	0.152	63.292
25	J	17	26	96	141	90	131	1.293	1.384	33.431	0.552	45.329	32.876	22.950	23.975	0.003	2.186	33.746	23.133	4.083	0.000	21.026
16B	J	48	72	17	25	48	72	23.816	0.272	0.126	0.133	0.085	4.228	2.051	14.512	3.313	0.328	23.985	0.354	0.009	0.000	0.084
21A	J	24	36	10	15	24	36	11.968	0.118	0.039	0.023	0.005	3.278	1.002	6.311	1.478	0.083	12.013	0.128	0.012	0.000	0.000
16C	J	22	33	8	12	22	33	10.463	0.417	1.438	0.001	0.113	1.029	3.943	7.097	0.201	0.162	10.483	1.381	0.470	0.000	0.098
16A	J	31	46	12	18	32	47	15.105	0.280	1.185	0.038	0.110	2.858	2.496	9.631	1.487	0.245	15.340	1.176	0.102	0.000	0.099
21B	J	42	62	93	137	101	148	12.532	7.517	24.864	0.875	20.286	34.422	25.354	5.143	0.011	1.142	40.239	21.652	2.409	0.008	1.766
16D	J	22	33	9	13	23	34	10.711	0.354	1.042	0.010	0.089	1.798	2.745	6.790	0.708	0.164	10.768	1.025	0.348	0.000	0.064
16E	J	25	37	20	28	28	41	8.690	1.568	14.571	0.003	0.045	2.583	12.014	9.928	0.118	0.233	8.736	8.402	7.737	0.000	0.001
15	J	67	100	28	41	68	102	30.413	3.169	8.741	0.005	0.063	3.560	13.351	22.879	0.807	1.794	30.507	5.494	6.353	0.000	0.037
24	K	56	84	50	74	74	110	25.699	1.265	8.549	0.234	3.432	18.949	9.429	9.490	0.891	0.421	35.324	3.214	0.161	0.000	0.481
22	K	17	26	12	17	20	30	7.955	0.667	1.449	0.072	0.049	4.117	2.651	1.887	1.299	0.239	9.730	0.427	0.015	0.000	0.021
23	K	78	116	115	171	139	208	30.343	4.817	31.500	0.441	8.817	48.887	14.008	11.830	0.249	0.944	66.770	5.877	0.278	0.000	2.994
26	L	29	42	93	138	98	146	5.579	4.642	32.698	0.763	16.059	39.670	12.307	7.175	0.012	0.577	43.637	12.255	0.336	0.000	3.514
27	L	15	22	44	65	47	70	3.165	2.897	14.289	0.530	6.019	19.128	4.742	2.723	0.046	0.261	21.385	4.612	0.179	0.000	0.725
33	M	11	17	57	85	57	85	0.188	0.034	26.963	0.064	31.527	26.727	3.397	1.575	0.000	27.076	26.745	3.402	1.299	0.057	27.273
31	M	35	53	163	241	164	242	0.625	0.030	85.266	0.000	130.064	65.378	27.178	20.060	0.000	103.369	65.400	27.207	21.819	0.000	101.559
32	M	31	46	126	186	129	191	2.785	2.627	56.787	0.164	94.919	53.761	17.500	6.401	0.020	79.600	55.516	17.186	7.047	0.130	77.404
39	M	8	12	7	11	11	17	1.229	1.547	9.900	0.297	55.290	2.274	1.233	3.965	0.041	60.750	3.228	1.708	8.209	0.273	54.845
40	M	13	19	9	14	15	22	1.195	1.757	21.569	0.917	72.265	1.106	0.912	16.025	0.320	79.338	1.897	2.510	21.001	0.826	71.468
52	N	19	28	2	4	19	28	8.759	0.679	1.377	0.000	0.080	0.218	0.185	2.972	3.077	4.444	8.838	0.735	1.321	0.000	0.001
4	N	32	48	6	8	33	49	15.685	0.824	0.660	0.022	0.771	0.958	1.684	3.119	4.889	7.313	15.965	1.162	0.322	0.015	0.498
12	O	70	103	51	71	75	109	21.888	17.099	27.574	0.072	0.573	3.606	41.735	16.589	0.033	5.244	22.465	24.140	20.533	0.000	0.069
56	P	8	12	5	7	8	12	3.524	0.568	1.267	0.609	40.100	1.449	1.686	0.966	0.159	41.809	3.526	0.571	1.267	0.609	40.095
57	P	13	19	4	6	13	19	6.059	0.570	0.482	0.408	3.468	1.658	0.682	0.830	0.174	7.644	6.060	0.570	0.481	0.408	3.467
58	P	12	17	4	5	12	17	2.645	4.746	5.218	0.900	26.116	1.118	1.022	0.977	0.244	36.264	2.708	4.861	5.218	0.794	26.044
29	Q	11	15	45	66	46	67	1.396	2.563	13.380	0.666	12.599	16.938	12.576	0.429	0.007	0.654	17.255	12.461	0.443	0.000	0.445
28	Q	8	12	37	54	34	51	0.674	2.600	10.864	0.163	13.449	13.960	6.878	6.783	0.000	0.130	14.214	6.699	0.058	0.003	6.778
30	Q	41	60	110	161	116	172	10.228	9.557	29.652	1.673	24.911	44.585	22.318	1.486	0.069	7.563	49.318	18.985	1.448	0.029	6.242
34	Q	55	83	44	65	71	106	24.861	4.362	4.485	0.399	9.035	15.100	9.667	13.221	0.776	4.378	33.324	5.003	0.524	0.085	4.205
55B	R	1	1	1	1	1	1	0.091	0.042	1.040	0.004	8.517	0.050	0.065	0.968	0.000	8.612	0.093	0.042	1.040	0.004	8.515
55A	R	74	111	19	28	75	112	36.608	0.545	0.287	0.147	2.968	4.155	1.694	18.081	7.645	8.980	37.036	0.552	0.280	0.139	2.546
54	R	13	19	3	5	13	19	6.363	0.157	0.126	0.160	2.093	0.712	0.194	2.386	2.507	3.100	6.364	0.161	0.122	0.160	2.092
8	S	22	33	12	17	23	34	8.861	1.208	7.501	0.011	6.286	2.142	6.816	3.093	0.878	10.937	8.888	4.025	4.662	0.010	6.281
14	S	35	53	25	36	41	61	14.219	1.619	13.184	0.003	13.857	4.392	13.089	10.557	1.062	13.784	15.676	9.327	4.363	0.002	13.515
35	T	34	51	13	19	35	52	16.503	0.720	0.361	0.011	0.160	3.353	2.589	8.850	0.303	2.661	17.190	0.361	0.047	0.002	0.156
11	T	23	35	15	21	24	35	9.457	3.564	3.525	0.007	0.105	2.472	10.088	2.085	0.000	2.014	9.517	3.650	3.437	0.000	0.054
1	T	78	116	89	128	116	170	25.311	3.463	58.335	2.528	11.884	19.826	36.313	41.011	0.939	3.433	38.349	29.025	32.766	0.108	1.273
3	T	54	80	20	29	55	82	24.253	2.669	6.476	0.168	0.614	2.137	11.930	13.708	0.341	6.064	24.618	3.840	5.300	0.108	0.314

* Habitat areas are given in 100sqKm increments

MONTANA MOUNTAIN LION
MONITORING & MANAGEMENT STRATEGY

MONTANA FISH, WILDLIFE & PARKS

WILDLIFE RESTORATION

Cover photo: R. Wiesner

TABLE OF CONTENTS

MOUNTAIN LION CONSERVATION AND MANAGEMENT GUIDELINES

With the publication of this document, Montana Fish, Wildlife & Parks (FWP) reaffirms its commitment, on behalf of the public, to the conservation and responsible management of mountain lion populations in Montana.

Many FWP wildlife biologists might find it redundant to first state that we are committed to conserving mountain lions. We tend to skip instead to describing specific strategies for mountain lion management, while taking our professional dedication to wildlife conservation for granted.

But we've learned over the years that an intensely interested and engaged public does not always accept FWP's commitment to mountain lion conservation as a given, and may not recognize FWP's management strategies as being consistent with conservation. Although our society has a long and evolving heritage of valuing wildlife, we acknowledge that Montana and other western states have risen relatively recently to the challenge of actively conserving mountain lions.

Many Montanans can still remember the bounty years when antagonistic public attitudes toward predatory wildlife were common. Since then, questions and concerns surrounding the management of mountain lions have increased as more people with a stake in mountain lion management come to the table.

One measure of Montana's commitment to wildlife conservation is the abundance, diversity, and distribution of our large predators. Wolves are now biologically and legally recovered, grizzly bear populations exceed restoration milestones, and the mountain lion has re-occupied its historic statewide habitat.

But with this success comes increased management complexity. Local declines in elk abundance and hunting opportunities, concerns about public safety, sharply responsive mountain lion hunting regulations, and uncertainties about management's effects on lion populations have sometimes strained a consensus about our values and management direction.

And conservation itself, we understand, is in the eye of the beholder. So, we strive to be clear. The following are the conservation and management guidelines that will direct FWP's decisions, and against which more specific management objectives will be measured.

FWP will conserve mountain lions as a functional and valued part of Montana's wildland ecosystems.

FWP will help manage suitable and connected habitat at a landscape scale for mountain lions and their prey.

FWP will responsibly manage mountain lions as a public trust resource and consistent with state law.

FWP will maintain and enhance public acceptance of mountain lions by helping landowners, homeowners, and the recreating public prevent conflicts with mountain lions. FWP will respond promptly and professionally when conflicts occur.

FWP will enhance public appreciation for mountain lions by providing information and insight about the role of mountain lions in the ecosystem and on practices for living and recreating in lion habitat.

FWP recognizes that mountain lion hunting is a highly valued recreational pursuit and that hunting plays a critical role in maintaining public advocacy and tolerance for the species. FWP will therefore manage for limited and sustainable mountain lion hunter-harvest opportunity on most lands within its jurisdiction. FWP will allocate hunting opportunities and experiences fairly among Montana resident, nonresident, and outfitted mountain lion hunters using simple and consistent regulations.

FWP will use an adaptive harvest management framework to develop and evaluate most mountain lion management decisions. Potential management objectives will be made explicit to all stakeholders throughout the decision-making process and the best available information will be used to evaluate whether those objectives are being met.

FWP will maintain a balance between mountain lion populations, their prey, and humans by directing local harvest of mountain lions, if and as needed, to manage prey survival and reduce human-lion conflicts. FWP specifically recognizes that mountain lion populations are most effectively conserved at the landscape scale, rather than within smaller individual Lion Management Units where prey survival or points of conflict may be concerns worthy of management.

FWP will develop informed public consent regarding the conservation status of mountain lions and the potential consequences of FWP management actions by instituting a credible, science-based system for estimating and monitoring Montana's lion populations.

FWP will consider, monitor, and conserve mountain lions at a landscape scale, consistent with the species' ecology. Specific management objectives will encourage sustainable and well-connected mountain lion populations within these landscapes.

EXECUTIVE SUMMARY

Despite historic persecution, mountain lions are thriving once again in Montana. Lions have reoccupied their historic statewide range and dispersing individuals now contribute to expanding populations across the western and midwestern U. S. This recovery is a testament to Montana's tradition of protecting habitat, conserving native wildlife populations, and investing in research that provides the scientific basis for sound wildlife management decisions.

The number of lion hunters and hound handlers has also increased during the last 40 years. These sportsmen and women became the state's most effective advocates for lion conservation and they have consistently encouraged FWP's efforts to improve lion management. Montanans, hunters and non-hunters alike, now expect assurances from FWP that lion populations remain healthy and that lion management decisions are informed by objective data instead of emotion.

Unfortunately, many past lion management decisions were controversial. Because it was impossible to precisely count lions or monitor population trends, Montanans who care deeply about lions and their prey often disagreed about the effects of lion harvest on both.

FWP clearly realized the need for better methods to track lion population changes and for a scientific framework upon which to base management recommendations. Over the last 25 years FWP made significant investments in field research that had improved our understanding of lion ecology and the way lions interact with their prey. FWP biologists and partners also developed new methods to monitor lion populations and built innovative population models that predict the effect of past and future harvest.

FWP intends to maintain sustainable lion populations across all suitable habitats within its jurisdiction. An important goal of this Strategy is to provide the public


West Fork Bitterroot River FWP Mountain Lion Study Area

and the Department with accurate and timely information so that both populations and harvest are more stable over time. Accurate monitoring and modeling data will enable simpler harvest regulations, improve our ability to reduce conflicts, and allow FWP to better manage local lion densities while protecting regional populations.

Research in Montana and other states has revealed that lion ecology is remarkably similar across the species' western North American range. Populations in western North America are well connected and generally resilient to moderate harvest. However, hunter harvest is often additive to other forms of mortality and should be limited to prevent unwanted population declines. Critically, we now understand that lion populations are most effectively managed at large spatial scales.

For this management strategy FWP used a habitat model, built using Montana-based research and harvest data, to describe four biologically meaningful mountain lion "ecoregions" within the state. These ecoregions will be the spatial basis of FWP's lion management. FWP will periodically develop estimates of mountain lion abundance within most ecoregions using genetically-based field sampling.

Managers will then include these population estimates, our understanding of lion ecology, and lion harvest data to inform statistical models that predict the effects of lion harvest on statewide populations. Over time, this monitoring program will reduce uncertainty about the effects of lion harvest and will improve FWP's ability to meet lion management objectives.

An adaptive harvest management process will guide most of Montana's mountain lion harvest decisions. FWP will work with the public to develop clear and measurable population objectives at the ecoregion scale, as well as hunting seasons and harvest prescriptions that are most likely to meet those objectives. The effects of lion harvest will be regularly monitored so that harvest can be adjusted based on current information.

Although overall management objectives and harvest prescriptions will be developed at a large (ecoregional) scale, harvest limits will generally be distributed across an ecoregion's lion management units to address social concerns, reduce hunter crowding, and focus or limit harvest where needed.

The following chapters describe FWP's mountain lion monitoring program and methods to produce periodic estimates of mountain lion abundance across the state. This Strategy includes a population model that will allow managers to effectively use those field-based estimates and other information to make predictions about the effect of future mountain lion harvest. We present policies detailing how FWP will reduce and respond to human-lion conflicts. Finally, we describe an adaptive harvest management process that will help FWP and the public build realistic lion management objectives and how to evaluate whether those objectives are being met.

This Management Strategy represents FWP's long term commitment to use the best available scientific information to ensure that mountain lion management decisions are as objective, transparent, and adaptive as possible.

ACKOWLEDGEMENTS

This document is a synthesis, and practical application, of fundamental mountain lion field research conducted over decades in western North America. We sincerely thank the many wildlife biologists, technicians, and managers whose efforts have contributed to our understanding of lion ecology. Their body of work specifically informed this effort and will help ensure the continued conservation of mountain lions in Montana.

Several biologists made specific and fundamental contributions to this strategy. Dr. Hugh Robinson of Panthera guided important Montana lion field research to publication and built lion habitat models that became critical components of this strategy.

Dr. Josh Nowak and Dr. Paul Lukacs, both with the University of Montana, worked with FWP to construct an interactive model that describes how harvest affects mountain lion populations. This model, and the web-based interface they built, will allow FWP to make better lion management decisions going forward.

FWP research scientist Dr. Kelly Proffitt developed innovative field and statistical methods to estimate local lion abundance and to extrapolate those estimates more broadly. Dr. Proffitt's work, and good advice, made this strategy possible.

FWP Game Management Bureau Chief John Vore patiently guided this strategy from its inception. His council and critical reviews vastly improved this document.

Justin Gude, FWP's Wildlife Research Chief, effectively advocated for and helped implement many of the projects that developed core components of this strategy. It would not have been possible without his vision and support.

FWP's Mike Thompson helped make clear that this strategy is intended to conserve Montana's mountain lions, not simply manage them. We sincerely appreciate both his perspective and eloquence.

Many FWP biologists and managers reviewed earlier drafts of this strategy and it was much improved by those efforts. Julie Cunningham, Adam Grove, Jessy Coltrane, Heather Harris, Elizabeth Bradley, Howard Burt, Ben Jimenez, James Jonkel, Jay Newell, Scott Eggeman, Justin Gude, Kelly Proffitt, Nick DeCesare, and Brent Lonner contributed and/or compiled particularly thorough and valuable comment.

Members of the Montana State Houndsmen Association, Northwest Houndsmen Association, Ravalli Co. Fish and Wildlife Association, unaffiliated hound handlers, and others with a stake in lion management provided important input during the development of this draft. Their continued engagement as the strategy is finalized and implemented will be critical.

Mountain lion hunting in snow, D. Neils

CHAPTER 1

MOUNTAIN LIONS IN MONTANA

Mountain lions were historically found in most of Montana except on its open plains and prairies (Young & Goldman 1946). Like other predators, Montana mountain lions had a bounty placed on them from 1879 to 1962. The number of bounties paid declined from a high of 177 in 1908 (at $8) to fewer than 5 per year by 1925 (at $25; $350 in 2016 dollars). At least 1,562 lion bounties were paid between 1900 and 1930 (Riley 1998). Mountain lions were nearly extirpated from the state by 1930 due to widespread persecution and the severe depletion of their ungulate prey.

Mountain lions began to recover in core Montana habitats during the 1950s as deer and elk numbers increased. Lions were designated as a predator from 1963 until 1971 when the state legislature reclassified the species as a game animal and transferred their management to the Fish and Game Commission.

Martin Bright and Ed Lord, Bitterroot Valley, 1890.

Lions expanded their range, and legal harvest increased, over the next 20 years (Figure 1, Table 1). In western Montana during the mid- to late-1990s the number of public lion sightings grew, human-lion conflicts became increasingly common, and harvest quotas filled quickly.

After the severe winter of 1996-97 caused white-tailed deer herds in west-central and northwest Montana to decline by as much as 50% (Montana Fish, Wildlife and Parks 2006), human-lion conflicts (including several nonfatal attacks)

Figure 1. Montana statewide mountain lion harvest, 1971 – 2016.

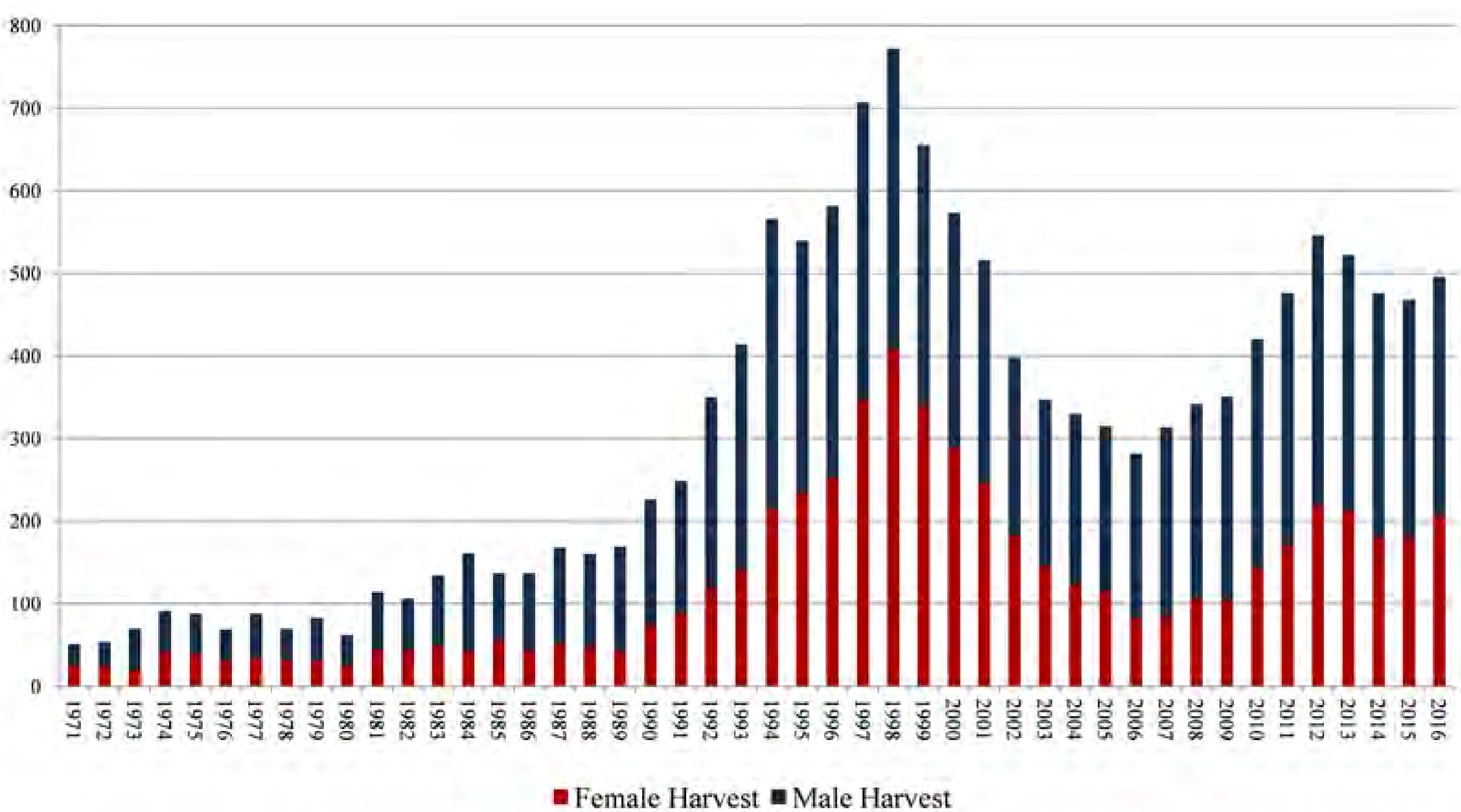


Figure. 2. Distribution of Montana mountain lion harvest, 1988 – 2015 (unshaded counties have had no harvests).

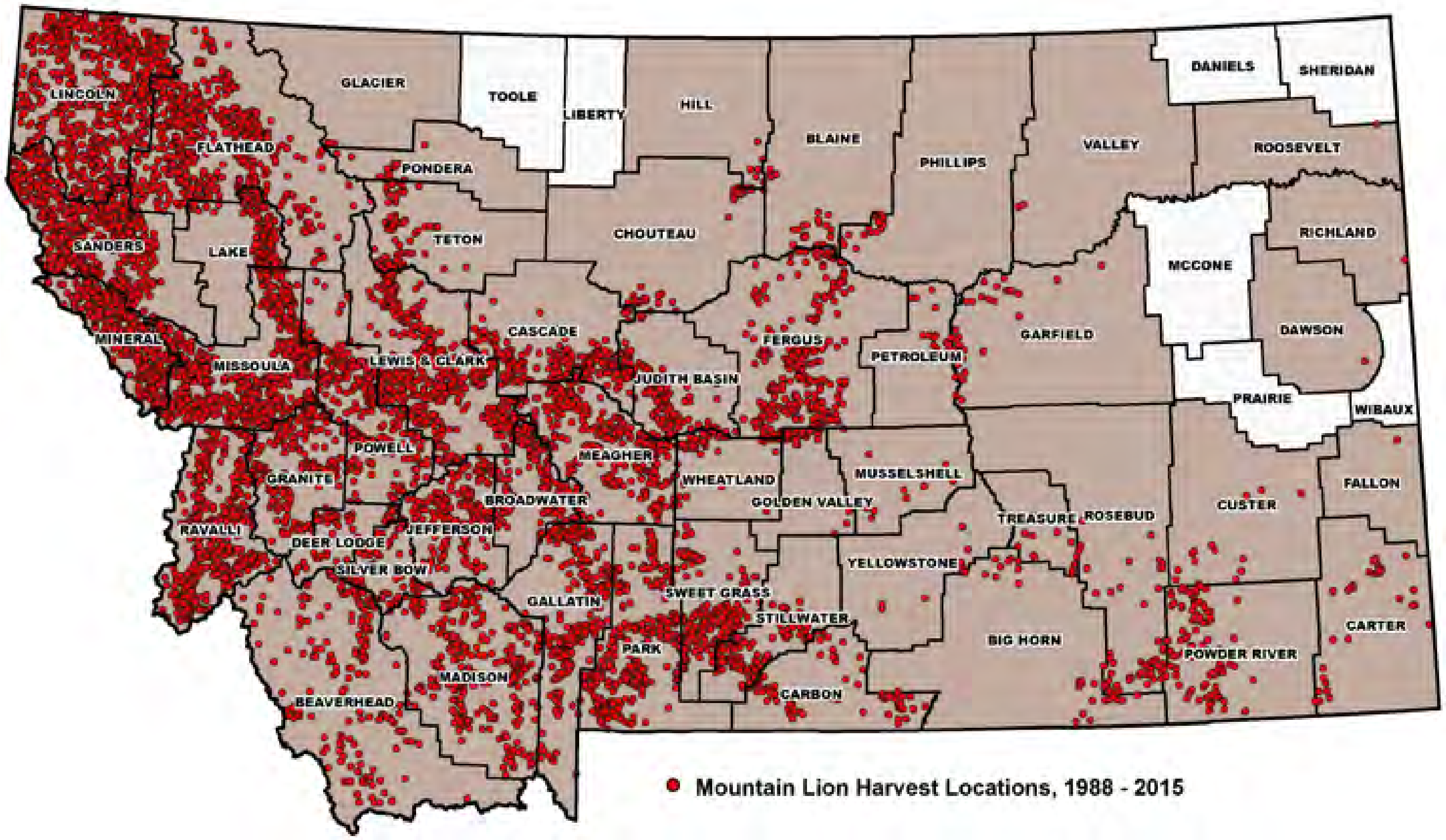


Table 1. Montana statewide mountain lion harvest, 1971 – 2016.

License	Statewide			
Year	F	M	Unk	Tot.
1971	26	25	0	51
1972	24	30	0	54
1973	19	51	2	72
1974	43	48	1	92
1975	40	48	0	88
1976	31	38	1	70
1977	35	53	0	88
1978	32	38	1	71
1979	32	51	0	83
1980	25	37	0	62
1981	45	69	0	114
1982	45	61	1	107
1983	49	85	2	134[1]
1984	43	118	4	161[1]
1985	56	81	6	137[1]
1986	44	93	4	137[1]
1987	50	118	2	168[1]
1988	48	112	1	160
1989	43	126	0	169
1990	74	152	0	226
1991	88	161	0	249[1]
1992	119	231	1	350
1993	141	273	0	414[1]
1994	214	352	0	566[1]
1995	233	307	0	540
1996	253	329	0	582
1997	347	360	0	707
1998	409	363	3	772
1999	339	316	0	655
2000	289	284	1	573
2001	246	270	0	516
2002	183	215	0	398
2003	146	201	0	347
2004	123	207	0	330
2005	116	199	3	315
2006	83	199	0	282
2007	84	230	0	314
2008	106	236	0	342
2009	104	247	0	351
2010	143	278	0	421
2011	171	305	0	476
2012	220	326	0	546
2013	213	309	0	522
2014	180	296	0	476
2015	181	287	0	468
2016	207	288	0	495

[1] Statewide totals differ from the Regions' sum because some harvest was reported as "unknown Region"

spiked. Managers were pressed to maintain historically high lion quotas in FWP Regions 1 and 2 because of concerns about public safety and to aid struggling prey populations. Lion harvest also reached record high levels during the late 1990s in Fish, Wildlife & Parks (FWP) Regions 3, 4, and 5.

By the early 2000s, many hound handlers believed that lion densities had significantly declined—an observation supported by ongoing FWP research in the Garnet Mountains. In response, the Fish and Wildlife Commission restricted the harvest of female lions during that decade in much of the state. By 2006, the Garnet Mountains research population had recovered to near 1990s densities (Robinson et al. 2014). Lions became increasingly common in eastern Montana FWP Regions 6 and 7 during the same period.

Mountain lions are now present in all suitable Montana habitats and continue to reoccupy neighboring states to the east. Between 1990 – 2016, an average of 450 lions were taken by licensed Montana hunters each year. Lions have been legally harvested in 49 of the state's 56 counties (Figure 2).

Harvest can be the most important factor affecting population size and growth where harvest occurs

Montana likely includes some of the most productive mountain lion habitat in North America. Although directly comparing lion densities across research projects and study areas is complicated (because of differences in field methods, inclusion of different sex-age classes in estimates, and the use of different areas over which density is calculated), reported North American lion densities generally range from 1 to 4 lions per 100 km^2 (37 mile^2; Hornocker & Negri 2009). In western Montana, researchers using DNA based detection methods have recently documented mountain lion densities exceeding 5 lions per 100 km^2 (Russell et al. 2012, Robinson et al. 2014, Proffitt et al. 2015).

GENETIC CONNECTIVITY

Mountain lion populations across the central Rocky Mountain west are genetically well connected. When wildlife populations are small and isolated, individuals can become more genetically similar over time. Although male lions are more frequent long-range dispersers (Logan & Sweanor 2001), Biek et al. (2006a) found that in Montana and Wyoming, neither male nor female resident lions shared more genes than expected by chance. Thus, frequent introduction of new genes by immigrating males is likely sufficient to maintain genetic diversity in females despite their lower dispersal rates and distances (Goudet et al. 2002).

Similarly, Anderson et al. (2004) found that there is ample gene flow between mountain lion populations in Wyoming and Colorado despite their being separated by large areas of relatively poor habitat. Even small and geographically isolated lion populations in North and South Dakota have maintained genetic diversity over time (Juarez et al. 2016).

In Montana, researchers genetically analyzed the fast-evolving feline immunodeficiency virus that commonly infects wild mountain lions. Although the study's 352 samples were collected as far as 1,000 km apart, there was no evidence of genetic sub-structuring, genetic drift, or barriers to gene flow within Montana populations (Biek et al. 2006b).

MOUNTAIN LION DISEASE, PARASITES, AND HUMAN HEALTH RISK

Mountain lions carry few communicable diseases that potentially threaten humans but certain precautions should still be taken when handling both live animals and carcasses. Fifty-four percent of lions sampled in Montana between 1971 and 1989 tested positive for the Trichinella roundworm. All harvested lions should be treated as if they are infected because a negative lab test does not mean Trichinella is not present. This parasite is transmissible to humans and pets if they consume undercooked infected mountain lion meat. Although mountain lion hunters are not required by Montana law to retain a harvested lion's meat (MCA 87-6-205), many hunters do. Trichinella infected lion meat that has been cooked to at least 165 degrees Fahrenheit is safe for human consumption (Western Wildlife Disease Workshop 2009).

Precautions protecting against the ingestion of other rare, but potentially fatal, air or blood-borne pathogens (i.e. pneumonic plague) should also be taken when handling a harvested lion carcass or one encountered in the field (Wong 2009). Pathogen infections or disease epizootics are not known to limit wild mountain lion populations in Montana.

EFFECTS OF HUNTER HARVEST

Mountain lion reproduction (age at first parturition, maternity, interbirth interval, litter size) and annual non-harvest mortality rates are remarkably consistent across western North American populations. Reproduction and non-harvest survival are also generally unaffected by hunter harvest. However, harvest can be additive to other forms of mortality and is often the most important factor affecting population size and growth in areas where harvest occurs. Lion populations are particularly sensitive to changes in adult female harvest rate (Anderson &


Mountain lion feeding on deer kill, D. Neils

Lindzey 2005, Stoner et al. 2006, Robinson et al. 2008, Cooley et al. 2009, Robinson et al. 2014).

Local mountain lion populations that are reduced by harvest can recover rapidly. Populations that are below prey limited densities can increase up to 30% annually when harvest (especially of females) declines and lions from other areas are able to immigrate (Ross & Jalkotzy 1992, Sweanor et al. 2000, Jenks 2011, Clark et al. 2014a). For example, in Utah, mountain lion densities that were reduced >60% over a 6-year period recovered to pretreatment levels after 5 years of reduced hunter harvest (Stoner et al. 2006). In New Mexico, an adult population that was experimentally reduced by >50% fully recovered in 31 months (Logan & Sweanor 2001), and in Wyoming a population that was lowered >40% by heavy harvest recovered in 3 years after harvest was reduced (Anderson & Lindzey 2005).

Montana lion populations are similarly resilient. Lion numbers in the Garnet Mountains declined nearly 50% during a period of heavy harvest but fully recovered within 5 years after the harvest rate was reduced there and in surrounding areas (Robinson et al. 2014).

The influence of dispersal and immigration on mountain lion population growth cannot be overemphasized. Even heavily hunted local populations may fail to decline if immigrants readily replace harvested lions (Cooley et al. 2009). On the other hand, a population (such as the one within the Garnet Mountains study area) may recover more slowly where high harvest rates are applied across a broader landscape.

Harvest can also alter a population's age structure. However, the interpretation of trends in the age of harvested mountain lions may be confounded by immigration, hunter selectivity, harvest regulations, and other factors. Monitoring changes in harvest-age composition can be a useful indication of a population's status in some cases. In general, the proportion of older age-class mountain lions in harvest—especially females—is higher within growing populations (Anderson & Lindzey 2005, Stoner et al. 2006, Wolfe et al. 2015). This index should only be used when monitored over a period of 3 or more years (Anderson 2003), and after considering other factors (i.e. immigration and harvest) that may be influencing age-at-harvest.

Within a lightly hunted lion population in western Montana's Bitterroot Mountains, 60% of independent aged lions were female (Proffitt et al. 2015). This is similar to the proportion of juvenile (13-24 month) females documented during a 10-year study of a lion population in west-central Montana, although the proportion of adult males to females varied widely during the study period depending on the level of hunter harvest (Robinson et al. 2014). Male:female ratios of 1:2 to 1:3 were commonly reported in other hunted populations (Hornocker & Negri 2009).

MOUNTAIN LION-PREY INTERACTIONS

The relationship between mountain lion predation and their prey populations is complex. This is especially true in Montana where lions often occupy multi-predator/multi-prey species systems. Mountain lions are the most influential ungulate carnivore across much of the state, especially where grizzly bears and wolves are absent or recovering. Therefore, wildlife managers must carefully consider the potential effects of mountain lion predation on prey populations when developing management prescriptions for both.

Mountain lions are opportunistic and adaptable foragers that prey or scavenge on a variety of species (Bauer et al. 2005, Murphy & Ruth 2011). In Montana, lions are obligate ungulate predators primarily preying on deer and elk. Mountain lion diet varies across the state depending on available prey, and lions may switch preferred prey seasonally as ungulate newborns become available or ungulate distribution changes (Williams 1992, Murphy 1998, Kunkel et al. 1999, Ruth & Buotte 2007). Mountain lions may also increasingly prey on pets, livestock (Torres et al. 1996), or other wildlife species (Logan & Sweanor 2001) following a significant decline in wild ungulate populations. Where hunter harvest is not an overriding factor, mountain lion densities are ultimately regulated by prey availability (Pierce et al. 2000a, Logan & Sweanor 2001, Stoner et al. 2006).

Mountain lion feeding on elk kill, western Montana, E. Bradley

GENERAL PREDATOR-PREY RELATIONSHIPS

In theory, compensatory predation removes a number of prey animals from a population that would have died anyway from another cause. Additive predation removes prey that would have otherwise survived. Predators regulate prey populations when the rate at which they remove prey changes along with prey population levels. Predation can limit prey population growth if the predation rate is independent of changes to a prey species' abundance—in these cases, predation can depress, rather than stabilize, prey populations.

Predation is more likely to limit a prey population when 1) an alternative and abundant prey species supports high predator densities, 2) prey is below carrying capacity despite weather and habitat that allow adequate survival and recruitment, and 3) there is a high predation rate relative to recruitment.

Predators can limit prey populations when predation is additive to other sources of mortality (i.e. severe weather or starvation). For example, in Idaho, when experimental mountain lion removals immediately increased mule deer fawn and adult survival, the effect of mountain lion predation initially appeared to be additive. However, reducing lion densities did not significantly affect overall deer population growth. In this case, weather and annual changes in forage quality ultimately regulated mule deer numbers — mountain lion predation was, in fact, compensatory over the long term (Bishop et al. 2009, Hurley et al. 2011).

In systems where most prey biomass is composed of a single, fecund, species (e. g. white-tailed or mule deer), predation itself is unlikely to depress prey populations for extended periods. However, when severe weather or other factors decrease populations significantly below habitat carrying capacity, mountain lion predation can delay the prey species' recovery (Ballard et al. 2001, Logan & Sweanor 2001, Pierce et al. 2012).

Where predator populations are sustained at high densities by an abundant prey species, populations of other relatively vulnerable or scarce prey species might decline or remain depressed (Messier 1994, Mills 2007). This apparent competition (Holt 1977) has been implicated in declines of mule deer (Robinson et al. 2002, Cooley et al. 2008), bighorn sheep (Logan & Sweanor 2001), mountain caribou (Kinley & Apps 2001) and other species (Sweitzer et al. 1997) due to lion predation.

Montana includes some of the most highly productive mountain lion habitat in North America

Winter severity explained most variation in annual white-tailed deer recruitment in northwest Montana. There, when harsh winter weather depressed reproduction and survival of hunted deer, predation (primarily by lions) became additive to other forms of mortality and exacerbated population declines (Montana Fish, Wildlife & Parks 2006).

Mountain lion kill rates vary by location and ecological system, but are generally reported as 1 kill per 7 days in deer dominated systems and 1 kill per 10 days in systems where elk are also available (Murphy 1998, Anderson & Lindzey 2003, Cooley et al. 2009). Lions tend to kill more frequently in warmer months, when ungulate newborns are available, and when competition with or rates of displacement by other predators is high.

Predation rates also vary depending on a mountain lion's age, sex, and reproductive status. Adults kill prey more frequently than younger lions. While adult females with dependent kittens exhibit the highest kill rate of any lion age/sex class, adult males kill a greater prey biomass on an annual basis (Nowak 1999, Buotte et al. 2008, Clark et al. 2014b). In Alberta, the annual live weight biomass of prey killed by mountain lions averaged 3,180 lbs. for subadult females, 4,520 lbs. for subadult males, 10,380 lbs for adult males, 5,340 lbs. for adult females, 6,160 lbs. for females with kittens < 6 months, and 9,440 lbs. for females with kittens > 6 months (Knopff et al. 2010).

Deer are the most common mountain lion prey species in Montana. In northwest Montana's Salish Mountains, lions were the most common predator of radio marked white-tailed deer (Montana Fish, Wildlife & Parks 2006). Similarly, 87% of lion kills documented in Montana's North Fork of the Flathead River drainage were white-tailed deer, where elk, mule deer, and moose were also present in lower numbers (Kunkel 1999).

However, in northeast Washington mountain lions disproportionately selected for mule deer even though white-tailed deer were more abundant (Cooley et al. 2008). The same was true in south-central British Columbia where mountain lion predation was implicated in mule deer declines (Robinson et al. 2002). Where both elk and mule deer were present, female mountain lions were more likely to kill mule deer, whereas male mountain lions killed elk more frequently (Anderson & Lindzey 2003). Female lions may also select for calf elk and younger or older mule deer (Nowak 1999, Pierce et al. 2000b).

Although most researchers found that mountain lions selected for male elk and deer (Hornocker 1970, Kunkel et al. 1999, Anderson & Lindsey 2003, Atwood et al. 2007, Blake & Gese 2016), others did not (Clark et al. 2014b). Adult male elk and deer are more often killed by mountain lions during and after the rut while most adult female elk and deer are killed before giving birth in late spring (Knopff et al. 2010, Clark et al. 2014b).

The annual risk of mountain lion predation to adult female elk across the western U. S. (Brodie et al. 2013) and in Montana (Hamlin & Cunningham 2009, Eacker et al. 2016) is low compared to other sources of mortality, including hunting. This is important because, in certain situations, adult female survival explains more of the variation in overall elk population growth rate than elk calf survival (Eacker et al. 2017).

Lions are often one of the primary predators of elk during their first year of life. The rate of calf predation by mountain lions increases with overall lion density, decreases when other predators (especially wolves and grizzly bears) are abundant, and increases when herds are nutritionally limited and concentrated during winter (Kortello et al. 2007, White et al. 2010, Griffin et al. 2011, Johnson et al. 2013, Eacker et al. 2016).

Elk calf survival and recruitment can influence a herd's growth and, subsequently, the number of elk available for hunter harvest (Raithel et al. 2007). Although calf survival does not appear to be strongly influenced by the physical (nutritional) condition of cow elk, poor forage on summer range can reduce a herd's pregnancy rate (Reardon 2005, Proffitt et al. 2016). Depressed calf production may then predispose that herd to the effects of mountain lion predation and exacerbate population declines (Clark et al. 2014b, Eacker et al. 2016).

Unlike bears, which primarily kill elk calves during the first 30 days of life, mountain lions prey on them throughout the year. Mountain lions were responsible for 70% of elk calf mortalities in northeastern Oregon where there are black bears but no wolves or grizzly bears (Reardon 2005). On a study site in western Montana where there were wolves

Wildlife managers must carefully consider the potential effects of mountain lion predation on prey populations when developing management prescriptions for both

and black bears (but no grizzlies), Eacker et al. (2016) found that 60% of known cause calf mortality was by mountain lions and male calves were 50% more likely to die than females.

Elk migration to areas of greater or lesser exposure to predation can also affect calf survival (Hebblewhite & Merrill 2007). For example, in Montana, seasonal migration of elk to ranges dominated by agriculture (where predators were rare) lowered predation risk while concentration on winter ranges increased it (Eacker et al. 2016).

The density of mountain lions in an area may itself be enough to explain predation's influence on elk calf recruitment. Where mountain lion densities are high they are capable of limiting elk recruitment enough that annual variation in lion densities explains most of the variation in annual calf survival (Johnson et al. 2013). In Montana's Bitterroot Range, where lion densities were relatively high, grizzlies absent, and wolves were present, lion predation accounted for most calf elk mortality (Eacker et al. 2016). In contrast, on Yellowstone's Northern Range and in Montana's Garnet Mountains where mountain lion density was relatively low, the rate of lion predation of elk calves was also low (Raithel 2005, Barber-Meyer et al. 2008).

The effect of mountain lion predation on bighorn sheep populations varies, but is most likely to limit population growth where herds are small and isolated (Ruth & Murphy 2011). The rate of predation can simply be a function of the overall mountain lion density within a sheep herd's range. However, in some cases bighorn sheep predation is a specialized behavior adopted by individual lions (Logan & Sweanor 2001).

Lion predation of bighorn sheep can increase where lion densities are buoyed by an abundant primary prey species or when a decline in the primary prey causes lions to switch to bighorn sheep (Kamler et al. 2002). Targeted removals of individual lions that specialize on sheep, or sustained efforts to suppress lion density in core bighorn sheep habitat, can effectively reduce the impact of lion predation on small, isolated herds (Ernest et al. 2002, McKinney et al. 2006).

MANAGEMENT CONSIDERATIONS

- Weather and forage availability are more likely than predation to explain chronically low ungulate populations. The influence of these potentially limiting factors should be evaluated before predation is implicated.

- Mountain lion predation is more likely to limit a prey population's growth if that population is below habitat carrying capacity and the lion predation rate is high. For instance, if a severe winter causes a significant deer die off but overall forage availability remains unchanged, mountain lion predation may slow the herd's recovery. In this case, preemptively and temporarily reducing mountain lion density through hunting could increase the deer population's growth rate while potentially reducing human-mountain lion conflicts.

- Mountain lion predation can limit a prey population where lions are the most abundant predator, lion density is supported by another abundant prey species, and the prey population is below its habitat's carrying capacity. In this case, managers should consider whether apparent competition is the ultimate cause of a secondary prey species' (e.g. mule deer or bighorn sheep) decline. Where abundant primary prey support dense mountain lion prey populations, sympatric populations of more vulnerable secondary prey may be disproportionately affected.

- The effect of predation on elk survival increases with the diversity of the predator community – the addition of grizzlies and wolves to a system with established mountain lions and black bears can change the influence of predation on ungulate prey.

- Mountain lion predation is unlikely to limit adult elk survival but can significantly reduce elk calf recruitment where lions are the predominant predator, lions occur at high densities, and where weather and/or habitat quality has reduced elk pregnancy rates.

- Targeted removal of individual lions that specialize on bighorn sheep, or sustained efforts to suppress lion density in core bighorn sheep habitat, may reduce the influence of mountain lion predation on the growth of small and isolated sheep herds.

-Attempts to locally reduce mountain lion populations will likely be confounded by the effect of immigration. Harvest treatments intended to reduce lion density should be sustained, broad scale, or both.

- Any proposal to reduce mountain lion density to benefit prey should be explicitly developed in an adaptive management framework. Managers should make measurable predictions about the outcome of a mountain lion harvest prescription (on lion and prey populations), monitor and evaluate the treatment's effects after a predetermined period, and be prepared to modify management based on that evaluation.

Bighorn sheep cached by a mountain lion, norhtwest Montana

CHAPTER 2

MOUNTAIN LION-HUMAN CONFLICT

Montana law grants FWP and the Fish and Wildlife Commission broad authority and discretion to manage wildlife. However, the legislature provided specific direction to the Department regarding the management of large predators, including mountain lions, that clearly emphasizes the protection of people and property over sport hunting of either mountain lions or their prey:

> 87-1-217. Policy For Management Of Large Predators - Legislative Intent
>
> (1) In managing large predators, the primary goals of the department, in the order of listed priority, are to:
>
> (a) protect humans, livestock, and pets;
> (b) preserve and enhance the safety of the public during outdoor recreational and livelihood activities; and
> (c) preserve citizens' opportunities to hunt large game species.

A mountain lion becomes a public safety concern when it appears habituated to human activity or development, attacks livestock or pets, or in any way behaves aggressively toward humans. FWP has developed specific Mountain Lion Depredation and Control Guidelines (Appendix 3) which describe and direct the Department's actions following a reported conflict between a human and a mountain lion.

The types and rate of conflicts between mountain lions, humans, and livestock are affected by mountain lion abundance, location, presence of attractants, and individual lion behavior. FWP will rely on the expertise and judgment of its field staff and agents (i.e. USDA Wildlife Services personnel) to investigate reported conflicts and determine the most appropriate response to a given situation. FWP's principal consideration when making these decisions will be reducing future risk of harm to people and/or property.

FWP will respond to human-lion conflicts in a manner that protects public safety, reduces property loss, and increases public tolerance for mountain lions. FWP will enforce state law (MCA 87-6-216) and local ordinances that prohibit certain wildlife attractants and will work to remove or contain attractants when a lion localizes in a problematic location. FWP will use hunter harvest when and where appropriate to manage lion density in high conflict areas. Finally, FWP may use targeted hazing or removal of individual offending mountain lions to mitigate ongoing or potential risk to people, pets, or livestock.

FWP will implement and facilitate programs that help livestock and pet owners protect their animals such as those currently offered by FWP, the Montana Livestock Loss Board, and nongovernmental organizations. FWP will continue to emphasize the importance of preventative efforts intended to reduce the risk of livestock loss in memoranda of understanding entered into with USDA Wildlife Services.

FWP does not maintain facilities to rear, hold, or rehabilitate mountain lions. Mountain lions that are injured so severely that they could pose a risk to humans or those that are unlikely to survive without intervention will be euthanized.

Montana hunting regulations prohibit the taking of a female lion accompanied by spotted kittens. However, in the unfortunate circumstance that a lactating female lion is mistakenly taken by a hunter or is otherwise killed, FWP staff may attempt to find the kittens and humanely euthanize them, unless an approved zoo or other facility is prepared to permanently assume responsibility for their care.

Capturing and relocating habituated, aggressive, or depredating mountain lions is not an effective conflict management response (Hornocker & Negri 2009). Mountain lions that are captured and translocated are

Table 2. Recorded non-harvest human-caused lion mortality, 1989 – 2015.

Year [2]	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
FWP, Private Party, & Other Removals [1,3]	**10**	**14**	**17**	**20**	**23**	**15**	**9**	**23**	**53**	**19**	**21**		**3**			**5**		**8**	**22**	**32**	**24**	**23**	**39**	**27**	**35**	**21**	**16**	**41**	**9**
Public Safety																			4	10	9	9	15	9	10	6	1	16	2
Depredation or Protection of Pets			1	2						3	2								5	4	5	2	6	5	2	6	5	10	2
Depredation or Protection of Livestock	1			1						6	1								5	8	4	6	15	6	14	8	4	2	3
Self Defense																			4	10	4	2	2	3	7	1	5	10	1
Other/Unknown	9	14	16	17	23	15	9	23	53	10	18		3			5		8	4		2	4	1	4	2	0	1	3	1
% Female (of those known)																			50%	50%	55%	41%	47%	36%	64%	42%	44%	32%	67%
Livestock Depredation USDAWS/APHIS [4]	**2**	**3**	**3**	**4**	**7**	**3**	**9**	**8**	**13**	**21**	**16**	**18**	**9**	**12**	**7**	**3**	**7**	**5**	**8**	**13**	**12**	**14**	**17**	**19**	**15**	**12**	**12**	**3**	**4**
Illegal	**2**	**2**	**2**	**4**	**9**	**5**	**11**	**6**	**18**	**7**	**5**	**0**	**2**	**0**	**1**	**0**	**0**	**2**	**4**	**2**	**5**	**6**	**7**	**5**	**9**	**7**	**3**	**3**	**7**
Incidental Trapping [5]	**2**	**2**	**2**	**4**	**5**	**9**	**7**	**4**	**6**	**4**	**2**	**0**	**1**	**3**	**3**	**1**	**1**	**1**	**10**	**9**	**9**	**8**	**8**	**16**	**16**	**12**	**13**	**6**	**4**
Snare																			7	2	7	4	6	7	2	6	8	5	3
Foothold																			2	7	2	4	2	9	13	6	5	1	1
Conibear																									1				
Unknown	2	**2**	**2**	**4**	**5**	**9**	**7**	**4**	**6**	**4**	**2**	**0**	**1**	**3**	**3**	**1**	**1**	**1**	1										
% Female (of those known)																			60%	78%	63%	50%	88%	75%	50%	89%	73%	67%	50%
Total	**16**	**21**	**24**	**32**	**44**	**32**	**36**	**41**	**90**	**51**	**44**	**18**	**15**	**15**	**11**	**9**	**8**	**16**	**44**	**56**	**50**	**51**	**71**	**67**	**75**	**52**	**44**	**53**	**24**

[1] Roadkill incidents are inconsistently reported in MT and are not included in this table

[2] FWP License Year, 8/1 - 7-31, unless otherwise noted

[3] Data from License Year 2000 to 2006 are incomplete and should be considered minimums

[4] Source: USDAWS/APHIS. Data recorded by Federal Fiscal Year, 10/1 - 9/30

[5] Data prior to 2007 are incomplete and should be considered minimums

unlikely to survive, often return (or attempt to return) to their capture location (Ross & Jalkotzy 1995, Ruth et al. 1998), and can cause future conflicts (Belden et al. 1991, Williams 1992). For these reasons, mountain lions shall not be captured and translocated under any circumstances. Mountain lions involved in any form of conflict will be dealt with per the Mountain Lion Depredation and Control Guidelines (Appendix 3).

Statewide records of reported mountain lion-human conflicts are historically incomplete (Table 2). In 2007, FWP created a centralized database to track harvest and most reported human caused non-harvest lion mortality. The same database has since been updated to also archive records of animals, including mountain lions, that are incidentally caught by recreational trappers and successfully released. This system will also be used to record all reported human-mountain lion conflict incidents, and their resolution. These more complete records will allow FWP to identify sources of and trends in mountain lion conflicts so that they can be more effectively addressed.

FWP actively educates the public about safely living with mountain lions, avoiding human-lion conflicts, and reducing the risk of property loss. The agency will continue to employ biologists and technicians who specialize in educating the public about, and responding to, human-predator conflicts. FWP will also maintain and periodically update educational materials and programs that teach the public about lion biology and behavior, ways to avoid and diffuse conflicts, strategies and methods to protect pets and livestock, and how to responsibly live and recreate in mountain lion habitat.

LIVESTOCK DEPREDATION

Mountain lions were confirmed to have killed an average of 136 head of livestock in Montana annually between 2006 and 2015 (USDA Wildlife Services, Table 3). However, only a fraction of actual livestock losses to mountain lions are found and formally documented (Jenks 2011). In Montana, male mountain lions were more likely than females to be removed in response to livestock depredation and most depredating lions were younger adults (1-4 years old) in good physical condition. The peak time period for both

Mountain lion killed following domestic sheep depredation, FWP

The rate of livestock loss may be partly a function of an area's mountain lion density

livestock and human conflict incidents was between June and November (Riley & Aune 1997).

Mountain lions most commonly kill livestock that weigh less than 300 pounds. Although full grown cattle and horses are occasionally killed, mountain lions mainly kill calves/foals and yearlings. Losses are highest where calves or foals are born in lion habitat (Cougar Management Guidelines Working Group 2005). Small livestock (sheep, goats, and fowl) are the domestic species most vulnerable to mountain lion predation in Montana (Figure 3). Livestock depredation predominately occurred in central Montana where sheep production is more common and in western valleys where there is a greater number of hobby livestock.

Montana law (MCA 87-6-106) allows private citizens to legally kill any mountain lion that is attacking, killing, or threatening to kill a person or livestock. Private citizens may also legally kill a mountain lion that is in the act of attacking or killing a domestic dog. A person who kills a mountain lion under this statute must notify a FWP employee within 72 hours and surrender the carcass. FWP may issue a permit to kill a mountain lion to a landowner which allows them to take a mountain lion, within a specific area and time period, that is threatening to or suspected of killing livestock.

FWP annually contracts USDA Wildlife Services to respond to reported depredation of commercial livestock. When a loss is reported, a Wildlife Services agent conducts a field investigation to determine whether the loss is a "probable" or "confirmed" depredation and what predator species is responsible. Based on that investigation, and whether predation is determined to be the likely cause, the agent decides what response is most likely to prevent further livestock losses. This may, but does not always, include attempting to lethally remove the offending individual predator. The annual FWP contract requires Wildlife Services to provide records of all reported incidents (including lethal removals) to FWP at the end of the federal fiscal year (October 1).

Montana's Livestock Loss Board may reimburse stock growers for up to fair market value of probable or confirmed livestock losses due to mountain lion predation. The Board may also issue grants supporting efforts to reduce or mitigate the risk of mountain lion depredation of livestock (MCA 2-15-3110 through 3113).

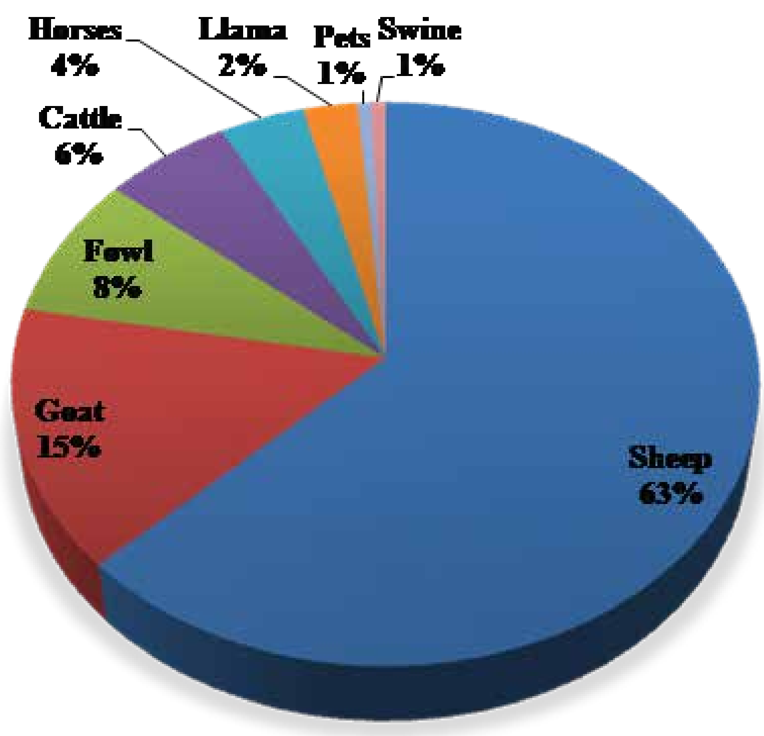
Table 3. Domestic livestock reported to and/or verified by USDA APHIS Wildlife Services as injured or killed by mountain lions, federal fiscal years 2006 – 2015.

	2006		2007		2008		2009		2010	
	Injured	Killed	Injured	Killed	Injured	Killed	Injured	Killed	Injured	Killed
Cattle		2		10		2		18	2	8
Horses	6	2	8	8	1	2	5	2		3
Goat		2		16	2	20		23	1	22
Llama		1				3		2		4
Sheep		23	1	26	4	115	2	157	2	128
Swine										
Fowl				7		8		49		25
Total	**6**	**30**	**9**	**67**	**7**	**150**	**7**	**251**	**5**	**190**

The rate of livestock loss may be partly a function of an area's mountain lion density. In Oregon, Hiller et al. (2015) found that as mountain lion population density increased, so did the number of mountain lions killed as a result of livestock predation. This relationship was especially strong at higher mountain lion densities. Livestock conflicts either decreased when mountain lion hunter harvest increased or remained constant where mountain lion densities were relatively low.

There is evidence that a similar relationship between lion abundance and livestock conflict may exist in Montana. There is a correlation ($r^2 = 0.66$) between the number of mountain lions that Wildlife Services agents annually killed in response to livestock depredations and the statewide mountain lion population estimated by FWP's Integrated Population Model (1990 – 2013; Chapter 6; Figure 4). Hunter harvest that maintains mountain lions at moderate densities may be a useful tool in managing livestock predation in some circumstances (Hiller et al. 2015).

Figure 3. Proportion of livestock killed by mountain lions by species, 2006 – 2015.



Otherwise, there are few practical measures that can completely prevent the loss of commercial livestock to mountain lions. Delaying turnout of cow-calf pairs into remote lion occupied pastures may reduce calf loss. Although guard dogs can reduce livestock losses to canine predators, guard dogs do not effectively protect against mountain lion depredation (Jenks 2011). If economically feasible, switching from raising small livestock (i.e. sheep) to less vulnerable species where mountain lions are common may also reduce depredation losses (Lindzey 1987). Owners of hobby livestock can effectively use practices unavailable to commercial producers such as night penning, lights, and clearing brush around paddocks to reduce depredation risk.

2011		2012		2013		2014		2015	
Injured	Killed	Injured	Killed	Injured	Killed	Injured	Killed	Injured	Killed
	3		14		14		2		10
2	2	2	4	2	1	3	1	1	2
	17	3	44		6		11		45
	10		10		5		1		
	67	1	79		162		64		55
					2		2		
	3						24		
2	102	6	151	2	190	3	105	1	112

MOUNTAIN LION-HUMAN INTERACTIONS

Mountain lion attacks on humans in Montana are extremely rare. The only fatal mountain lion attack in modern times was that of a 5-year old boy killed near Evaro, on the Flathead Indian Reservation, in September of 1989. Several nonfatal attacks have also occurred in the state and, like elsewhere, overwhelmingly involved children (Beier 1991). Juvenile and subadult mountain lions are responsible for most human-lion conflicts across the western U. S. (Mattson 2007), including Montana.

Subadult lions of both sexes are also more likely than adults to use urban and exurban residential areas (Kertson et al. 2013). Although in Montana males were more likely than females to take livestock, sex ratios of lions involved in human incidents were not significantly different from 50:50. Human incidents mostly occurred near western intermountain valley communities.

Mountain lions commonly live adjacent to, or travel through, developed areas but most lions travel at night and are rarely seen (Kertson et al. 2013). Individuals that are routinely sighted during daylight hours near homes and people, or those that appear accustomed to human activity and development, have become habituated and are a public safety concern. Individual lion behavior often escalates from natural to habituated to nuisance to dangerous, at which point the lion may begin to kill pets in populated areas and/or to display aggression toward humans (Cougar Management Guidelines Working Group 2005).

Mountain lions commonly live adjacent to, or travel through, developed areas but most lions travel at night and are rarely seen


Habituated mountain lion removed by FWP conflict specialist , R. Wiesner

If an investigation reveals that a habituated mountain lion has become a nuisance or aggressive, FWP staff should document the behavior, notify area residents of the situation (especially those with children and/or outdoor pets), and immediately attempt to either aversively haze or lethally remove the offending individual.

Field staff should closely follow the approved protocols for responding to human-lion conflicts in the Mountain Lion Depredation and Control Guidelines (Appendix 3).

SPECIAL MANAGEMENT AREAS

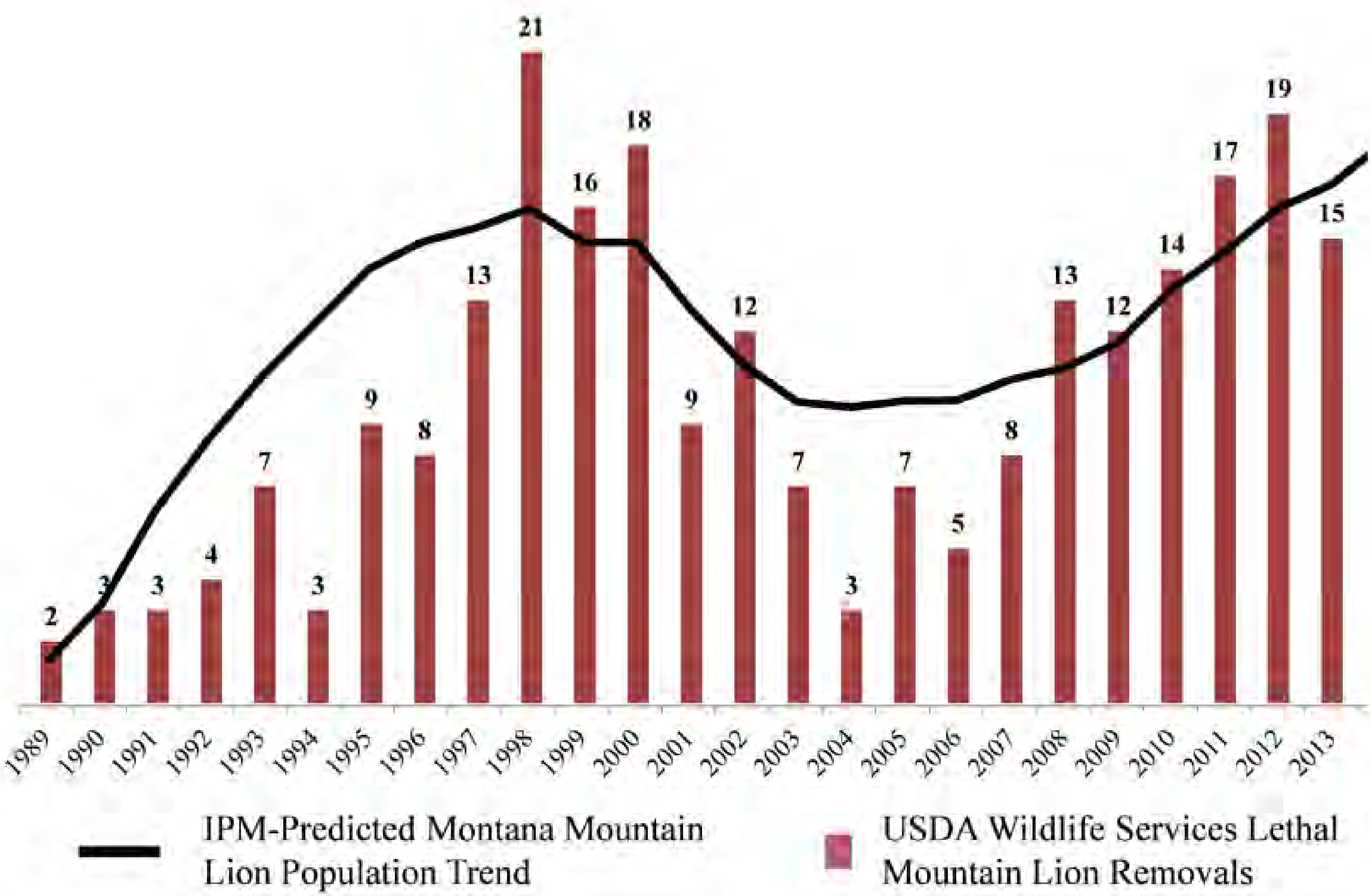
Montana has designed certain Lion Management Units (LMUs) specifically to encompass urban, suburban, or agricultural areas where the tolerance for mountain lion presence is low and the potential for human-mountain lion conflict is high. The Commission may designate these LMUs “Special Management Areas” (described by Logan & Sweanor 2001) and either elect to assign an “unlimited” harvest quota (e.g. LMU 170, immediately surrounding Kalispell) or a high annual quota that it is rarely, if ever, met.

If a Special Management Area contains suitable mountain lion habitat, the management approach may not significantly reduce mountain lion densities because of rapid immigration into vacated home ranges (Robinson et al. 2008, Cooley et al. 2009). However, specifically designating Special Management Areas can ease social and political concerns (Jenks 2011) and, importantly, ensure that legal hunter harvest remains a management tool throughout the fall and winter hunting seasons.

For example, the Missoula Special Management Area (MSMA), a LMU surrounding the highly developed Missoula Valley, was established in 1994. Relatively high quotas in this LMU are rarely met even though the area contains high-quality lion habitat and General License hunting was allowed for nearly 7 months each year.

The average age of a mountain lion harvested within the MSMA between 2000 and 2015 (3.09 years; n = 421) was slightly lower than that of lions harvested during the same period in the remainder of Region 2 (3.58 years; n = 2319). However, this small difference does not indicate that higher hunter harvest opportunity meaningfully increased the proportion of more conflict prone juveniles in the LMU. Although FWP staff lethally removed several nuisance mountain lions from the MSMA each year, FWP hunting regulations were not publicly perceived as limiting legal hunter harvest during established seasons in this high conflict area.

Figure 4. The relationship between Montana's modeled mountain lion population trend and annual mountain lion removals by Wildlife Services in response to livestock depredation, 1989 - 2013.



CHAPTER 3

2016 MONTANA MOUNTAIN LION RESOURCE SELECTION FUNCTION

INTRODUCTION

To produce accurate estimates of mountain lion abundance, managers first need to understand what habitat features are important to lions and how that habitat is distributed across the state. Accurate spatial models that describe mountain lion habitat use can also be used to monitor lion populations over time. While producing reliable maps of relative mountain lion habitat quality and landscape linkages is critically important (Cougar Management Guidelines Working Group 2005, Jenks 2011) they have previously been difficult to produce and validate.

Managers need accurate spatial data that depict mountain lions' use of their habitat in order to predict lion abundance and to monitor their populations over time

Montana FWP will use a "resource selection function" (RSF) model to depict and analyze the state's mountain lion habitat. A RSF is a statistical model that represents the relative probability that an animal will select a particular place or resource (Manly et al. 2002). A RSF is simply a spatial surface of pixels or cells that are each assigned a statistical value based on what we know about a species' habitat selection. This surface can then be used to mathematically analyze and describe the species' habitat use at larger scales.

A RSF is often displayed as a map showing the relative likelihood a species will use a particular resource or available habitat. Biologists construct RSFs from field data that describe an animal's spatial use (such as telemetry relocations collected using radio or GPS collars) and the habitat variables that likely cause the animal to select (or avoid) certain resources or areas. Habitat variables may include vegetation type, canopy closure, elevation, terrain, or other features that affect an animal's habitat selection.

It's impossible to quantify all the habitat variables that cause an animal to select a certain location. However, we can often identify a combination of measurable factors that accurately predict the relative likelihood that a species is present in a certain habitat type. If we also have information about a population's vital rates and population density, we can also estimate how many individuals a larger area likely supports.

A well designed RSF can help biologists better manage wildlife in many important ways. RSFs can describe the kind of habitat where we'd expect to find a certain species, map corridors that are potentially important connections between larger habitat patches, and identify isolated areas of suitable habitat that may support a species, even if the species is not currently there. RSFs help managers identify resources that are important for the conservation of a species or that may be limiting its use of an area. Finally, a RSF allows biologists to make inferences about an animal's abundance across broad landscapes using monitoring data that provides information on the population's current density.

FWP will use a statewide mountain lion RSF to:

1. Define distinct mountain lion ecoregions.
   The RSF surface consists of many small cells, or "pixels", that are each assigned a value based on the habitat features present within them. The average RSF value of all the pixels within a hunting district or lion management unit generally describes the overall quality of that unit's lion habitat. FWP used these average values to define large, biologically meaningful, ecoregions within the state where lion habitat is similar in type and

distribution. These ecoregions will be the primary spatial basis of its mountain lion population monitoring program (Chapter 4).

2. Improve population monitoring.
   The RSF helped FWP identify representative population Trend Monitoring Areas within the Northwest, West-central, and Southwest ecoregions. The RSF will also be used to guide periodic field sampling within these Monitoring Areas (Chapter 4).

3. Enable FWP to estimate mountain lion abundance.
   When the relationship between observed lion abundance and the RSF is known, we can estimate lion abundance within both Trend Monitoring Area(s) and the larger ecoregion. Integrating the RSF with field sampling such as spatial capture-recapture (Chapter 5) makes these monitoring methods more effective. Including a RSF as a covariate in the density estimation model—that is, formally assuming that an animal's activity center is more likely to fall in higher quality habitat—significantly improves the population estimate's biological realism and precision.

MONTANA MOUNTAIN LION RESOURCE SELECTION FUNCTION

Robinson et al. (2015) produced the first comprehensive winter mountain lion resource selection function for the state of Montana. The authors used mountain lion telemetry relocations (both VHF and GPS) from 10 individual mountain lion field research projects conducted throughout Montana and Yellowstone National Park between 1979 and 2012 to train and validate the RSF (Table 4). A significant number of telemetry locations were withheld from the training data for internal model validation. Mountain lion harvest locations (1988 – 2011; generalized to the center of the 640-acre section of harvest) were also used to validate the model. The original manuscript contains a detailed description of how this original RSF was constructed, was tested, and performed.

The most important measure of a RSF's utility is its ability to predict a species' use of available habitat (Boyce et al. 2002). The 2015 RSF model predicted both out-of-sample lion telemetry locations and hunter harvest locations quite well across Montana. Although there was generally excellent agreement between the location of harvested animals and predicted areas of lion habitat use, the 2015 model was most predictive in FWP Regions 1, 2, 4 and 6. In Regions 3, 5, and 7, a higher proportion of animals were harvested in areas that the RSF predicted to be lower quality habitat, compared to other FWP Regions.

D. Neils

Table 4. Field studies and sampling data used to develop the Robinson et al. (2015) and 2016 MT Mountain Lion Resource Selection Function.

Study	Location	Years	N	Telemetry Method	2016 Model Training Locations
Murphy (1983)	Fish Creek	1979–1982	9 (6F, 3M)	VHF	127
Williams (1992)	Sun River	1991–1992	24 (15F, 9M)	VHF	104
Murphy (1998)	Yellowstone National Park	1987–1995	41 (29F, 12M)	VHF	1335
Ruth (2004)	North Fork Flathead	1993–1997	38 (28F, 8M)	VHF	692
Ruth & Buotte (2007)	Yellowstone National Park	1986–2006	39 (21F, 18M)	VHF and GPS	2782
Choate (2009)	National Bison Range	2000–2003	8 (7F, 1M)	VHF	576
Robinson & DeSimone (2011)	Garnet Range	1998–2006	39 (31F, 8M)	VHF and GPS	14,127
Kunkel et al. (2012)	Rocky Boys Reservation	2006–2009	6 (2F, 4M)	GPS	1786
Kunkel et al. (2012)	Fort Belknap Reservation	2008–2010	3 (2F, 1M)	GPS	281
Matchett (2012)	Missouri Breaks	2011–2012	2 (2M)	GPS	785

Table 5. Montana mountain lion winter Resource Selection Functions developed as part of Robinson et al. (2015) and the revised 2016 model.

Covariate	**Robinson et al. 2015** Coefficient (SE)	**2016 (revised) RSF** Coefficient (SE)
South Aspect	0.3181 (0.0274)	0.3716 (0.0249)
High Montane	-1.3883 (0.3093)	-0.4619 (0.2116)
Agriculture	-1.9151 (0.1512)	-1.5664 (0.1115)
Developed	-0.6110 (0.1706)	-1.0656 (0.1642)
Transitional Vegetation	-0.7200 (0.0453)	-1.3047 (0.0417)
Elevation	0.0191 (0.0002)	0.0084 (0.0002)
$Elevation^2$	-0.000006 (8.67E-08)	-0.000003 (7.13 E-08)
Percent Slope	0.0264 (0.0017)	0.0229 (0.0014)
Percent $Slope^2$	-0.00015 (1.96E-05)	-0.0001 (1.3E-05)
Distance from forest	-0.0078 (0.0002)	N/A
Canopy	N/A	0.1688 (0.0029)
$Canopy^2$	N/A	-0.0022 (0.00004)
Constant	-14.9483 (0.2250)	-6.4305 (0.1551)

Figure 5. The 2016 Montana Mountain Lion Resource Selection Function map. Higher values indicate an area is more likely to be used by mountain lions.

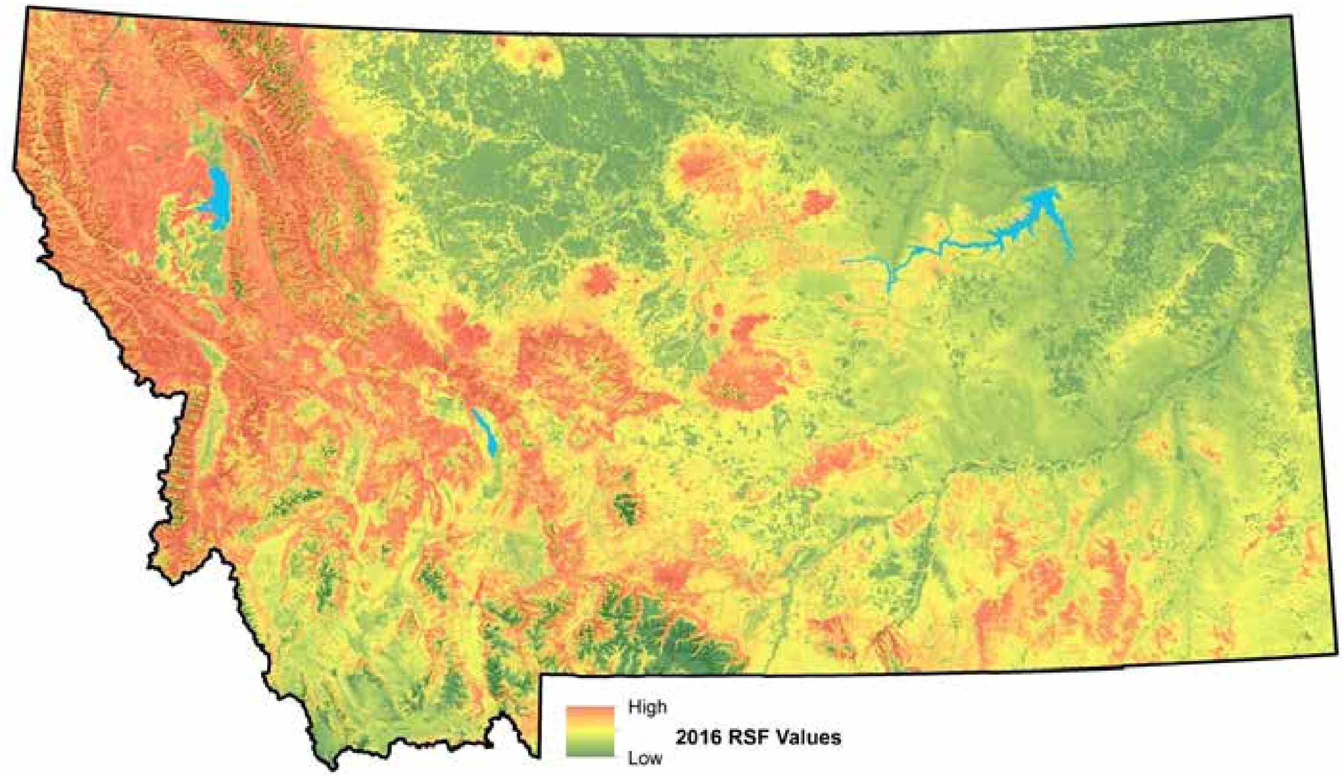


Figure 6. The 2016 Montana Mountain Lion Resource Selection Function map with 22,595 mountain lion telemetry model training points (1979 – 2012) and 10,503 harvest location validation points (1988 – 2015).

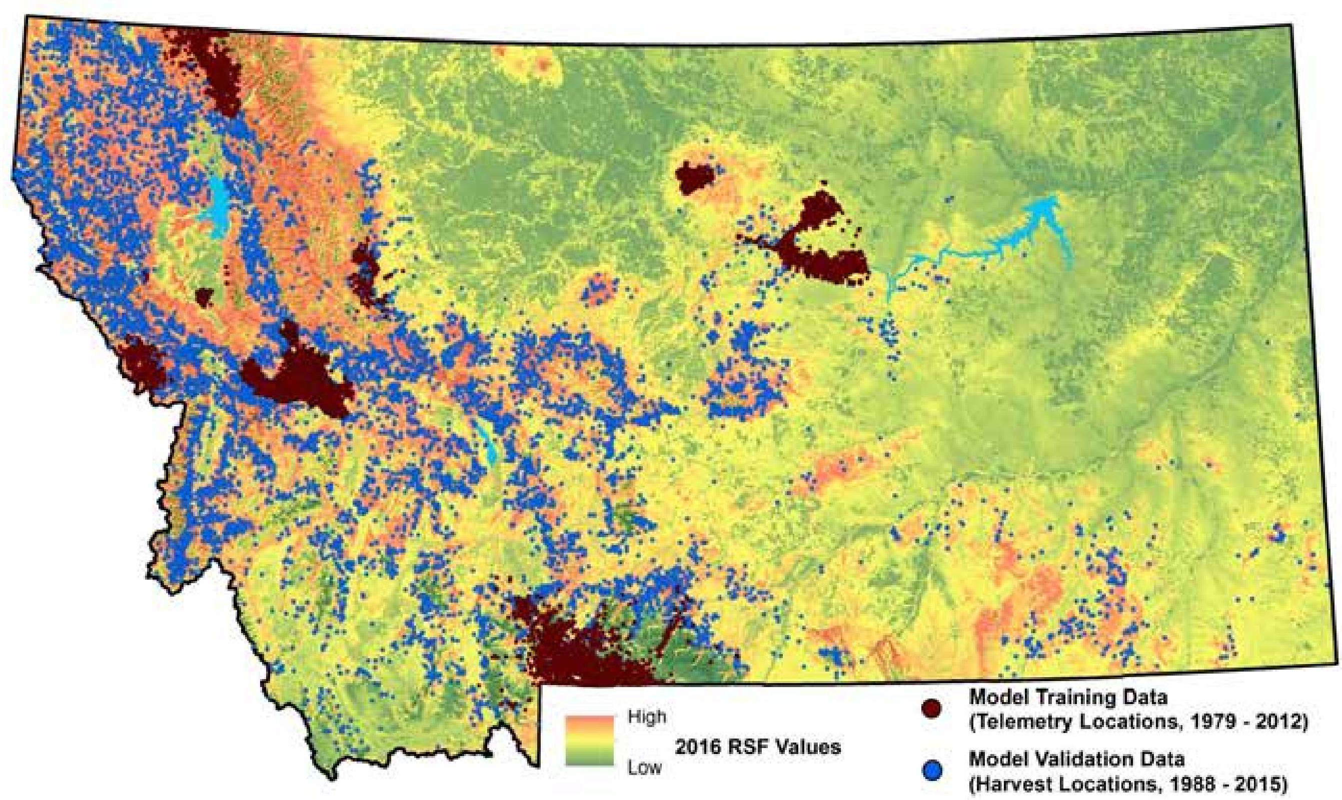
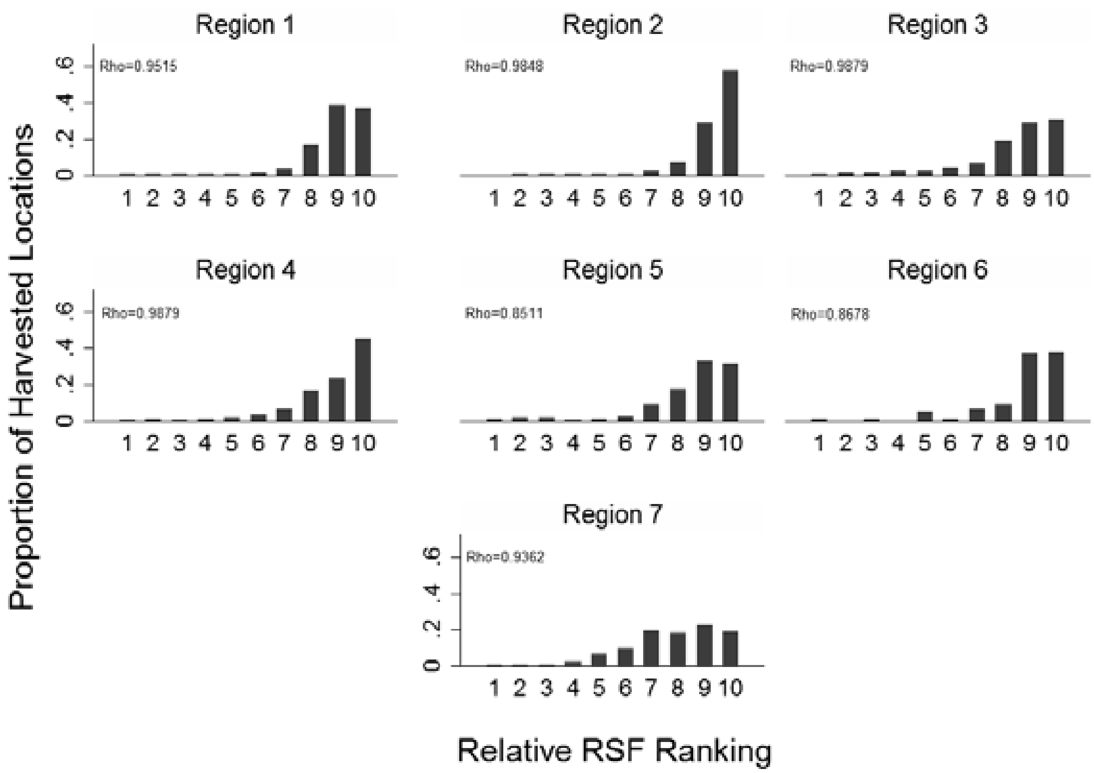


Figure 7. 2016 Montana Mountain Lion Resource Selection Function values and proportion of lion harvest locations per equal-sized bin (bin 1 = lowest quality predicted habitat; bin10 = highest quality habitat) by FWP administrative Region.



2016 MONTANA MOUNTAIN LION RSF

In 2016, FWP and Dr. Robinson worked together to improve the mountain lion RSF's ability to predict lion habitat selection statewide — specifically, in southern and eastern Montana. The same methods used by Robinson et al. (2015) were used to develop a revised version of the RSF, with three important refinements:

1. All available mountain lion telemetry relocations (n = 22,595) from the 10 Montana and Yellowstone National Park studies were used to train the revised model. "Study Area" was then used in the Generalized Linear Model as a random effect to account for varying levels of sampling intensity amongst studies.

2. FWP reexamined approximately 3,800 individual harvest locations reported between 2007 and 2015 - hundreds of location errors were found and corrected. The more accurate and complete 1988 – 2015 harvest data set (totaling 10,503 mountain lion harvest locations) was then used for external validation of the refined winter RSF model.

3. The revised winter RSF contained the same variables as described by Robinson et al. (2015) except that the variable "distance to forest" was replaced by a quadratic of "canopy closure" (Table 5). The revised model included a random intercept for each study area/data set.

We refer to this refined model (Figures 5 and 6) as the 2016 MT Mountain Lion RSF and it is the model used throughout this Strategy. The 2016 RSF performed similarly to Robinson et al.'s original 2015 model in FWP Regions 1, 2, 4, and 6 while the agreement between harvest locations and predicted high-quality habitat in Regions 3, 5 and 7 was significantly improved (Figure 7).

It is important to note that the RSF does not describe all the variables that affect mountain lion distribution or abundance. There are factors such as prey density, habitat disturbance (i.e. wildfire), or harvest history that are important to mountain lions and that vary over time. Therefore, it will be necessary to periodically reassess the relationship between the RSF and actual mountain lion density in an area (as described in Chapter 5).

CHAPTER 4

MONTANA MOUNTAIN LION ECOREGIONS

Mountain lions currently occupy nearly all of their suitable habitat in Montana. However, the quality, quantity, and arrangement of that habitat— thus the number of lions an area can support—varies significantly across the state. Mountain lion habitat in northwest Montana is nearly continuous, but habitat quality generally declines and becomes patchily distributed in more southern and eastern portions of the state (Figure 5).

The average RSF values of individual Lion Management Units reflects this pattern (Figure 8). This gradient in lion habitat quality across Montana allowed FWP to partition the state into distinct mountain lion "ecoregions". These ecoregions are large, contiguous areas of the state within which lion habitat is broadly similar. Mountain lion ecoregions are the spatial basis of FWP's lion population monitoring program.

Mountain lion harvest management is most effective when it's done at a large and biologically meaningful scale (Cougar Management Guidelines Working Group 2005, Jenks 2011). In lightly hunted populations, virtually all males and a significant proportion of females disperse from their natal area. Lion populations are best thought of as many connected sub-populations linked by dispersing animals. Local areas generally depend on immigration to recruit breeding males and, often, a large portion of breeding females.

These local sub-populations (i.e. within a LMU) can be resilient to harvest because lions are able to readily emigrate from adjacent areas and refill available habitat. Dispersal can also cause local populations to exhibit lower growth rates than expected, given their intrinsic vital rates (Sweanor et al. 2000, Logan & Sweanor 2001, Stoner et al. 2006, Cooley et al. 2009, Robinson et al. 2008 & 2011, Newby et al. 2011). Therefore, even if a LMU's harvest rate appears sustainable (when supported by immigration), the same harvest level could cause the unit's population to decline if harvest in adjacent areas increases. Similarly, specific attempts to reduce local lion populations can fail over the long term because of increased immigration from outside the treatment unit (Clark 2014a).

Monitoring and management programs are most effective when implemented across large landscapes. The effects of immigration and emigration on local population dynamics are less pronounced when considering large scale trends (Robinson et al. 2015). Importantly, large-landscape (i.e. > 35,000 km^2, an area ~ 115 x 115 miles) lion populations can be considered statistically "closed" (that is, the influence of immigration/emigration is eliminated) for most analyses (Robinson et al. 2008). Harvest treatments and abundance estimates are therefore less likely to be confounded by metapopulation dynamics if they are conducted across broad landscapes.

Montana includes a diverse range of habitat types, prey communities, weather patterns and other factors that affect mountain lion abundance. The relationship between an area's lion abundance and the range of RSF values within that area is unlikely to be the same across the state. Therefore, conducting field population monitoring and modeling efforts within large but discrete ecoregions (containing similar lion habitat) helps take this habitat variability into account.

FWP can more accurately estimate broad scale (ecoregion) lion abundance when using monitoring data collected from within that same ecoregion because mountain lion habitat and harvest history is more similar within ecoregions than across them (Boyce & McDonald 1999). FWP will produce periodic estimates of lion abundance and forecast the effects of harvest based only on monitoring data collected within those respective ecoregions (Chapters 5 and 6).

Mountain lion harvest management is most effective when it's done at a large and biologically meaningful scale

Figure 8. Avg. Mountain Lion Resource Selection Function values (0 = lowest quality habitat, 1 = highest quality habitat) for Montana's 2016 Lion Management Units.

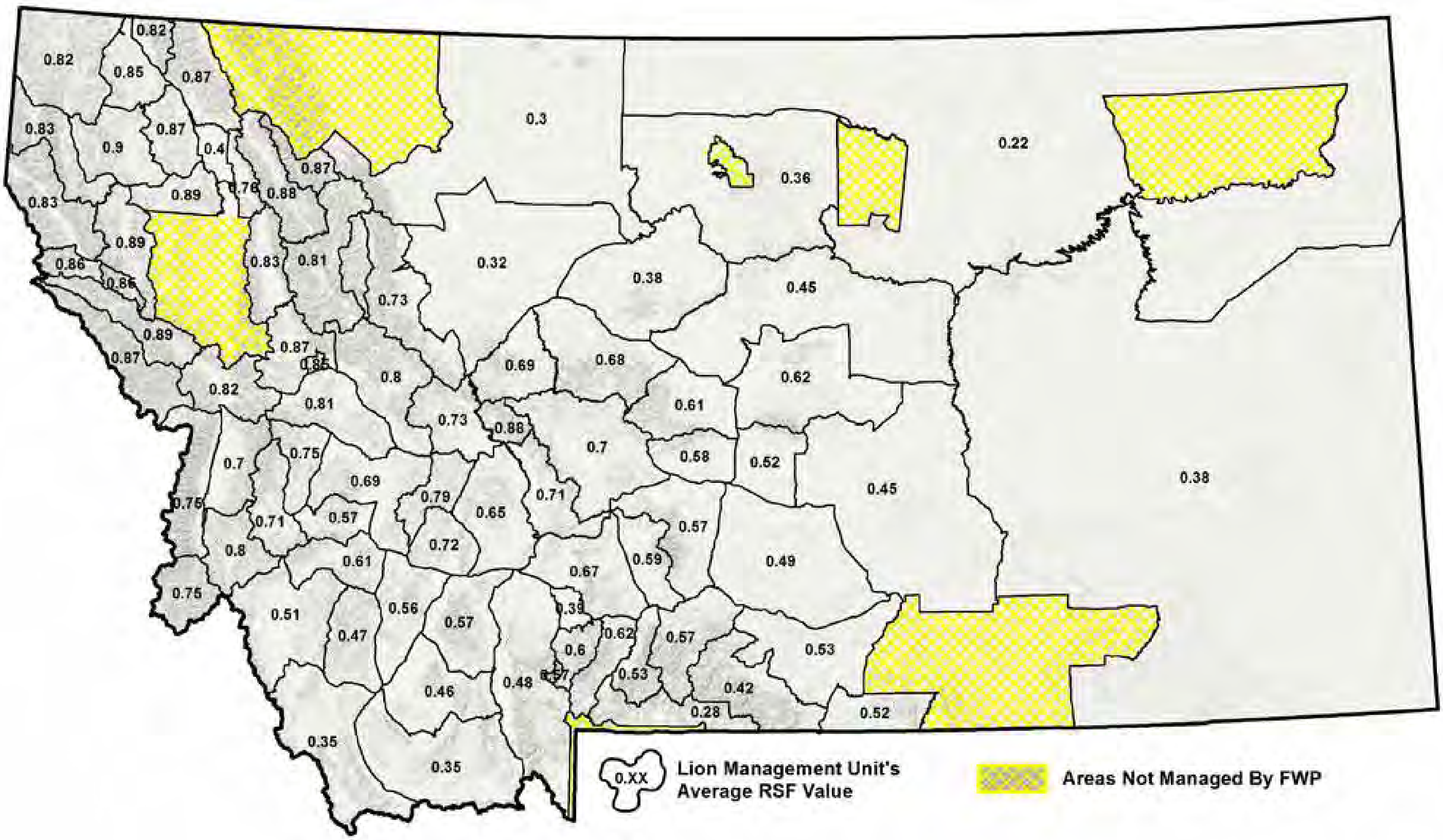
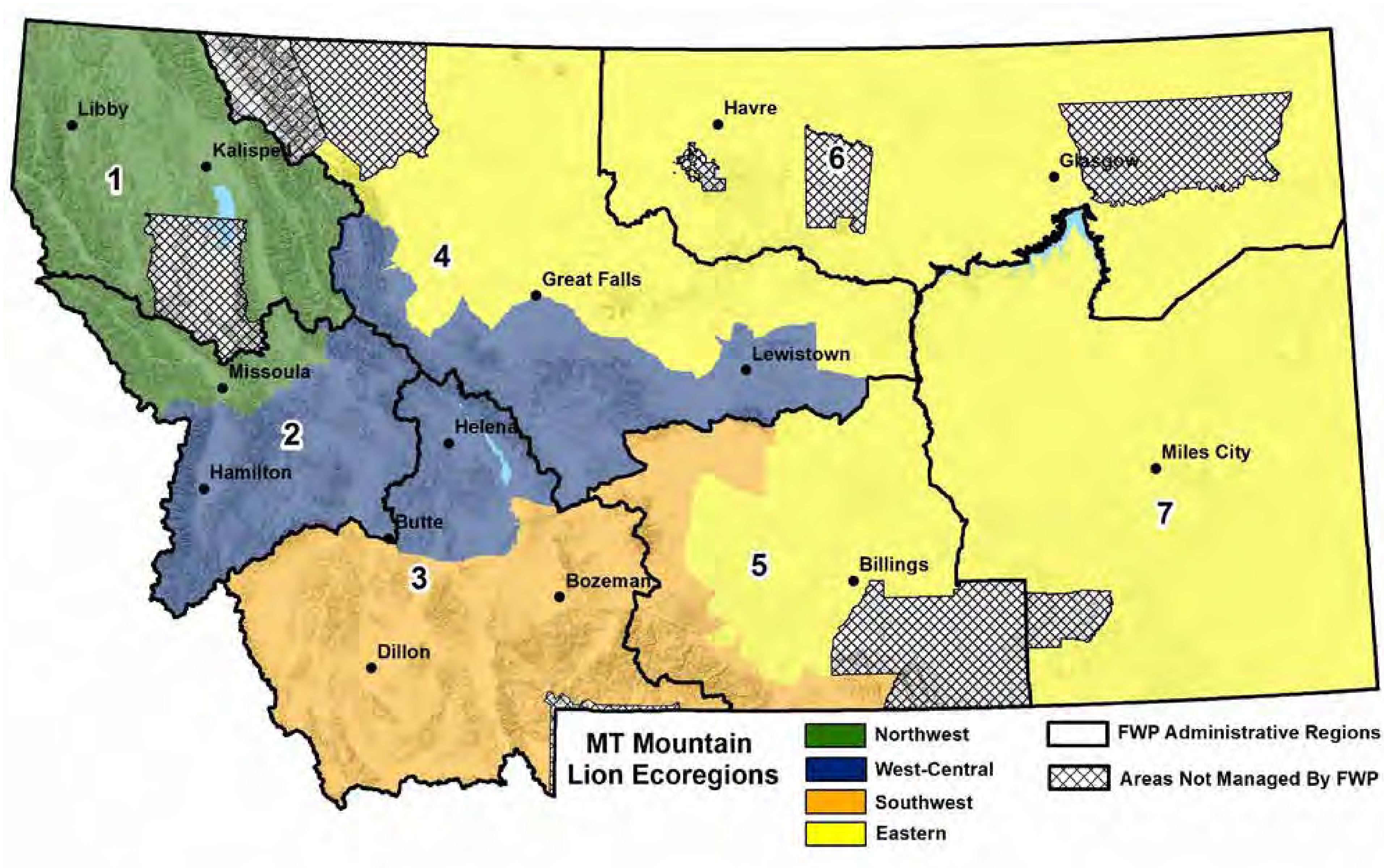


Figure 9. Montana's four mountain lion ecoregions and seven FWP administrative regions.



For the same reason, it is also only statistically and logistically practical to estimate lion population trend at a large scale. Mountain lion ecoregions should contain enough lions that populations can be modeled assuming that those populations are statistically closed. Population models then consider vital rates (from research on marked animals), harvest records, and periodic abundance estimates to allow managers to better understand past and future population trends (Chapter 6). This ability to describe the effects of past harvest and to predict the effect of future harvest prescriptions is a cornerstone of an adaptive harvest management program (Chapter 8).

FWP considered four factors when identifying individual mountain lion ecoregions:

1. They include contiguous LMUs with broadly similar habitat quality (RSF values).

2. They are large enough to allow management prescriptions to be effective despite internal lion metapopulation dynamics.

3. They are well distributed and represent the range of Montana lion habitat types.

4. The total number of ecoregions is limited so that monitoring can occur frequently enough to provide meaningful and timely data to managers. There is a tradeoff between the number of statewide ecoregions and how often each of them can be monitored. Budgets and available personnel limit the amount of effort FWP can expend field sampling lion populations.

FWP grouped 2016 LMUs' using a k-Nearest Neighbor algorithm (ESRI ArcGIS 10.1) based on their RSF values and proximity. Local biologists then helped identify four contiguous mountain lion ecoregions that met the above criteria and that could be reasonably managed as distinct units (Figure 9). FWP will periodically collect field data to produce abundance estimates for each of the three western MT ecoregions (where approximately 90% of harvest annually occurs). Estimates of future lion abundance and trend will also be modeled for these ecoregions.

Each Montana mountain lion ecoregion includes all or portions of two or more FWP administrative Regions. FWP managers and the public from different administrative Regions will collectively evaluate an ecoregion's monitoring data, develop management objectives, and decide on an overall management prescription (harvest) for the ecoregion. Managers will then recommend individual LMU harvest limits that implement the prescription, distribute hunter effort, and address local concerns.

FWP also identified a permanent population Trend Monitoring Area in each of the state's three western ecoregions. These Trend Monitoring Areas will be periodically sampled to produce estimates of lion abundance within them, and in their respective ecoregions. The criteria used to select Trend Monitoring Areas are described in Appendix 1.

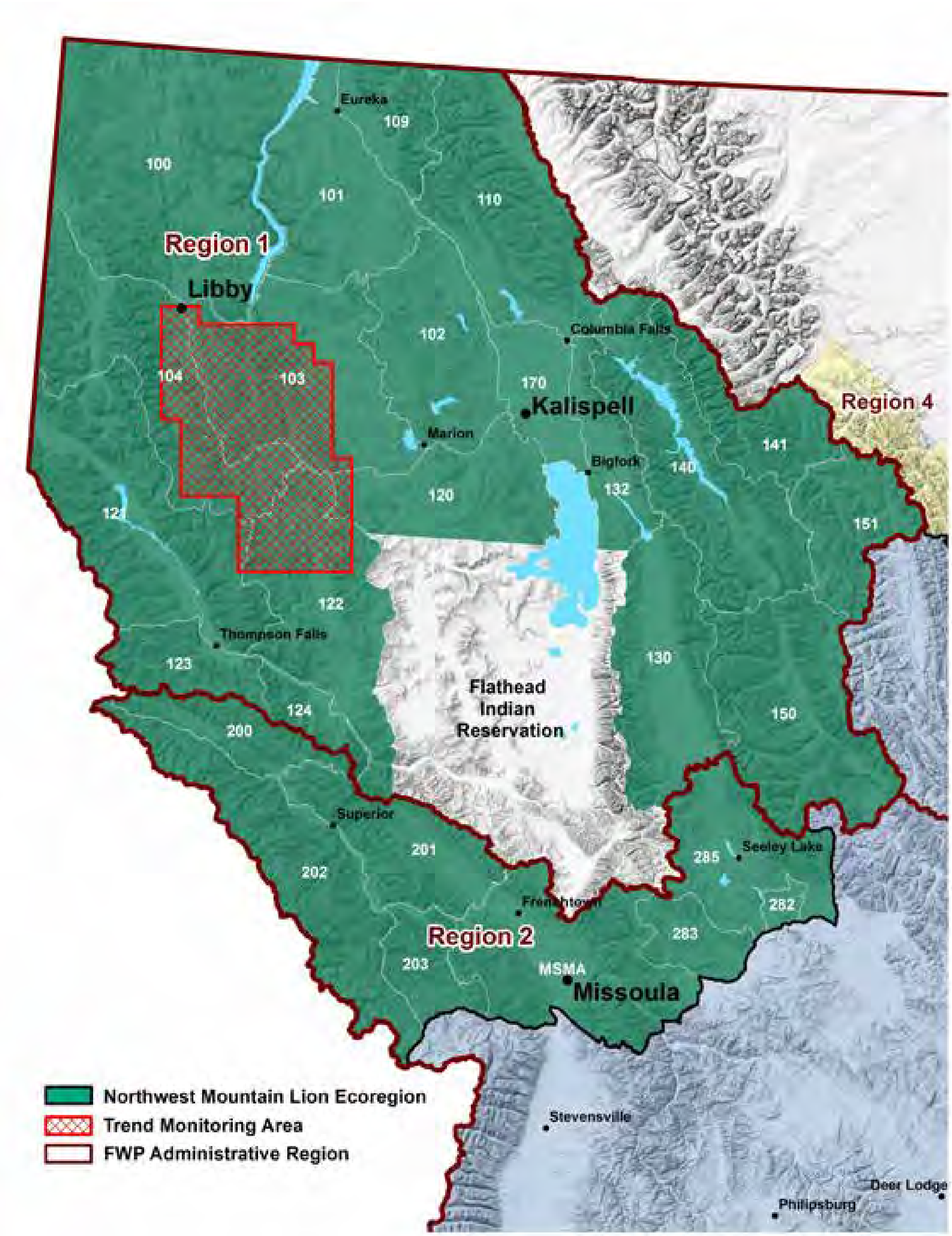
To be clear, the following ecoregions will be the basis of Montana's mountain lion population monitoring program. Information about the status and trend of lion populations within these ecoregions will inform adaptive management proposals that affect lion populations at the ecoregion scale. FWP and the public in two or more FWP administrative regions will periodically collaborate to develop certain population objectives for each ecoregion. For example, biologists and the public in FWP Regions 1 and 2 may agree to an objective of a moderately positive, negative, or stable population growth rate over the following 6 years in the Northwest ecoregion.

However, biologists and the public in each of the seven FWP administrative regions have local expertise, experience, and relationships. FWP public meetings and many wildlife advocacy groups are also organized by FWP administrative region. Therefore, specific management recommendations about harvest prescriptions and season structure for individual LMUs will be developed by FWP staff and the public in each of the seven administrative regions. The cumulative effect of these individual LMU prescriptions (i.e. the overall harvest within an ecoregion) will be considered, and periodically assessed, at the ecoregion scale.

ECOREGION DESCRIPTIONS

Northwest Ecoregion

Figure 10. The Northwest mountain lion ecoregion, trend monitoring area, and 2016 FWP hunting districts.



The Northwest mountain lion ecoregion encompasses all of FWP Region 1 (except for the Flathead Indian Reservation) and Region 2's northern Blackfoot and middle Clark Fork River drainages (Figure 10). It is Montana's smallest ecoregion at 36,893 km^2 but it contains the state's most continuous and highest quality lion habitat (average LMU RSF value = 0.83). Forests cover more than 90% of the Northwest ecoregion due to its Pacific maritime climate and moderate elevations.

Most of this ecoregion's lion habitat is either public land or publicly accessible private land. Hunter access during winter is extensive outside of designated wilderness areas. Tracking snow is generally present throughout the Winter Season.

The 2,550 km^2 Northwest mountain lion ecoregion Trend Monitoring Area includes the Libby Cr., Thompson River, and Fisher River drainages southeast of Libby. (Figure 11).

Mountain lion harvest in the Northwest ecoregion steadily increased during the 1990s, reaching a historic high of 344 (57% females) in 1998 (Fig 12). White-tailed deer make up as much as 90% of mountain lion prey in northwest Montana (Kunkel 1999, Montana Fish, Wildlife & Parks 2006). The ecoregion's white-tailed deer numbers were high in the mid-1990s before the severe 1996-97 winter significantly reduced this prey base. Lion harvest density, especially of females, was low during the 2000s but increased through the mid-2010s to approximately 4.6 lions per 1,000 km^2 (42% female), less than half the harvest density observed in the late 1990s.

Figure 11. The Northwest mountain lion ecoregion trend monitoring area divided into a grid of 102 5x5 km sampling cells.

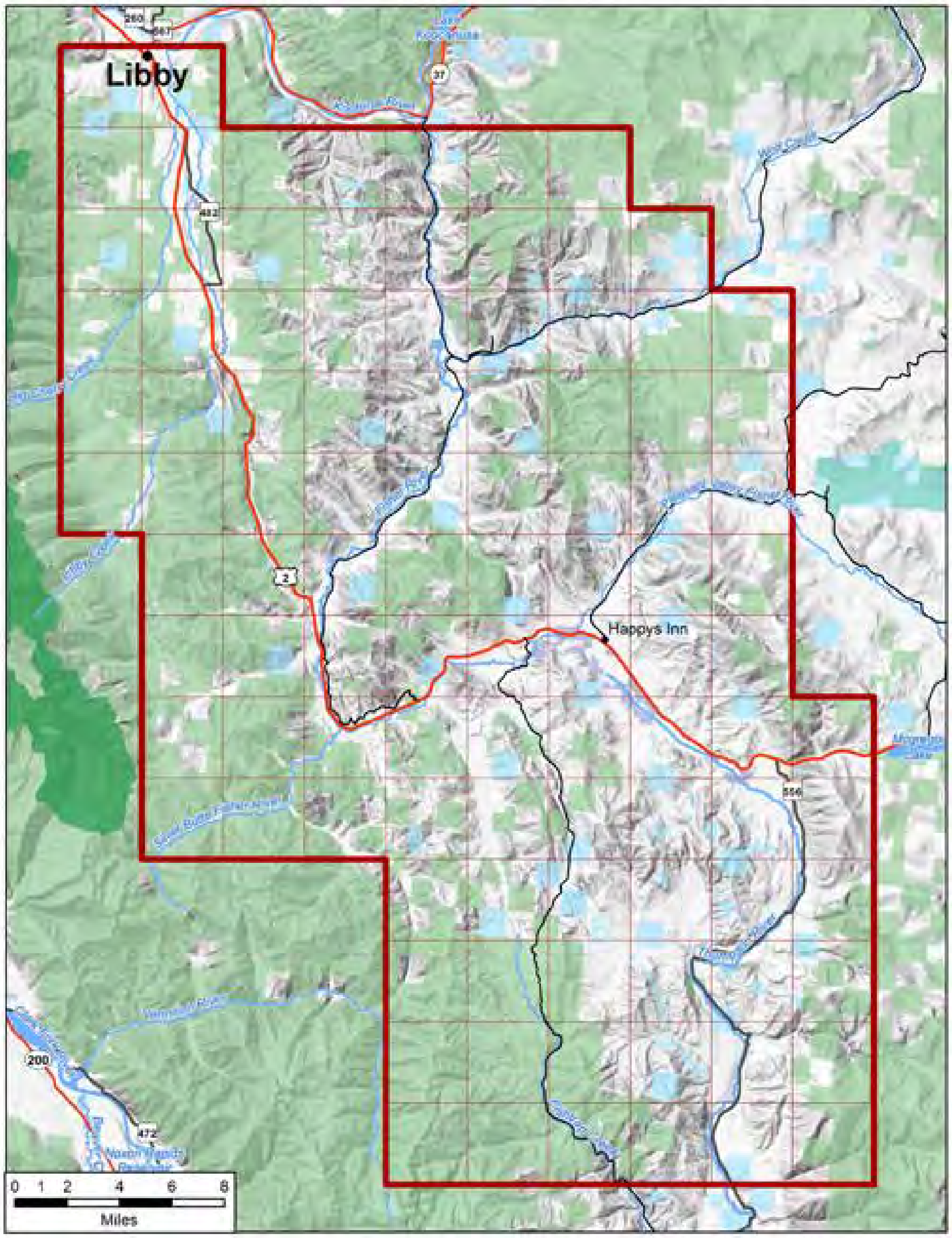
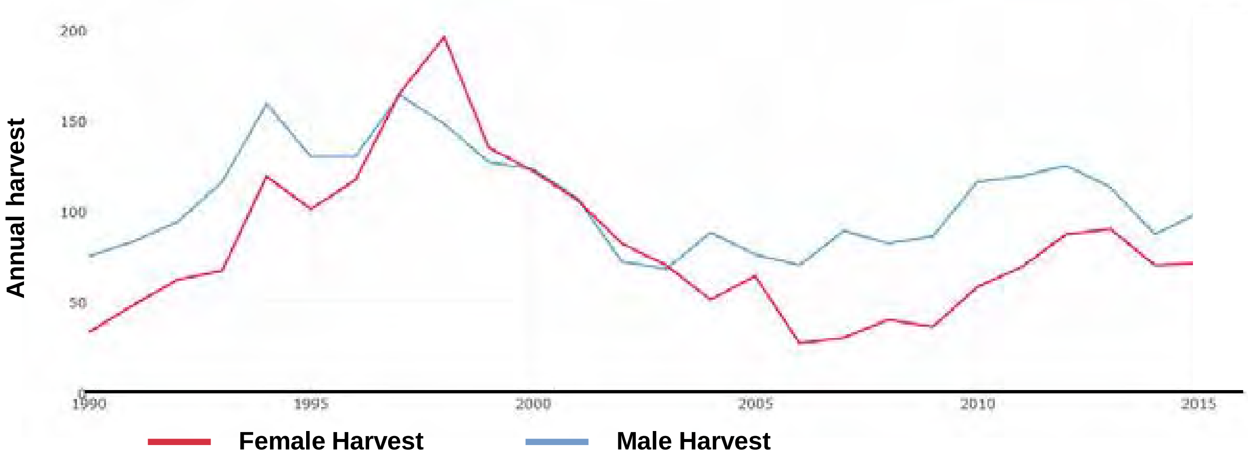


Figure 12. Northwest ecoregion mountain lion harvest, 1990 – 2015.



West-central Ecoregion

The 51,665 km^2 West-central ecoregion includes the forested mountain ranges and intermountain valleys of the Bitterroot, southern Blackfoot, and upper Clark Fork watersheds west of the Continental Divide and the Rocky Mountain Front, Helena/Boulder valleys, Belt and Snowy Mountains to the east (Figure 13). The ecoregion includes portions of FWP Regions 2, 3 and 4.

Forests across the ecoregion are diverse and often separated by broad intermountain valleys. The average mountain lion habitat quality (average LMU RSF value = 0.72) is generally lower than in northwest Montana because high-quality lion habitat is more intermittent. There is extensive and well distributed public recreational access to winter lion habitat, although some local private land refuges exist. Snow conditions annually vary within and between watersheds—a lack of adequate tracking snow occasionally limits winter lion harvest in some areas.

The ungulate prey base and density varies across the ecoregion. Although white-tailed deer are generally common, mule deer and elk make up a greater proportion of available ungulates than in northwest Montana.

The 2,200 km^2 West-central ecoregion's Trend Monitoring Area includes the upper Blackfoot and east Nevada Cr. Valleys west of the Continental Divide (Region 2) and the Canyon Creek/Little Prickly Pear drainages east of the Divide in Region 3 (Figure 14).

Mountain lion harvest in the West-central ecoregion climbed to a high of 294 lions (53% female) in 1998 (Figure 15). Hunter harvest, particularly of females, was significantly reduced in the 2000s following perceived population declines. By 2015, overall harvest density increased to 3.1 per 1,000 km^2, well below the nearly 6.0 per 1,000 km^2 in the late 1990s—specifically, the 2015 female harvest was one third of the 1998 peak.

Figure 13. The West-central mountain lion ecoregion, trend monitoring area, and 2016 FWP hunting districts.

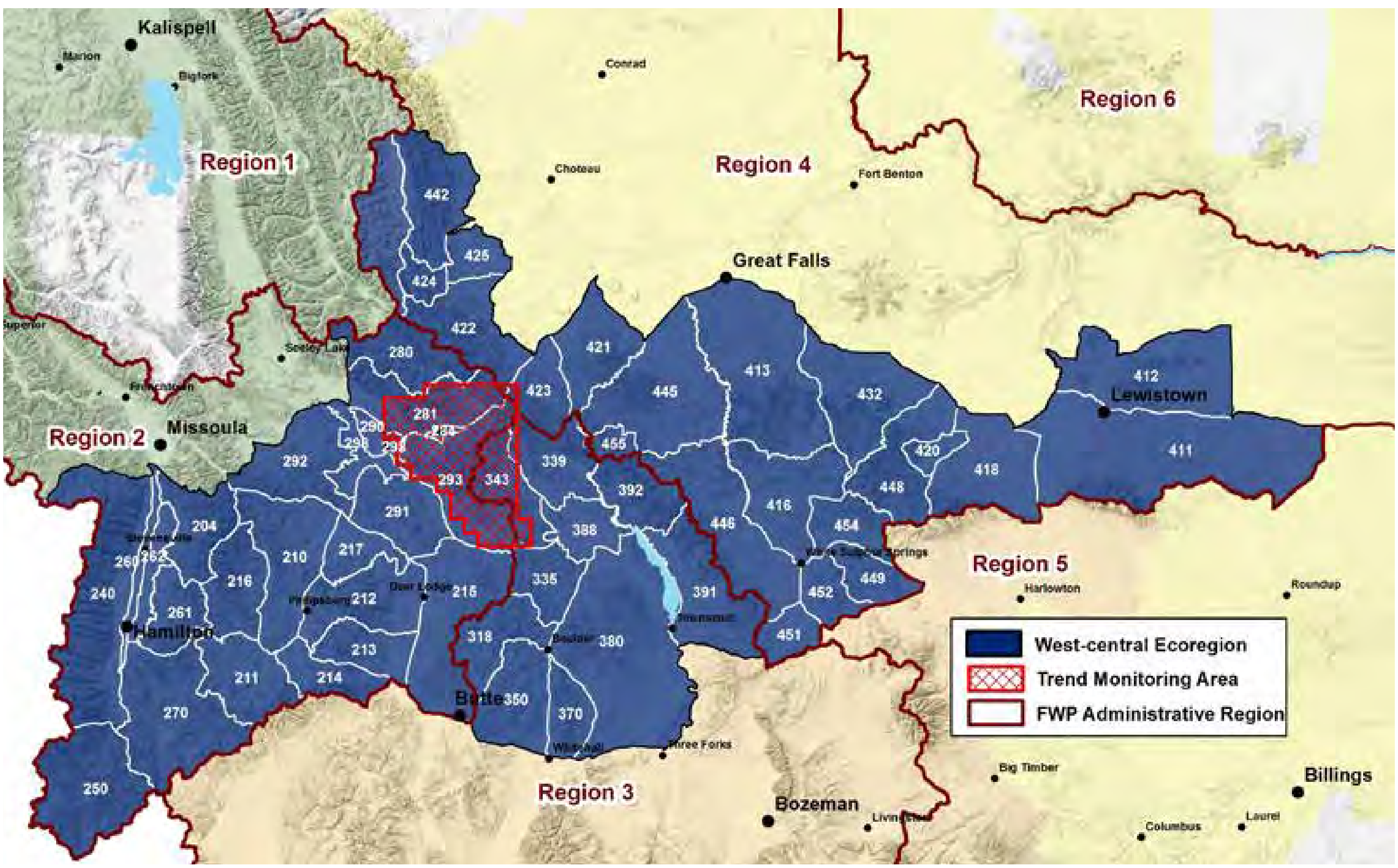


Figure 14. The West-central mountain lion ecoregion trend monitoring area divided into a grid of 101 5x5 km sampling cells.

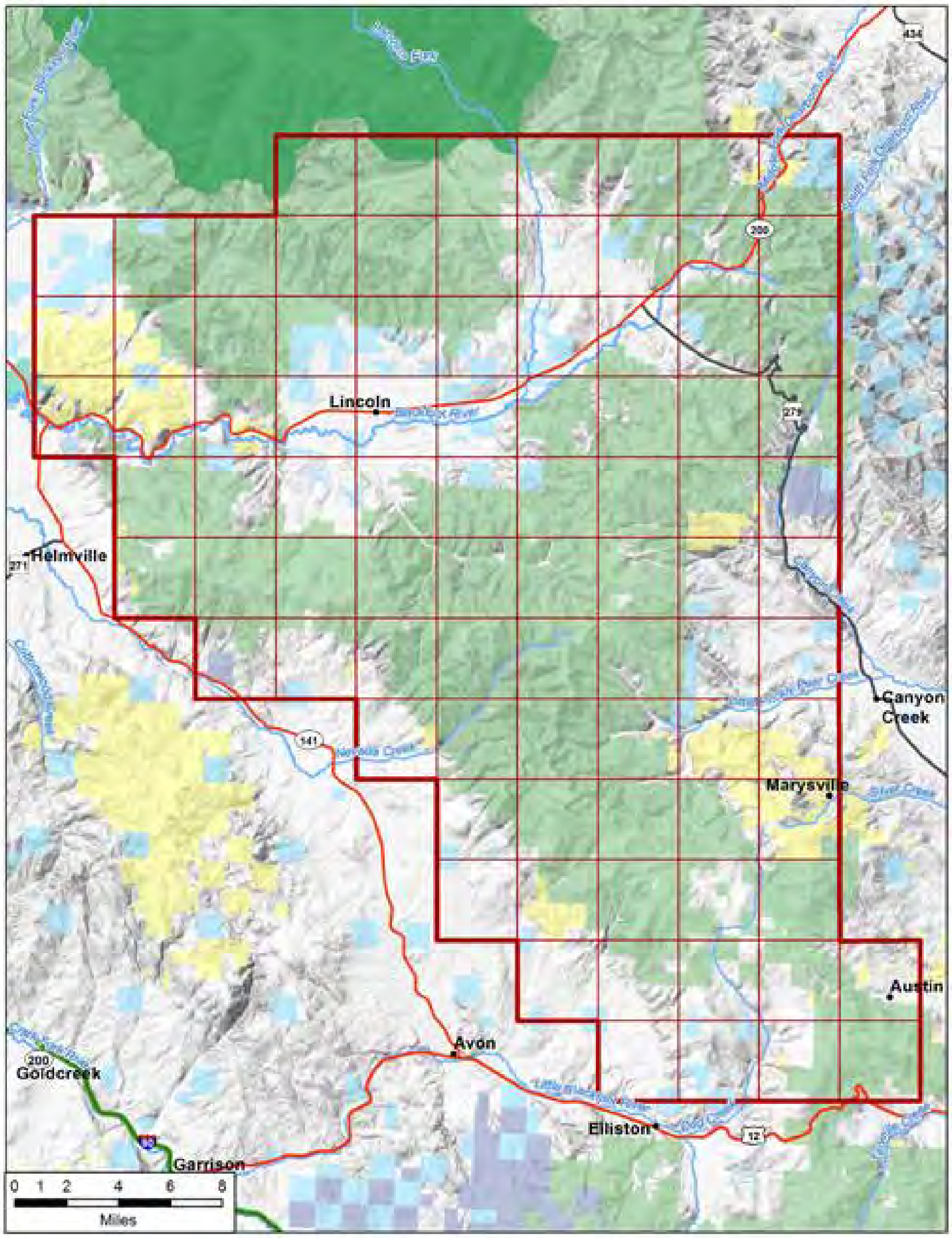
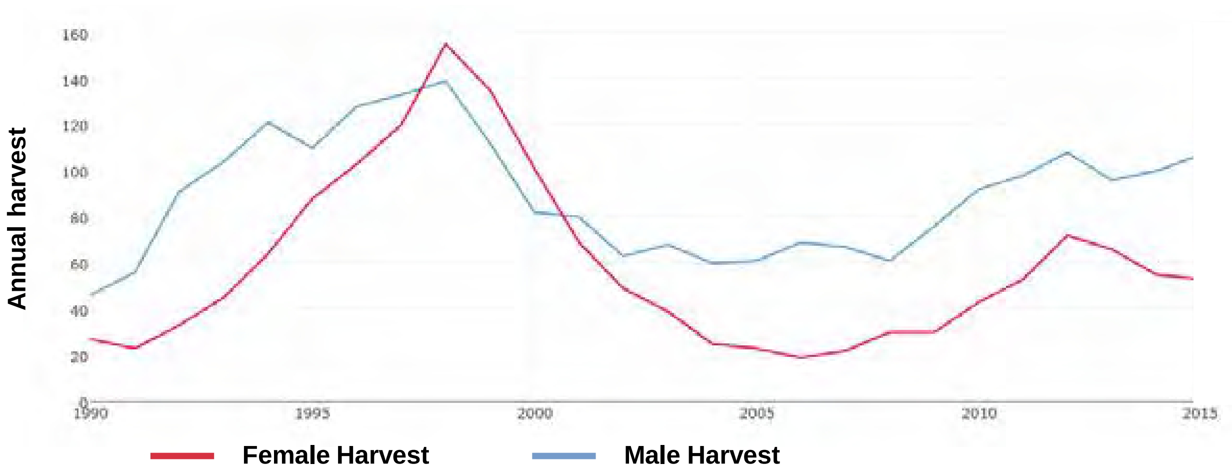


Fig. 15. West-central ecoregion mountain lion harvest, 1990 – 2015.



Southwest Ecoregion

Mountain lion habitat is relatively patchy and linearly distributed in much of the 52,487 km^2 Southwest ecoregion. This area extends from the Continental Divide and southwest Montana's island ranges, across the Greater Yellowstone Ecosystem to the Beartooths, Crazy Mountains, southeastern Little Belts, and southern Big Snowy Mountains. The ecoregion includes much of FWP Region 3 and western Region 5 (Figure 16). Although many portions of the ecoregion include high-quality lion habitat, only about a third of the total area is forested—the average LMU's RSF value in this ecoregion is 0.51.

Public access to winter mountain lion habitat is mixed; approximately 75% of lions harvested between 2007 and 2015 were taken on public land. Winter snow tracking conditions vary and can, at times, limit effective harvest.

The 2,525 km^2 Southwest ecoregion mountain lion Trend Monitoring Area is located in the Gallatin Range between Bozeman and Yellowstone National Park (Figure 17).

Total mountain lion harvest in this ecoregion peaked in the late 1990s, declined in the 2000s, then returned to near the 25-year average level by 2015. Much of this variation, however, was due to fluctuations in female lion harvest; male harvest has remained relatively constant since the mid-1990s (Fig. 18). Overall Southwest ecoregion harvest density was 1.75 lions per 1,000 km^2 in 2015.

Figure 16. The Southwest mountain lion ecoregion, trend monitoring area, and 2016 FWP hunting districts.

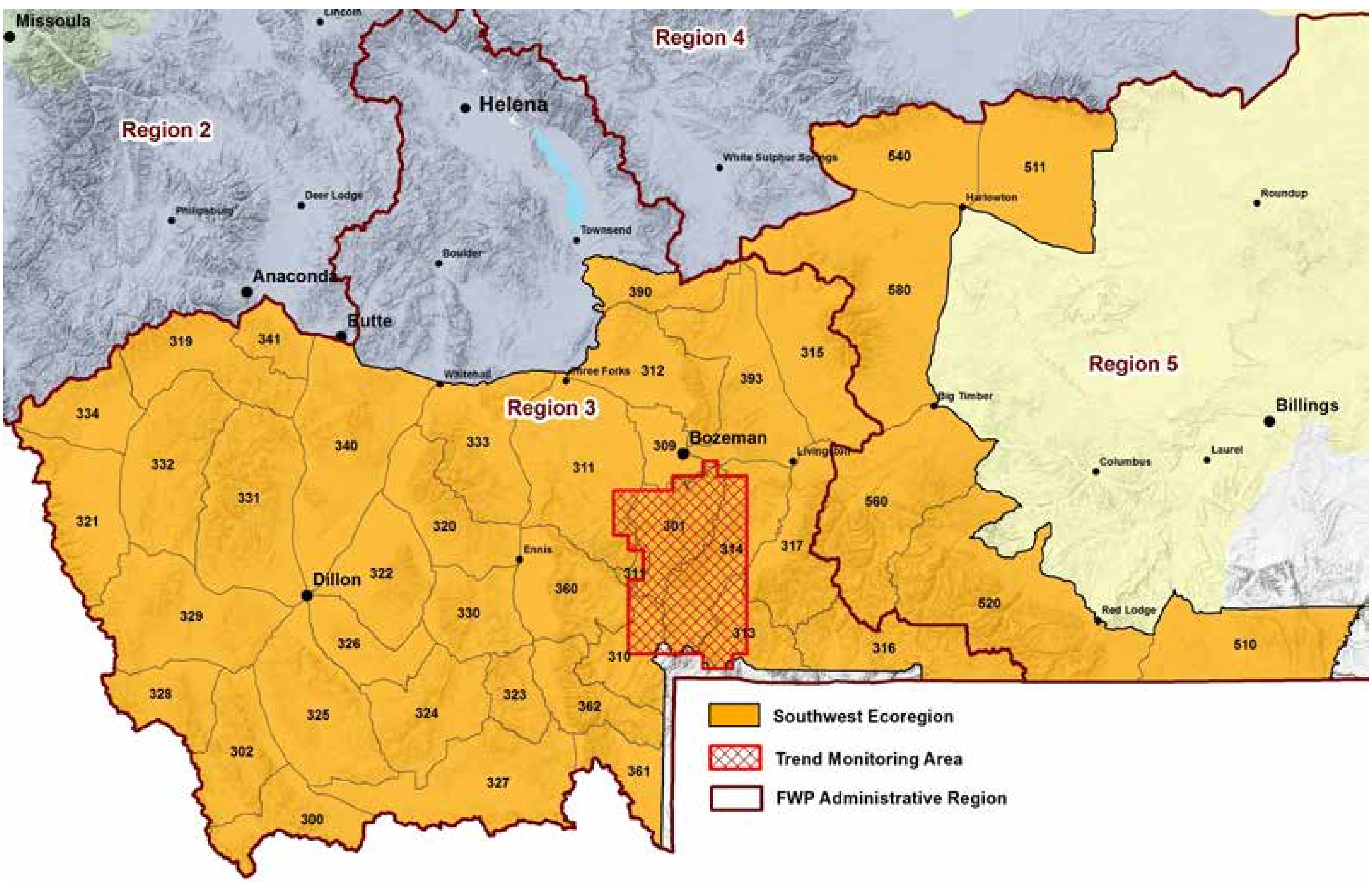


Figure 17. The Southwest mountain lion ecoregion trend monitoring area divided into a grid of 101 5x5 km sampling cells.

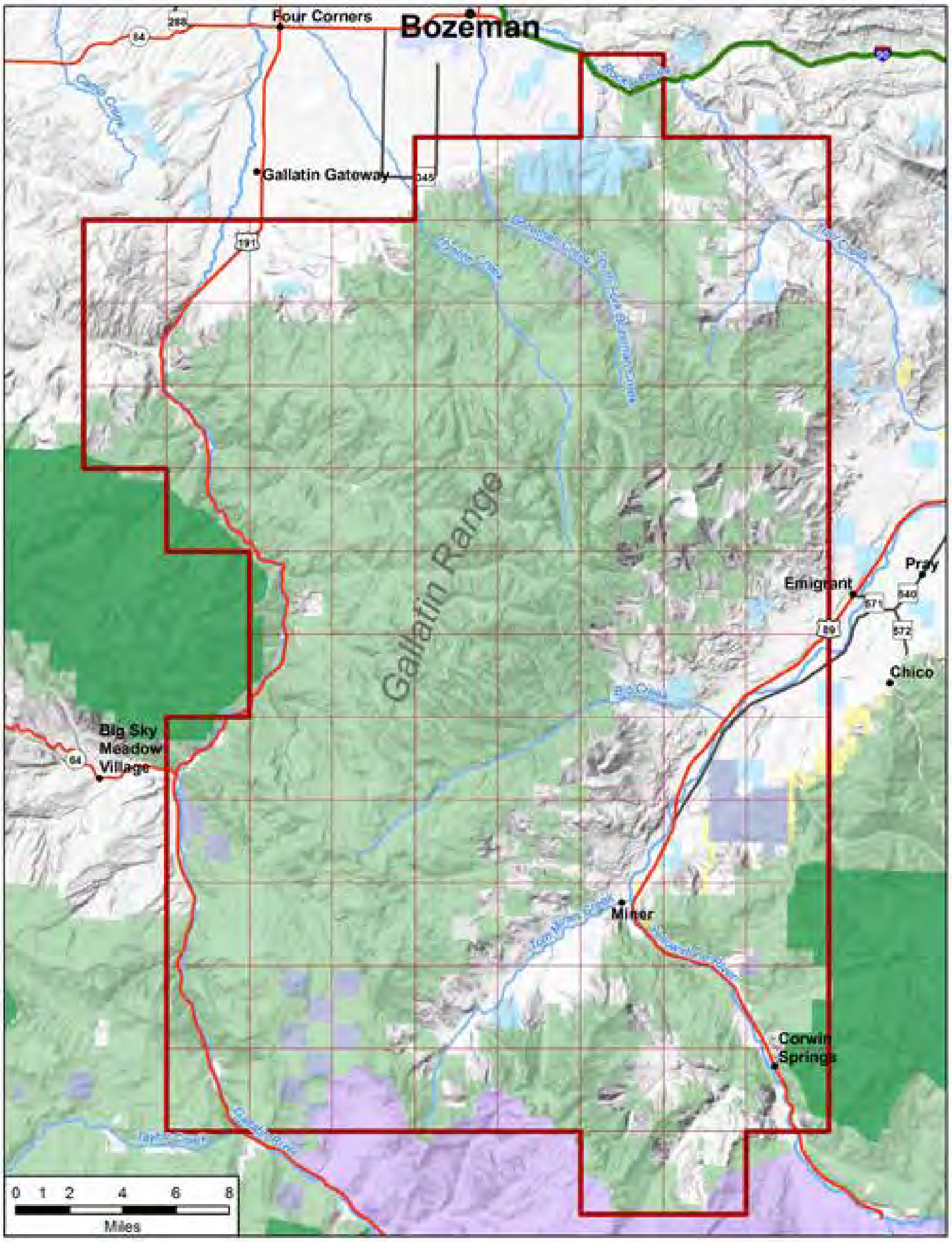
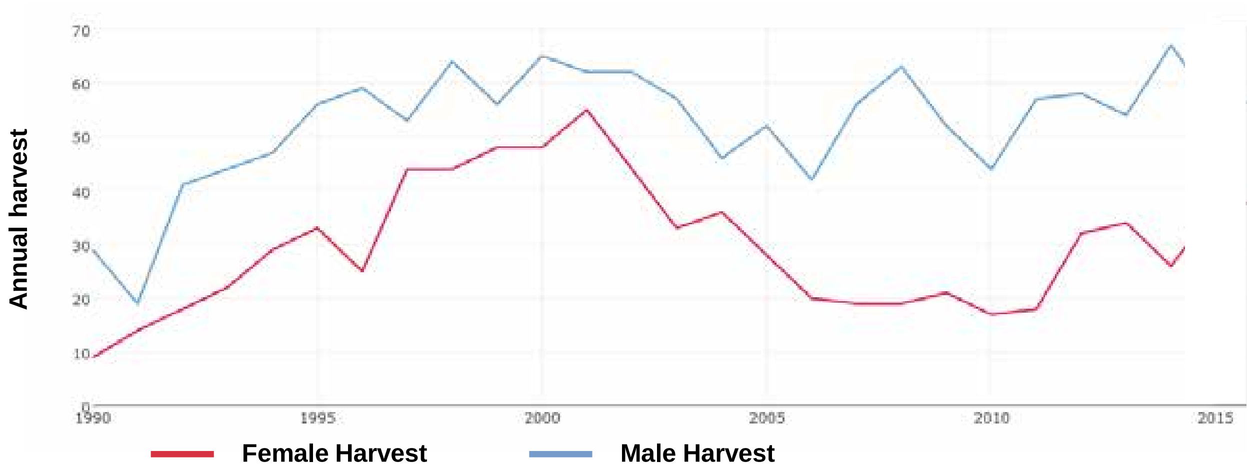


Fig. 18. Southwest ecoregion mountain lion harvest, 1990 – 2015.



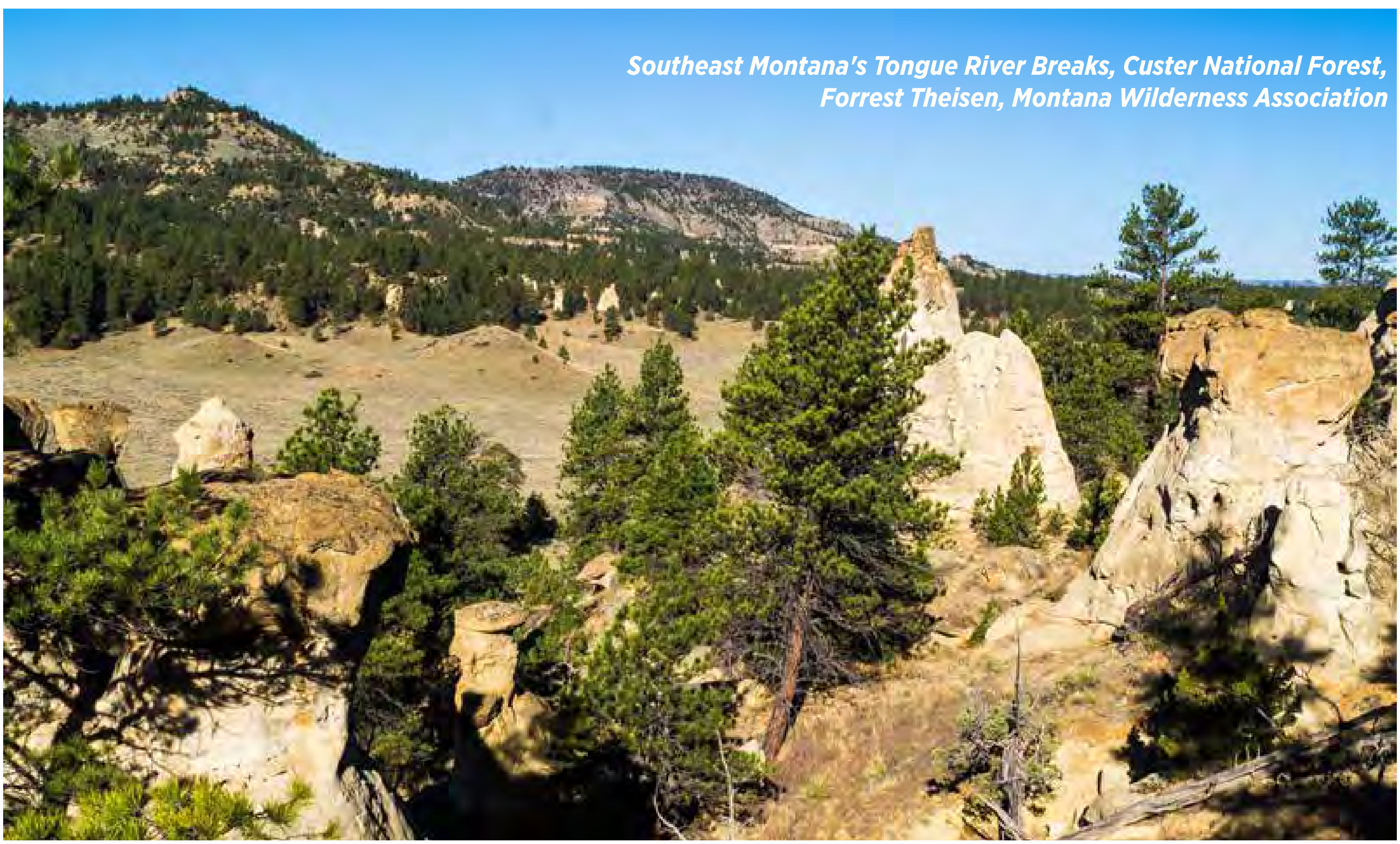
Eastern Ecoregion

The 198,175 km^2 Eastern ecoregion is, by far, the largest in the state and includes all or portions of FWP Regions 4, 5, 6 and 7 (Fig 19). Much of the highest quality mountain lion habitat in eastern Montana lies within Indian reservations—FWP does not have routine mountain lion management jurisdiction on these reservations and they are excluded from the ecoregion for analysis and planning purposes. Less than 10% of the remaining ecoregion supports ponderosa pine or juniper-dominated forest. In general, patches of high-quality lion habitat are relatively small and widely distributed (average LMU RSF value = 0.38).

Genetic field monitoring data will not be routinely collected in the Eastern ecoregion and, therefore, no permanent Trend Monitoring Area has been designated. Lions in this ecoregion occur at an overall low density and sub-populations occur in discontinuous patches of suitable habitat. Inferences drawn from field sampling in one area would be of limited use for broad scale management of this ecoregion.

Mountain lion distribution and abundance has significantly increased in eastern Montana since the 1980s and recovery likely continued through the 2010s. Harvest has steadily increased since the 1990s (Fig. 20). Intermittent snow cover in eastern Montana can significantly reduce hound hunting's effectiveness. Therefore, in this ecoregion, quotas are more likely to serve as limits on harvest during years when snow conditions are favorable than as reliable annual harvest prescriptions.

Lion harvest in the Eastern ecoregion generally occurs in areas that the RSF describes as high-quality habitat on or near the Custer National Forest, Bureau of Land Management lands surrounding the Charles M. Russell National Wildlife Refuge, private land in the Bears Paw Mountains, in the Highwood Mountains, and along the northern Rocky Mountain Front.



Southeast Montana's Tongue River Breaks, Custer National Forest, Forrest Theisen, Montana Wilderness Association

Figure 19. The Eastern mountain lion ecoregion and 2016 FWP hunting districts.

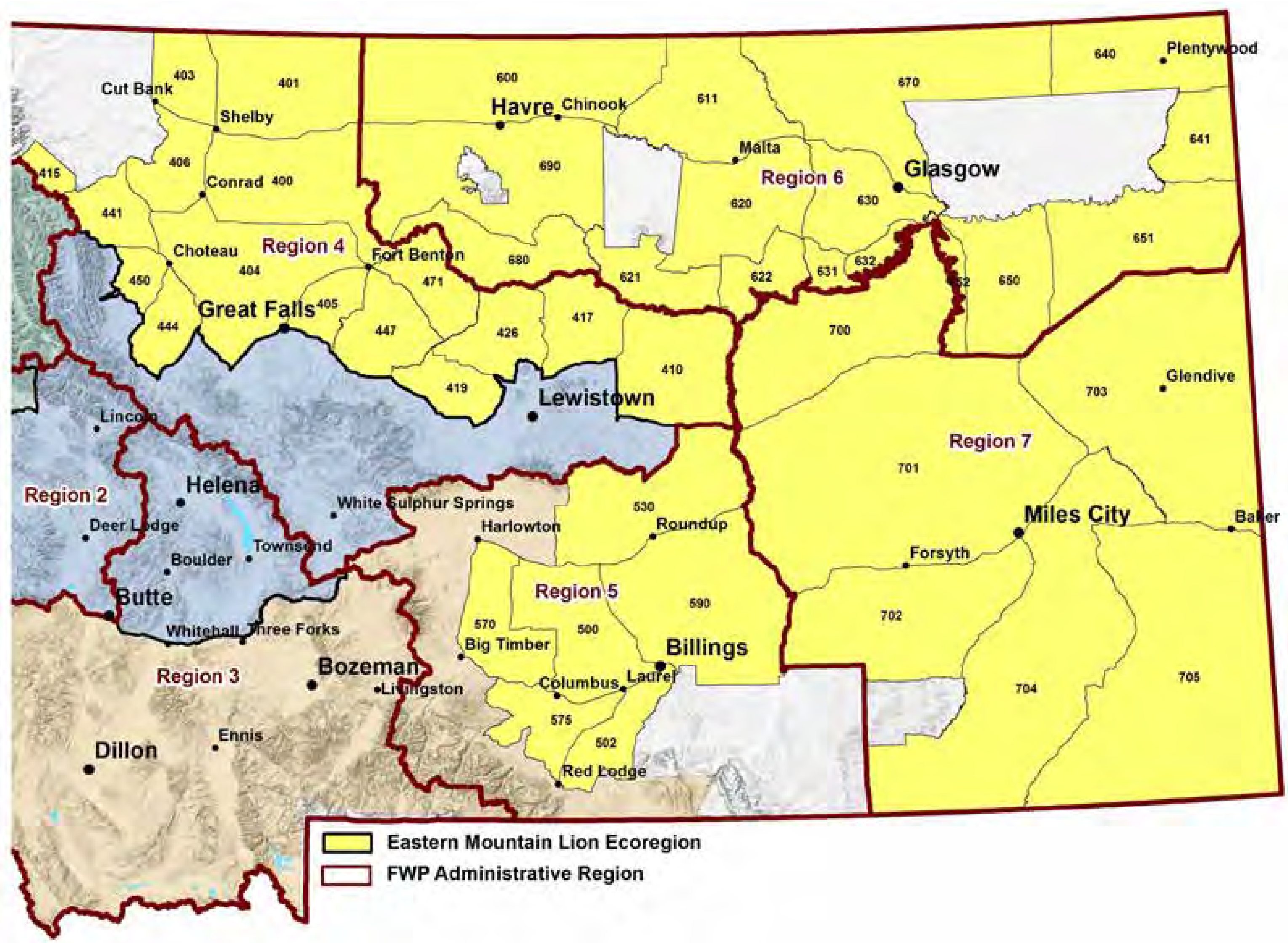
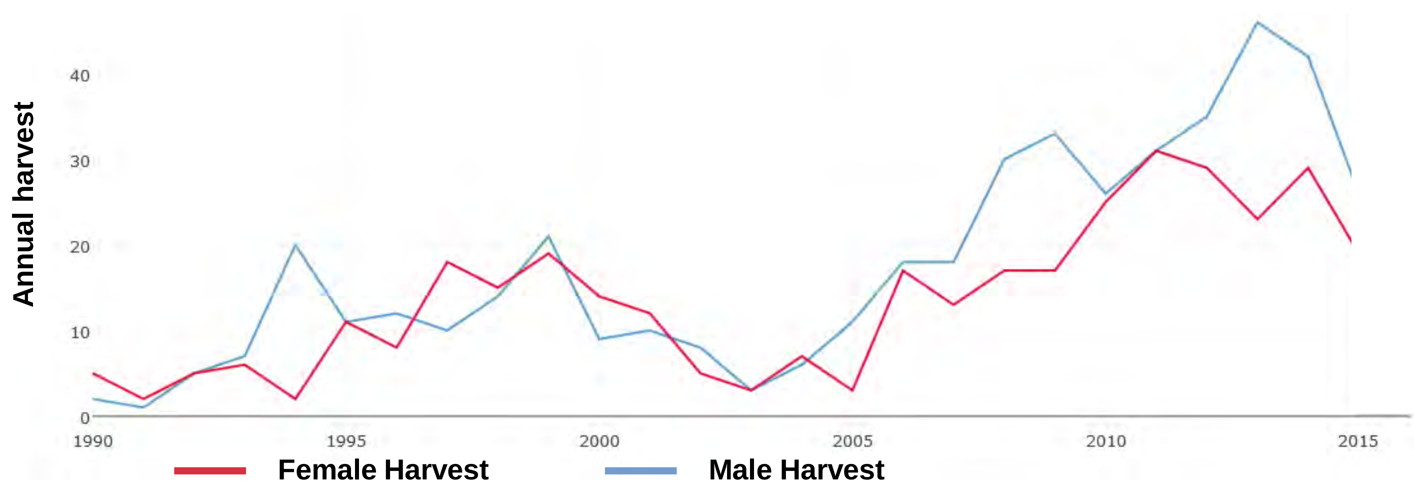


Fig. 20. Eastern ecoregion mountain lion harvest, 1990 – 2015.



CHAPTER 5

MONITORING MOUNTAIN LION ABUNDANCE

" The Holy Grail of cougar management has always been the question of 'How many are there?'"

Managing Cougars in North America— J. A. Jenks, editor (2011)

FWP biologist preparing to fire biopsy dart to collect a genetic sample from a treed mountain lion, Western Montana, R. Wiesner

INTRODUCTION

To conserve mountain lions while ensuring sustainable recreational hunting opportunities, FWP needs accurate and up-to-date information about mountain lion population size and trend. In the past, managers used indirect measures of lion abundance, inferences drawn from long term field research projects, or anecdotal information about population status to inform decisions. Unfortunately, these sources of information often fail to accurately describe the effects of previous management actions and don't allow us to precisely predict the effects of future harvest (Beausoleil et al. 2013).

Developing a method to obtain regular, accurate, extensive, and affordable estimates of the size of lion populations has been one of the highest priority mountain lion management needs (Beausoleil et al. 2008, Jenks 2011). Until recently, there was no cost effective and relatively quick way to produce reliable lion population estimates at a large enough scale to be meaningful for management (Choate et al. 2006, Beausoleil et al. 2016).

Many agencies that are charged with managing mountain lions rely on indirect measures, or indices, of lion abundance to make inferences about population changes because these indirect data are already available or relatively easy to collect. However, the actual relationship (if one exists) between a population index and true population size is rarely known and may be inconsistent over time (Anderson 2003).

When potential indices of abundance were formally compared to known populations, the indices often proved too insensitive to be useful management triggers. For example, Wolfe et al. (2015) found that although the number of lions treed-per-day, permit fill rate, and the proportion of females in harvest were correlated with abundance, those relationships were weak. These indices are also not generally relevant in Montana where most harvest is regulated by sex-specific quotas.

Although the sex and age of harvested lions can eventually indicate significant changes in a lion population's size or growth rate, these harvest indices are only able to detect relatively large and long term increases or declines (Stoner 2004, Anderson & Lindzey 2005, Robinson & DeSimone 2011).

In Montana, changes in harvest-age structure appear to broadly correspond to observed, long term, changes in lion abundance. When populations were thought to be high and growing during the early 1990s, a greater proportion of the harvest consisted of older lions (Table 6). Lion populations apparently declined during the early 2000s before recovering; both the average ages of harvested lions and the proportion of older lions in the harvest reflected this trend. A similar relationship was documented in western Montana's Garnet Mountains between 1997 and 2006 (Figure 21).

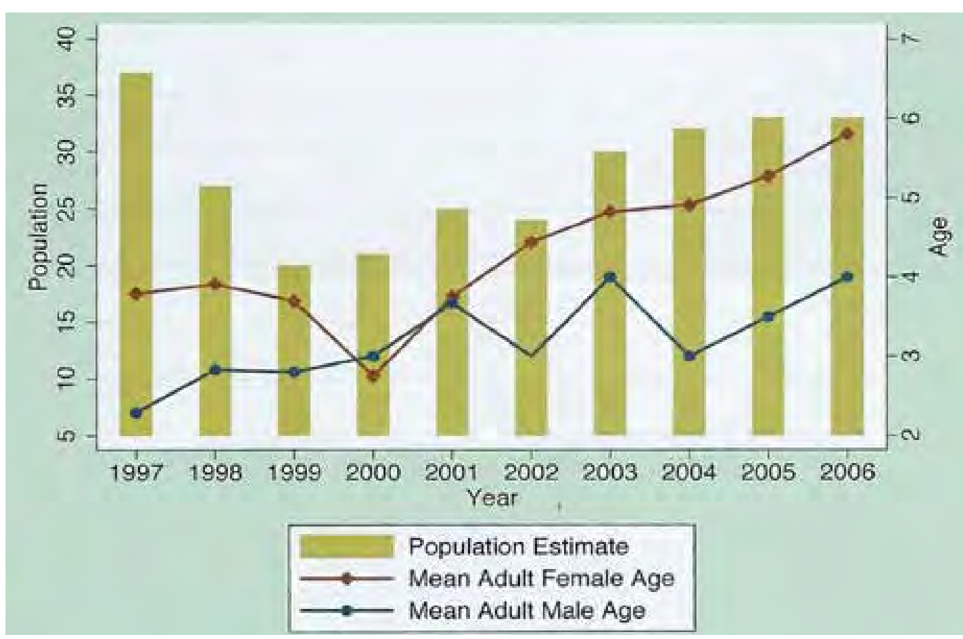
Statewide lion density declined and recovered dramatically between the mid-1990s and late 2000s. This pattern was, in part, driven by dramatic changes in statewide harvest rates that are unlikely to be applied in the future. The current magnitude of variation in statewide age-at-harvest is relatively small and annually variable. During periods when the amplitude of population change is moderate, trends in harvest-age are less informative.

Tracking changes in the ages of harvested animals may be somewhat useful where more direct measures of population trend are not available (such as eastern Montana), but the index is too insensitive to detect moderate, short term changes in an area's lion density. The proportion of older adult animals in harvest (especially females)

Table 6. Montana mountain lion age-in-harvest, 1988 – 2015.

	Female, Average Age	Male, Average Age	Combined, Average Age	% of Harvest > 5 Y.O.
1988	3.45	2.94	3.10	10.3
1989	3.21	3.94	3.75	16.7
1990	4.38	4.38	4.38	26.1
1991	5.04	4.94	4.97	37.6
1992	6.59	6.40	6.46	58.8
1993	4.99	5.39	5.25	39.0
1994	3.67	3.98	3.86	24.0
1995	4.29	4.30	4.29	27.0
1996	3.81	3.07	3.39	13.3
1997	3.70	3.18	3.44	15.4
1998	3.34	2.71	3.04	11.3
1999	3.21	2.60	2.91	12.5
2000	3.42	3.18	3.30	13.2
2001	3.33	3.28	3.31	12.6
2002	3.17	3.07	3.11	4.3
2003	2.93	2.73	2.81	5.5
2004	3.24	2.53	2.79	9.7
2005	3.22	2.95	3.05	10.6
2006	2.76	2.89	2.85	4.7
2007	3.46	3.43	3.44	11.8
2008	3.14	3.53	3.41	14.3
2009	3.34	3.13	3.19	10.8
2010	4.02	3.45	3.65	17.2
2011	3.42	3.00	3.14	10.1
2012	3.76	3.45	3.57	16.7
2013	3.62	3.13	3.33	13.1
2014	3.34	3.35	3.34	11.0
2015	3.09	2.89	2.97	6.8

Figure 21. Minimum mountain lion population estimate, and mean adult (> 24 months) age of harvested lions, Garnet Mountains, MT (Robinson & DeSimone 2011)



is more strongly correlated with annual adult survival than is the overall mean or median age-in-harvest (Wolfe et al. 2015).

Relying on past years' harvest to inform future quotas is also problematic. This "sledgehammer approach" (Logan & Sweanor 2001) uses previous seasons' hunter success rates to determine future harvest quotas. Even if managers reduce harvest quotas as hunter success decreases, these incremental reductions may not match existing population levels and can lead to further declines. Harvest indices are also much less informative in jurisdictions, like Montana, where most harvest is limited by sex-specific quotas.

Patterns in total annual harvest or days required to fill an area's quota can be misleading when factors that are independent of mountain lion population trend most strongly predict year-to-year harvest. For example, in much of the Eastern ecoregion adequate tracking snow is present only sporadically— during winters when there is snow cover, harvest increases. In these cases, quotas effectively prevent excessive harvest during years with favorable tracking conditions even though they will not be routinely met in other years.

Intensive winter track surveys, surveys of public lion observations, and hunter effort generally failed to detect known lion population changes quickly or before large changes in population size had already occurred (Beier & Cunningham 1996, Jenks 2011, Robinson & DeSimone 2011).

Long term capture and radio-telemetry studies were traditionally considered to be the most reliable way to estimate local lion populations (Cougar Management Guidelines Working Group 2005, Jenks 2011). This method requires researchers to attempt to capture and mark all resident individuals within a study area, account for additional unmarked animals, and then extrapolate observed and suspected home ranges across a study area to produce an estimate of abundance (Lambert et al. 2006, Cooley et al. 2009, Robinson et al. 2008 & 2014).

However, capturing, marking, and counting individual lions is impractical for routine lion population monitoring. Intensive capture and radio-tracking projects can take many years to complete, require significant field resources, and are prohibitively expensive (Hornocker & Negri 2009). The uncertainty around estimates developed using this field method is also often difficult, or impossible, to assess. Finally, this technique usually produces only minimum counts because all individuals in a study area are rarely captured and nonresident (transient) individuals are often either missed or discounted (Robinson et al. 2015).

Because it was so difficult to directly monitor mountain lion population size and trend at a large scale, some researchers suggested implementing "zone management" (Logan & Sweanor 2001) or a similar "metapopulation model" (Laundre & Clark 2003) instead. These strategies advise maintaining large and well-distributed lightly hunted refuge areas (sources) that sustain more heavily-hunted areas (sinks) through emigration. Although metapopulation management doesn't rely on accurate population estimates, it does require knowledge of immigration rates between heavily and lightly-hunted areas. Few studies have rigorously estimated these immigration rates and the metapopulation management model's effectiveness remains largely untested.

Although several large patches of un- or lightly-hunted lion habitat (including national parks, wilderness areas, and Indian reservations) undoubtedly act as sources of

FWP biologists recover a DNA biopsy dart from treed mountain lion

lions that disperse to other areas in Montana (Robinson et al. 2015), these refuges are neither extensive or well distributed enough to subsidize unlimited harvest in the remainder of the state.

FWP will not further restrict lion harvest across broad areas of the state in order to create additional specific "source" areas and, therefore, does not intend to use the metapopulation model as the basis for its mountain lion Management Strategy.

Instead, FWP will manage for limited and sustainable mountain lion hunter-harvest opportunity on most lands within its jurisdiction. To enable this approach, FWP will periodically monitor the size and trend of lion populations in the Northwest, West-central and Southwest ecoregions. We will use rigorous, field-based techniques to estimate population size and trend, and we will remain open to incorporating new monitoring methods as they are developed and validated. Distributing this monitoring effort across these three biologically distinct ecoregions will reduce the uncertainty of the estimates developed using local monitoring data (Walters & Holling 1990, Conroy et al. 2012).

Subsequent Trend Monitoring Area abundance estimates can be directly compared to past estimates from the same area. Abundance estimates for the Trend and Supplemental Monitoring Areas (see Montana Mountain Lion Monitoring section, Chapter 5) can also be used to develop abundance estimates for their respective ecoregions. These periodic ecoregional estimates will allow managers to track changes in mountain lion abundance over time and will be included in the Integrated Population Model (Chapter 6) to predict the effect of future harvest prescriptions.

The same regular field monitoring will not be conducted in the Eastern ecoregion. There, lion subpopulations are patchily distributed and the ecoregion annually produces <15% of the state's annual harvest. Other population indices and harvest management strategies will be used in this ecoregion to conserve hunted populations. However, Eastern ecoregion managers may choose to sample lion abundance in specific areas of interest to better understand local populations.

ESTIMATING MOUNTAIN LION POPULATIONS

Capture-recapture (CR) sampling has been a standard method used to estimate a population's abundance for many years (Seber 1982). To produce a traditional CR estimate, some animals in a population are captured, marked, and released. Later, there is another capture effort and the number of marked animals within the second sample is counted. The proportion of the first sample detected in the subsequent sample is then used to calculate a population estimate.

Conventional CR sampling assumes that the effective sampling area's size is known, that animals don't enter or leave the study area, and that all animals have a similar probability of detection (Royle et al. 2013). Species like mountain lion that are wide-ranging, occur at low densities, and are difficult to detect violate these assumptions and may cause CR methods to produce misleading results.

SPATIAL CAPTURE-RECAPTURE

A newer spatial capture-recapture (SCR) method specifically addresses the shortcomings of traditional CR techniques when working with wide ranging, low-density species. SCR has been successfully used to estimate carnivore populations (Royle et al. 2011, Blanc et al. 2013) including mountain lions in Montana (Russell et al. 2012, Proffitt et al. 2015). SCR also works well with less invasive data collection techniques such as acquiring genetic samples from biopsy darts, hair, or scat.

Biopsy darts used to collect genetic samples from mountain lions

The SCR approach allows biologists to estimate population abundance within a defined area while also accounting for animals whose ranges partially or occasionally overlap the area surveyed. SCR methods consider the spatial organization of individual animals and the fact that the probability of an individual being recaptured decreases the farther that animal is from where it was originally detected or is known to reside. SCR methods also allow for sampling effort to vary across a study area when sampling wide ranging species (such as mountain lion) that use heterogeneous habitat.

Mountain lions in Montana prefer areas with habitat features such as forest cover, moderate slopes, forest edges, and intermediate elevations (Newby 2011, Robinson et al. 2015). Consequently, lions are not evenly distributed across different habitat types within an area. SCR methods use information about lion habitat preferences (specifically, the 2016 Montana mountain lion RSF) to inform estimates of population abundance.

Because estimated abundances are spatially explicit, population abundances associated with habitat of a certain quality within a sampling area can be extrapolated across broad landscapes as a function of that landscape's habitat quality. This allows information about lion abundance within Monitoring Areas to be used to estimate lion populations at the ecoregion scale.

SCR methods can also include information from harvested animals in population estimation models, thus allowing sampling to occur where hunter harvest is expected on and around the study area during the period the sampling is taking place (Efford 2014).

ABUNDANCE ESTIMATES

Monitoring an area's mountain lion abundance over time is essential to understanding the effect of hunter harvest on lion populations. However, variation in the ways researchers have defined their study areas, inconsistent reporting of age-classes included in population estimates, and the differences in estimation methodology make directly comparing lion densities reported in the literature nearly impossible (Hornocker & Negri 2009).

FWP will monitor and report the estimated winter density of all non-dependent individual lions—that is, lions that are legal to harvest—within an area

For example, researchers have variously reported densities of all mountain lions (including dependent kittens), the minimum number of resident adults, and the density of lions estimated across both seasonal and annual ranges. FWP will monitor and report the estimated winter density of all non-dependent individual lions—that is, lions that are legal to harvest—within an area.

In Montana, the average age that a young lion becomes independent of its mother is approximately 15 months (Robinson & DeSimone 2011). Montana law prohibits the harvest of young lions with body spots; these spots are nearly gone by 15 months of age (Currier 1983, Lindzey 1987).

Young lions make up a significant proportion of legal harvest. Of the known age lions legally harvested in Montana between 1988 and 2014, 42% were <3 years old and 15% were <2 years old. Many of these juveniles and subadults are transient, having yet to establish a fixed home range. The number of transient mountain lions in a population is difficult to quantify using traditional field sampling methods and this age class is often underrepresented in population estimates reported in the literature (Logan & Sweanor 2001).

Thus, an advantage of the SCR monitoring approach is that abundance estimates will include resident and transient animals, both of which are legal to harvest. The SCR method that FWP will initially use estimates the abundance of all independent aged lions within Trend Monitoring Areas and ecoregions during the winter monitoring period. Because all independent aged lions (including transients) are included, genetically based SCR abundance estimates may well be higher than estimates previously developed using other methods.

MONTANA MOUNTAIN LION MONITORING

FWP will use scientifically sound techniques to monitor Montana lion populations and produce periodic estimates of their size and trend. However, currently available monitoring techniques are both expensive and labor intensive. As field-based monitoring and analytical techniques improve and become more practical, FWP will remain open to incorporating them.

Initially, FWP will use the SCR sampling and analysis methods described by Proffitt et al. (2015) to periodically estimate independent aged mountain lion populations in the Northwest, West-central, and Southwest ecoregions. FWP has identified permanent Trend Monitoring Areas within each of these three western ecoregions which will be sampled on a rotating basis.

An additional Supplemental Monitoring Area within each ecoregion may also be sampled the year after the Trend Monitoring Area is sampled. Unlike the Trend Monitoring Areas, the location of Supplemental Monitoring Areas can change over time. These additional Monitoring Areas will allow FWP to sample a broader range of habitats within the ecoregions. Methods for selecting the permanent Trend and Supplemental Monitoring Areas, the field protocol for collecting data, and a description of the data analysis are included in Appendix 1.

Each new estimate of a Trend Monitoring Area's lion population can be directly compared to past estimates for that same area. In addition, the relationship between lion density and the 2016 RSF within an ecoregion's Trend Monitoring Area (sampled Year 1) and Supplemental Monitoring Area (sampled in subsequent years) can be combined to develop an estimate of population abundance for the larger ecoregion. If, over time, pooling the two Monitoring Areas' data produces ecoregional estimates that are functionally similar to estimates calculated from using the Trend Monitoring Area data alone, continued sampling of Supplemental Monitoring Areas may not be necessary.

Finally, an ecoregion's population estimate will be input into the Mountain Lion Integrated Population Model (Chapter 6) to increase our understanding of past and predicted mountain lion population trend and to evaluate alternative harvest prescriptions. Uncertainty about mountain lion abundance impedes effective harvest management. More accurate abundance estimates will be used in an adaptive management framework to make management more predictable over time. The frequency of monitoring will affect the rate at which this uncertainty is reduced, but monitoring frequency will also depend on the availability of funding and other priorities.

Treed mountain lion, western Montana

CHAPTER 6

THE MONTANA MOUNTAIN LION INTEGRATED POPULATION MODEL

INTRODUCTION

Wildlife biologists use mathematical models to approximate the real ecological systems they manage. These models allow them to better understand how populations work and to make more accurate predictions about how they're likely to change in the future. The most useful models are built using rigorously collected field research data and have a clearly defined purpose. These data (such as the age a male lion will most likely disperse or an adult female's annual survival rate) describe what's most likely to occur as well as the range of probable outcomes we should expect. By combining the best information available about a species or system we can better understand them.

Dr. Paul M. Lukacs and Dr. Joshua Nowak of the University of Montana collaborated with FWP to develop the Montana Mountain Lion Integrated Population Model (IPM; Nowak et al. 2018). The IPM is a tool that combines available information about a mountain lion population (i.e. harvest, abundance, survival, and reproduction) into a single analysis of that population's demography. Managers can use the IPM to describe the effects of past management and make predictions about future population trends.

PREDICTING LION POPULATIONS USING THE IPM

The primary purpose of the IPM is to help wildlife managers, decision makers, and the public understand the effect of past and future harvest on mountain lion populations. The IPM is directly linked to the FWP lion harvest database, and a web interface allows users to input future possible harvest prescriptions (by sex and age class).

Using this information, the model forecasts the future population trend that would likely result from an ecoregion's proposed harvest prescription. The output clearly shows the range and magnitude of the predictions' uncertainty for each year of the analysis; this uncertainty increases the further into the future the model is asked to make predictions.

Periodic abundance estimates that are developed from field-based monitoring (described in Chapter 5) can also be input into the model. These estimates make the IPM's predictions more precise. The IPM outputs the results of model runs as graphs (by population and by age and sex-class) as well as in a tabular format.

Montana's mountain lion IPM was built using the software program PopR which was developed in collaboration with Idaho Fish and Game, South Dakota Game, Fish and Parks and The University of Montana in 2014 (Nowak et al. 2018). PopR is a web based application linked directly to agency harvest databases through an interactive graphic user interface. It allows non-expert users to easily update data and change model parameters (such as assumed survival rates or reproduction) to evaluate the potential effects of future harvest levels. The IPM and web application were specifically designed to be repeatable, transparent, and easy for biologists to use.

The Montana mountain lion IPM can analyze populations within the three western Montana mountain lion ecoregions. Harvest data are input into and analyses are output by the IPM at the ecoregion scale.

The Integrated Population Model is a tool that combines all available information into a single analysis of mountain lion population demographics


Mountain lion traveling through snow, D. Neils

The IPM contains two underlying model components: a biological process model and an observation model (Schaub & Abadi 2011). The biological process model describes what we know about lion population dynamics and vital rates (Caswell 2001). It uses parameters including age-class and sex-specific survival probabilities, fecundity by age-class, and estimates of overall population size (when those field estimates are periodically available). The observation model describes the data collection process and the link between field data, harvest records, and biological parameters.

Field-based estimates of population vital rates have some statistical uncertainty and fluctuate over time. That is, field data (i.e. litter size) occur as a distribution of observed values that produce both a point estimate and a range of likely values. The IPM combines and considers all sources of uncertainty when predicting mountain lion population size and trend.

Field research has shown us that although many lion population vital rates (including reproduction and non-hunting survival) are remarkably consistent across the species' range, variability around average rates can significantly influence populations (Robinson et al. 2014). This variability is explicitly incorporated into the model and carried forward into predictions. The IPM allows users to estimate sex and age-specific population size and growth, as well as the precision of those predictions.

It's difficult to directly measure mountain lion vital rates and population trend frequently or extensively. Fortunately, lion ecology has been studied for decades in Montana and throughout the western U.S. The lion IPM allows for a straightforward application of expert knowledge even when specific information about local or contemporary populations is sparse. The model generates reasonable estimates of those parameters managers cannot directly measure based on the range of values researchers have previously collected in the field.

The IPM uses Bayesian statistics that allow a range of possible but uncertain values to be substituted in lieu of new field data. The range of values can be 'uninformative' (allowing a wide range of values to be equally likely) or 'informative' (where values known to be more likely are given a higher probability). For example, the annual survival probability for mountain lions can take any value from 0 (certain to die) to 1 (certain to live). Field research suggests that annual adult female mountain lion survival is near 0.85 in the absence of harvest. Therefore, an uninformative range of values could be a uniform (0,1) while a more useful informative range of values would have a mean of 0.85 with a standard deviation based on the range of values reported in the research literature. Montana's lion IPM uses informative values based on previous field research to improve model performance because it's impossible to directly measure vital rates every place or every year.

MOUNTAIN LION IPM MULTI-STATE SURVIVAL MODEL

Long-lived species with moderate reproductive rates (like lions) are particularly sensitive to changes in survival rates (Gaillard et al. 1998). The chances of a lion surviving each year also changes as it grows older. Kitten survival is the lowest of any age-class. Field estimates of kitten survival are often biased high because dens are usually located sometime after birth occurs (eg. Robinson et al. 2014) and kitten deaths between birth and when researchers discover the den may not be accounted for. Juveniles and subadults typically experience higher mortality during transient and dispersal movements (Sweaner et al. 2000, Robinson et al. 2008). Once a lion establishes a home range, nonhunting mortality risk decreases until the lion reaches old age. Adult lions typically die from intraspecific strife and human caused sources like road kills, management removals, and sport hunting (Hornocker 1970, Logan et al. 1986, Cooley et al. 2009, Robinson et al. 2014).

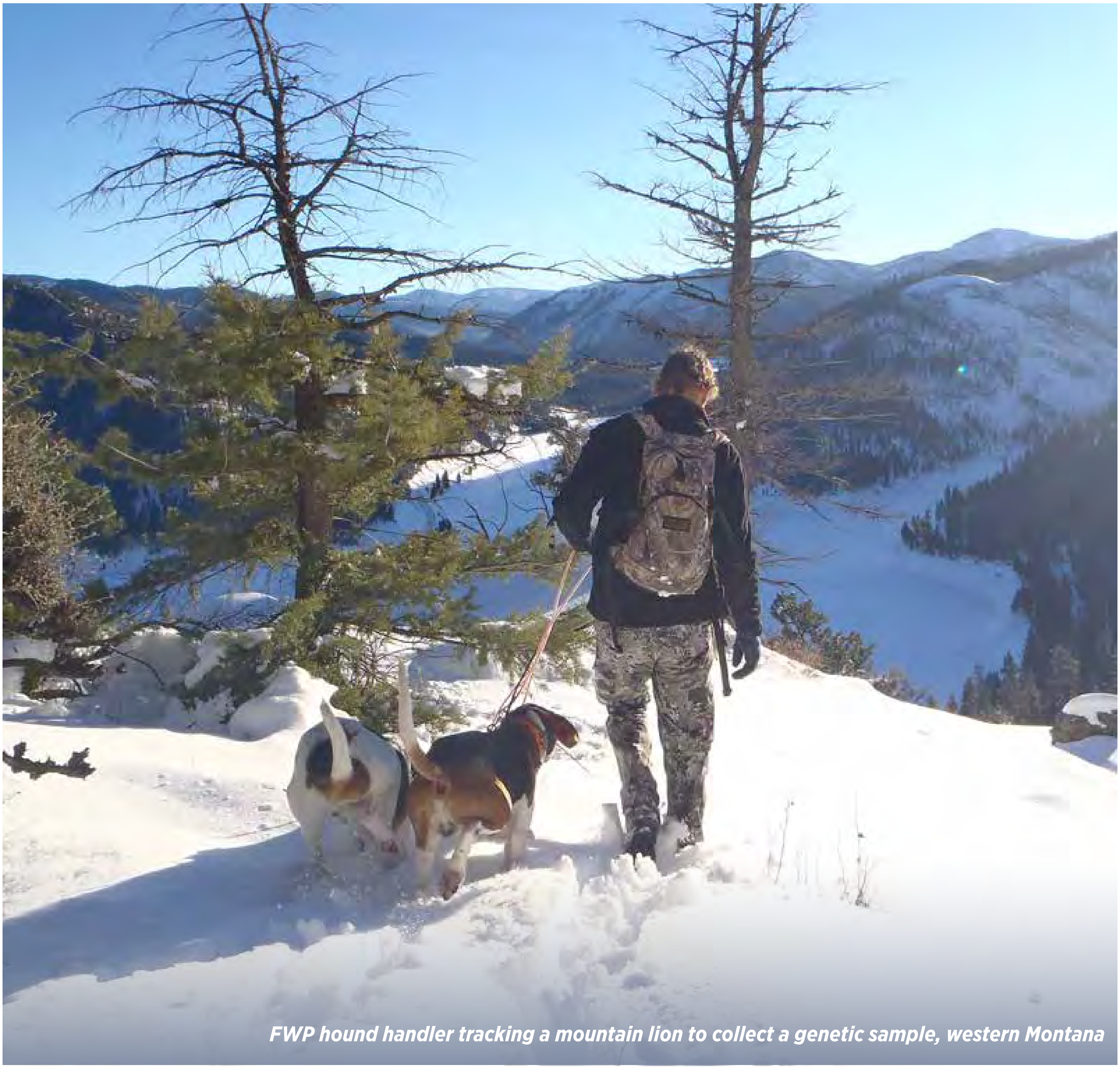
The model generates reasonable estimates of parameters managers cannot directly measure based on the range of values researchers have previously collected in the field

Reported rates of lion survival vary and are plagued by small sample sizes (Hornocker & Negri 2009). The lion IPM default parameters are based on telemetry data from marked lions in Wyoming's Teton Mountains (n = 100, 2001-2012), Washington's Kettle Range (n = 36, 2002-2006) and studies in Montana's Garnet Mountains and National Bison Range (combined n = 127, 1998-2006). These field data describe age and sex-class annual survival probabilities and error distributions used in the model (Appendix 2). Biologists can easily adjust input values if they have reason to believe that vital rates in their area are different from those observed during these field studies.

The IPM uses a known-fate multi-state survival model (Lebreton et al. 1992, Schaub et al. 2010, Servanty et al. 2010, Kery & Schaub 2011). The known fate assumption was necessary because the data included summaries of collar deployments but not true encounter histories. The IPM assumes that at the end of each month an animal could be in one of four states: a lion could be alive, dead by harvest, dead by other causes, or already dead at the beginning of that month. Animals whose fate was unknown because they left the area or whose collar failed are only included in the analysis up until the time they were last observed. Similarly, animals harvested outside Montana were only included up until they left the state so they did not contribute to Montana's estimated harvest rates. A description of these specific biological inputs and assumptions is included in Appendix 2.

POPULATION RECONSTRUCTION

With the exception of kittens, Montana mountain lion reproduction and nonhunting mortality is not significantly affected by typical changes in harvest levels. That is, harvest doesn't reduce the probability of animals otherwise dying and changes in a population's harvest rates don't significantly affect the surviving individuals' fecundity. In much of Montana hunter harvest is the most likely cause of lion mortality. Research on hunted populations in Montana's Garnet Mountains showed harvest to be largely additive to more consistent background nonhunting mortality risk (Robinson et al. 2014), and FWP is not aware of research results demonstrating that harvest of independent aged mountain lions is compensatory with other mortality sources. Because nonhunting mortality occurs at a relatively constant rate, the overall number of animals that die from nonhunting causes will vary with increases or decreases of the overall population.



FWP hound handler tracking a mountain lion to collect a genetic sample, western Montana

Hunter harvest can, and often does, affect lion population growth (Cooley et al. 2009, Hornocker & Negri 2009). Harvest data also gives managers information about past population numbers and sex/age composition in an area. When managers have reliable estimates of past and current population levels, they are better able to predict the effect of future harvest prescriptions on the lion populations they manage. The IPM uses survival estimates along with the annual harvest records to reconstruct past mountain lion populations (Gove et al. 2002, Conn et al. 2008). A description of these specific biological inputs and assumptions is included in Appendix 2.

If we have an estimate of the harvest mortality rate (from telemetry data) and know the number of lions harvested, dividing the number harvested by the harvest mortality rate gives us an estimate of the pre-hunt population size. This is then corrected for an "other mortality" rate, which is relatively constant.

"Population reconstruction" methods have been successfully used to estimate the size and trend of harvested fish and wildlife populations for over 70 years. The technique uses age-at-harvest, total harvest, harvest rate, and the rate of non-harvest mortality to "rebuild" the past population that must have existed in order to have produced the known type and level of harvest.

The IPM uses these age and sex-specific survival estimates (from field research studies) along with the annual harvest rate to reconstruct past mountain lion populations. Current hunter harvest by sex, age, and location (data that, in Montana, are collected during the mandatory lion harvest inspection) is input to the model after the close of the harvest season each year. By combining survival models with observed harvest data, the IPM estimates annual population size as well as a confidence interval around these estimates.

Direct, field-based estimates of population abundance may be input into the model when they are available. These periodic field estimates can significantly improve past and future population estimates for individual lion ecoregions.

MOUNTAIN LION REPRODUCTION INTEGRATED POPULATION MODEL INPUTS

Lions can begin reproducing as early as 17 months of age or as late as 3 years old (López-González & González-Romero 1998). Studies focused on modeling cougar population dynamics often assume females reproduce for the first time at 24 months (Robinson et al. 2008, 2014; Cooley et al. 2009); the IPM uses this same convention.

Lions are induced ovulators, they can conceive during any month of the year (Bonney et al. 1981, Robinson et al. 2014), and gestation lasts about 92 days (Logan & Sweanor 2001). Despite their ability to give birth year round, most researchers working in northern latitudes report a birth pulse in mid or late summer (Laundre & Hernandez 2007, Robinson et al. 2014). The IPM assumes a default birth date of July 1.

Montana mountain lion reproduction and non-hunting mortality is not significantly affected by typical changes in harvest levels

Intervals between subsequent births are a function of gestation length, kitten time to independence, and any lag that may exist between rearing and breeding. Previous population models have assumed a 24-month interbirth period (Robinson et al. 2008 & 2014, Cooley et al. 2009). Field researchers measuring interbirth intervals in the wild report a range of about 17 to 24-months between litters (Lindzey et al. 1994, Logan & Sweanor 2001, Hornocker & Negri 2009). Newborn kittens trail their mothers for 1 to 2 years before dispersing or achieving independence (Hornocker & Negri 2009). In the Garnet Mountains of Montana, Robinson et al. (2014) observed an average dispersal age of 15 months (n = 33, range: 11-23 months), similar to that observed by others (Sweanor et al. 2000; Logan & Sweanor 2001). The IPM uses an interbirth interval of 24 months as the model default.

Mountain lion litter sizes are remarkably similar across a wide range of locations and conditions. A common estimate of litter size is 3 kittens (Spreadbury et al. 1996, Logan & Sweanor 2001, Robinson et al. 2014). Litter size does not appear to vary with harvest intensity, but may fluctuate with prey density (Wilson et al. 2004, Stoner et al. 2006, Robinson et al. 2014). The IPM uses the estimate of an average of 2.92 kittens per litter derived from recent research in Montana's Garnet Mountains (Robinson et al. 2014; n = 24 litters) and it assumes that half of the kittens are female. Throughout the model, the average and range of litter sizes observed in the Garnet study is used to describe a normal distribution of litter sizes truncated between 0 and 3. The model also assumes that litter size remains constant through time and does not fluctuate with population size, prey density, or the female's age. A description of the specific biological inputs and assumptions used is included in Appendix 2.

USER CONTROLS

Biologists can adjust most model inputs such as biological assumptions, future harvest prescriptions, and model controls. The default biological assumptions are based on field research data and should only be changed if users believe that future or local circumstances have changed lion reproduction or non-harvest survival.

Users can easily use sliding scales provided on the user interface to change future harvest prescriptions by sex and to allow the model to estimate the effects of those changes. Users only need to input total anticipated hunting mortality by sex—the model will assign future harvest mortality to age classes that are consistent with the distribution of previously observed harvest ages. If the user believes that the harvest-age distribution will be different than past years, a different distribution can be manually assigned.

For more information on the model controls and settings, including the IPM model's computer code in programming language R, see Appendices 2 and 7.

CHAPTER 7

MOUNTAIN LION HARVEST REGULATION

REGULATION HISTORY

Montana's mountain lion hunting regulations became increasingly complex, and inconsistent, during the 45 years since lions were designated as a big game species. New and modified regulations were adopted in an ad hoc fashion as various Fish and Wildlife Commissions struggled to address public concerns about harvest levels, prey populations, harvest distribution, parity between hound handlers and hunters without dogs, nonresident and outfitter participation, human-lion conflicts, and scores of other issues.

In FWP regions where hunting was allowed, mountain lion harvest was not restricted by quotas or limited licenses until the mid-1980s. Hunters were simply required to purchase a license and allow FWP personnel to inspect lions following harvest. By 1988, most FWP regions had established Lion Management Units with individual harvest quotas (and/or female subquotas) to limit harvest. The Department began to require harvested lions to be reported to a hotline within 48 hours and presented for physical inspection within 10 days. The reporting period was reduced to 12 hours in subsequent seasons.

Until 1997, most Winter lion hunting seasons ran from 12/1 to 2/15, after which hound handlers could continue to pursue lions with dogs during dedicated "chase" or "training seasons" that extended into April. More recently, hound training seasons open 12/2 and run concurrent with established harvest seasons.

Montana lion populations appeared to significantly expand and grow after 1980, as did the popularity of recreational hound hunting. Both resident and nonresident hunter participation increased to historically high levels by the mid-1990s (Figure 22) and the number of nonresident hunters was not limited. During that period, conflicts between resident hound handlers, nonresident hunters, and outfitters were common in portions of northwest and west-central Montana where winter snow is consistently present and there is plentiful access to public land lion habitat. For example, In Region 1 approximately half of harvested mountain lions were taken by outfitted or nonresident hunters during the 1990s—guided hunter harvest often closed LMUs before local "weekend" hunters had an opportunity to hunt. Similarly, over 30% of successful hunters in Region 2 were nonresidents during the 1990s; this proportion rose to 47% by 2005.

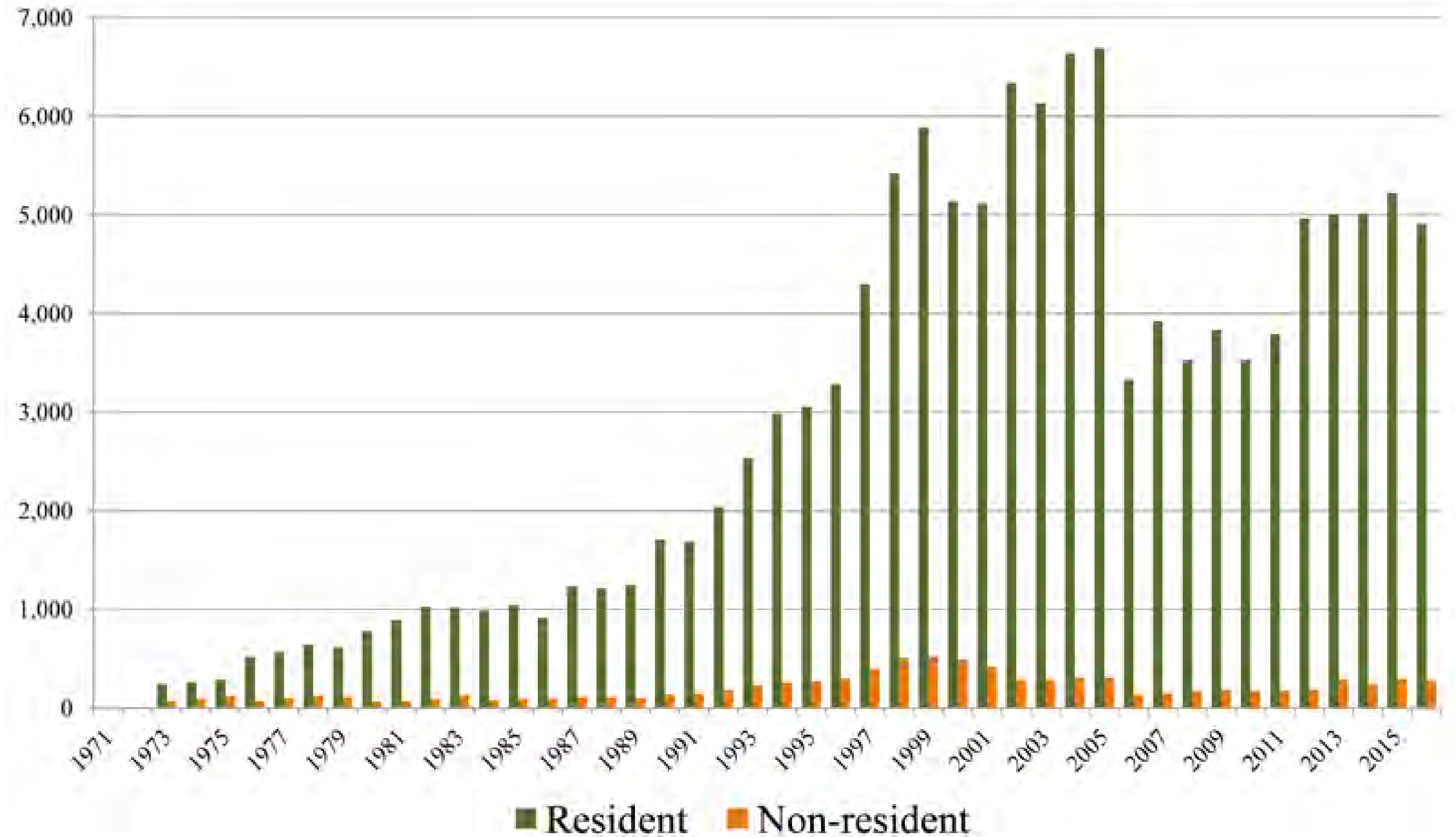
In 2000, FWP's Region 1 began to issue resident mountain lion hunting permits which, in effect, limited nonresident hunters' opportunity. Beginning in 2005, most Region 1 LMUs were managed using limited Special Mountain Lion Licenses that restricted nonresidents to no more than 10% of the licenses offered in a drawing.

Montana's mountain lion hunting regulations became increasingly complex, and inconsistent, during the 45 years since lions were designated as a big game species

Similarly, in 2006, Region 2 began to require that nonresidents draw a Special Mountain Lion License to harvest a lion in most of the region. Resident lion harvest was managed using a quota and nonresident Special License numbers could not exceed 10% of an LMU's total quota. The Fish and Wildlife Commission required that both resident and nonresident hunters draw a Special Mountain Lion License in most Region 2 LMUs beginning in 2008.

In Region 2, managers were not able to achieve predictable harvest using only these Special Mountain Lion Licenses. License fill rates varied widely from year-to-year and across LMUs. Female lion harvest was also virtually eliminated despite rapidly increasing populations. Therefore, in 2012,

Figure 22. Montana mountain lion license sales, 1973 – 2015.



Region 2 introduced an additional Late Winter Season (opening 2/1) during which hunters with a General Lion License could hunt until any quotas previously unfilled by Special Mountain License holders were met (this became known as a "hybrid" season). Nonresident participation was unlimited during the Late Winter Season and nonresident harvest rates more than doubled after the Late Winter Season was adopted.

Regions 3-7 continued to limit harvest during this period using sex-specific quotas and subquotas. Conflict between resident and nonresident hunters in these regions was low and the Fish and Wildlife Commission did not impose restrictions on nonresident harvest opportunity in these Regions.

Prior to 1997, all legal harvest occurred during the Winter Season (that immediately followed the 5-week fall General Deer/Elk season) during which hunting with the aid of dogs was allowed. Beginning that year, portions of the state began to also allow lion harvest during the fall General Deer/Elk Season but without the use of dogs—fall seasons were adopted statewide in 1999. In 2010, the Commission added a statewide Archery Only Season that corresponded with the Archery Only Deer/Elk Season.

The Commission responded to concerns that Fall Season harvest could significantly reduce winter hound harvest opportunity by adopting separate LMU harvest quotas for the combined Archery Only and Fall Seasons. In most cases, if harvest prior to the Winter Season(s) exceeded 20% of a lion management unit's total quota or number of Special Lion Licenses, that LMU's Fall Season would be closed.

The separate quota for Archery Only and Fall Season harvest added complexity to the regulations but did not appear to meaningfully affect the seasonal distribution of lion harvest. Between 2007 and 2016, 95% of all hunter harvested lions in Montana were taken during the Winter Seasons with the aid of dogs. During that same period 11% of the state's LMUs were closed during any given Archery

Only or Fall Season due to the 20% quota being met and 85% of those LMUs had an Archery Only/Fall quota equal to only one lion. Harvest that met fall quotas in these LMUs occurred a median of 16 days from the end of the 85-day Archery Only/Fall Season. The Archery Only/Fall Season quota was unlikely to reduce overall harvest in LMUs because that harvest was deducted from the LMU's quota and subquota.

However, harvest during the fall seasons is additive to prescribed Winter Season harvest in LMUs where the number of Special Mountain Lion Licenses issued serves as the effective harvest limit. Because of this difference, maintaining a separate Archery Only/Fall Season harvest quota may be necessary in LMUs where harvest is managed using Special Mountain Lion Licenses, instead of quotas.

HARVEST SEASON SETTING

This Strategy identifies four mountain lion ecoregions within the state that will be the basis for both monitoring populations and establishing broad harvest objectives. Within an ecoregion, FWP managers will work with the public and the Fish and Wildlife Commission to:

1. Develop clear and measurable population, harvest, and hunter opportunity objectives for the ecoregion.
2. Determine an overall harvest prescription that is likely to achieve the ecoregion's explicit population objectives.
3. Distribute harvest opportunity across the ecoregions' LMUs to address local concerns, reduce hunter crowding, and to focus or limit harvest where necessary.
4. Actively monitor the effect of the harvest prescription over time.
5. Adjust management objectives and harvest prescriptions, as necessary.

This process is described, in detail, in Chapter 8.

The amount of harvest that occurs in any one LMU matters much less to an ecoregion's mountain lion population than the overall harvest within that LMU's ecoregion. That is, whether an individual LMU's harvest limit (or quota) is reached or exceeded during a given year (due to weather, hunter participation, or other factors) is less important that the total annual ecoregional harvest.

Managers may intentionally recommend a relatively high harvest rate in certain LMUs (e.g. those including urban areas) or relatively low harvest rate in others (where access is challenging or tolerance for lions is high). As long as harvest is generally distributed across an ecoregion, the sum total of harvest is what will affect the ecoregion's population status and trend.

Therefore, in an LMU where harvest is limited by a quota, that quota will simply serve as "trigger" to initiate the closing of the LMU to further harvest. A quota is not necessarily a harvest objective for the LMU. When setting LMU quotas, biologists will anticipate how much additional harvest (if any) is likely to occur between the time the LMU's Season closure is publicly noticed and when the closure is effective. Subsequent ecoregional harvest decisions will consider the actual harvest that occurred in previous years' Seasons. Individual LMU quota "over runs" or "under runs" will be fully accounted for in future management decisions.

From a population standpoint, harvest that occurs in any one LMU matters much less than the overall level of harvest within that LMU's ecoregion

In LMUs managed using Special Mountain Lion Licenses, an area's average Special License fill rate (by sex) will be used to determine the overall number of licenses that should be offered to meet the ecoregion's harvest objective. Any differences between projected and observed Special License fill rates will be considered when determining future license levels. As with General License areas, decisions about future harvest prescriptions will be based on the modeled and measured effect the actual past harvest had on ecoregional populations.

There is little biological justification to frequently adjust mountain lion harvest prescriptions. Large scale mountain lion populations are very resilient to moderate changes in harvest and updated population estimates (both within trend areas and for the western ecoregions) will be available only periodically. Therefore, although FWP will routinely consider changes to mountain lion hunting season structure and quota levels, actual adjustments could be made less frequently.

LEGAL AUTHORITY

The Montana Fish and Wildlife Commission has statutory authority to regulate the management of wildlife (87-1-201), specifically "Large Predators" (87-1-217), including mountain lions. The Commission may determine seasons, bag limits, possession limits, and means of take for mountain lions as it deems appropriate (87-1-304). Montana statute describes specific resident and nonresident licenses required to hunt mountain lions (87-2-507, 508) and the license necessary for residents to pursue lions with dogs during the Training Season (87-2-521). Montana law limits hunters to taking no more than one mountain lion per license year (87-2-702) and allows the use of dogs to hunt or capture mountain lions during designated seasons (87-6-404). It is legal to kill a mountain lion at any time that is attacking, killing, or threatening to kill a person or livestock (87-6-106), using dogs if necessary (87-3-127).

Consistent with Montana law and Administrative Rules, when the Commission decides that it's necessary to limit nonresident harvest opportunity

Montana law specifically allows the Commission broad discretion to regulate the allocation of hunting opportunity among resident and nonresident hunters:

87-1-301. Powers Of Commission

(6) (a) The commission may adopt rules to:

(i) limit the number of nonresident mountain lion hunters in designated hunting districts; and

(ii) determine the conditions under which nonresidents may hunt mountain lion in designated hunting districts

(b) The commission shall consider, but is not limited to consideration of, the following factors:

(i) harvest of lions by resident and nonresident hunters;

(ii) history of quota overruns;

(iii) composition, including age and sex, of the lion harvest;

(iv) historical outfitter use;

(v) conflicts among hunter groups;

(vi) availability of public and private lands; and;

(vii) whether restrictions on nonresident hunters are more appropriate than restrictions on all hunters.

under the above statute, nonresident licenses will be limited to numbers not exceeding 10% of the total licenses or quotas assigned to a given hunting area (87-2-506, 12.3.105). LMUs with a quota (or number of licenses) of less than 10 will be combined with similar Regional LMUs and a number of nonresident licenses, not exceeding 10% of the combined total quota(s), will be allocated among those districts on a rotating basis (as described in ARM 12.3.116)

MODEL HARVEST REGULATIONS

Following are the three mountain lion hunting season structure alternatives Montana will use to manage hunter harvest. Managers may select an LMU's Season Type from among these three alternatives to consistently address the diversity of management challenges and needs across the state while minimizing regulation complexity. In most cases, changes to an individual LMU's season structure and/or quota(s) will be considered every second year.

Season Type 1: Special Mountain Lion License LMU

MCA 87-1-304(e) allows the Fish and Wildlife Commission to issue limited Resident (Class D-2) and Nonresident (Class D-1) Special Mountain Lion Licenses. These licenses are valid in a single LMU and hunters can harvest a mountain lion only in that LMU during the Winter Season. FWP offers a limited number of these Special Licenses each season. Therefore, they are allocated by a random drawing and nonresident hunters are limited to no more than 10% of the total number of available licenses (87-1-301). Sex-specific licenses or subquotas may also be designated to help achieve harvest objectives. Once a subquota is met (and the season for that sex closes), Special License holders may continue to hunt for lions of the remaining sex through the end of the legal harvest season. Both Special License holders and General License holders may harvest a lion during the Archery Only and Fall Season Without Dogs in these LMUs, but that harvest will be subtracted from any sex-specific subquotas for that LMU. Managers may choose to implement a combined Archery Only/Fall Season quota or subquota where necessary.

Season Type 2: General License LMU

Hunters possessing a General License may harvest a mountain lion during the Archery Only, Fall Season Without Dogs, or Winter Seasons until the total or sex-specific quota for that LMU is met. There is no additional limit to nonresident opportunity to harvest a mountain lion using this Season Type.

Season Type 3: Resident General License, Nonresident Special Mountain Lion License LMU

Resident hunters possessing a General License may harvest a mountain lion during the Archery Only, Fall Season Without Dogs, or Winter Seasons until the total or sex-specific quota for that LMU is filled. Nonresident hunters must apply for, and receive, a LMU-specific Special Mountain Lion License to harvest a mountain lion in that LMU during the Archery Only, Fall Season Without Dogs or Winter Season. Special Mountain Lion Licenses will be offered to nonresident applicants in quantities not exceeding 10% of the LMUs total combined harvest quota(s). LMUs with a total quota of less than 10 will be combined with similar Regional LMUs and a number of nonresident licenses, not exceeding 10% of the combined total quota(s) for those LMUs, will be allocated among those LMUs on a rotating basis (as described in ARM 12.3.116).

CHAPTER 8

ADAPTIVE HARVEST MANAGEMENT

This Strategy will provide FWP and the public with more accurate information about Montana's current, and likely future, mountain lion populations. However, there will always be some uncertainty about the precise effects of our management actions on lion populations. Although the overriding Conservation and Management Guidelines that direct Montana's mountain lion management decisions will not change, specific local management objectives may well need to be refined over time as more information becomes available and conditions change.

In this chapter, we describe the adaptive harvest management process FWP will use to develop, evaluate, and adjust specific mountain lion management actions. This process relies on field monitoring and population modeling data (described earlier in this Strategy) to measure the results of management actions against explicit objectives that the public, FWP, and the Fish and Wildlife Commission collaboratively develop.

FWP hound handler collects genetic sample during mountain lion SCR monitoring in western Montana's Region 2.

Adaptive management can help reduce decision-making gridlock by making it clear that decisions are provisional, their effects will be carefully monitored, and that modifications are expected

Adaptive management is a science based approach to decision making that's useful when there is uncertainty about a decision's outcome. It is a cycle of planning for an action, doing the action, measuring what happened, and then modifying the next action (if needed) based on what you learned. The basic principles of adaptive management have been used for centuries (Falaruw 1984) and are increasingly employed by natural resource management agencies, including FWP (Montana Fish, Wildlife and Parks 2001).

The process works to continually improve our understanding of a system by comparing the resource's actual versus predicted response to management treatments (Nichols & Williams 2006, Williams et al. 2007). Adaptive management emphasizes 'learning while doing' and then adjusting management based on what was learned (Walters & Holling 1990). It is specifically not 'trial and error'— instead, managers explore alternative ways to meet management objectives, predict the outcomes of those alternatives based on the current state of knowledge, implement one or more alternatives, monitor the impacts of the management actions, and then use the results to adjust management actions as needed to more effectively meet objectives. Over time, resource management improves while uncertainty is reduced.

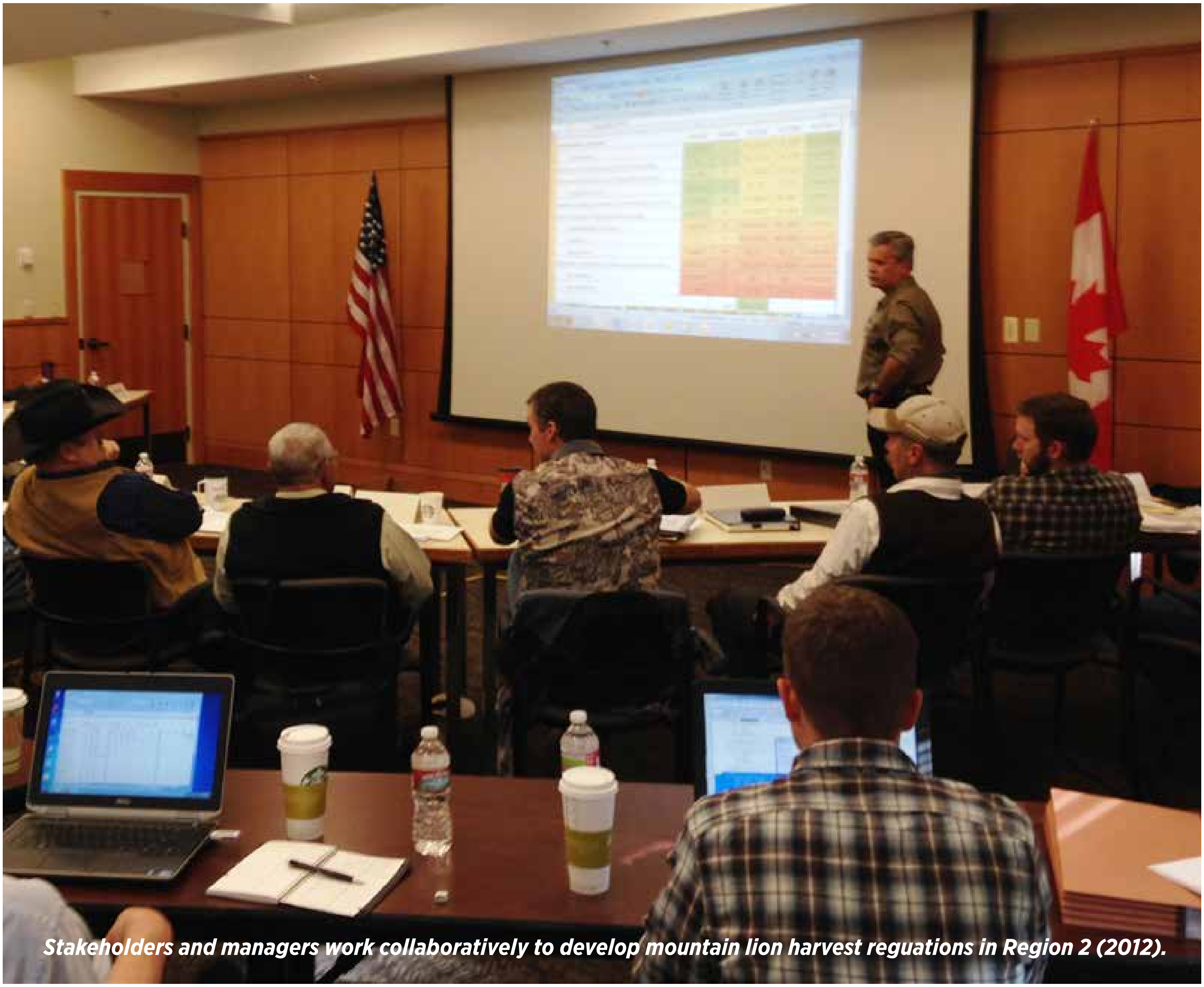
An adaptive management system requires the following conditions (Williams & Brown 2012):

- Resources are responsive to management but actual outcomes are uncertain;
- Management objectives are clear and measurable;
- There is both a range of management alternatives and the flexibility to change prescriptions as understanding improves over time;
- Monitoring can effectively describe the effect of the management action;
- There is a sustained commitment to the process by both stakeholders and decision makers.

Resource models are a critical component of the adaptive management approach. Models allow managers to use the most current information to predict the effect of possible treatments. They also represent what we don't yet know about how the system works—these uncertainties are explicitly incorporated into the model. The credibility of predictive models can improve through time as new information becomes available and uncertainty is reduced.

The effects of management actions must also be monitored so that the actual response can be compared to what was initially predicted. A successful monitoring program provides data that specifically describes the effects of the management action. Monitoring efforts must be designed from the start with that goal in mind (Szaro et al. 1999, Nichols and Williams 2006).

Disagreement about the past, and potential, effects of management decisions often leads to conflict among stakeholders. Adaptive management can help reduce decision making gridlock by making it clear that decisions are provisional, that their effects will be carefully monitored, and that modifications are expected. Management itself allows us to learn about, and therefore better manage, the resource through time.



Stakeholders and managers work collaboratively to develop mountain lion harvest reguations in Region 2 (2012).

MONTANA'S ADAPTIVE MOUNTAIN LION HARVEST MANAGEMENT PROGRAM

An adaptive harvest management process will guide most of Montana's mountain lion harvest decisions. FWP will use the best available science to develop the modeling and monitoring methods necessary to fully implement this Strategy. The modeling and monitoring techniques described in this document will be periodically reviewed and updated to ensure that we continue to use the most rigorous and up-to-date scientific methods practically available.

FWP used a habitat model (Chapter 3) to describe four distinct and biologically meaningful mountain lion "ecoregions" within the state (Chapter 4). These ecoregions will be the spatial basis of FWP's lion monitoring program. FWP will work with stakeholders to periodically develop measurable mountain lion management objectives for each of these ecoregions. These objectives will be periodically reviewed, and potentially refined, by FWP and the public.

The likely effects of alternative harvest prescriptions will be evaluated using an Integrated Population Model (Chapter 6). These predictions will help stakeholders and FWP recommend an alternative to the Fish and Wildlife Commission that is most likely to meet that ecoregion's objectives.

In most cases, management alternatives will include an overall harvest prescription for each ecoregion. Harvest opportunity will then be allocated among the ecoregions' individual lion management units to distribute hunter effort and address local issues.

FWP will use field data to periodically estimate mountain lion population size, composition, and trend within the Northwest, West-central, and Southwest ecoregions (Chapter 5). These periodic population estimates will be used to improve the IPM's predictions, to assess how well management objectives are being met, and to inform decisions about future harvest prescriptions.

Other monitoring data including hunter effort and success, location and age of harvested animals, conflict rates, and prey status will be collected annually throughout the state. These additional data will be considered when evaluating management alternatives. Harvest data, weather, patterns of conflict, harvest success and other metrics will be the primary data used to guide management in the Eastern ecoregion.

The adaptive management approach includes the following basic steps (Figure 23):

Step 1 – Involve stakeholders

Stakeholders (including the public, managers, and decision makers) help design an adaptive management program, set management objectives, and develop management actions. Stakeholders must be committed to the adaptive management process for the long term.

FWP biologists and managers routinely meet with hound handlers, other hunters, and mountain lion advocates to share data and solicit public input concerning ongoing mountain lion management. The Fish and Wildlife Commission will generally consider proposals to adjust harvest season structure and/or harvest quotas every two years during the biennial season setting process.

Step 2 – Set objectives

Objectives must be clear and measurable. These objectives are benchmarks against which to compare the potential effects of management alternatives. They also serve as means to evaluate how effective management actions were, once implemented.

There may be discrete objectives for population composition and trend, hunter experience, harvest distribution, rates of reported conflict, etc. It's important that an objective identifies a clear time by which it should be met and clearly describes how progress toward that objective will be measured.

An example of clear and measurable objectives would be:

> ***"The 2023 Northwest ecoregion estimated population of independent age mountain lions will be between 1,100 and 1,300 animals", and***
>
> ***"The proportion of >5-year-old male mountain lions harvested in the Northwest ecoregion will exceed 12% during 4 of the next 6 hunting seasons"***

Step 3 – Develop management alternatives

Identify a set of potential management actions that, based on the best information available, are likely to help meet the objectives.

For example, competing harvest alternatives could be:

> ***Alternative 1: "Offer a total of 160 Special Licenses with a male subquota of 70 in LMUs 100 – 130; maintain a total "any legal" mountain lion quota of 30 in LMUs 132 – 170; and maintain a quota of 30 females and 50 males distributed across LMUs 200 – 203, the MSMA, and 283/285 during the 2018 – 2019 hunting seasons in order to harvest an average of 130 male and 90 female lions annually", or***
>
> ***Alternative 2: "Offer a total of 200 Special Licenses with a male subquota of 80 in LMUs 100 – 130 and maintain a total any legal mountain lion quota of 30 in LMUs 132 – 170; and maintain a quota of 45 females and 70 males distributed across LMUs 200 – 203, the MSMA, and 283/285 during the 2018 – 2019 hunting seasons in order to harvest an average of 150 male and 110 female lions annually"***

Step 4 – Use models to predict the alternatives' effects

Models can describe our current understanding about how a system works and explicitly represent our uncertainties. Models are used to predict likely responses of a resource to management actions.

In our example, biologists would use the Integrated Population Model to evaluate which of the previous alternatives is most likely to move the overall Northwest Ecoregion's independent aged mountain lion population toward the 1,100-1,300-objective range in 6 years and recruit sufficient older age-class toms each year to also meet the harvest-age composition objective. If neither alternative is likely to meet both objectives, new alternatives will be developed and evaluated.

Step 5 – Develop monitoring plans

Design a monitoring plan that effectively tracks the resource's status relative to the objectives. Monitoring must produce data relevant to the management situation that motivated the monitoring in the first place.

For our example, there would be three monitoring plans in place:

> ***1. Teeth will be extracted from all harvested lions upon mandatory inspection resulting in a >90% age assignment rate using cementum annuli analysis, and***
>
> ***2. Actual 2018 and 2019 Northwest ecoregion harvest, by sex, will be input into the Integrated Population Model following the 2019 season to reassess population trend relative to the population objective, and***
>
> ***3. A Spatial Capture-Recapture field estimate of lion abundance will be developed for the Northwest ecoregion Trend Monitoring Area in 2023 and Supplemental Monitoring Area in 2024. Biologists will directly compare the 2018 and 2023 Trend Monitoring Area population estimates. The relationship between observed mountain lion abundance and the RSF for both monitoring areas will be combined to produce an estimate of independent age mountain lions in 2024, which will be input into the IPM.***

Step 6 – Make management decisions

Select management actions that are likely to move the resource toward the objectives.

For our example:

> ***Managers will recommend a preferred alternative or alternatives to the Fish and Wildlife Commission who will make a management decision for the upcoming hunting seasons.***

Step 7 – Monitor the resource

Measure the resources' response to management actions.

FWP will implement the monitoring plans described in Step 5.

Step 8 – Assess management success

Compare the predicted vs. observed changes in the resource's status to improve our understanding of the system and allow better decisions to be made in the future.

For our example:

> ***Monitoring data indicate that the overall population objective has been (or is likely to be) achieved but the harvest-age composition objective has not.***

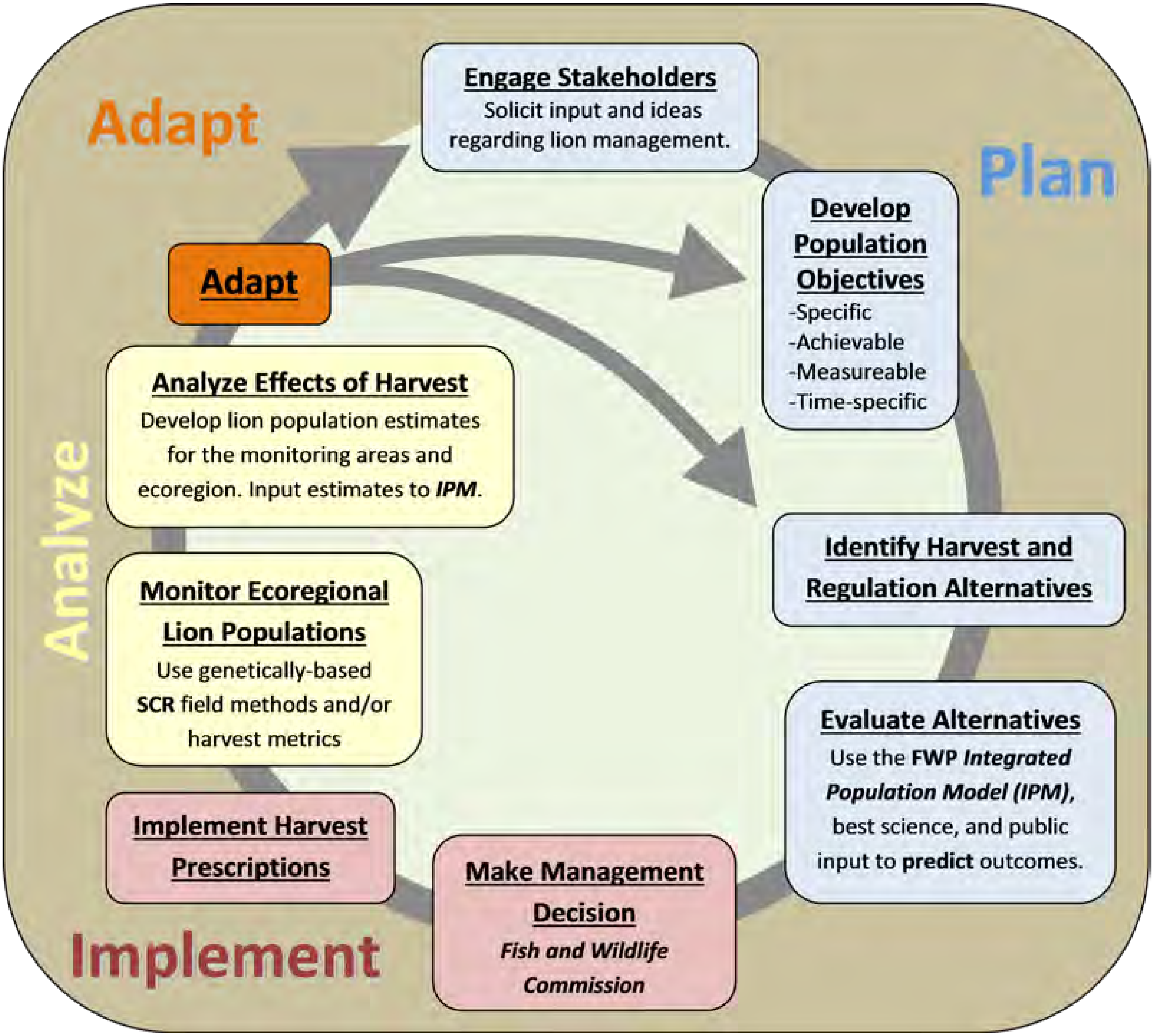
Step 9 – Repeat the process

Cycle back to Step 6 and, less frequently, to Step 1. Predictive models will improve based on new information. Objectives can change over time.

For our example:

> ***Managers propose a revised harvest prescription that maintains female harvest at a similar level while reducing male harvest.***

Figure 23. Adaptive mountain lion harvest management process.



CHAPTER 9

REGIONAL MANAGEMENT CONSIDERATIONS AND OBJECTIVES

Mountain lion populations will be monitored, modeled, and managed at the ecoregion scale. However, it is important to recognize the social and biological issues that are unique to each FWP administrative Region. FWP wildlife managers are experts in their regional landscapes and communities, opportunities to gather public input are organized regionally, and regional managers develop and submit individual hunting season proposals for Fish and Wildlife Commission consideration. Responses to human-lion conflicts are also coordinated by Regional managers and field staff.

This Strategy will require that FWP and the public work across FWP regional boundaries to develop management objectives and alternatives for each of the 4 broader mountain lion ecoregions. They will also need to collaboratively work to distribute an ecoregion's harvest prescription because the ecoregion's constituent LMUs lie within more than one FWP administrative region.

This chapter presents each FWP administrative region's mountain lion management history and some local factors that will need to be considered as ecoregional management proposals are developed and evaluated.

This Strategy will require that FWP and the public work across FWP regional boundaries to develop management objectives and alternatives for each of the 4 broader mountain lion ecoregions

REGION 1

Approximately 80% of FWP Region 1's area is high-quality mountain lion habitat (Chapter 3), the most of any of the state's 7 administrative Regions (Figure 24). Because of this, and the Region's abundant white-tailed deer, it may support the highest overall mountain lion density in the state. Mountain lion habitat occurs almost entirely on either public or publicly accessible private land and tracking snow is generally present throughout the Winter Season.

Region 1 lion harvest was unlimited until specific LMU quotas were adopted in 1986. Harvest was managed using a system of total quotas and female subquotas through 1994, followed by a total quota system until 1999 (Table 8).

Regional harvest steadily increased throughout the 1990s (Table 7) and the average age of harvested lions also increased during this same period. In the late 1980s, only 38% of the harvest was made up of older (≥ 3 years) lions. That proportion increased to 66% older individuals as the harvest steadily increased from 1990 to 1996.

Mountain lion harvest increased during the 1990's such that even historically-high quotas were exceeded in 1995 and 1997. Harvest then began to decline in 1999 following a drop in harvest-age structure that began in 1997. The effect of high harvest levels (especially of females) was likely exacerbated by a severe winter in 1996-1997 that significantly reduced both the Region's deer populations and subsequent recruitment (Montana Fish, Wildlife and Parks 2006).

Quota-based, General License harvest regulations did not limit nonresident hunter participation during the 1990s and conflicts between nonresident/outfitted hunters (who in some years took nearly half of all Region 1 lions) and resident hunters became unacceptably common.

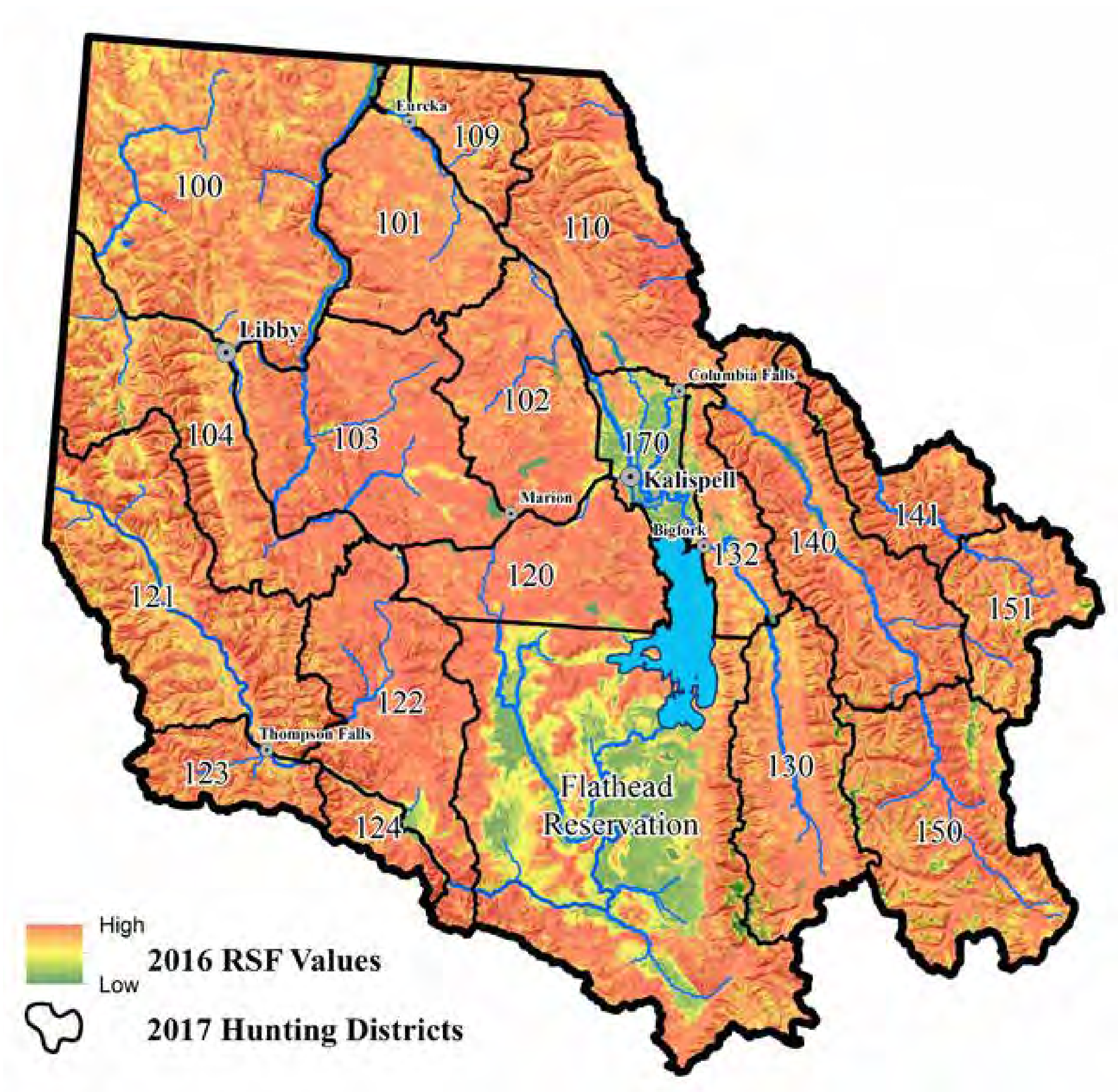
Between 1997 and 2004, only 39% of harvested lions were 3 years old or older. In 2000, declines in the Region's age-in-harvest and overall harvest, combined with a public demand to prioritize resident hunter opportunity, led the Fish and Wildlife Commission to change the Region's management approach. The Commission restricted resident and nonresident harvest by requiring a Special Lion License, obtained through a drawing, across much of the Region that year.

Table 7. Region 1 mountain lion harvest, 1971 – 2016.

License Year	R1			
	F	M	Unk	Tot.
1971	10	11	0	21
1972	9	13	0	22
1973	4	19	0	23
1974	23	23	0	46
1975	27	27	0	54
1976	18	20	0	38
1977	21	21	0	42
1978	12	14	0	26
1979	8	21	0	29
1980	9	6	0	15
1981	20	25	0	45
1982	18	26	1	45
1983	27	31	0	58
1984	13	29	1	43
1985	17	30	1	48
1986	16	32	0	48
1987	22	25	0	47
1988	18	34	0	52
1989	20	46	0	66
1990	30	55	0	85
1991	40	69	0	109
1992	50	67	1	118
1993	53	86	0	139
1994	81	122	0	203
1995	80	100	0	180
1996	87	94	0	181
1997	119	112	0	231
1998	139	105	1	245
1999	92	86	0	178
2000	103	93	0	196
2001	80	83	0	163
2002	67	61	0	128
2003	57	47	0	104
2004	42	69	0	111
2005	52	59	2	113
2006	20	50	0	70
2007	20	64	0	84
2008	32	62	0	94
2009	29	63	0	92
2010	42	83	0	125
2011	53	89	0	142
2012	46	78	0	124
2013	50	79	0	129
2014	43	57	0	100
2015	41	68	0	109
2016	49	56	0	105

In 2005, a combination of limited entry (Special Licenses) and quota systems were adopted in Region 1. The goals of this harvest strategy were to 1) maintain a high-quality hunting experience, 2) limit nonresident hunter harvest in some LMUs, 3) prevent the overharvest of adult females while recruiting more mature males into the population, and 4) prevent FWP regulations from limiting effective harvest in LMUs where tolerance for lion presence was low. Region 1 documented a higher percentage (55%) of older individuals (≥ 3 years) in the harvest during the years following the change (2005 – 2013). In 2014, the Commission adopted a male subquota, limited entry hunting season type for most Region 1 LMUs.

Figure 24. FWP Region 1 2016 mountain lion winter RSF and hunting districts.



In 2017, 13 of the Region's 18 LMUs issued a limited number of Special Licenses, available through a drawing, with nonresidents limited to 10% of the total number of Licenses offered. The Region's remaining 5 LMUs managed harvest using General Lion Licenses; harvest in these Units is generally limited by overall quotas and male subquotas. LMU 170 (the Flathead Valley) is the single exception. An unlimited number of lions could be taken each season in this highly developed, urban, LMU. In practice, however, lions are rarely harvested in LMU 170—only 4 lions were taken by hunters in that Unit between 2007 and 2016.

The predominant use of limited Special Licenses in Region 1 has effectively emphasized resident hunter harvest—between 2007 and 2016 an average of only 13% of harvested lions were taken by nonresidents there.

Region 1 lies entirely within the Northwest mountain lion ecoregion (Figure 25). The Region's biologists and public will work with their counterparts in Region 2 (that includes the remainder of the Northwest ecoregion) to adaptively manage the ecoregion's mountain lion population.

Model Harvest Regulation **Season Type 1: Special Mountain Lion License** and **Season Type 2: General License** will initially need to be employed to address Region 1's diverse social and biological management needs.

Figure 25. FWP Region 1 hunting districts and mountain lion ecoregion.

Specific harvest and population objectives will be identified and evaluated through the adaptive harvest management process (Chapter 8). However, Region 1 will generally advocate for limited adult female harvest in the Northwest ecoregion so that the overall, long term, population growth rate within the ecoregion is stable or positive. Region 1 will also support harvest proposals designed to recruit and maintain older age-class males in the ecoregion. Mountain lion harvest across the Region will be generally distributed in proportion to the various LMUs' estimated mountain lion habitat quantity and quality.

Region 1 will recommend season types that effectively limit nonresident hunter harvest, where necessary, to maintain a high-quality hunting experience for resident mountain lion hunters.

Region 1 will also ensure that hunting regulations do not limit hunter harvest in densely populated areas of the Region (such as LMU 170) where human-lion conflicts are likely. Human-lion conflicts will be mitigated using both hunter harvest and effective responses to individual incidents that are consistent with the Depredation and Control Guidelines (Appendix 3).

Table 8. Summary of Region 1 mountain lion harvest regulations, 1971 – 2017.

License Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Mandatory Inspection	None		10 Day Inspection					4 Day Inspection				48 Hr. Inspection		10 Day Inspection	72 Hr. Inspection	48 Hr. Inspection
Hunting season	Opening of General D/E - 4/30			Opening of General D/E - 4/30; HD 150 9/15 - 11/24			12/1 - 4/30; HD 150 9/15 - 11/27	12/1 - 4/30; HD 150 9/15 - 4/30	12/1 - 2/15; HD 150 9/15 - 2/15	12/1 - 2/15; HD 150 & 151 9/15 - 2/15						
Chase/Hound Training	None								2/16 - 4/30							
Regional Quotas	UNLIMITED; One ES Adult Lion per Hunter															Total = 52; FSQ = 26

License Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Mandatory Inspection	48 Hr. Report; 10 Day Inspection								24 Hr. Report; 5 Day Inspection			24 Hr. Report; 10 Day Inspection	12 Hr. Report; 10 Day Inspection			
Hunting season	12/1 - 2/15; HD 150 & 151 9/15 - 2/15										Fall Season w/o dogs; 12/1 - 2/15; HDs 150 & 151, 9/15 - 2/15	Fall Season w/o dogs; Winter Season, 12/1 - 4/14; HDs 150 & 151, 9/15 - 4/14				
Chase/Hound Training Season	2/16 - 4/30											No dedicated Chase Season, Hound Training allowed during Winter Hunting Season				
Regional Quotas	Total = 52; FSQ = 26	Total = 55; FSQ = 28	Total = 68; FSQ = 32	Total = 77; FSQ = 38	Total = 98; FSQ = 51	Total = 95; FSQ = 53	Total = 97; FSQ = 51	Total = 119; FSQ = 90	Total = 145, Any Legal Lion	Total = 175, Any Legal Lion	Total = 204, Any Legal Lion	Total = 229, Any Legal Lion	Total = 216, Any Legal Lion	Total = 203, Any Legal Lion	Total = 199, Any Legal Lion	Total = 164, Any Legal Lion

License Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Mandatory Inspection	12 Hr. Report; 10 Day Inspection														
Hunting season	Fall Season w/o dogs; Winter Season, 12/1 - 4/14; HDs 150 & 151, 9/15 - 4/14							Archery-only Season w/o dogs; Fall Season w/o dogs; Winter Season, 12/1 - 4/14; HDs 150 & 151, 9/15 - 4/14							
Chase/Hound Training Season	Hound Training Season 12/2 - 4/14														
Regional Quotas	Total = 154, Any Legal Lion	Total = 141, Any Legal Lion	Total = 141, Any Legal Lion	Total = 136; FSQ (some LMUs) = 41	Total = 148; FSQ (some LMUs) = 41	Total = 158; FSQ (some LMUs) = 51	Total = 172; FSQ (some LMUs) = 54	Total = 191; FSQ (some LMUs) = 55	Total = 191; FSQ (some LMUs) = 55	Total = 223; FSQ (some LMUs) = 69	Total = 223; FSQ (some LMUs) = 69	Total = 190; MSQ (some LMUs) = 71	Total = 190; MSQ (some LMUs) = 71	Total = 190; MSQ (some LMUs) = 71	Total = 190; MSQ (some LMUs) = 71

REGION 2

High-quality mountain lion habitat is distributed throughout FWP Region 2, especially in the lower Clark Fork, Blackfoot, and portions of the Bitterroot Valleys (Figure 26). The Region has a diverse and abundant ungulate prey base. Recent field estimates of mountain lion abundance (using SCR) in portions of the Blackfoot and Bitterroot Valleys were high compared to the range of densities previously reported for western North America.

Important field research into mountain lion ecology, the effects of harvest, and new population monitoring techniques has been conducted in Region 2 and the results of this work were used to develop this Strategy (Hornocker & Negri 2009, Robinson & DeSimone 2011, Russell et al. 2012, Proffitt et al. 2015).

Region 2 lion abundance and harvest opportunity increased dramatically during the 1990s, reaching a peak of 267 lions taken (more than half of them females) during the 1998 seasons (Table 9). Historically high harvest continued through the late 1990s even after the severe winter of 1996-97 reduced deer and elk herds in several areas of the Region.

By the early 2000s, the average age of harvested lions had fallen. FWP significantly reduced harvest quotas during the 2000s after both ongoing research and hound handlers' field observations indicated that lion numbers had declined (Table 10). Research in the Garnet Mountains (Robinson & DeSimone 2011), public observations, and rates of human-lion conflict all suggested that Region 2 lion populations had recovered to near 1990s levels by the late 2000s.

In 1994, Region 2 established a new LMU—the Missoula Special Management Area—surrounding the densely populated Missoula Valley. FWP prescribed high quotas (that were rarely met) in this LMU to ensure that hunting regulations were not publicly perceived as limiting legal hunter harvest in this high conflict area.

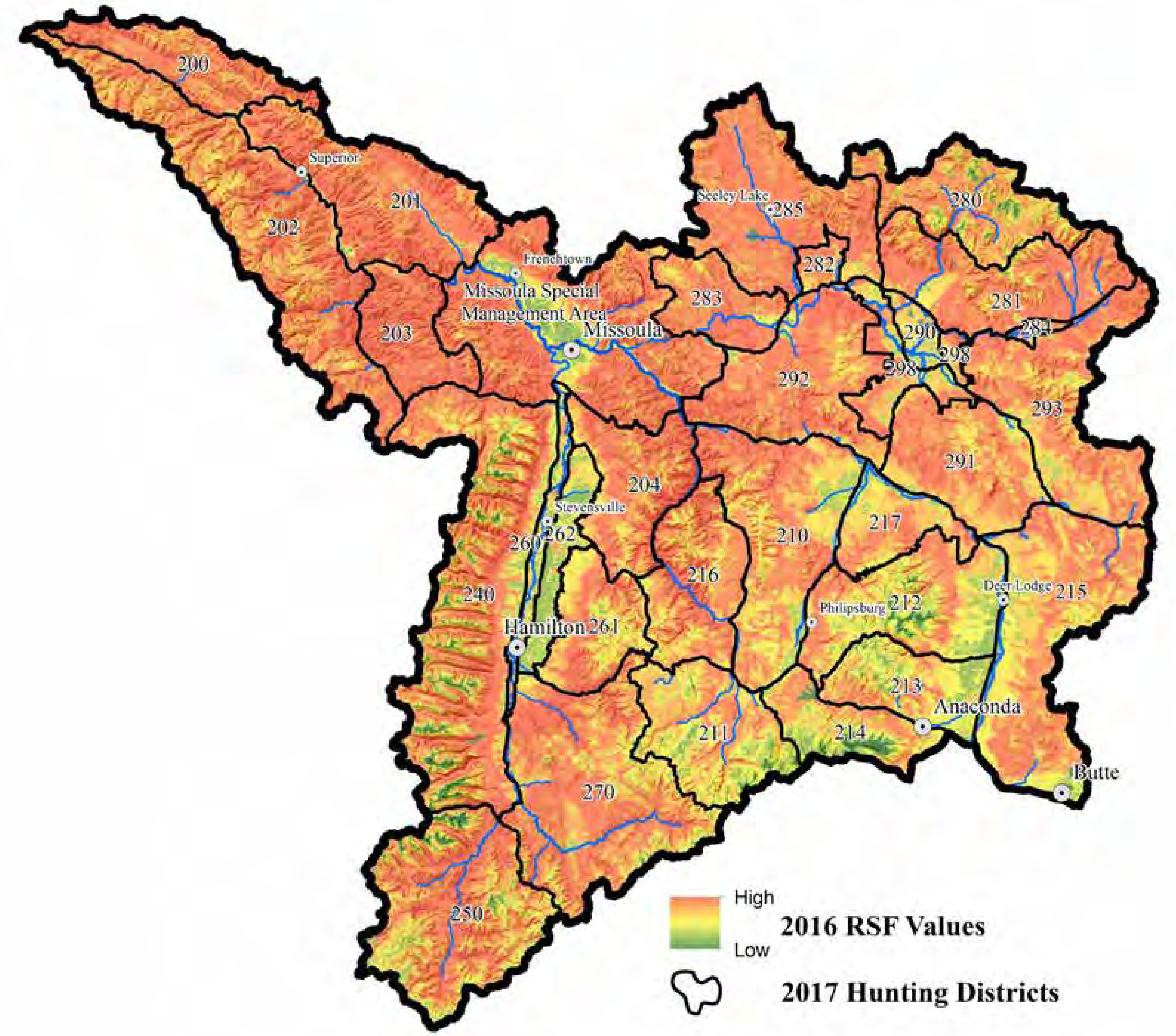
Tension between Region 2 nonresident/outfitted and resident hunters increased during the 1990s and early 2000s; By 2005, nonresident hunters harvested nearly 50% of the Region's lions. These conflicts were particularly acute in the Bitterroot and Blackfoot watersheds. In 2006, Region 2 began to require that nonresident hunters draw a limited Special Lion License to harvest a lion in most Region 2 LMUs—the number of these nonresident Special Licenses were equal to 10% of the total harvest quota.

Table 9. Region 2 mountain lion harvest, 1971 – 2016.

License	R2			
Year	F	M	Unk	Tot.
1971	10	8	0	18
1972	10	10	0	20
1973	11	26	2	39
1974	16	19	0	35
1975	8	13	0	21
1976	7	12	1	20
1977	5	14	0	19
1978	8	16	0	24
1979	8	16	0	24
1980	6	14	0	20
1981	9	21	0	30
1982	13	17	0	30
1983	13	22	1	36
1984	14	34	1	49
1985	13	13	0	26
1986	9	22	1	32
1987	4	56	1	61
1988	16	34	1	51
1989	12	39	0	51
1990	19	44	0	63
1991	18	42	0	60
1992	30	84	0	114
1993	36	82	0	118
1994	62	99	0	161
1995	64	88	0	152
1996	84	103	0	187
1997	112	127	0	239
1998	143	123	1	267
1999	107	101	0	208
2000	60	70	0	130
2001	43	56	0	99
2002	26	36	0	62
2003	26	47	0	73
2004	14	37	0	51
2005	12	41	0	53
2006	8	43	0	51
2007	10	48	0	58
2008	10	36	0	46
2009	10	52	0	62
2010	31	73	0	104
2011	34	74	0	108
2012	76	97	0	173
2013	68	72	0	140
2014	45	71	0	116
2015	47	78	0	125
2016	47	69	0	116

In 2008, the Commission began to require that both resident and nonresident hunters draw a Special Lion License to harvest a lion in most of the Region's LMUs. This season type resulted in unpredictable harvest rates and female harvest objectives were rarely met using Special Lion Licenses alone. Therefore, in 2012 the Commission adopted a Late Winter Season (beginning 2/1) in most Region 2 LMUs. During the late Winter Season, hunters with a General Lion License could harvest lions until any quotas previously unfilled by Special Lion License holders

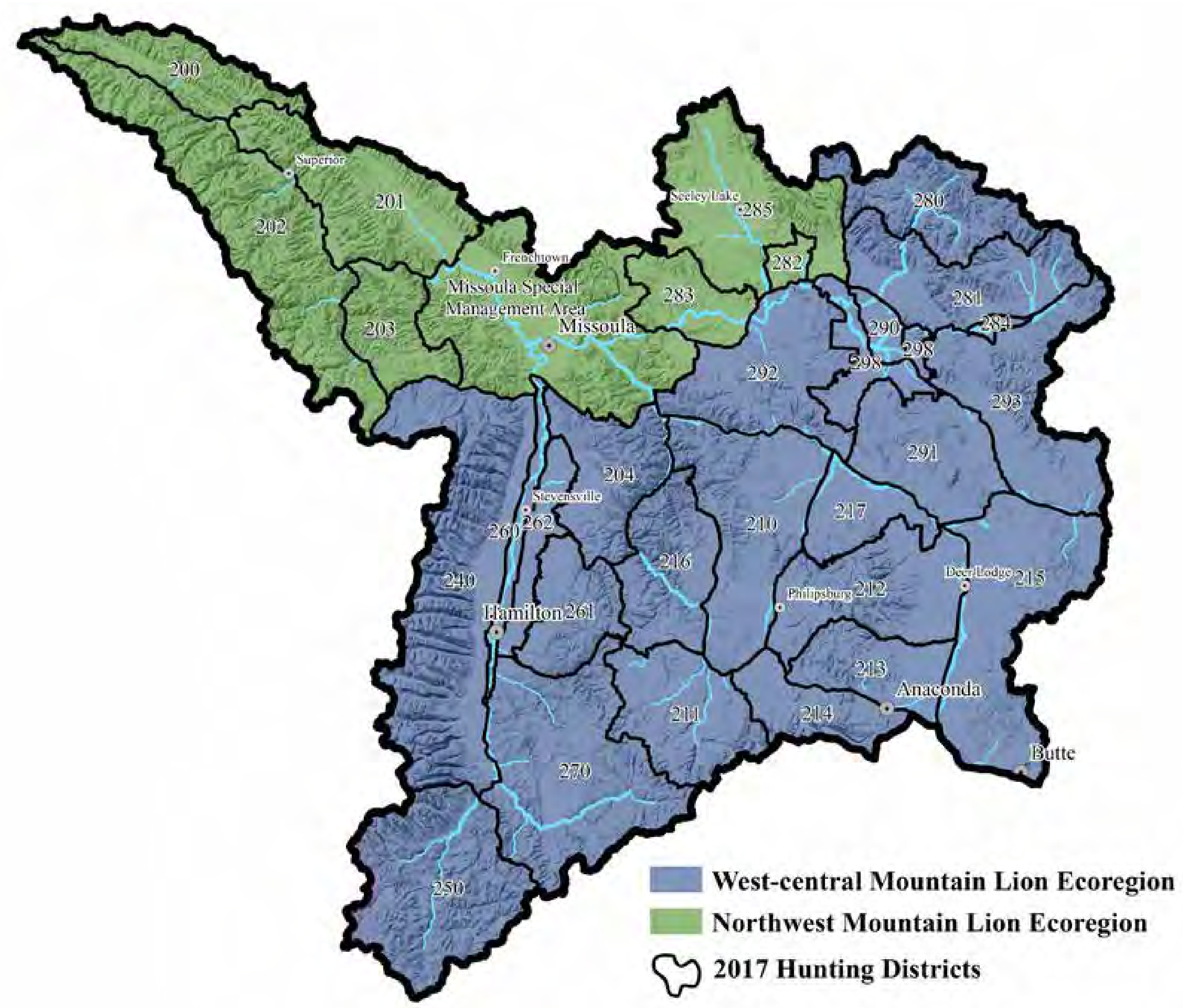
Figure 26. FWP Region 2 2016 mountain lion winter RSF and hunting districts.



were met (this became known as a "hybrid" season). Although this season type allowed more precise harvest management, nonresident participation was unlimited during the Late Winter Season and Region 2 nonresident harvest rates more than doubled after the Late Winter Season was adopted.

Most Region 2 lion habitat is on public or publicly accessible private land. Tracking snow is generally present during the Winter Season, although snow conditions are more likely to limit effective harvest in the upper Clark Fork and Bitterroot drainages.

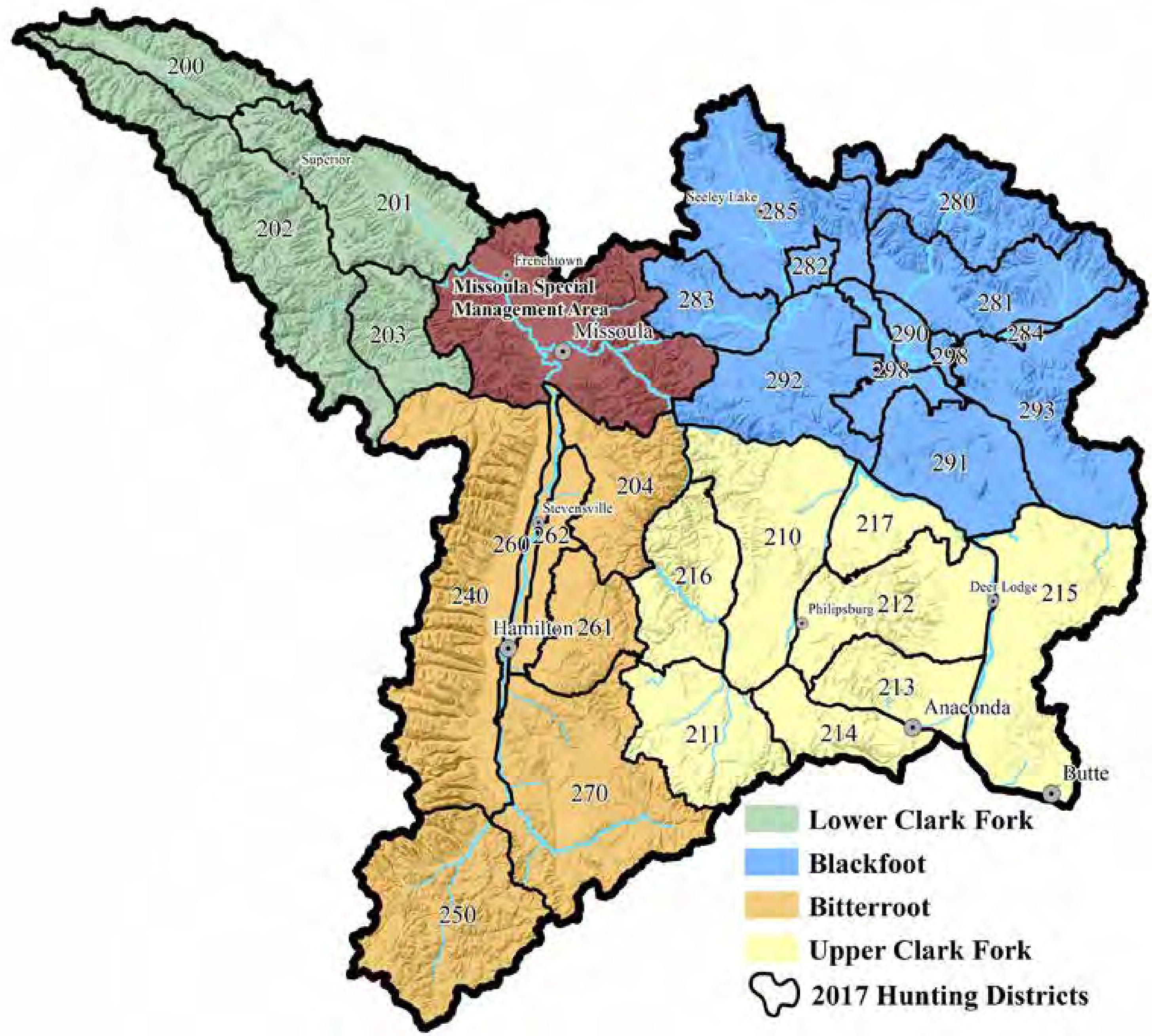
Figure 27. FWP Region 2 hunting districts and mountain lion ecoregions.



FWP Region 2 includes portions of both the Northwest and West-central mountain lion ecoregions (Figure 27). Region 2's biologists and public will work with their counterparts in Regions 1, 3 and 4 to set specific objectives for, and adaptively manage, these ecoregions' mountain lion populations.

Region 2 is comprised of 5 distinct management areas: the Region's four major watersheds and the Missoula Special Management Area (Figure 28). Region 2 will initially recommend either Model Harvest Regulation **Season Type 2: General License** or **Season Type 3: Resident General License**, **Nonresident Special Mountain Lion License** for each of these distinct areas.

Figure 28. Region 2's four major watersheds and the Missoula Special Management Area.



Specific harvest and population objectives will be identified and evaluated through the adaptive harvest management process (Chapter 8). In general, Region 2 will support ecoregion management objectives that result in generally stable lion populations and annual harvest levels. FWP will consider adjustments to management prescriptions based on contemporary monitoring data and significantly changed local circumstances.

Region 2 will minimize human-lion conflicts using both hunter harvest and effective responses to individual incidents that are consistent with the Depredation and Control Guidelines. Hunting regulations and harvest quotas for the Missoula Special Management Area will not significantly limit hunter harvest opportunity there during open seasons.

Region 2 will recommend season types that effectively limit nonresident hunter harvest where necessary to maintain a high-quality hunting experience for resident mountain lion hunters.

Table 10. Summary of Region 2 mountain lion harvest regulations, 1971 – 2017.

License Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Mandatory Inspection	None		10 Day Inspection					4 Day Inspection				48 Hr. Inspection		10 Day Inspection	72 Hr. Inspection	48 Hr. Inspection
Hunting season	Opening of General D/E - 4/30			Opening of General D/E - 4/30; HD 280, 9/15 - 11/24	Opening of General D/E - 4/30; HD 280 9/15 - 4/30	12/1 - 4/30; HD 280 9/15 - 4/30	12/1 - 4/30; HD 280 9/15 - 11/27; HD 282, CLOSED	12/1 - 4/30; HD 280 9/15 - 4/30; HD 282, CLOSED	12/1 - 2/15; HD 280 9/15 - 2/15; HD 282, CLOSED							
Chase/Hound Training Season	None								2/16 - 4/30; HD282, CLOSED							
Regional Quotas	UNLIMITED; One ES Adult Lion per Hunter															

License Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Mandatory Inspection	48 Hr. Report; 10 Day Inspection								24 Hr. Report; 5 Day Inspection			24 Hr. Report; 10 Day Inspection	12 Hr. Report; 10 Day Inspection			
Hunting season	12/1 - 2/15; HD 280, 9/15 - 2/15; HD282, CLOSED											12/1 - 4/14; HD 280, 9/15 - 4/14; HD282, CLOSED	Fall Season w/o dogs; 12/1 - 4/14; HD282, CLOSED			
Chase/Hound Training Season	2/16 - 4/30; HD282, CLOSED											No dedicated Chase Season, Hound Training allowed during Winter Hunting Season; HD 282 Closed				
Regional Quotas	UNLIMITED One ES Adult Lion per Hunter	Total = 46; FSQ = 21	Total = 52; FSQ = 21	Total = 55; FSQ = 22	Total = 74; FSQ = 28	Total = 104; FSQ = 46	Total = 106; FSQ = 47	Total = 133; FSQ = 78	Total = 172; Male = 94; Female = 78	Total = 212; Male = 109; Female = 103	Total = 299; Male = 135; Female = 164	Total = 305; Male = 127; Female = 178	Total = 232; Male = 101; Female = 131	Total = 167; Male = 96; Female = 71	Total = 111; Male = 61; Female = 50	Total = 93; Male = 57; Female = 36

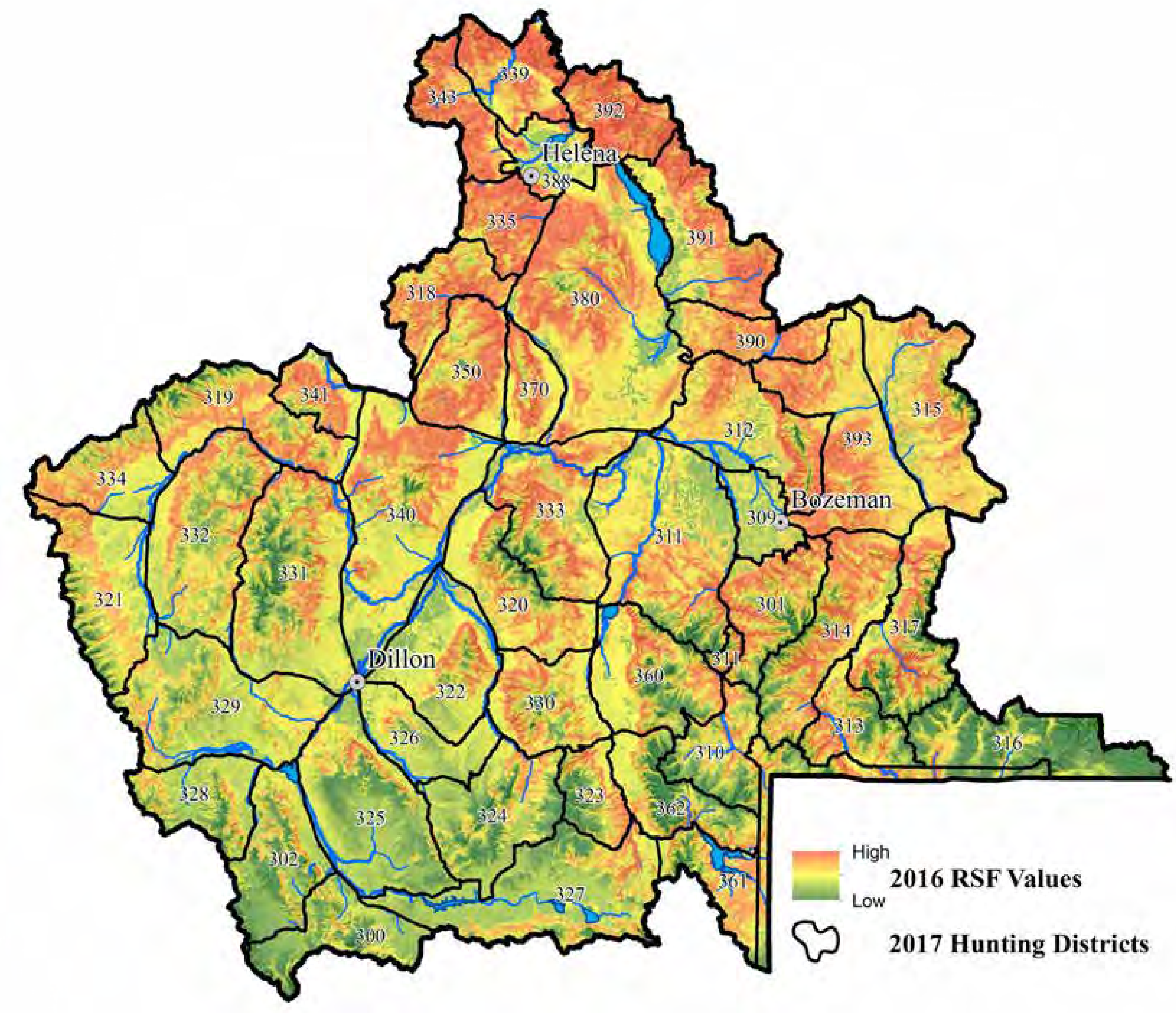
License Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Mandatory Inspection	12 Hr. Report; 10 Day Inspection														
Hunting season	Fall Season w/o dogs; 12/1 - 4/14; HD282, CLOSED							Archery-only Season; Fall Season; 12/1 - 4/14; HD282, CLOSED		Archery-only Season; Fall Season w/o dogs; 12/1 - 4/14; Late Winter Season, 2/1 - 4/14; HD282, CLOSED					
Chase/Hound Training Season	Hound Training Season 12/2 - 4/14														
Regional Quotas	Total = 85; Male = 48; Female = 36	Total = 72; Male = 44; Female = 28	Total = 70; Male = 47; Female = 23	Total = 71; Male = 52; Female = 12	Total = 64; Male = 48; Female = 12	Total = 88; FSQ (some LMUs) = 16	Total = 126; FSQ (some LMUs) = 19	Total = 192; FSQ (some LMUs) = 38	Total = 219; FSQ (some LMUs) = 54	Total = 202; Male = 119; Female = 81	Total = 197; Male = 110; Female = 85	Total = 163; Male = 96; Female = 65	Total = 160; Male = 102; Female = 56	Total = 158; Male = 100; Female = 56	Total = 158; Male = 100; Female = 56

REGION 3

Mountain lions occur throughout their suitable habitat in southwest Montana's Region 3 (Figure 329). The Region has a diverse and abundant ungulate prey base that inhabits a mix of publicly accessible and privately-owned land.

Lion abundance increased in Region 3 during the 1980s and 1990s but, unlike other areas of the state, did not appear to fall as sharply during the 2000s. Instead, anecdotal evidence and harvest records suggest that mountain lion distribution and abundance have remained relatively stable

Figure 29. FWP Region 3 2016 mountain lion winter RSF and hunting districts.



in the Region since the mid-1990s. Variation in the total annual harvest (Table 11) is almost entirely due to changes in female harvest quotas. Sustained harvest in the late 2010s was similar to harvest levels in both Regions' 1 and 2 during the same period.

Region 3 generally managed harvest using simple harvest quotas and female subquotas (Table 12). However, the Region historically designated a large number of LMUS (23 in 2017)—the number of these individual LMUs may be reduced during future season setting processes. Region 3 quotas serve as harvest limits in all LMUs.

Public access to winter mountain lion habitat is mixed, although most harvest occurs on public land. Winter snow tracking conditions vary annually and can, at times, limit effective harvest. Nonresidents accounted for 15% of all successful hunters in the Region between 2007 and 2016 even though there was no regulatory limit on nonresident hunter harvest during that period.

Region 3 manages LMU 309, (the Gallatin Valley around Bozeman) as a Special Management Area. Lions are rarely harvested in this LMU (2 between 2007 and 2016), but the quota is high enough to ensure that FWP regulations do not limit legal harvest. Similarly, the Fall Season Without Dogs in LMU 309 opened with the beginning of the Deer/Elk Archery Only Season and remained open through the General Deer/Elk Season. The Region also designated a specific quota for the Spanish Peaks portion of LMU 311 to reduce lion predation on the resident bighorn sheep herd.

FWP Region 3 contains portions of both the Southwest and West-central Mountain Lion Ecoregions (Figure 30). Region 3's biologists and public will work with their counterparts in Regions 2, 4 and 5 to set objectives for, and adaptively manage, these ecoregions' mountain lion populations.

Region 3 will be able to meet lion management objectives by primarily using Model Harvest Regulation **Season Type 2: General License**.

FWP and public stakeholders will determine and evaluate specific lion population objectives using the Adaptive Harvest Management process (Chapter 8). The Region will generally support objectives for stable lion populations and annual harvest, while considering contemporary monitoring data and local circumstances. Region 3 will recommend the least complex harvest regulations that will allow management objectives to be met.

Table 11. Region 3 mountain lion harvest, 1971 – 2016.

License	R3			
Year	F	M	Unk	Tot.
1971	1	2	0	3
1972	2	2	0	4
1973	1	0	0	1
1974	2	2	1	5
1975	2	2	0	4
1976	2	0	0	2
1977	1	8	0	9
1978	7	6	0	13
1979	9	5	0	14
1980	1	6	0	7
1981	6	10	0	16
1982	7	11	0	18
1983	4	12	1	17
1984	5	21	0	26
1985	10	11	2	23
1986	4	13	1	18
1987	5	15	0	20
1988	1	17	0	18
1989	2	16	0	18
1990	6	23	0	29
1991	11	19	0	30
1992	11	33	0	44
1993	18	41	0	59
1994	32	52	0	84
1995	33	53	0	86
1996	29	60	0	89
1997	43	56	0	99
1998	51	66	0	117
1999	54	63	0	117
2000	55	55	1	111
2001	52	57	0	109
2002	46	64	0	110
2003	32	57	0	89
2004	34	44	0	78
2005	23	51	1	75
2006	16	45	0	61
2007	12	57	0	69
2008	13	61	0	74
2009	14	53	0	67
2010	17	50	0	67
2011	17	57	0	74
2012	33	68	0	101
2013	33	61	0	94
2014	33	70	0	103
2015	44	72	0	116
2016	44	69	0	113

Hunting regulations will not limit hunter harvest in highly developed areas where human-lion conflicts are likely (such as LMU 309) or where suppression of local lion density is desired (such as the Spanish Peaks portion of LMU 311).

FWP will minimize human-lion conflicts using both hunter harvest and effective responses to individual incidents that are consistent with the Depredation and Control Guidelines.

Figure 30. FWP Region 3 hunting districts and mountain lion ecoregions.

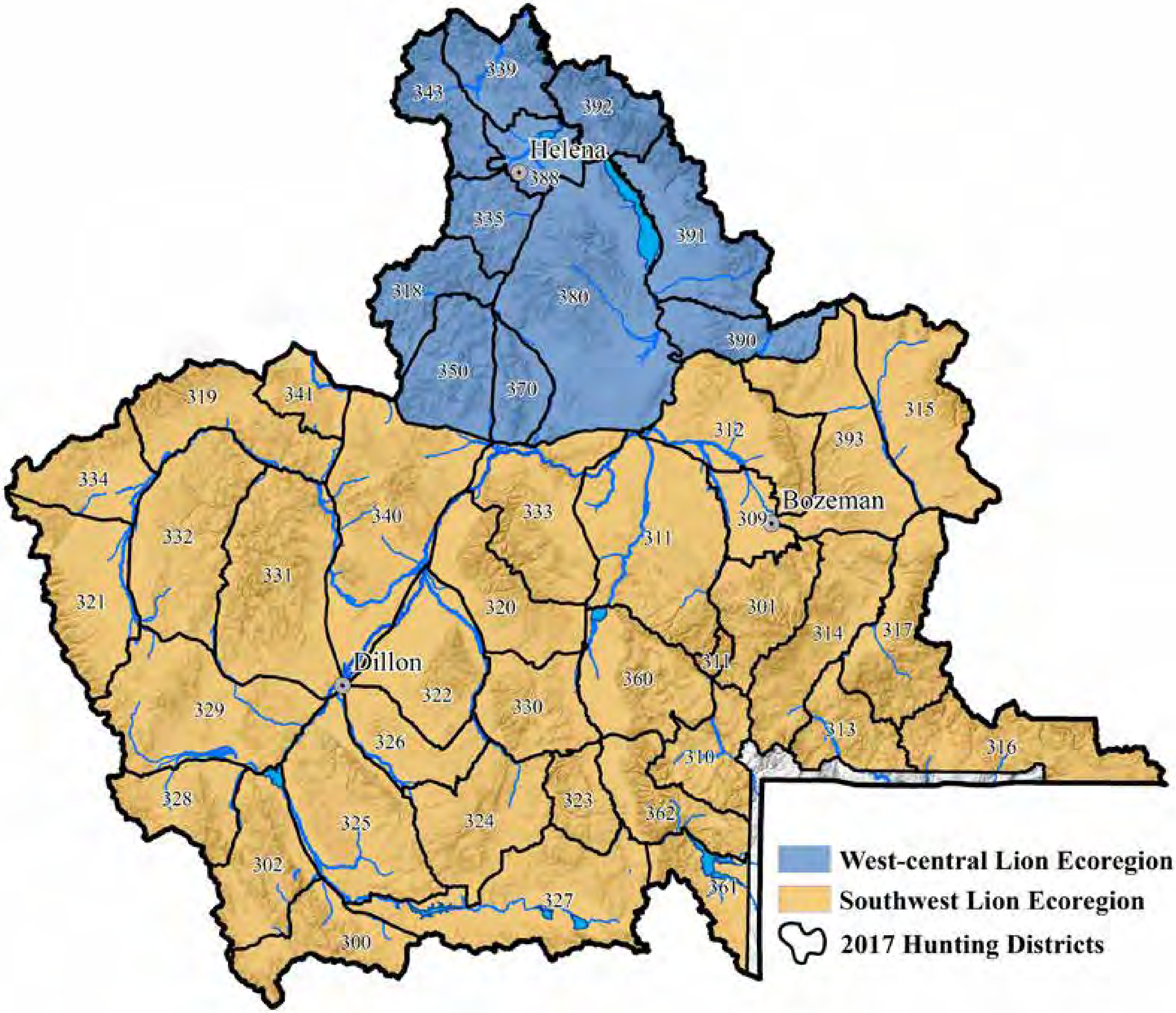


Table 12. Summary of Region 3 mountain lion harvest regulations, 1971 – 2017.

License Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Mandatory Inspection	None		10 Day Inspection					4 Day Inspection				48 Hr. Inspection		10 Day Inspection	72 Hr. Inspection	48 Hr. Inspection
Hunting season	Opening of General D/E - 4/30					12/1 - 4/30			12/1 - 2/15							
Chase/Hound Training Season	None								2/16 - 4/30;							
Regional Quotas	UNLIMITED; One ES Adult Lion per Hunter															Total = 32; FSQ = 16 [1]

License Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Mandatory Inspection	48 Hr. Report; 10 Day Inspection								24 Hr. Report; 5 Day Inspection			24 Hr. Report; 10 Day Inspection	12 Hr. Report; 10 Day Inspection			
Hunting season	12/1 - 2/15											12/1 - 4/14	Fall Season w/o dogs; 12/1 - 4/14			
Chase/Hound Training Season	2/16 - 4/30											No dedicated Chase Season, Hound Training allowed during Winter Hunting Season				
Regional Quotas	Total = 32; FSQ = 20	Total = 34; FSQ = 21	Total = 34; FSQ = 21	Total = 34; FSQ = 21	Total = 39; FSQ = 21	Total = 37; FSQ = 21	Total = 45; FSQ = 23	Total = 69; FSQ = 33	Total = 86; FSQ = 39; MSQ (R8) = 19	Total = 89; FSQ = 41; MSQ (some LMUs) = 19	Total = 104; FSQ = 49; MSQ (some LMUs) = 21	Total = 123; FSQ = 47; MSQ (some LMUs) = 22	Total = 123; FSQ = 60; MSQ (some LMUs) = 22	Total = 134; FSQ = 67; MSQ (some LMUs) = 25	Total = 132; FSQ = 60; MSQ (some LMUs) = 19	Total = 136; FSQ = 63; MSQ (some LMUs) = 23

License Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Mandatory Inspection	12 Hr. Report; 10 Day Inspection														
Hunting season	Fall Season w/o dogs; 12/1 - 4/14							Archery-only Season; Fall Season w/o dogs; 12/1 - 4/14							
Chase/Hound Training Season	Hound Training Season 12/2 - 4/14														
Regional Quotas	Total = 117; FSQ (some LMUs) = 41	Total = 105; FSQ (some LMUs) = 40	Total = 101; FSQ (some LMUs) = 30	Total = 76; FSQ (some LMUs) = 16	Total = 66; FSQ (some LMUs) = 12	Total = 73; FSQ (some LMUs) = 12	Total = 72; FSQ (some LMUs) = 12	Total = 80; FSQ (some LMUs) = 16	Total = 77; FSQ (some LMUs) = 16	Total = 109; FSQ (some LMUs) = 34	Total = 109; FSQ (some LMUs) = 34	Total = 126; FSQ (some LMUs) = 41	Total = 135; FSQ (some LMUs) = 46	Total = 140; FSQ (some LMUs) = 48	Total = 138; FSQ (some LMUs) = 48

REGION 4

Mountain lion abundance and distribution generally increased in Region 4 from the 1980s to mid-2010s — only toward the end of that period was all suitable habitat (including the Missouri River Breaks and Sweet Grass Hills) fully reoccupied (Figure 31).

Region 4 includes portions of both the West-central and Eastern Mountain Lion Ecoregions (Figure 32). Most of the Region's high-quality lion habitat lies within the West-central ecoregion, although quality habitat exists in portions of the Eastern ecoregion along the northern Rocky Mountain front, the Highwoods, the Sweet Grass Hills and Missouri River Breaks. Most lion harvest within Region 4 occurs on public land.

Region 4's annual harvest peaked in the late 1990s and stabilized somewhat below those historic high levels in the mid-2010s (Table 13). The Region traditionally managed harvest by prescribing male and female quotas to individual LMUs. Nonresident hunters accounted for 19% of all lions harvested between 2007 and 2016; less than 20% of those successful nonresident hunters used the services of an outfitter.

Reducing and mitigating conflicts between lions and agricultural interests is a high Regional priority. Region 4 staff will actively respond to potential and ongoing mountain lion conflicts, consistent with the Depredation and Control Guidelines, in order to maintain landowner tolerance for lions.

Region 4 will generally support management objectives that maintain stable lion abundance, distribution, and harvest across the Region's suitable habitat. Region 4's biologists and public will work with their counterparts in other Regions to set objectives for, and adaptively manage, the West-central and Eastern ecoregions' mountain lion populations.

Region 4 will recommend the least complex harvest regulation that will allow management objectives to be met, primarily using Model Harvest Regulation **Season Type 2: General License** with male and female quotas.

Table 13. Region 4 mountain lion harvest, 1971 – 2016.

License	R4			
Year	**F**	**M**	**Unk**	**Tot.**
1971	3	3	0	6
1972	2	4	0	6
1973	1	5	0	6
1974	2	4	0	6
1975	2	4	0	6
1976	1	5	0	6
1977	4	6	0	10
1978	2	2	1	5
1979	2	3	0	5
1980	5	7	0	12
1981	7	7	0	14
1982	4	5	0	9
1983	1	10	0	11
1984	7	18	1	26
1985	10	14	3	27
1986	4	7	1	12
1987	10	16	0	26
1988	6	16	0	22
1989	5	16	0	21
1990	10	17	0	27
1991	10	17	0	27
1992	15	22	0	37
1993	16	39	0	55
1994	24	46	0	70
1995	32	39	0	71
1996	37	47	0	84
1997	44	41	0	85
1998	54	39	0	93
1999	56	37	0	93
2000	45	36	0	81
2001	39	36	0	75
2002	24	26	0	50
2003	21	27	0	48
2004	17	27	0	44
2005	17	26	0	43
2006	18	35	0	53
2007	25	30	0	55
2008	32	37	0	69
2009	30	35	0	65
2010	32	43	0	75
2011	32	46	0	78
2012	35	44	0	79
2013	34	48	0	82
2014	31	47	0	78
2015	28	37	0	65
2016	38	42	0	80

Figure 31. FWP Region 4 2016 mountain lion winter RSF and hunting districts.

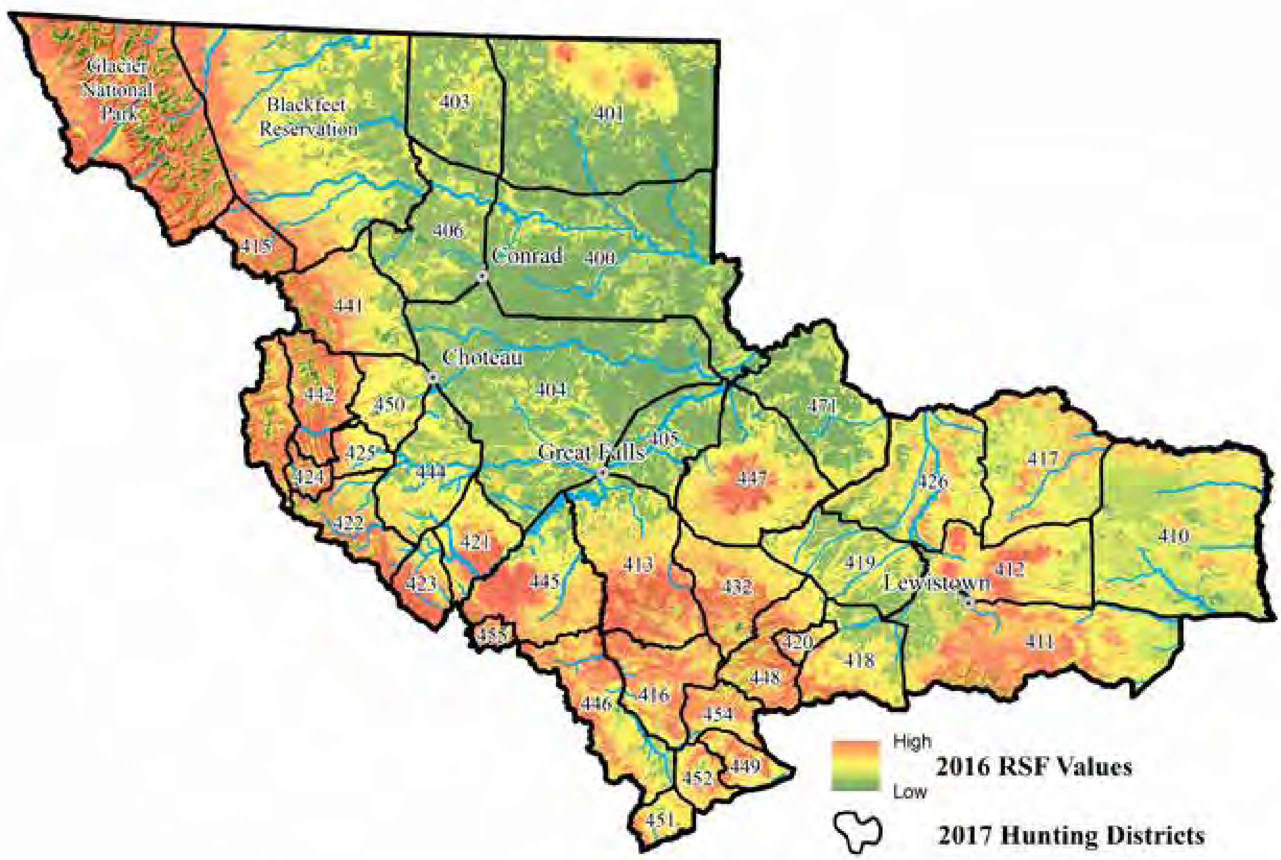


Figure 32. FWP Region 4 hunting districts and mountain lion ecoregions.

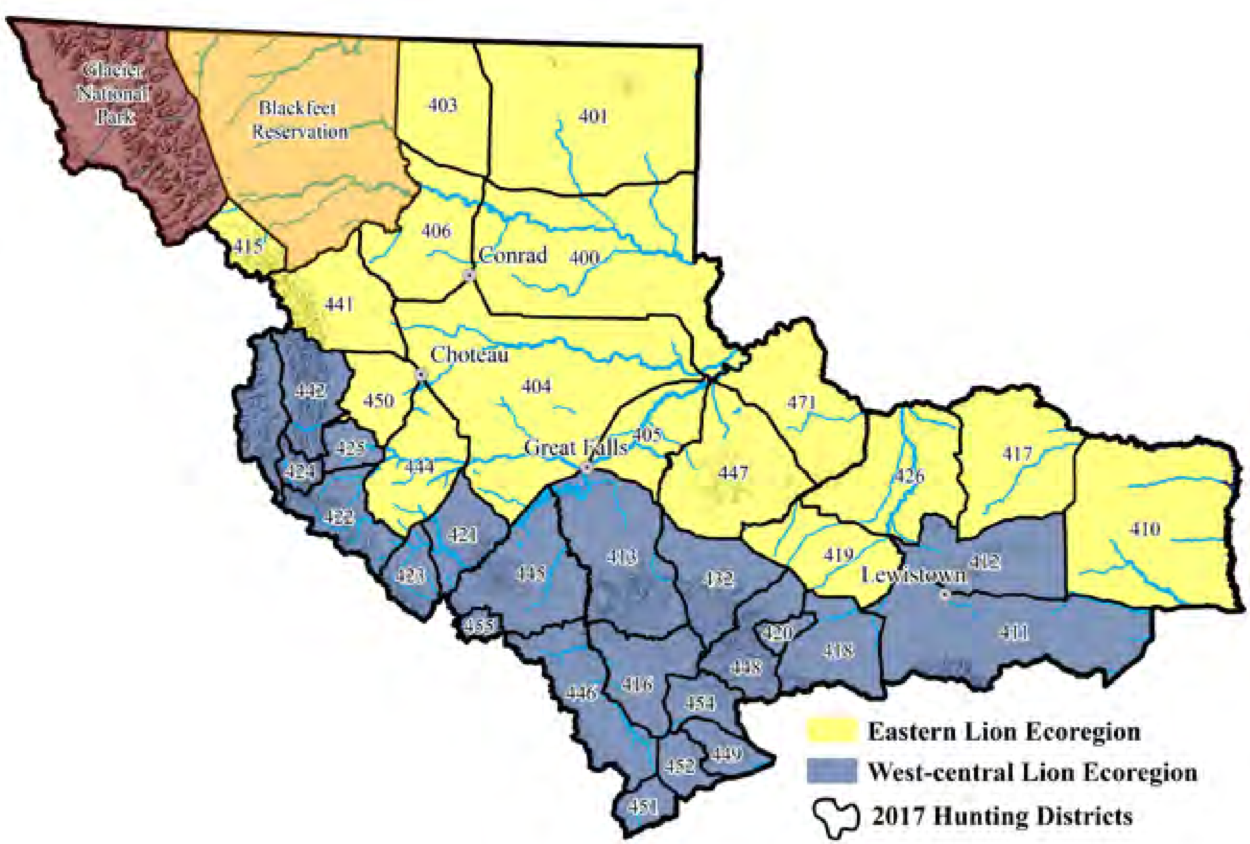


Table 14. Summary of Region 4 mountain lion harvest regulations, 1971 – 2017.

License Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Mandatory Inspection	None		10 Day Inspection					4 Day Inspection				48 Hr. Inspection		10 Day Inspection	72 Hr. Inspection	48 Hr. Inspection
Hunting season	Opening of General D/E - 4/30					12/1 - 4/30			12/1 - 2/15			12/1 - 2/15; HDs 427 & 428, 1/1 - 2/15				
Chase/Hound Training Season	None								2/16 - 4/30							
Regional Quotas	UNLIMITED; One ES Adult Lion per Hunter															

License Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Mandatory Inspection	48 Hr. Report; 10 Day Inspection								24 Hr. Report; 5 Day Inspection			24 Hr. Report; 10 Day Inspection	12 Hr. Report; 10 Day Inspection			
Hunting season	12/1 - 2/15; HDs 427 & 428, 1/1 - 2/15							12/1 - 2/15				12/1 - 4/14	Fall Season w/o dogs; 12/1 - 4/14			
Chase/Hound Training Season	2/16 - 4/30											No dedicated Chase Season, Hound Training allowed during Winter Hunting Season				
Regional Quotas	UNLIMITED One ES Adult Lion per Hunter	Total = 30; FSQ = 10	Total = 35; FSQ = 10	Total = 35; FSQ = 10	Total = 40; FSQ = 12	Total = 46; FSQ = 14	Total = 46; FSQ = 14	Total = 65; FSQ = 26	Total = 80; Male = 46; F = 34	Total = 110; Male = 57; F = 53	Total = 108; Male = 49; Female = 59	Total = 133; Male = 52; Female = 81	Total = 126; Male = 48; Female = 78	Total = 124; Male = 48; Female = 76	Total = 110; Male = 47; Female = 63	Total = 106; Male = 48; Female = 58

License Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Mandatory Inspection	12 Hr. Report; 10 Day Inspection														
Hunting season	Fall Season w/o dogs; 12/1 - 4/14							Archery-only Season; Fall Season w/o dogs; 12/1 - 4/14							
Chase/Hound Training Season	Hound Training Season 12/2 - 4/14														
Regional Quotas	Total = 103; Male = 48; Female = 55	Total = 91; Male = 45; Female = 46	Total = 91; Male = 45; Female = 46	Total = 83; Male = 43; Female = 40	Total = 85; Male = 45; Female = 40	Total = 80; Male = 40; Female = 40	Total = 80; Male = 40; Female = 40	Total = 88; Male = 44; Female = 44	Total = 91; Male = 46; Female = 45	Total = 93; Male = 46; Female = 47	Total = 93; Male = 46; Female = 47	Total = 98; Male = 48; Female = 50	Total = 98; Male = 48; Female = 50	Total = 98; Male = 48; Female = 50	Total = 100; Male = 48; Female = 52

REGION 5

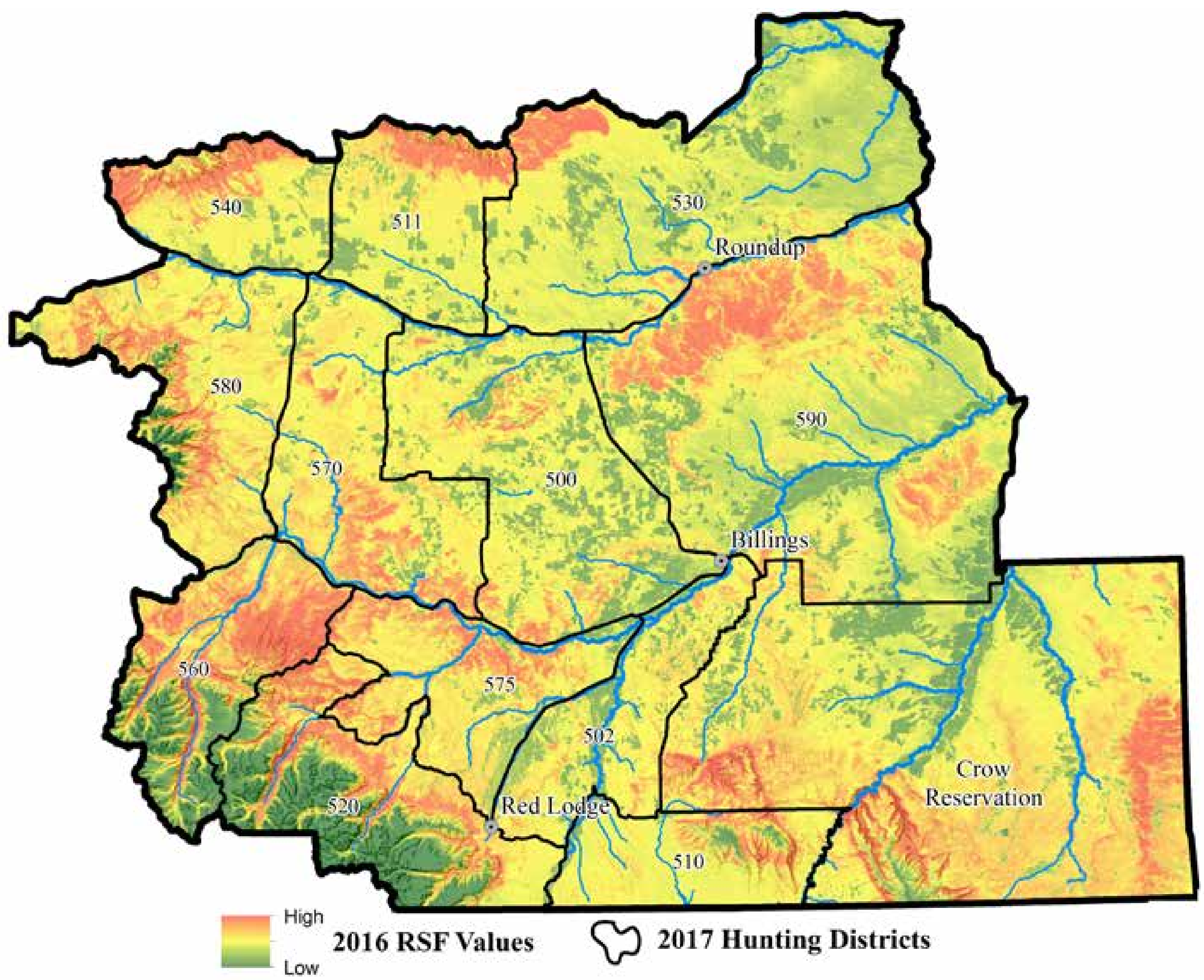
Mountain lion hunter harvest opportunity was generally stable in Region 5 from the 1990s to late 2010s. However, annual harvest success varied year-to-year depending on winter snow-tracking conditions. Most of the Region's publicly accessible, high-quality, lion habitat lies in its peripheral mountain foothills (Figure 33). While the Region includes portions of both the Southwest and Eastern Mountain Lion ecoregions, most lions are harvested in the Southwest ecoregion (Figure 34). Nonresidents took 18% of all lions harvested in Region 5 between 2007 and 2016, most without the aid of an outfitter.

Although Region 5 harvest is well distributed across suitable lion habitat, individual LMU quotas may not be consistently reached because annual harvest is dependent on the presence of adequate tracking snow. Region 5 may consider reducing the number of Regional LMUs to simplify harvest management.

Managers will generally recommend harvest objectives that maintain stable lion abundance, distribution, and harvest across all suitable habitat in Region 5. Biologists and the public will work with their counterparts in other Regions to set objectives for, and adaptively manage, the Southwest and Eastern Ecoregions' mountain lion populations.

Region 5 historically used overall LMU quotas (with female subquotas) to manage harvest (Table 16). The Region will be able to meet lion management objectives by using the similar Model Harvest Regulation **Season Type 2: General**

Figure 33. FWP Region 5 2016 mountain lion winter RSF and hunting districts.



License season type that employs individual male and female quotas.

Minimizing human-lion conflicts and livestock depredation is a high Regional priority. Region 5 will use both hunter harvest and effective responses to individual incidents that are consistent with the Depredation and Control Guidelines to reduce potential conflicts.

Table 15. Region 5 mountain lion harvest, 1971 – 2016.

License	R5			
Year	F	M	Unk	Tot.
1971	2	0	0	2
1972	1	1	0	2
1973	2	1	0	3
1974	0	0	0	0
1975	1	2	0	3
1976	3	1	0	4
1977	4	4	0	8
1978	3	0	0	3
1979	5	6	0	11
1980	4	4	0	8
1981	3	6	0	9
1982	3	2	0	5
1983	4	7	0	11
1984	2	12	0	14
1985	3	6	0	9
1986	4	11	0	15
1987	9	6	0	15
1988	7	11	0	18
1989	4	9	0	13
1990	8	13	0	21
1991	8	12	0	20
1992	10	21	0	31
1993	15	20	0	35
1994	13	19	0	32
1995	19	23	0	42
1996	13	22	0	35
1997	23	21	0	44
1998	17	23	1	41
1999	23	21	0	44
2000	19	24	0	43
2001	25	25	0	50
2002	16	17	0	33
2003	9	18	0	27
2004	12	22	0	34
2005	12	15	0	27
2006	12	13	0	25
2007	10	18	0	28
2008	10	21	0	31
2009	12	24	0	36
2010	8	10	0	18
2011	13	21	0	34
2012	11	20	0	31
2013	16	20	0	36
2014	8	28	0	36
2015	11	12	0	23
2016	13	26	0	39

Figure 34. FWP Region 5 hunting districts and mountain lion ecoregions.

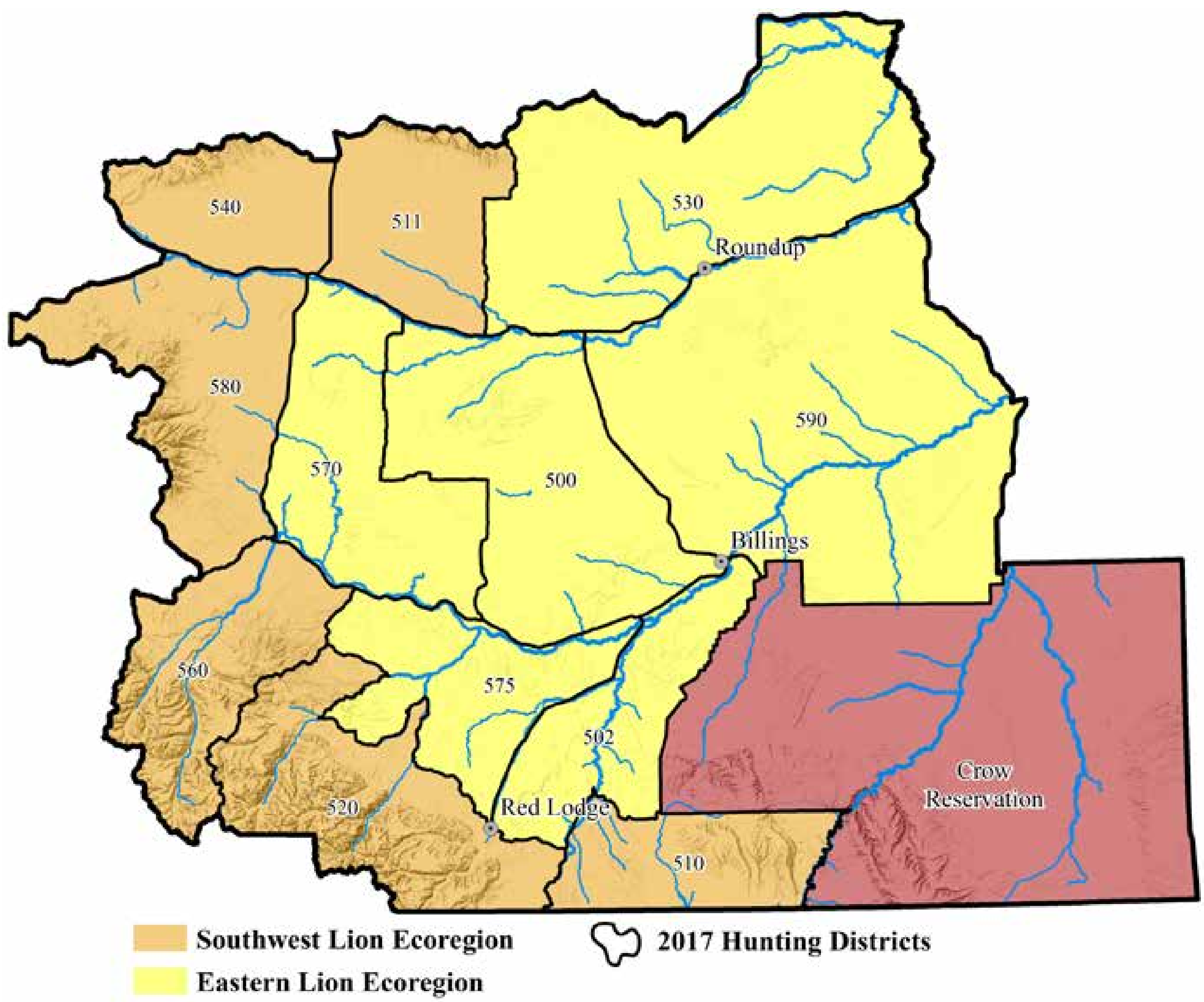


Table 16. Summary of Region 5 mountain lion harvest regulations, 1971 – 2017.

License Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Mandatory Inspection	None		10 Day Inspection					4 Day Inspection				48 Hr. Inspection		10 Day Inspection	72 Hr. Inspection	48 Hr. Inspection
Hunting season	Opening of General D/E - 4/30					12/1 - 4/30			12/1 - 2/15							
Chase/Hound Training Season	None								2/16 - 4/30							
Regional Quotas	UNLIMITED; One ES Adult Lion per Hunter															

License Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Mandatory Inspection	48 Hr. Report; 10 Day Inspection								24 Hr. Report; 5 Day Inspection			24 Hr. Report; 10 Day Inspection	12 Hr. Report; 10 Day Inspection			
Hunting season	12/1 - 2/15											12/1 - 4/14	Fall Season w/o dogs; 12/1 - 4/14			
Chase/Hound Training Season	2/16 - 4/30											No dedicated Chase Season, Hound Training allowed during Winter Hunting Season				
Regional Quotas	UNLIMITED One ES Adult Lion per Hunter	Total = 22; FSQ = 10	Total = 25; FSQ = 11	Total = 30; FSQ = 13	Total = 33; FSQ = 13	Total = 37; FSQ = 15	Total = 37; FSQ = 15	Total = 44; FSQ = 22	Total = 44; FSQ = 22	Total = 50; FSQ (some LMUs) = 20	Total = 52; FSQ (some LMUs) = 21	Total = 58; FSQ (some LMUs) = 23	Total = 56; FSQ (some LMUs) = 22	Total = 56; FSQ (some LMUs) = 22	Total = 57; FSQ (some LMUs) = 22	Total = 57; FSQ (some LMUs) = 22

License Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Mandatory Inspection	12 Hr. Report; 10 Day Inspection														
Hunting season	Fall Season w/o dogs; 12/1 - 4/14							Archery-only Season; Fall Season w/o dogs; 12/1 - 4/14							
Chase/Hound Training Season	Hound Training Season 12/2 - 4/14														
Regional Quotas	Total = 57; FSQ (some LMUs) = 22	Total = 49; FSQ (some LMUs) = 18	Total = 49; FSQ (some LMUs) = 18	Total = 49; FSQ (some LMUs) = 18	Total = 49; FSQ (some LMUs) = 18	Total = 49; FSQ (some LMUs) = 18	Total = 49; FSQ (some LMUs) = 21	Total = 44; FSQ (some LMUs) = 15	Total = 44; FSQ (some LMUs) = 15	Total = 44; FSQ (some LMUs) = 15	Total = 44; FSQ (some LMUs) = 15	Total = 47; FSQ (some LMUs) = 15	Total = 47; FSQ (some LMUs) = 15	Total = 47; FSQ (some LMUs) = 15	Total = 47; FSQ (some LMUs) = 15

REGION 6

Most suitable mountain lion habitat in Region 6 lies in the Bears Paw and Little Rockies ranges, as well as along the Missouri River (Figure 35). A significant portion of the Region's lion habitat is included within the Rocky Boy's and Fort Belknap Reservations—FWP does not have wildlife management authority within these jurisdictions.

There was no open mountain lion hunting season between 1976 and 1992 in Region 6 (Table 18); mountain lions became increasingly common in the Region 6 during this period. Harvest quotas have remained relatively stable since hunting seasons were re-opened in 1993 but the annual FWP managed harvest varies annually depending on winter tracking conditions, hunter access, and individual hunters' participation in the harvest season (Table 17).

Mountain lion harvest that occurs on the Rocky Boy's and Fort Belknap reservations may not be reported to FWP, and thus, regional harvest totals should be viewed as minimums. Kunkel et al. (2012) documented a relatively high annual hunter harvest rate and low adult survival for Region 6 lions during their study. The authors suggested that Region 6 lion populations may be sustained by immigration rather than local recruitment. If so, continuing to protect adult females from harvest may allow local reproduction to supplement lions that disperse into the Region.

Table 17. Region 6 mountain lion harvest, 1971 – 2016.

License Year	R6		
	F	M	Tot.
1971	0	0	0
1972	0	0	0
1973	0	0	0
1974	0	0	0
1975	0	0	0
1976	0	0	0
1977	0	0	0
1978	0	0	0
1979	0	0	0
1980	0	0	0
1981	0	0	0
1982	0	0	0
1983	0	0	0
1984	0	0	0
1985	0	0	0
1986	0	0	0
1987	0	0	0
1988	0	0	0
1989	0	0	0
1990	0	0	0
1991	0	0	0
1992	2	2	4
1993	2	2	4
1994	2	4	6
1995	3	3	6
1996	1	2	3
1997	5	2	7
1998	4	3	7
1999	4	4	8
2000	2	1	3
2001	3	2	5
2002	1	1	2
2003	0	0	0
2004	0	1	1
2005	0	0	0
2006	0	1	1
2007	1	2	3
2008	0	7	7
2009	1	3	4
2010	2	4	6
2011	5	4	9
2012	4	3	7
2013	2	3	5
2014	2	3	5
2015	2	4	6
2016	4	9	13

Lions are only likely to be resident in hunting districts 680, 690, 621, 622, 631 and 632. The remainder of the Region may be considered a Special Management Area where tolerance for lions is low. In this area, liberal quotas may be recommended so that hunter harvest is available when needed to minimize conflict while still allowing for lion movement between resident populations.

All of Region 6 lies within the Eastern Mountain Lion ecoregion (Figure 36). Routine lion abundance estimates and population modeling will not be available in this ecoregion. Because of annual variations in tracking snow cover, annual harvest varies independent of population trend. Regional managers will therefore rely on indirect indications of lion abundance and public input to monitor lion populations. Region 6 may also choose to produce a baseline Regional abundance estimate (either alone or in collaboration with Tribal partners) following SCR or other field methods (Chapter 5) if funding is available.

Region 6 will be able to meet lion management objectives by using Model Harvest Regulation **Season Type 2: General License** with individual male and female quotas or subquotas.

Figure 35. FWP Region 6 2016 mountain lion winter RSF and hunting districts.

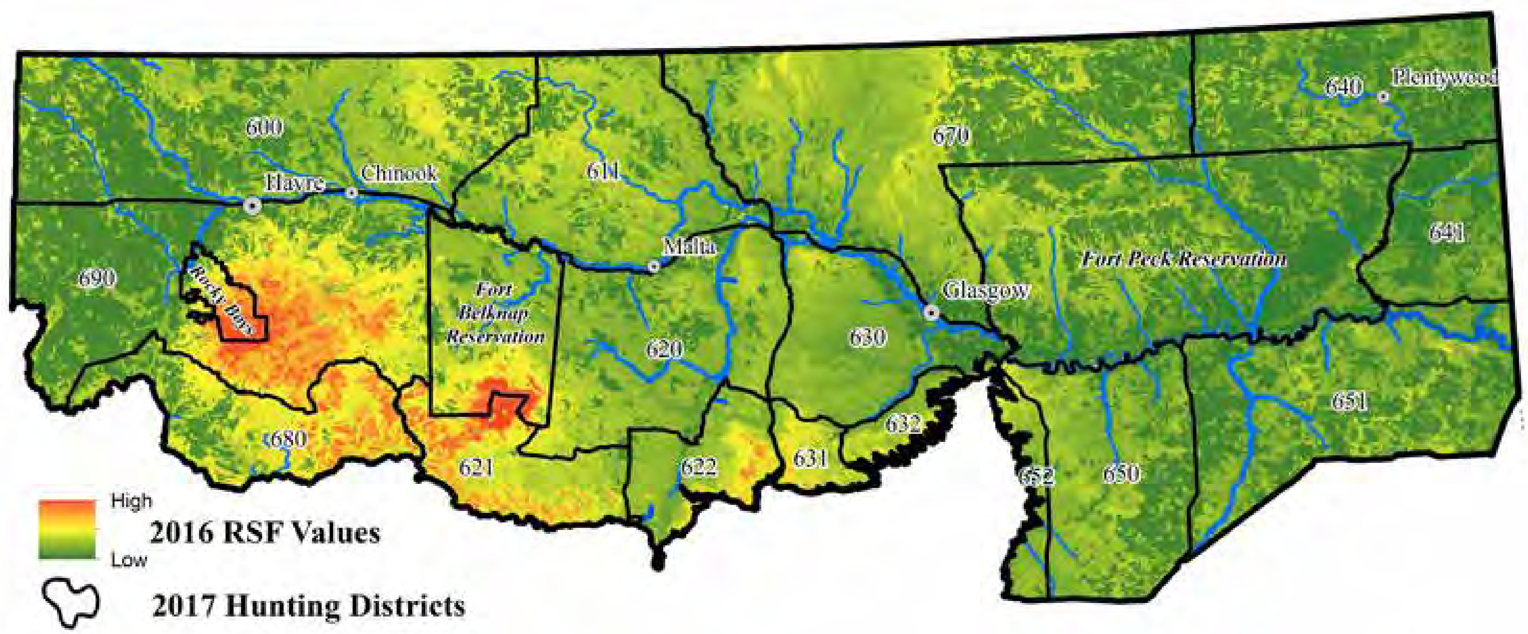


Figure 36. FWP Region 6 hunting districts and mountain lion ecoregion.

Table 18. Summary of Region 6 mountain lion harvest regulations, 1971 – 2017.

License Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Mandatory Inspection	NONE		10 Day Inspection													
Hunting season	Opening of General D/E - 4/30					CLOSED										
Chase/Hound Training Season	NONE								CLOSED						2/16 - 4/30	
Regional Quotas	UNLIMITED; One ES Adult Lion per Hunter					CLOSED										

License Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Mandatory Inspection						48 Hr. Report; 10 Day Inspection			24 Hr. Report; 5 Day Inspection			24 Hr. Report; 10 Day Inspection	12 Hr. Report; 10 Day Inspection			
Hunting season	CLOSED					12/1 - 2/15						12/1 - 4/14	Fall Season w/o dogs; 12/1 - 4/14			
Chase/Hound Training Season	12/1 - 4/30					2/16 - 4/30						No dedicated Chase Season, Hound Training allowed during Winter Hunting Season				
Regional Quotas	CLOSED					3 Any Legal Lion	3 Any Legal Lion	5 Any Legal Lion	Total = 10; FSQ = 3	Total = 10; FSQ = 3	Total = 13; FSQ (some LMUs) = 5; MSQ (some LMUs) = 3	Total = 13; FSQ (some LMUs) = 6	Total = 13; FSQ (one LMUs) = 6	Total = 16; FSQ (one LMUs) = 5	Total = 11; FSQ (one LMUs) = 3	Total = 11; FSQ (one LMU) = 3

License Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Mandatory Inspection	12 Hr. Report; 10 Day Inspection														
Hunting season	Fall Season w/o dogs; 12/1 - 4/14							Archery-only Season; Fall Season w/o dogs; 12/1 - 4/14							
Chase/Hound Training Season	Hound Training Season 12/2 - 4/14														
Regional Quotas	Total = 11; FSQ (one LMU) = 3	Total = 11; FSQ (one LMU) = 3	Total = 11; FSQ (one LMU) = 3	Total = 11; FSQ (one LMU) = 3	Total = 11; FSQ (one LMU) = 3	Total = 11; FSQ (one LMU) = 3	Total = 12; FSQ = 3	Total = 11; FSQ (one LMU) = 2	Total = 11; FSQ (one LMU) = 2	Total = 11; FSQ (one LMU) = 2	Total = 12; FSQ = 4	Total = 12; FSQ = 4	Total = 12; FSQ = 4	Total = 12; FSQ = 4	Total = 12; FSQ = 4

REGION 7

Mountain lions have expanded their range into eastern Montana since the 1980s and are now found in all suitable Region 7 habitats (Figure 37). The first mountain lion hunting season in Region 7 occurred in 1985 but no harvest was recorded until 1990. FWP incrementally raised quotas as the Region's lion abundance and distribution increased. Mountain lion age-in-harvest, harvest sex ratios, and hunter effort remained stable through the late 2010s.

Because lions only recently recovered in Region 7, neither biological nor social carrying capacities are as well known. Incidents of human-lion conflict and livestock depredation remained low through the mid-2010s and landowners were generally tolerant of mountain lion presence.

Region 7 lies entirely within the Eastern mountain lion ecoregion (Figure 38). Estimates of lion abundance will not be routinely produced using SCR or other field methods for this ecoregion. Managers will need to instead rely in indirect indices of abundance, harvest success, and public input to help guide management decisions.

Intermittent winter snow cover in the Region limits hound hunting's effectiveness. Annual lion harvest is correlated with the number of days the Region has snow cover (FWP data). Therefore, Region 7 quotas are more likely to serve as limits on harvest during years when snow conditions are favorable than as reliable annual harvest prescriptions. If quotas are met despite annually variable environmental conditions, managers may consider whether an increase is appropriate. Overharvest in Region 7 is unlikely because these favorable tracking conditions are rare and hunters have limited access to occupied habitat.

Region 7 traditionally prescribed a single, Region-wide, harvest quota. This approach was intended to both maximize hunter opportunity and regulation simplicity. It also allowed flexibility to direct harvest to areas with higher lion densities, more conflicts, or better tracking conditions. Region 7 may continue to comprise a single LMU within the Eastern ecoregion to maintain this management approach.

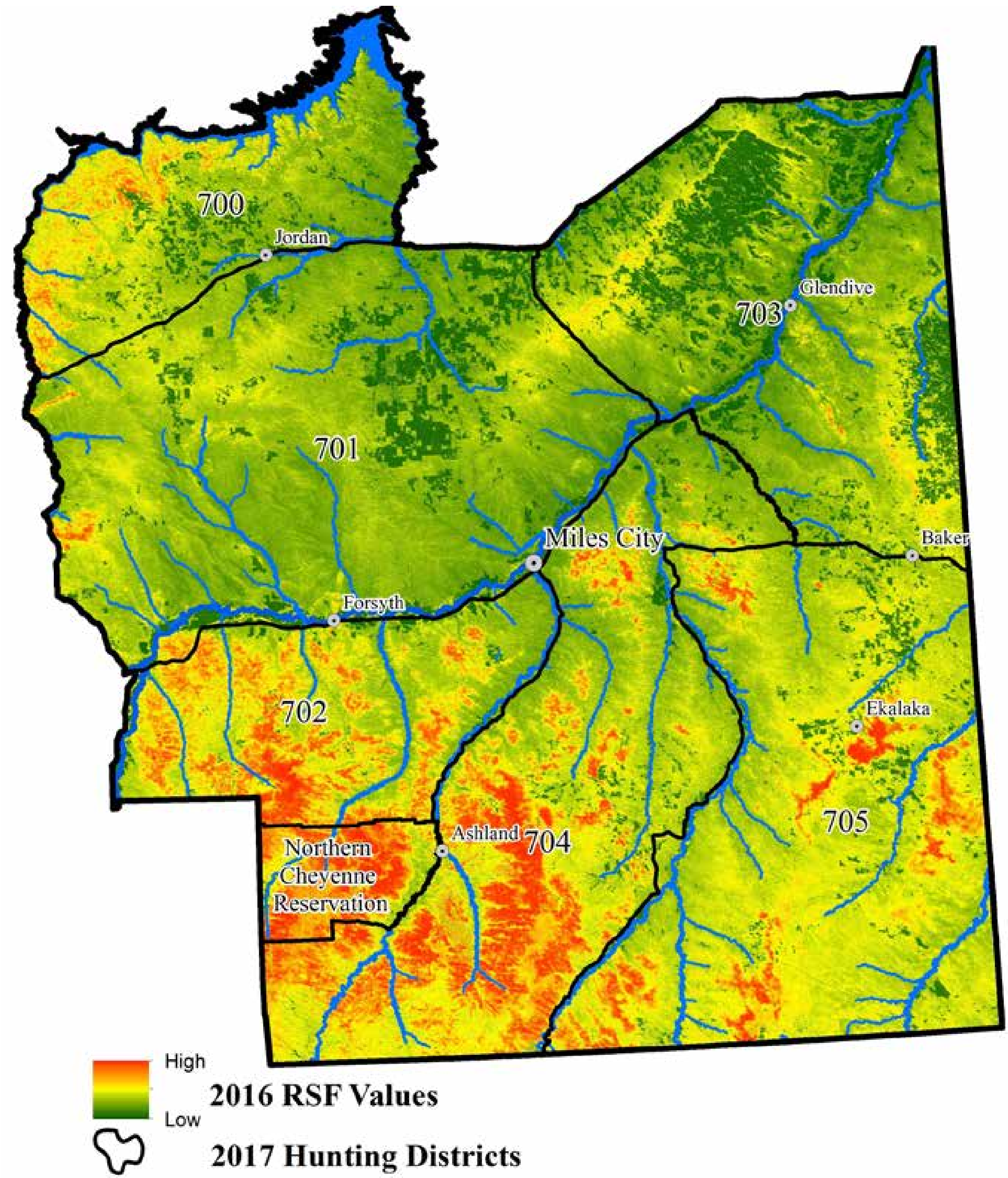
Table 19. Region 7 mountain lion harvest, 1971 – 2016.

License Year	R7		
	F	M	Tot.
1971	0	1	1
1972	0	0	0
1973	0	0	0
1974	0	0	0
1975	0	0	0
1976	0	0	0
1977	0	0	0
1978	0	0	0
1979	0	0	0
1980	0	0	0
1981	0	0	0
1982	0	0	0
1983	0	0	0
1984	0	0	0
1985	0	0	0
1986	0	0	0
1987	0	0	0
1988	0	0	0
1989	0	0	0
1990	1	0	1
1991	0	0	0
1992	1	2	3
1993	1	2	3
1994	0	5	5
1995	2	1	3
1996	2	1	3
1997	1	1	2
1998	1	4	5
1999	3	4	7
2000	5	5	10
2001	4	11	15
2002	3	10	13
2003	1	5	6
2004	4	7	11
2005	0	7	7
2006	9	12	21
2007	6	11	17
2008	9	12	21
2009	8	17	25
2010	11	15	26
2011	17	14	31
2012	15	16	31
2013	10	26	36
2014	18	20	38
2015	8	16	24
2016	12	17	29

FWP biologists will carefully monitor harvest distribution within the Region. Region 7 contains three lion management areas: 1) the Ashland Ranger District of the Custer National Forest (where the majority of Region 7 mountain lion harvests occurs) and adjacent lands, 2) the Sioux Ranger District (Chalk Butte, Ekalaka Hills and Long Pines units) of the Custer National Forest, plus several adjacent large tracts of BLM and private land and, 3) lands on and adjacent to the Charles M. Russell Wildlife Refuge.

Patterns in harvest among these units will be tracked over time. If there is a significant reduction in the distribution of harvest that cannot be attributed to tracking conditions

Figure 37. FWP Region 7 2016 mountain lion winter RSF and hunting districts.

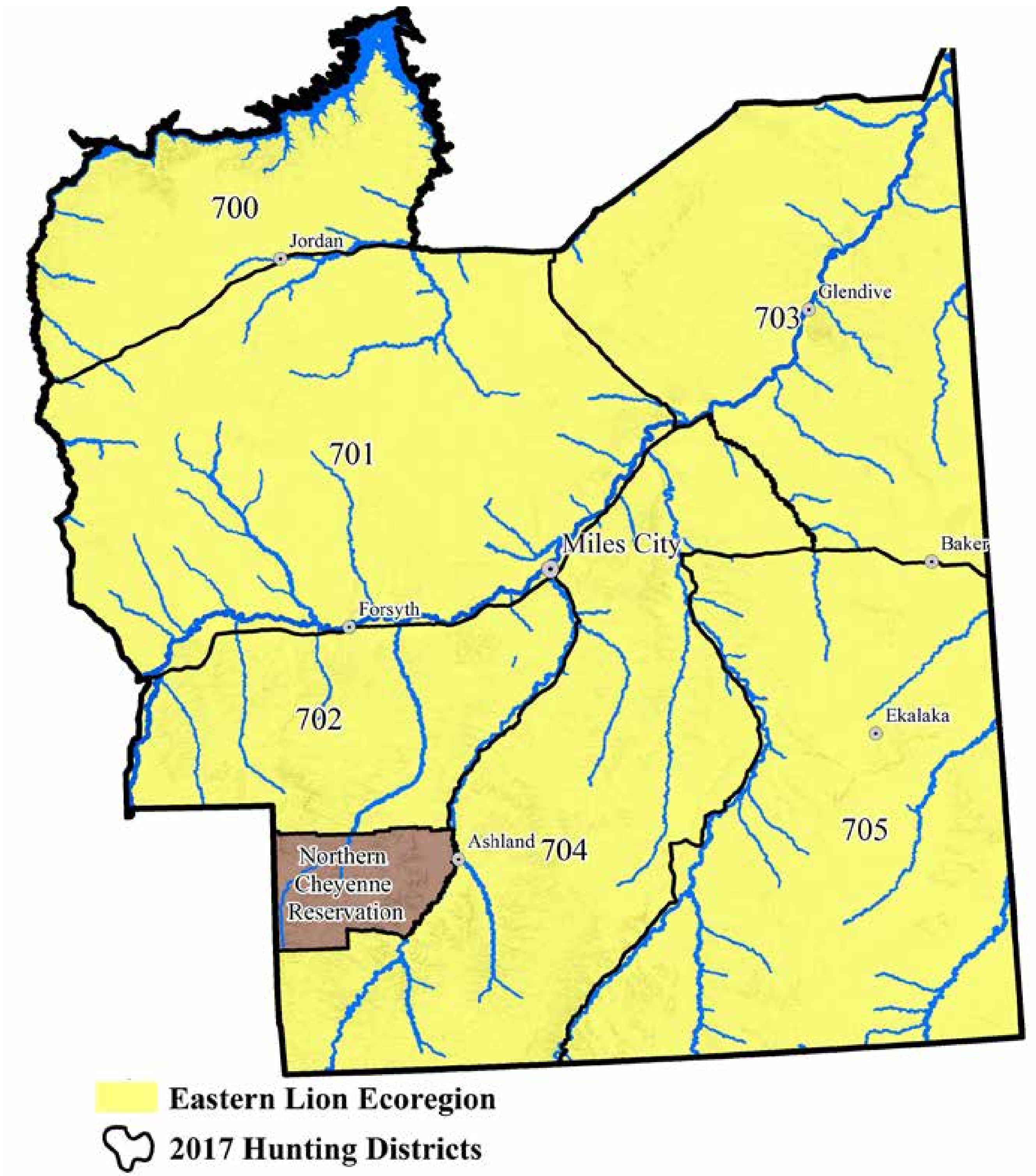


or changes in hunter access, the Region may consider management alternatives. Regional managers will also consider the pattern and rate of Regional human-lion conflicts and landowner input when evaluating these alternatives.

Nonresident hunters take an average of 15% of the lions harvested in Region 7 each year.

Minimizing human-lion conflicts and livestock depredation is a high priority in Region 7. The Region will use both

Figure 38. FWP Region 7 hunting districts and mountain lion ecoregion.



hunter harvest and effective responses to individual incidents that are consistent with the Depredation and Control Guidelines to minimize potential conflicts.

Region 7 will be able to meet lion management objectives by using Model Harvest Regulation **Season Type 2: General License**.

Table 20. Summary of Region 7 mountain lion harvest regulations, 1971 – 2017.

License Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Mandatory Inspection	None		10 Day Inspection					4 Day Inspection				48 Hr. Inspection		10 Day Inspection	72 Hr. Inspection	48 Hr. Inspection
Hunting season	Opening of General D/E - 4/30					CLOSED									12/2 - 2/15	
Chase/Hound Training Season	NONE								CLOSED							
Regional Quotas	UNLIMITED; One ES Adult Lion per Hunter					CLOSED									3 Any Legal Lion	

License Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Mandatory Inspection	48 Hr. Report; 10 Day Inspection								24 Hr. Report; 5 Day Inspection			24 Hr. Report; 10 Day Inspection	12 Hr. Report; 10 Day Inspection			
Hunting season	12/1 - 2/15											12/1 - 4/14	Fall Season w/o dogs; 12/1 - 4/14			
Chase/Hound Training Season	CLOSED		2/16 - 4/30									No dedicated Chase Season, Hound Training allowed during Winter Hunting Season				
Regional Quotas	3 Any Legal Lion	3 Any Legal Lion	3 Any Legal Lion	3 Any Legal Lion	3 Any Legal Lion	3 Any Legal Lion	3 Any Legal Lion	5 Any Legal Lion	7 Any Legal Lion	7 Any Legal Lion	7 Any Legal Lion	7 Any Legal Lion	7 Any Legal Lion	10 Any Legal Lion	15 Any Legal Lion	20 Any Legal Lion

License Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Mandatory Inspection	12 Hr. Report; 10 Day Inspection														
Hunting season	Fall Season w/o dogs; 12/1 - 4/14							Archery-only Season; Fall Season w/o dogs; 12/1 - 4/14							
Chase/Hound Training Season	Hound Training Season 12/2 - 4/14														
Regional Quotas	20 Any Legal Lion	20 Any Legal Lion	20 Any Legal Lion	20 Any Legal Lion	25 Any Legal Lion	25 Any Legal Lion	25 Any Legal Lion	25 Any Legal Lion	30 Any Legal Lion	30 Any Legal Lion	35 Any Legal Lion	45 Any Legal Lion	45 Any Legal Lion	45 Any Legal Lion	45 Any Legal Lion

APPENDIX 1

POPULATION MONITORING, FIELD PROTOCOL, AND DATA ANALYSIS

Trend Monitoring Area Selection

FWP identified permanent trend monitoring areas within the Northwest, West-central, and Southwest ecoregions based on the following criteria:

- The area is approximately 2,600 km^2 (1,000 mi^2) in size, and
- The habitat quality (assessed both qualitatively and as predicted by the 2016 RSF) within the trend area is representative of the lion habitat type and quality present in the remainder of the ecoregion, and
- There is current and long term physical and legal access to the majority of the trend monitoring area during winter, and
- Regional wildlife managers and the public are committed to prescribing annual mountain lion harvest rates for the trend monitoring area's LMUs that are representative of the annual harvest rate in the larger ecoregion.

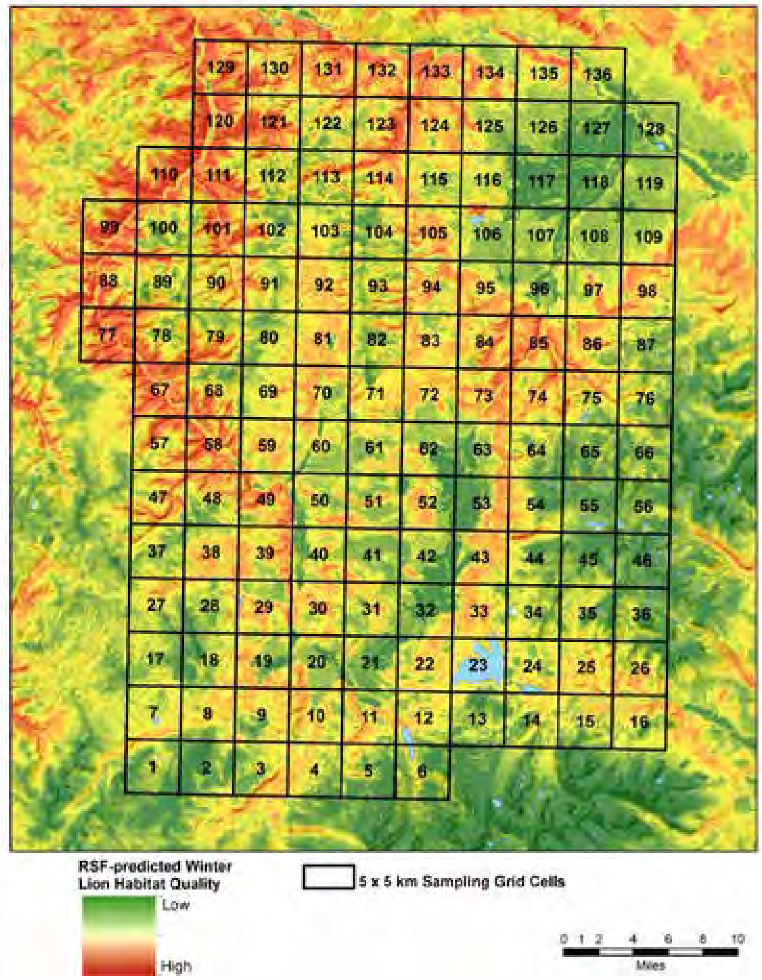
Locations of the Northwest, West-central, and Southwest trend monitoring areas are shown in Chapter 4.

Supplemental Monitoring Area Selection

Supplemental monitoring areas in each of the Northwest, West-central, and Southwest ecoregions may be sampled the year after each ecoregion's trend monitoring area is sampled. The supplemental monitoring areas will be selected using the following criteria:

- The area is approximately 2,600 km^2 (1,000 mi.2) in size, and
- There is sufficient physical and legal access (i.e. public land or prior permission from private landowners) to allow sampling of most of the predicted mountain lion habitat in the monitoring area during winter, and
- Harvest rates for the proposed supplemental monitoring area's LMUs have been representative of the annual harvest rate in the larger ecoregion for at least the last 6 years.

Figure 39. An example of a sampling grid overlaid on a 3,400 km^2 monitoring area and the underlying 2016 RSF for the area (Proffitt et al. 2014; Upper Clark Fork River, MT).



Initial Field Protocol

Collection and analysis of field data will initially follow methods described in detail by Proffitt et al. (2015). Population monitoring and field sampling techniques may change as improved methods are developed and validated in the future.

Monitoring areas will be sampled between 12/1 and 4/15. Field staff will overlay a 5x5 km grid across the study area and assign each cell a number. Cells will then be stratified into classes according to their habitat quality (RSF value) and a random search order will be assigned to cells in each class. Although each day's search effort will begin in a randomly assigned grid cell, more overall search effort will be dedicated to cells with higher quality habitat (Figure 39).

Trackers and hound handlers will search their assigned cell(s) to collect genetic samples from mountain lion hair, scat, and muscle. The location where each sample is collected will be recorded, as will the search route trackers used to survey the cells (Figure 40).

When a fresh track of a suspected independent-aged mountain lion is located, the hound handlers will attempt to tree the lion and collect a muscle sample using a biopsy dart fired from a pneumatic gun. The tracks will then be backtracked and inspected to determine if the lion was independent or associated with a family group—if it was traveling with other animals, the group size will be recorded. Sex of the treed lion will be determined based on genetic analysis.

When older mountain lion tracks are located, a tracker or hound handler will backtrack and collect any hair or scat samples present along the track. All field crews will use a Global Positioning System to record the length and location of their search effort (Figure 40).

Figure 40. An example of the distribution of search effort within a SCR sampling area. In total, 12,785 km of trails within 127 grid cells were sampled over 121 days (Proffitt et al. 2014; Upper Clark Fork River, MT).

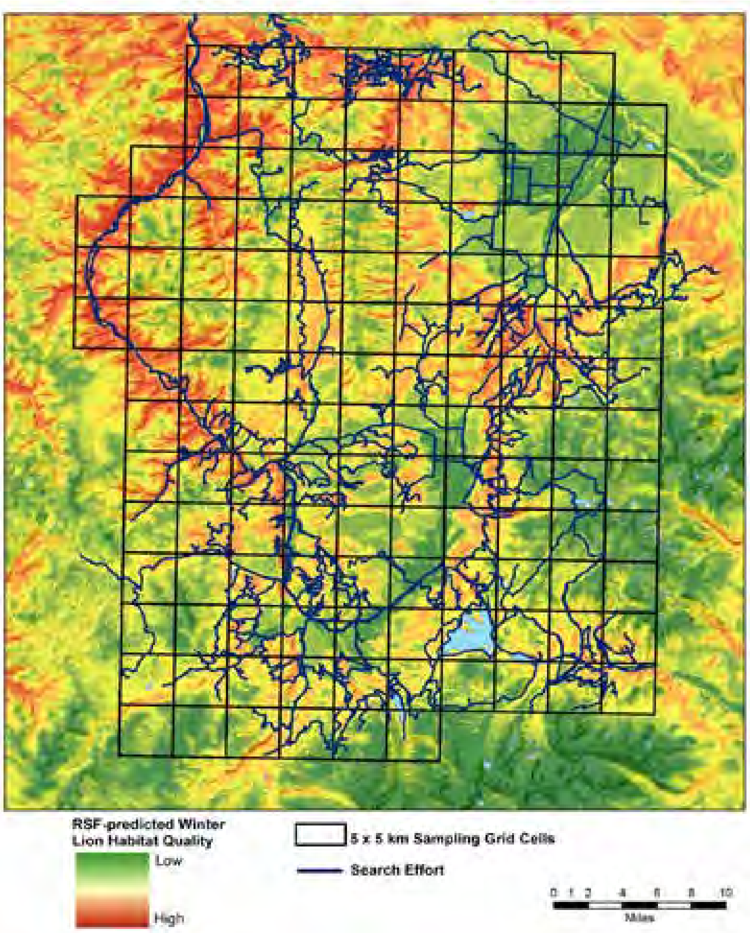
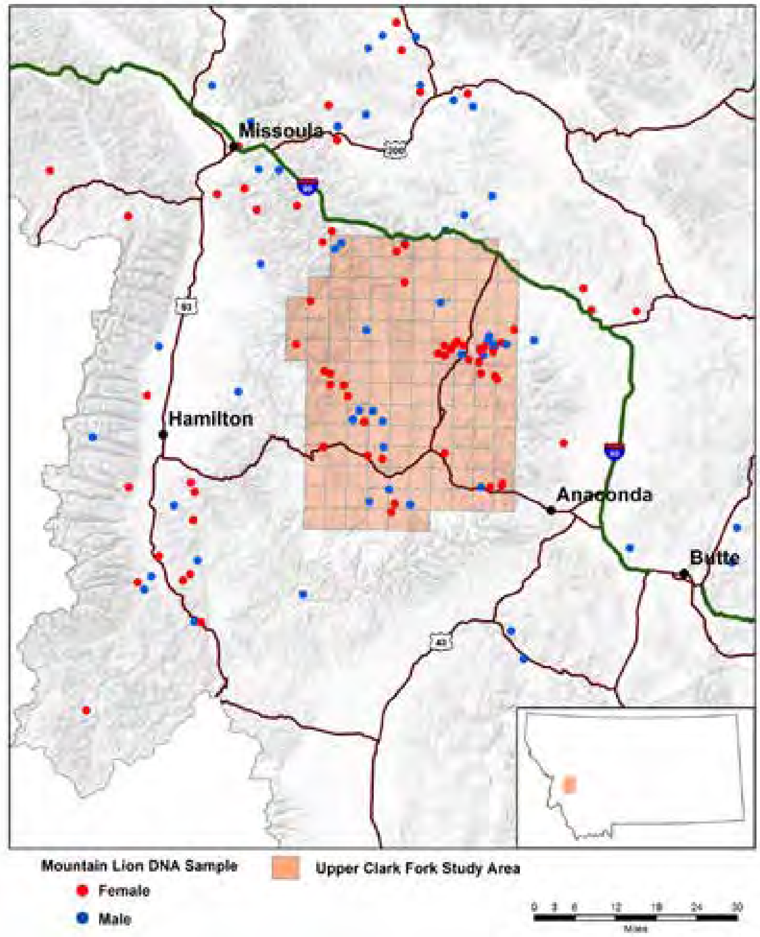


Figure 41. An example of a SCR sampling area and the locations of 132 mountain lion tissue samples (from both field sampling and harvest) that had DNA successfully extracted and analyzed to determine individual ID (Proffitt et al. 2014).



In Montana, the hide and skull of all harvested mountain lions must be presented to a FWP employee within 10 days. FWP will collect genetic samples from all know lion mortalities that occur in or adjacent to the monitoring area. Hair and muscle samples from these lions will be genetically analyzed to determine sex and the individual lions' identities (Figure 41).

Field Sampling Recommendations

A "sample" is a successfully extracted and identified individual mountain lion DNA sequence. Because not all non-invasive DNA samples will generate amplifiable DNA, not all material collected in the field will provide a useful DNA sample. Even after a single sample is collected in a cell, field staff are generally encouraged to continue to expend effort in that cell to obtain either additional lower quality samples (scat, hairs) or a high-quality sample (muscle biopsy). For hound handlers, this means collecting a biopsy dart sample, and a backup high-quality hair sample. For snow backtrackers, multiple scat samples from different scats, and/or hair samples are ideal.

Field staff will collect tissue from biopsy darts, scats from backtracking, hairs from both biopsy darting (as a backup sample) and hairs from snow tracking, and harvested lion muscle samples. During previous studies (Russell et al. 2012, Proffitt et al. 2015) DNA extraction success was highest for muscle/biopsy samples and lowest for hair and scat. Because not all biopsy samples generate successful DNA sequences, a second set of high-quality hair samples (with follicles attached) should also be collected. Hound handlers should collect these samples opportunistically while tracking the animal to the tree, then search for hair and/or scat around the tree and while back tracking from the tree.

There is a critical difference between when a survey cell has been searched versus when a cell has been successfully sampled. Survey effort was an important predictor of detection in previous SCR studies of lions (Russell et al. 2012). Therefore, field staff must carefully collect a GPS track log of all daily search effort. If a cell is searched and lion sign is present but a sample is not obtained, then the cell was not successfully sampled.

Search effort should be spatially distributed by randomly assigning cells to be searched each day. These random grid cells are the starting point for the day's search. However, if new tracks are encountered while traveling to the days starting grid cell, the tracker should follow those tracks if that grid cell has not been successfully sampled yet. If tracks of a lion previously captured in that grid cell are detected, however, the tracker should proceed to the day's assigned starting location.

The hound handler/tracker should confine search activity to the assigned focal cell or its 8 adjacent grid cells on any particular day. Field crews may choose to skip a randomly assigned cell if multiple teams are working nearby and the randomly assigned cell could lead to survey overlap. Likewise, assigned cells may be skipped if that cell has been surveyed within the previous month and a high-quality sample already obtained. Field crews may choose to skip assigned cells if conditions in the assigned cell will not allow snow tracking.

Once a hound handler is assigned a starting grid cell, subsequent sampling effort may proceed in one of several ways. If the assigned cell and adjacent cells are searched, no sign is detected, and the hound handler believes the area is likely void of lions at that time (e.g. too high of an elevation, too much snow, etc.), the hound handler will receive a new randomly assigned starting cell the next day. The cell will remain on the sampling list for that period.

If after the assigned cell and adjacent cells are searched, all tracks are followed, and the hound handler believes that all lions currently detected within the area have been sampled, the cell(s) from which samples were collected will be removed from the sample list for that period. The hound handler will then get a new starting cell from the sampling list the next day.

If the assigned cell and adjacent cells are searched, multiple tracks are found, and the hound handler believes that NOT all lions currently within the area have been sampled, only the cell(s) from which samples were collected will be removed from the list. The hound handler will then return to the area and continue to work there until their shift is over, or they believe they have sampled all of the lions thought to be in the area. A new starting cell from the sampling list will be assigned the next day.

All samples will be carefully stored in desiccant and labeled with a unique sample ID. Hound handlers and trackers will record their daily search effort using GPS tracks from GPS units.

Estimating Ecoregional Lion Abundance

Montana FWP will monitor and manage mountain lions within large (>35,000 km^2) ecoregions. To do so, managers will need to periodically estimate lion population size within these ecoregions and make predictions about the effect of future harvest at this scale. Once an overall harvest prescription has been developed for an ecoregion, individual harvest limits will be assigned to the ecoregions' LMUs to distribute harvest and address local management objectives.

Spatially explicit abundance estimates from representative sampling areas can be extrapolated across a broader area of inference to estimate that landscape's population size (Boyce & McDonald 1999). This method of extrapolating animal abundance as a function of RSF-predicted habitat quality has been used to estimate populations of many species (Boyce et al. 2016), including mountain lions in Montana (Robinson et al. 2015).

Several important factors must be considered when using data collected from sampling areas to estimate a species' population size across a larger area (Wiens et al. 2008, Boyce et al. 2016):

- The relationship between the observed number of animals and available habitat (ie. the 2016 RSF) within a sampling area should be similar to that same relationship across the larger landscape, and
- Harvest management within sampling areas should be representative of the broader area of inference (Reynolds et al. 2016). Specifically, it's important that the long-term mountain lion hunter-harvest rate within an ecoregion's monitoring areas is similar to the harvest rate within the larger landscape for which the estimate is being made, and
- Because a species' abundance can vary over time for reasons unrelated to habitat quality (ie. hunting or changes in prey density), representative sampling area(s) must be periodically re-sampled. This helps ensure that up-to-date relationships between abundance and RSF values are used to estimate current populations.

Producing Ecoregion Population Estimates
The relationship between mountain lion density and habitat within an ecoregion's monitoring area(s) will be most similar to other areas within that same ecoregion. Therefore, the mountain lion abundance data collected on monitoring areas will only be used to estimate the population size of the ecoregion where that monitoring area is located—they will not be used to develop population estimates for other ecoregions.

Even within ecoregions, the relationship between mountain lion abundance and habitat quality varies. To improve the accuracy of an ecoregion's population estimate, FWP may initially collect data from both a fixed Trend Monitoring Area (sampled Year 1) and a Supplemental Monitoring Area (sampled Year 2). The locations of Supplemental Monitoring Areas may vary over time, Trend Monitoring Area locations will not.

Combining the data collected from both the trend and supplemental monitoring areas may generate a more representative ecoregional estimate of the relationship between lion abundance and the RSF as compared to using data from the trend monitoring area alone (Howe et al. 2013). Therefore, the results of the two subsequent samples will be pooled to describe the current relationship between lion abundance and the RSF within an ecoregion. This pooled relationship will be used to estimate the population of independent-aged mountain lions within that ecoregion.

Ecoregion population estimates will also be produced using monitoring data from the fixed trend monitoring area alone. FWP will compare the estimate derived using the pooled areas' data and the estimate using only the trend monitoring area data. If the two methods consistently produce similar estimates, supplemental monitoring areas will not continue to be sampled.

The initial FWP SCR model predicts the abundance of independent-aged mountain lions at a 4 km^2 resolution (Proffitt et al. 2015). The following regression equation is an example of one way to estimate the effect of RSF on abundance across the ecoregion:

$$\text{Abundance} = \beta 0+\beta 1*\text{RSF}+e$$

FWP continues to test and validate extrapolation methods.

FWP will estimate the mean RSF value over the same spatial extent (4 km^2) for both the trend and supplemental monitoring areas, and use these mean RSF values in the regression model. The above regression equation represents the effect of the mean 4 km^2 RSF on predicted spatial abundances within the pooled trend and supplemental monitoring areas. Using this relationship, FWP will predict mountain lion abundance for the entire ecoregion by extrapolating the observed relationship between RSF values and mountain lion abundance (Boyce & McDonald 1999). FWP will use the 95% confidence interval around β RSF to estimate the 95% upper and lower confidence intervals around the predicted mean abundance for the ecoregion.

FWP will periodically sample mountain lion populations and produce estimates for the Northwest, West-central, and Southwest ecoregions. An estimate of the overall abundance of mountain lions within these ecoregions will then be developed based on the sampling data. These estimates will be input into the IPM (Chapter 6) as additional data. The IPM then considers the field-based abundance estimates along with harvest prescriptions and lion vital rates when generating more complete predictions of past and future ecoregional population trends.

Data Analysis

To estimate the abundance of independent lions in the sampling area, FWP will initially fit the SCR model to a dataset that includes only samples from independent animals or the adult female of a family group. This eliminates multiple samples from within family groups as well as all groups where only a subadult animal was sampled.

The monitoring period will be divided into sampling periods within the winter season (December, January, February, and March-April). An encounter history will be developed for each detected individual during each sampling period and the detection probability for harvested animals will be adjusted to '0' for the sampling periods following their death.

FWP will initially use a Bayesian SCR model to estimate the number of mountain lions present within the sampling area. This method explicitly incorporates the spatial organization of individuals through the estimation of specific capture probabilities (Efford 2004, Efford et al. 2009, Gardner et al. 2010, Royle et al. 2013).

To account for individuals that had a home range only partially within the sampling area, FWP will buffer the study area by 10 km and estimate spatial densities within the larger area. We will then evaluate potential models that include all possible combinations of the covariates for search effort and sex, RSF-driven densities, and sex-specific activity center distributions (Russell et al. 2012). We will conduct model selection using a combination of Bayesian Information Criteria (BIC), examination of the posterior significance of the parameters in each model, and two goodness of fit statistics (as described in Proffitt et al. 2015). All of these factors will be weighted by our prior knowledge of mountain lion biology.

We will then estimate the independent-aged lion abundance, with confidence intervals, for the trend and supplemental monitoring areas. Because these abundances are spatially explicit functions of the areas' underlying habitat quality, we will then extrapolate the monitoring areas' relationship between abundance and the RSF to produce an estimate of lion abundance across the larger ecoregion.

Cost

Field monitoring will occur at a significant periodic cost to Fish, Wildlife and Parks. The Department will need to hire one staff biologist who will work half-time (6 months) to plan and organize logistics, contract field staff, coordinate day-to-day field operations, and prepare data for analysis. Enough hound handlers will be contracted to successfully sample approximately 60% of grid cells within the Monitoring Area during the four sampling periods. The number of contractors may vary depending on each contractor's seasonal availability. Genetic analysis of the collected samples will also be contracted through an independent laboratory.

Table 21. Approximate costs (2016) to collect and analyze mountain lion monitoring area data.

Contracted Hound Handlers	$65,000
Genetic Analysis	$9,500
Fuel and housing	$6,500
FWP Biologist (1/2 FTE)	$32,500
Misc. Supplies	$2,000
Total	$115,500

APPENDIX 2

MOUNTAIN LION INTEGRATED POPULATION MODEL DEFINITION AND USER INPUTS

The Montana mountain lion integrated population model is generally described in Chapter 6 and in Nowak et al. 2018. Following are more complete descriptions of the several internal models, the data and prior assumptions that the IPM includes, and an explanation of the controls that users can manipulate to improve the IPM's outputs.

Reproduction Model Definition

The equation describing the number of kittens in year y is as follows:

$$N_{kit,f,y} = \left(N_{sa,f,y} * P_s a * LS_s a * 0.5 + N_{a,f,y} * P_a * LS_a * 0.5 * 0.5\right) * Survival_{kit,y-1}$$

Thus, we calculate the number of female kittens ***f*** in year ***y*** as a function of the number of subadult ***SA*** and adult ***A*** females ***f*** in year ***y***. For the subadult contribution we take the product of the number of subadults, the age specific pregnancy rate ***P***, and litter size ***LS***.

Only a fraction of the resulting kittens will be female and so the final term in the product simply assumes that half of the kittens born are female. The adult contribution to the kitten population is calculated as the product of the number of adults, the age specific pregnancy rate, litter size, and 0.25 (0.5 * 0.5). Because we assume the adult inter-birth interval is 24 months, only half of the adult females are available to reproduce in any given year. We therefore multiply the reproductive term by 0.5. Said another way, the first 0.5 represents the assumption that half of the kittens born are females and the second 0.5 reflects our assumption that the birth interval is 24 months, which results in half of the adult female population giving birth each year.

Multi-state Survival Model Definition

The mountain lion IPM in ***PopR*** is built around a 4-age class and 2-sex population model. The 4 age classes are ***kittens*** (0-6 months), ***juveniles*** (6-18 months), ***subadults*** (18-30 months) and ***adults*** (30+ months). We assume a 50:50 sex ratio at birth but, starting with the juvenile age class, each sex is modeled separately. The process model describing lion ecology is represented by a series of equations that describe transitions from one age class to the next each year.

$$N_{kit,f,y} = \left(N_{sa,f,y} * P_s a * LS_s a * 0.5 + N_{a,f,y} * P_a * LS_a * 0.5 * 0.5\right) * Survival_{kit,y-1}$$

$$N_{juv,f,y} = N_{kit,f,y-1} * Survival_{juv,f,y-1} - harvest_{juv,f,y-1} + \epsilon_{juv,f,y}$$

$$N_{sa,f,y} = N_{juv,f,y-1} * Survival_{sa,f,y-1} - harvest_{sa,f,y-1} + \epsilon_{sa,f,y}$$

$$N_{ad,f,y} = \left(N_{sa,f,y-1} + N_{ad,f,y-1}\right) * Survival_{ad,f,y-1} - harvest_{ad,f,y-1} + \epsilon_{ad,f,y}$$

where,

$$N_{age,sex,y}$$

is the abundance of age class age, sex sex in year y

$$Survival_{age,sex,y}$$

is the survival of age class age, sex sex in year y

$$P_{age}$$

is the age-specific pregnancy rate

$$LS_{age}$$

LS is the age-specific litter size

$$\epsilon_{age,sex,y}$$

is the age, sex and year-specific residual variation

Kittens born to subadults and adults the previous year are recruited as juveniles on December 1st each year. The number of subadults and adults is indexed to year ***y*** based on the number of reproductive females in the population on December 1. The model then takes into account the probability these females will survive until they give birth (assumed to be July 1). We also assume that kittens whose mothers die within the first six months after giving birth will not survive.

The model does not make kittens available for harvest because it assumes they become juveniles on December 1 at 6 months old but would not be independent (and legally harvestable) until after the winter hunting season ends. Although some subadults may reproduce, they do so at a lower rate than adults. Subadults transition to adults on December 1st of the following year. Any mountain lion older than 30 months is considered either an adult male or female. As adults, the model assumes that each sex survives (except for harvest) and reproduces at the same respective rate for the remainder of their lives.

The lion IPM primarily uses estimates and variability of documented vital rates (from the research literature) rather than raw field data itself (Table 22). This model structure provides several advantages. First, it allows lion research data collected using a wide variety of field sampling protocols to fit into the IPM framework—once the parameter and its error distribution is described it can be entered into the IPM. Because we also include a measure of the field estimate's precision, all sources of uncertainty remain in the IPM.

The general form of the observation model in ***PopR*** is:

$$\hat{\theta} \sim Normal\left(\bar{\theta}, \widehat{SE}(\hat{\theta})\right)$$

where,

$\theta =$ field estimate

$\widehat{SE}(\hat{\theta}) =$ estimated standard error of

$\bar{\theta} =$ IPM parameter.

The observation model is like a multi-dimension regression model. The model fitting process seeks to minimize the distance between the IPM parameter (ie. Adult Female Survival) and the associated field estimate simultaneously across all IPM parameters.

Population Reconstruction Model Definition

The IPM uses survival estimates along with the annual harvest rate to reconstruct past mountain lion populations. It is based on examples of live recapture/dead recovery models from the literature that consider sex, age and year specific abundance estimates from records of harvested animals (Brownie et al. 1985, Link et al. 2003, Conn et al. 2008, Buderman et al. 2014). Current hunter harvest by sex, age, and location is input to the model after the close of the harvest season each year. By combining the multi-state survival model with observed harvest data, we can intuitively estimate population size by assuming a simple binomial distribution whose expectation is equivalent to:

$$N_{age,sex,y} = \frac{harvest_{age,sex,y}}{harvestMortality_{age,sex,y}}$$

where,

$$harvest_{age,sex,y}$$

is the number of age a, sex s, animals harvested in year y

$$N_{age,sex,y}$$

is the age, sex and year specific abundance

$$harvestMorality_{age,sex,y}$$

describes the relationship between abundance and harvest.

In practice, we implement harvest reconstruction as a binomial distribution:

$$harvest_{age,sex,y} \sim Binomial\left(harvestMortality_{age,sex,y}, N_{age,sex,y}\right)$$

Because the model requires that annual harvest data are input annually by both sex and age, FWP determines the age of harvested lions using cementum age analysis (Trainer & Matson 1988). In cases where teeth cannot be successfully extracted or an age confidently determined, the model randomly samples the distribution of known-age animals by sex and assigns an age to that animal for the purpose of the population reconstruction.

Direct estimates of population abundance (Proffitt et al. 2015) will be input into the model when they are available. These periodic field estimates can significantly improve past and future population estimates for individual lion ecoregions. Direct population estimates will be periodically developed for most lion ecoregions following the methods described in Chapter 5.

PopR uses Markov Chain Monte Carlo (MCMC) methods to "fit" IPM population estimates to the available data. MCMC methods estimate parameters in complex models by systematically updating informed prior distributions with information gleaned from field data (e.g. observed harvest). Therefore, they allow us to describe each parameter in terms of a distribution and that distribution's shape. Parameters described by a narrow and peaked distribution are more precisely estimated than those that are flatter and less peaked.

PopR provides generally acceptable default MCMC settings but also allows users to easily adjust them in the web-based user interface. Typically, 25,000-100,000 MCMC iterations will be required to fit an IPM. ***PopR*** provides convergence diagnostics in the output report.

IPM USER CONTROLS

Demographic Variation

These settings allow users to decide whether to allow estimates of population vital rates to be drawn from a single distribution (“Constant”) or from a range of all possible distributions that differs every year (“Time Varying”). Biologists should only choose “Time Varying” if they have reason to believe that non-harvest factors (such as weather or prey density) introduce additional volatility in these vital rates that would not have been present during the field research projects from which the “Constant” rate distribution was developed. Research has demonstrated that mountain lion non-harvest survival and reproductive rates are remarkably stable and the “Constant” setting should be considered the default.

Burn-in Length

“Burn-in” is a colloquial term for an initial process that gives the Markov Chain time to approach the solution to the problem by throwing away some less reasonable starting points at the beginning of a Markov Chain Monte Carlo run. Allowing the Burn-in process to establish an equilibrium distribution reduces the number of subsequent MCMC sampling iterations needed to provide an estimate with reasonable certainty. In PopR, managers should simply use the default Burn-in Length setting when developing an estimate through the standard user interface.

Markov Chain Monte Carlo (MCMC) Iterations

If the number of MCMC iterations is set too low the uncertainty about an estimate is likely to be misrepresented. In ***PopR***, we use the Brooks-Gelman-Rubin (BGR) statistic as an initial assessment and this is the statistic used when automating convergence. The BGR statistic suggests convergence when estimates of Rhat are below 1.1 or more generally close to 1. This statistic is reported under the “Table” tab and highlighted in red when Rhat estimates are above 1.1. The default settings will produce results that are unlikely to change even if run longer, but users should increase the number of MCMC iterations to 15,000 or greater if either Rhat estimates are above 1.1 and/or computing time allows.

Thinning Rate

Thinning tells the sampler to only retain every nth value from the chains. This technique is sometimes used to reduce autocorrelation in the chains, but comes at the cost of reduced efficiency of the sampler. A more reasonable use of thinning is when hardware limitations are being reached, which typically comes in the form of running out of memory. This will not be an issue in ***PopR*** and, therefore, the recommended setting for the Thinning slider is ***1.***

Automate Convergence

Users may choose to simply check the “Automate Convergence” box below the MCMC sliders menu in the ***PopR*** interface. Although this option will increase the time necessary to produce an estimate, it will assure that an adequate Burn-in Length and number of MCMC Iterations have been used to produce a statistically sound estimate and error distribution.

Table 22. Default mountain lion vital rates used in Montana’s 2016 Integrated Population Model. Rates are based on field data collected from 263 radio-monitored lions from Montana, Wyoming and Washington.

Parameter	Age	Sex	Mean	SE
Survival	YOY	F	0.5	0.1
Survival	Juvenile	F	0.75	0.1
Survival	SubAdult	F	0.57	0.1
Survival	Adult	F	0.8	0.05
Survival	YOY	M	0.5	0.1
Survival	Juvenile	M	0.75	0.1
Survival	SubAdult	M	0.49	0.1
Survival	Adult	M	0.65	0.05
HarvMort	Juvenile	F	0.01	0.01
HarvMort	SubAdult	F	0.25	0.1
HarvMort	Adult	F	0.1	0.1
HarvMort	Juvenile	M	0.01	0.1
HarvMort	SubAdult	M	0.35	0.1
HarvMort	Adult	M	0.2	0.1
OtherMort	Juvenile	F	0.24	0.1
OtherMort	SubAdult	F	0.18	0.1
OtherMort	Adult	F	0.05	0.1
OtherMort	Juvenile	M	0.24	0.1
OtherMort	SubAdult	M	0.16	0.1
OtherMort	Adult	M	0.15	0.1
Fetus Count	SubAdult	F	3	0.1
Fetus Count	Adult	F	3	0.1
Pregnancy	SubAdult	F	0.5	0.01
Pregnancy	Adult	F	1	0.01

APPENDIX 3

MOUNTAIN LION DEPREDATION AND CONTROL GUIDELINES

In accordance with Montana Code Annotated 87-1-201, 87-1-217, 87-1-225, 87-1-301, 87-1-304, 87-3-127, 87-3-128, 87-5-713, 87-5-725, and 87-6-106, Montana Fish, Wildlife and Parks (FWP) and the Fish and Wildlife Commission are both authorized and charged with the duties of protecting persons and personal property from damage and depredation resulting from ingress or attack by wildlife. The goal of the **Mountain Lion Depredation and Control Guidelines** is to minimize damage to property and to prevent public safety problems. For the purpose of these Guidelines, a Public Safety Problem is defined as: Any situation where a FWP employee (or their agent) reasonably determines that a human has been physically injured or killed as a result of contact with a mountain lion, that an attack by a mountain lion has resulted in the loss of livestock or pets, or that the continued presence of a mountain lion poses a threat to human safety.

Any mountain lion that is lethally removed by FWP or its agents must be retained and transferred to the Montana Livestock Loss Board for sale or auction pursuant to MCA 2-15-3110 to 3113 and 87-1-217.

I. DEFINITIONS

The following are definitions designed to standardize the vocabulary used in the investigation and reporting of human/lion conflicts. It is important that the same terms be used to describe the different types of encounters that occur between humans and mountain lions. The definitions presented here are similar to those used in other western states.

<u>Sighting</u>: A visual observation of a mountain lion.

<u>Encounter</u>: An unexpected direct meeting between a human and a mountain lion without incident or the recurrent sighting in close proximity to human development or habitation.

<u>Incident</u>: A conflict between a human and mountain lion that may have serious results (i.e. a mountain lion killing or attempting to kill a pet that must be forced to back down).

<u>Attack</u>: When a human is bodily injured or killed by physical contact by a mountain lion.

<u>Nuisance Lion</u>: A mountain lion involved in encounters and incidents (i.e. pet attacks, continual presence around humans or areas of high human activity, presence near where children are or will be shortly) but is showing no aggression and/or flees when encountered by a human.

<u>Depredation Lion</u>: A mountain lion involved in the killing of livestock.

<u>Aggressive Lion</u>: An individual mountain lion exhibiting aggressive behavior towards humans including a mountain lion that attacks a person without provocation, intentionally approaches humans or fails to retreat when a human takes aggressive actions, or forces a human to take evasive action to avoid attack.

<u>Livestock Depredation</u>: Livestock attacked or killed by a mountain lion.

<u>Conflict</u>: When a human and mountain lion are involved in an encounter, incident or attack, or a mountain lion is determined to be aggressive, a nuisance, or involved in livestock depredation.

II. DOCUMENTATION OF HUMAN-MOUNTAIN LION CONFLICTS

1. Each FWP Region is responsible for responding to reports of mountain lion damage to property and human-mountain lion encounters, incidents, or attacks. Regional Supervisors shall ensure the following procedures are used upon FWP employees' receiving such reports.

    a. Obtain the name, address, and telephone number of the person making the report, the person receiving the call, and the time and date of the call.

    b. Record if the conflict involves an Encounter, an Incident, an Attack, or a Livestock Depredation.

    c. If a Livestock Depredation is reported or suspected, record the number and type of livestock involved and immediately contact the USDA APHIS Wildlife Services agent with responsibility for the area where the incident occurred.

    d. Record the number of mountain lions involved, its/their age class (if known), and the date and time of the conflict.

    e. If the conflict was a human Attack, record the name, sex, and age of the victim, location, and the extent of any injuries. IMMEDIATELY notify both 911 (if that had not already occurred) AND FWP Enforcement Division staff, who will determine whether a Wildlife Human Attack Response Team (WHART) should be convened to initiate a response following WHART Guidelines (Appendix 4).

    f. Record the location of Encounters, Incidents, and Attacks as specifically as possible, including physical address and/or geospatial coordinates.

    g. For Encounters, Incidents, or Attacks, record the behavior of the mountain lion and what, if any, action was taken on the part of the person involved.

    h. Record which FWP personnel responded to investigate, the time and date of the response, and what action(s) was taken.

2. A description of all reported conflict incidents, including the above information, will be entered into the designated FWP wildlife conflict database as soon as possible following receipt of the report. This record should be updated when the situation is resolved.

III. FWP ACTIONS TO BE TAKEN WHEN HUMAN-MOUNTAIN LION CONFLICTS ARE REPORTED

A FWP employee shall promptly investigate the validity, severity, and details of any reported human-mountain lion conflict. The following guidelines are the minimum actions required of FWP when conflicts are reported. Additional investigation into a conflict, or higher levels of response, will occur at the discretion of the Regional Supervisor and the investigating FWP employee. All interviews and investigations will begin no more than 48 hours after the conflict is reported in accordance with MCA 87-1-225.

CONFLICT	ACTIONS THAT WILL BE TAKEN
Encounter	The reporting party will be contacted and the details of the Encounter (Section II. (1)) will be documented. If the mountain lion involved in the conflict is determined to be a Nuisance Lion, the responding FWP employee and Regional Supervisor may choose to either haze (i.e. using less-than-lethal ammunition or pursued with trained dogs) or lethally remove the mountain lion(s). This decision will depend on the severity of the conflict, location, pattern of habituation, escalation of behavior, or other relevant factors. FWP may also issue a kill permit to the affected landowner. Mountain lions shall not be captured and translocated under any circumstances. Information about the Encounter and FWP's response will be

recorded and entered into the FWP wildlife conflict database.

Incident

A FWP employee will conduct an on-site investigation to determine if the mountain lion involved in the conflict is Aggressive. All Aggressive mountain lions will be lethally removed as soon as is practical. If the mountain lion involved in the conflict is determined to be a Nuisance Lion, the responding FWP employee and Regional Supervisor may choose to either haze (i.e. using less-than-lethal ammunition or pursued with trained dogs) or lethally remove the mountain lion(s) depending on the severity of the conflict, location, pattern of habituation, escalation of behavior, or other relevant factors. FWP may also issue a kill permit to the affected landowner. Mountain lions shall not be captured and translocated under any circumstances. Information about the Encounter and FWP's response will be recorded and entered into the FWP wildlife conflict database.

Depredation

Attack

The FWP employee receiving a report of an Attack will record the name, sex, and age of the victim, location, and the extent of any injuries. The employee will IMMEDIATELY notify both 911 (if that had not already occurred) AND FWP Enforcement Division staff, who will determine whether a Wildlife Human Attack Response Team should be convened and to initiate a response following WHART Guidelines. Measures to lethally remove the offending mountain lion(s) will be immediately initiated.

Montana law (MCA 87-6-106) gives private citizens the right to kill, without fear of penalty, any mountain lion attacking, killing, or threatening to kill a person or livestock. Private citizens may also kill a mountain lion that is in the act of attacking or killing a domestic dog. A person who kills a mountain lion under this statute must notify a FWP employee within 72 hours and surrender the carcass to FWP.

Livestock

If a Livestock Depredation is reported or suspected, the FWP employee will record the number and type of livestock involved, location, livestock owner's contact information, and number of mountain lions involved. The FWP employee will then immediately contact the USDA APHIS Wildlife Services agent with responsibility for the area where the incident occurred and convey that information. That Wildlife Services agent will be responsible for investigating the reported Livestock Depredation and determining the appropriate response.

Montana law (MCA 87-6-106) gives private citizens the right to kill, without fear of penalty, any mountain lion attacking, killing, or threatening to kill a person or livestock. Private citizens may also kill a mountain lion that is in the act of attacking or killing a domestic dog. A person who kills a mountain lion under this statute must notify a FWP employee within 72 hours and surrender the carcass to FWP.

These **Mountain Lion Depredation and Control Guideline**s are effective upon Fish and Wildlife Commission's adoption of this Strategy and supersede any previously-adopted versions.

APPENDIX 4

GUIDELINES FOR RESPONDING TO WILDLIFE ATTACKS THAT RESULT IN HUMAN INJURY OR DEATH: "WHART" GUIDELINES

(Note: attachments and appendices referenced in this section are available from FWP Enforcement Division, upon request)

INTRODUCTION:

This document will provide guidance in the process for handling responses to a wildlife attack that causes human injury or death. In order to provide guidance and standardize the response of FWP personnel, the following guidelines will direct their actions in dealing with wildlife attacks on humans that result in injury and/or death to human victims. It may not be possible to follow these guidelines in every situation.

FIRST RESPONDERS:

An immediate field response is required for any wildlife-caused human injury or death.

In the event of an attack, the responding department employee may take any action necessary that is in the scope of the employee's authority to protect public safety. The following steps should be taken:

1. Secure the safety of the public (ensure proper medical aid for the victim, aid with evacuation of injured or other members of a group, and assist other agencies in removal of the body or victim. Identify the victim's name, address and phone number).

2. Report the incident to 911.

3. Immediately notify the Regional FWP Enforcement Personnel and/or WHART Team personnel.

4. FWP Enforcement personnel confirm as wildlife attack and identify species if possible; if the offending animal is identified the wild animal may be humanely killed, if possible and depending on the circumstances. Always consult with WHART Team leader and Warden Captain if unsure of actions to be taken with offending animal.

5. If medical, rescue and/or sheriff department personnel arrive on scene before the FWP Incident Commander, advise them about the Wildlife Attack-Victim Kit (Attachment 1 (follow guidelines in Appendix B)) for collecting possible animal saliva stains or hair that might be on the victim prior to cleaning the victim's wounds.

INITIATE THE INCIDENT COMMAND SYSTEM:

- **If a human death or injury has occurred, the Region Warden Captain or other Enforcement designee shall:**

  - Respond to the scene and assume the lead role for FWP.

  - The County Sheriff's Office/Coroner has the initial lead in the investigation of a human death and at first FWP's role is that of assistance.

  - The Warden Captain or Enforcement designee holds FWP Incident Commander responsibility and authority over the scene, locating the animal, its resultant carcass, and any other physical evidence from the attack.

  - The Warden Captain or Enforcement designee will ensure proper collection, transfer, and disposition of all physical evidence and reports.

  - Contact the appropriate landownership, enforcement, and wildlife governing agencies. (refer to Inter Agency Jurisdiction Section)

- **The first warden on the scene shall secure the area in order:**

    1. To protect as much of the immediate attack scene as possible, establishing a perimeter as large as possible to avoid contamination or destruction of any evidence.

    2. To determine the offending animal and preserve as much on-scene evidence as possible.

    3. The area should be excluded from public access by using flagging tape and/or signing stating "Do Not Enter".

    4. To preserve the scene, one entry and exit port should be established; only essential personnel should be permitted in the area.

- **If a warden is the first Law Enforcement person on the scene of an attack:**

    1. Their first notification should be the County Sheriff's Office.

    2. If it appears the incident is an attack only and not a death then FWP will be the lead agency in the in the incident investigation.

    3. If it appears there is a human death the warden should advise the Sheriff's Office that a Coroner will be needed.

    4. In the case of a death it should be clear that FWP would at first be in an assisting role to the Sheriff's Office and the Coroner, but FWP's guidelines should be followed as closely as possible.

    5. In a human fatality FWP is the lead agency in processing and handling of the offending wildlife, if possible in coordination with County Sheriff/Coroner.

    6. Before the victim's body is removed and with the Coroners assistance it is important to use a Wildlife Attack -Victim Kit (Appendix B and Attachment 1) to collect any forensic evidence possible.

    7. The lead investigator must complete Attachment 5 and the investigator will need to work with the Coroner, in the case of a fatality, or the attending physician/medical personnel, in the case of an attack incident victim(s).

- **Once the Warden Captain or the Enforcement designee has been notified of an attack that resulted in human injury or death, he/she must:**

    1. Notify the FWP Regional Supervisor (who will notify the Directors Office), FWP Regional Wildlife Management Specialist, and Regional Wildlife Manager.

    2. Notify the Regional Information Officer to give him/her initial information; and once notified the Regional Information Officer will become the only contact with the media for FWP in regards to this incident.

- **Upon arrival on scene the Warden Captain or Enforcement designee will set up an area outside the initial crime scene as the Command Post.**

- **The Warden Captain or Enforcement designee will formulate a plan for the systematic investigation of the scene using available manpower and resources.**

- **If applicable, (not all FWP regions utilize this option) activate the Wildlife Human Attack Response Team (WHART).**

- **If applicable, the Enforcement designee, shall assume the role of WHART leader, and shall coordinate and delegate duties before attending the attack site and are responsible for the management of the attack scene from the FWP purview.**

- **WHART Team members will wear fluorescent vests with the Team leader wearing a different color fluorescent vest. These vests will designate the team to other individuals and aid in the safety of the team members while at the scene.**

At this time, with the information available, options should be discussed with the Regional Supervisor and Regional Wildlife Manager on what actions to take regarding the offending animal.

- The suggested approach to a systematic investigation would include:

   1. The Warden Captain, Enforcement designee, or WHART leader will appoint a lead investigator. The lead investigator will conduct the investigation and write a final report of their investigation findings. The lead investigator will be responsible for the investigation at the attack site. The lead investigator should have a team of at least three individuals to assist in evidence collection, securing the scene and photographing and logging of all evidence. One of those members should be the Wildlife Management Specialist or another person that is very experienced in wildlife behavior. The lead investigator shall refer to the "Forensic Guidelines/Wildlife attack Scene Investigation/Management" (Appendix A) as a possible baseline to conduct their investigation and should have attended at least one Wildlife Human Attack Response Training Course. If necessary, the Warden Captain, Enforcement Designee, or WHART leader will appoint a lead person for the potential capture or kill of the offending animal. This person will have to rely on their experience/training and the resources available to locate the offending animal as quickly as possible. If necessary, the animal may be tranquilized, captured, held for DNA testing, or removed from the system. The animal should be shot in the body, to preserve the head. After capture, use the Wildlife Carcass Collection Kit (Appendix C & Attachment 4) and the Wildlife Attack Kit for Sampling the Animal and Evidence at the Scene (Appendix D & Attachment 4); and the listed Appendices are only suggested guides. The animal should be handled with rubber gloves. The animal must be treated as evidence and be handled to protect the animal's external body from loss of bloodstains or other such physical evidence originating from the victim. Tape paper or cloth bags over the head and paws. Plug wounds with tight gauze to minimize contamination of the animal with its own blood. Place the carcass inside a protective durable body bag. Avoid dragging the carcass, if possible.

   2. The Warden Captain, Enforcement Designee, or WHART leader will designate the task of notifying surrounding residences or persons of the event and safety concerns (usually wildlife biologists will be assigned this task). Land/area closures will have to involve the agencies or owner of the property involved, but it is necessary to restrict public access to the area until the attack scene has been processed and the offending animal captured.

   3. The Warden Captain, Enforcement Designee, or WHART leader will notify the FWP Wildlife Lab of the attack and inform them that a potential offending animal will be transported as quickly as possible to the FWP Lab directly for forensic examination/necropsy. A completed Wildlife Attack Response Form and Animal Necropsy form (Appendix E & F) must accompany the animal to the lab.

   4. In a fatal incident, the Warden Captain and the Enforcement Designee or WHART leader will meet with the County Coroner/Sheriff, the Regional Supervisor, and the Regional Information Officer to decide how and who will approach the victim's family to gather information and to provide the family with investigation information.

5. In an attack incident, the Warden Captain, Enforcement Designee, or WHART leader will determine who will meet with the victim and family members in order to obtain investigative information and disseminate investigation information to the victim and family. All interviews will follow Attachment 2 and should be recorded when possible.

6. All media questions should be directed to the Regional Information Officer and the media will not be allowed on scene or at the Command Post.

7. Once evidence has been collected, photographed and logged (Attachment 3) it shall be placed into the custody of the Regional Investigator or designee, who will maintain the evidence and the chain of custody.

8. The Warden Captain, Enforcement designee, or WHART leader will keep a log of the events (Attachment 6) as they occurred at the Command Post and this will be included in the final report.

INFORMATION/MEDIA:
In conjunction with the wildlife attack response guidelines listed above, the following provides direction and guidance in handling the media in the event of an attack on a human by wildlife.

1. The Regional Information Officer (RIO) will be notified immediately in the event of an attack resulting in human injury from big game animals or any wildlife species. Complete and accurate information should be provided to the RIO and inquiries regarding the incident should be handled by the RIO or Regional Supervisor. Media consultation regarding human injuries resulting from federally listed grizzly bears will be coordinated with the USFWS.

   Incidents that result from interaction with other species of wildlife will be managed by personnel within the region where the incident occurred.

   County Sheriff/Coroner's offices will coordinate all media regarding status of human deaths. In the event of taking of federally listed species by a public citizen, the USFWS will coordinate all media responses.

2. Department personnel should be helpful and open with the media, but specific questions relating to the incident should be directed to the RIO. It is imperative that appropriate personnel with the region be kept current on developments and all involved receive the same information.

3. A fact sheet and/or statewide press release may be developed with information about the situation and provided upon request to media outlets.

4. If deemed necessary by the RIO, Regional Supervisor, Regional Wildlife Manager, and Warden Captain or Enforcement designee a press conference may be initiated.

5. Appropriate information will be made available to citizens in the vicinity of the incident upon request.

GUIDELINE TRAINING:
The Warden Captain or Enforcement designee is responsible for the distribution of the guidelines and annual training of employees that may be involved in wildlife attack incidents, including first responders.

The Warden Captain or Enforcement designee will assign employees to contact County Sheriff and Search and Rescue teams, and Land Management agencies and offer a review of the guidelines and training.

Employees' responding to attacks incidences, as investigators on the incident shall participate in at least one formal Wildlife Attack Response training each year. The FWP Law Enforcement Program Training Officer will approve these annual Wildlife Human Attack Response training sessions.

INTER-AGENCY JURSIDICTION ISSUES:

U.S. Fish and Wildlife Service, Grizzly Bear Recovery Coordinator

U.S. Fish and Wildlife Service Special Agent – based upon their administrative region.

Land Management Agencies, Companies and Emergency Response Teams

The Warden Captain or Enforcement designee will delegate FWP personnel to work in advance with the US Forest Service, BLM, DNRC, Plum Creek Timber, and Search & Rescue Teams to arrange for FWP to enact temporary closures or post warnings to protect the public at a moment's notice as needed. This advanced contact will include an offer to review the guidelines with all contacts. As soon as possible thereafter, FWP would follow up with the agencies to keep them informed and address any issues or concerns. Search and Rescue Teams and other emergency response units should be kept abreast of special risks on recreational lands in the event that these teams are deployed while the risk of a dangerous bear encounter is elevated.

County Sheriff and Coroner

If an FWP employee is the first on the scene of an attack their first notification should be the County Sheriff's Office and if it appears there is a human death the employee should advise the Sheriff's Office that a Coroner will be needed. In the event of a human death, FWP will, at first, be in an assisting role to the Sheriff's Office and the Coroner, but FWP's guidelines should be followed as closely as possible. Before the victim's body is removed and with the Coroners assistance it is important to use a Wildlife Attack -Victim Kit (Attachment 1 & Attachment 5) to collect any forensic evidence possible.

FINAL REPORT:

The Warden Captain, Enforcement designee, or WHART leader is responsible for producing a final report. The report will include a detailed Investigative Summary of the events, how it was resolved, evidence and lab reports, and conclusions. The completed report will be reviewed and released in a timely manner by the Regional Supervisor.

Attachments and WHART Appendices (available from FWP Enforcement Division, upon request)

Attachment 1 – First Responder Kit Wildlife Attack Human Victim Kit

Attachment 2 – Interview with Victim and/or witness

Attachment 3 – Wildlife Attack Scene Evidence Log

Attachment 4 – Wildlife Attack Animal Evidence Collection Information

Attachment 5 – Wildlife Attack Victim Evidence Collection Information

Attachment 6 – Events/Contacts Log

Appendix A – Wildlife Attack Scene Investigations/ Management

Appendix B – Carnivore Attack Victim Sampling Kit

Appendix C – Carnivore Carcass Collection Kit

Appendix D – Carnivore Attack Animal Sampling Kit

Appendix E – Wildlife Attack Response Form

Appendix F – Wildlife Attack Animal Necropsy Form

MONTANA MOUNTAIN LION LICENSE SALES, PRICE, AND REVENUE, 1973 - 2015

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
License Type											
Res. Mountain Lion	**241**	**259**	**286**	**517**	**574**	**639**	**614**	**787**	**893**	**1,027**	**1,021**
Nonres. Mountain Lion	**70**	**92**	**120**	**70**	**102**	**123**	**111**	**61**	**69**	**91**	**132**
Total	**311**	**351**	**406**	**587**	**676**	**762**	**725**	**848**	**962**	**1,118**	**1,153**
Fees											
Res. Mountain Lion	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5
Nonres. Mountain Lion	$25	$25	$25	$25	$25	$25	$25	$100	$100	$100	$100
License Revenue											
Res. Mountain Lion	$1,205	$1,295	$1,430	$2,585	$2,870	$3,195	$3,070	$3,935	$4,465	$5,135	$5,105
Nonres. Mountain Lion	$1,750	$2,300	$3,000	$1,750	$2,550	$3,075	$2,775	$6,100	$6,900	$9,100	$13,200
Total	$2,955	$3,595	$4,430	$4,335	$5,420	$6,270	$5,845	$10,035	$11,365	$14,235	$18,305

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
License Type											
Res. Mountain Lion	**984**	**1,045**	**916**	**1,237**	**1,210**	**1,250**	**1,708**	**1,687**	**2,038**	**2,535**	**2,984**
Nonres. Mountain Lion	**80**	**92**	**92**	**108**	**109**	**98**	**136**	**146**	**177**	**230**	**258**
Total	**1,064**	**1,137**	**1,008**	**1,345**	**1,319**	**1,348**	**1,844**	**1,833**	**2,215**	**2,765**	**3,242**
Fees											
Res. Mountain Lion	$10	$10	$10	$10	$10	$10	$10	$10	$13	$13	$15
Nonres. Mountain Lion	$300	$300	$300	$300	$320	$320	$320	$320	$320	$320	$320
License Revenue											
Res. Mountain Lion	$9,840	$10,450	$9,160	$12,370	$12,100	$12,500	$17,080	$16,870	$26,494	$32,955	$44,760
Nonres. Mountain Lion	$24,000	$27,600	$27,600	$32,400	$34,880	$31,360	$43,520	$46,720	$56,640	$73,600	$82,560
Total	$33,840	$38,050	$36,760	$44,770	$46,980	$43,860	$60,600	$63,590	$83,134	$106,555	$127,320

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
License Type											
Res. Mountain Lion	3,056	3,287	4,297	5,421	5,886	5,138	5,116	6,337	6,130	6,635	6,688
Nonres. Mountain Lion	270	301	394	510	519	493	421	281	282	312	311
Res. Hound Training									207	289	340
Total	3,326	3,588	4,691	5,931	6,405	5,631	5,537	6,618	6,619	7,236	7,339
Fees											
Res. Mountain Lion	$15	$15	$15	$15	$15	$15	$15	$15	$15	$15	$15
Nonres. Mountain Lion	$320	$320	$320	$320	$320	$320	$320	$320	$320	$320	$320
Res. Hound Training									$5	$5	$5
License Revenue											
Res. Mountain Lion	$45,840	$49,305	$64,455	$81,315	$88,290	$77,070	$76,740	$95,055	$91,950	$99,525	$100,320
Nonres. Mountain Lion	$86,400	$96,320	$126,080	$163,200	$166,080	$157,760	$134,720	$89,920	$90,240	$99,840	$99,520
Res. Hound Training									$1,035	$1,445	$1,700
Total	$132,240	$145,625	$190,535	$244,515	$254,370	$234,830	$211,460	$184,975	$183,225	$200,810	$201,540

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
License Type											
Res. Mountain Lion	3,331	3,922	3,529	3,832	3,535	3,788	4,964	5,007	5,016	5,221	4,912
Nonres. Mountain Lion	133	145	167	179	170	172	182	286	240	292	271
Res. Hound Training	488	423	471	424	441	405	352	364	389	239	216
Total	3,952	4,490	4,167	4,435	4,146	4,365	5,498	5,657	5,645	5,752	5,399
Fees											
Res. Mountain Lion	$19	$19	$19	$19	$19	$19	$19	$19	$19	$19	$19
Nonres. Mountain Lion	$320	$320	$320	$320	$320	$320	$320	$320	$320	$320	$320
Res. Hound Training	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5
License Revenue											
Res. Mountain Lion	$63,289	$74,518	$67,051	$72,808	$67,165	$71,972	$94,316	$95,133	$95,304	$99,199	$93,328
Nonres. Mountain Lion	$42,560	$46,400	$53,440	$57,280	$54,400	$55,040	$58,240	$91,520	$76,800	$93,440	$86,720
Res. Hound Training	$2,440	$2,115	$2,355	$2,120	$2,205	$2,025	$1,760	$1,820	$1,945	$1,195	$1,080
Total	$108,289	$123,033	$122,846	$132,208	$123,770	$129,037	$154,316	$188,473	$174,049	$193,834	$181,128

APPENDIX 6

APPLICABLE MONTANA STATUTE AND ADMINISTRATIVE RULES

Montana Code Annotated statutes and Administrative Rules of Montana describing FWP and the Fish & Wildlife Commission's authorities and responsibilities, regulation of the licensed hunting of mountain lions, enumeration of stock grower and personal protection rights, and disclosure of information.

2-15-3110. (Temporary) Livestock loss board - purpose, membership, and qualifications

(1) There is a livestock loss board. The purpose of the board is to administer the programs called for in the Montana gray wolf conservation and management plan, the Montana mountain lion management plan, and the Montana grizzly bear management plan and established in 2-15-3111 through 2-15-3113, with funds provided through the accounts established in 81-1-110, in order to minimize losses caused by wolves, mountain lions, and grizzly bears to livestock producers and to reimburse livestock producers for livestock losses from wolf, mountain lion, and grizzly bear predation.

(2) The board consists of five members, appointed by the governor, as follows:

(a) three members who are actively involved in the livestock industry and who have knowledge and experience with regard to wildlife impacts or management; and

(b) two members of the general public who are or have been actively involved in wildlife conservation or wildlife management and who have knowledge and experience with regard to livestock production or management.

(3) The board is designated as a quasi-judicial board for the purposes of 2-15-124. Notwithstanding the provisions of 2-15-124(1), the governor is not required to appoint an attorney to serve as a member of the board.

(4) The board is allocated to the department of livestock for administrative purposes only as provided in 2-15-121.

(5) The board shall adopt rules to implement the provisions of 2-15-3110 through 2-15-3114 and

(6) The board shall prioritize grants for prevention of wolf and grizzly bear predation over those for mountain lion predation.

2-15-3111. Livestock loss reduction program

The livestock loss board shall establish and administer a program to cost-share with individuals or incorporated entities in implementing measures to prevent wolf, mountain lion, and grizzly bear predation on livestock, including:

(1) eligibility requirements for program participation;

(2) application procedures for program participation and procedures for awarding grants for wolf, mountain lion, and grizzly bear predation prevention measures, subject to grant priorities and the availability of funds;

(3) criteria for the selection of projects and program participants, which may include establishment of grant priorities based on factors such as chronic depredation, multiple depredation incidents, single depredation incidents, and potential high-risk geographical or habitat location;

(4) grant guidelines for prevention measures on public and private lands, including:

(a) grant terms that clearly set out the obligations of the livestock producer and that provide for a term of up to 12 months subject to renewal based on availability of funds, satisfaction of program requirements, and prioritization of the project;

(b) cost-share for prevention measures, which may be a combination of grant and livestock producer responsibility, payable in cash or in appropriate services, such as labor to install or implement preventive measures, unless the board adjusts the cost-share because of extenuating circumstances related to chronic or multiple depredation; and

(c) proactive preventive measures, including but not limited to fencing, fladry, night penning, increased human presence in the form of livestock herders and riders, guard animals, providing hay and dog food, rental of private land or alternative pasture allotments, delayed turnouts, and other preventive measures as information on new or different successful prevent ion measures becomes available; and

(5) reporting requirements for program participants to assist in determining the effectiveness of loss reduction relative to each grant."

2-15-3112. Livestock loss mitigation program - definitions

The livestock loss board shall establish and administer a program to reimburse livestock producers for livestock losses caused by wolves, mountain lions, and grizzly bears, subject to the following provisions:

(1) The board shall establish eligibility requirement s for reimbursement, which must provide that all Montana livestock producers are eligible for coverage for losses by wolves, mountain lions, and grizzly bears to cattle, swine, horses, mules, sheep, goats, llamas, and livestock guard animals on state, federal, and private land and on tribal land that is eligible through agreement pursuant to 2-15-3113(2).

(2) Confirmed and probable livestock losses must be reimbursed at an amount not to exceed fair market value as determined by the board.

(3) Other losses may be reimbursed at rates determined by the board.

(4) A claim process must be established to be used when a livestock producer suffers a livestock loss for which wolves, mountain lions, or grizzly bears may be responsible. The claim process must set out a clear and concise method for documenting and processing claims for reimbursement for livestock losses.

(5) A process must be established to allow livestock producers to appeal reimbursement decisions. A producer may appeal a staff adjuster's decision by notifying the staff adjuster and the board in writing, stating the reasons for the appeal and providing documentation supporting the appeal. If the documentation is incomplete, the board or a producer may consult with the U.S. department of agriculture wildlife services to complete the documentation. The board may not accept any appeal on the question of whether the loss was or was not a confirmed or probable loss because that final determination lies solely with the U.S. department of agriculture wildlife services and may not be changed by the board. The board shall hold a hearing on the appeal within 90 days of receipt of the written appeal, allowing the staff adjuster and the producer to present their positions. A decision must be rendered by the board within 30 days after the hearing. The producer must be notified in writing of the board's decision.

(6) As used in this section, the following definitions apply:

(a) "Confirmed" means reasonable physical evidence that livestock was actually attacked or killed by a wolf, mountain lion, or grizzly bear, including but not limited to the presence of bite marks indicative of the spacing of tooth punctures of wolves, mountain lions, or grizzly bears and associated subcutaneous hemorrhaging and tissue damage indicating that the attack occurred while the animal was alive, feeding patterns on the carcass, fresh tracks, scat, hair rubbed off on fences or brush, eyewitness accounts, or other physical evidence that allows a reasonable inference of wolf, mountain lion, or grizzly bear predation on an animal that has been largely consumed.

(b) "Fair market value" means:

(i) for commercial sheep more than 1 year old, the average price of sheep of similar age and sex paid at the most recent Billings livestock sale ring or other ring as determined by the board;

(ii) for commercial lambs, the average market weaning value;

(iii) for registered sheep, the average price paid to the specific breeder for sheep of similar age and sex during the past year at public or private sales for that registered breed;

(iv) for commercial cattle more than 1 year old, the average price of cattle of similar age and sex paid at the most recent Billings livestock sale ring or other ring as determined by the board;

(v) for commercial calves, the average market weaning value;

(vi) for registered cattle, the average price paid to the owner for cattle of similar age and sex during the past year at public or private sales for that registered breed;

(vii) for other registered livestock, the average price paid to the producer at public or private sales for animals of similar age and sex. A producer may provide documentation that a registered animal has a fair market value in excess of the average price, in which case the board shall seek additional verification of the value of the animal from independent sources. If the board determines that the value of that animal is greater than the average price, then the increased value must be accepted as the fair market value for that animal.

(viii) for other livestock, the average price paid at the most recent public auction for the type of animal lost or the replacement price as determined by the board.

(c) "Probable" means the presence of some evidence to suggest possible predation but a lack of sufficient evidence to clearly confirm predation by a particular species. A kill may be classified as probable depending on factors including but not limited to recent confirmed predation by the suspected depredating species in the same or a nearby area, recent observation of the livestock by the owner or the owner's employees, and telemetry monitoring data, sightings, howling, or fresh tracks suggesting that the suspected depredating species may have been in the area when the depredation occurred."

2-15-3113. Additional powers and duties of livestock loss board

(1) The livestock loss board shall:
(a) process claims;
(b) seek information necessary to ensure that claim documentation is complete;
(c) provide payments authorized by the board for confirmed and probable livestock losses, along with a written explanation of payment;
(d) submit monthly and annual reports to the board of livestock summarizing claims and expenditures and the results of action taken on claims and maintain files of all claims received, including supporting documentation;
(e) provide information to the board of livestock regarding appealed claims and implement any decision by the board;
(f) prepare the annual budget for the board; and
(g) provide proper documentation of staff time and expenditures.
(2) The livestock loss board may enter into an agreement with any Montana tribe, if the tribe has adopted a wolf, mountain lion, or grizzly bear management plan for reservation lands that is consistent with the state wolf, mountain lion, or grizzly bear management plan, to provide that tribal lands within reservation boundaries are eligible for mitigation grants pursuant to 2-15-3111 and that livestock losses on tribal lands within reservation boundaries are eligible for reimbursement payments pursuant to 2-15-3112.
(3) The livestock loss board shall:
(a) coordinate and share information with state, federal, and tribal officials, livestock producers, nongovernmental organizations, and the general public in an effort to reduce livestock losses caused by wolves, mountain lions, and grizzly bears;
(b) establish an annual budget for the prevention, mitigation, and reimbursement of livestock losses caused by wolves, mountain lions, and grizzly bears;
(c) perform or contract for the performance of periodic program audits and reviews of program expenditures, including payments to Individuals, incorporated entities, and producers who receive loss reduction grants and reimbursement payments;
(d) adjudicate appeals of claims;
(e) investigate alternative or enhanced funding sources, including possible agreements with public entities and private wildlife or livestock organizations that have active livestock loss reimbursement programs in place;
(f) meet as necessary to conduct business; and
(g) report annually to the governor, the legislature, members of the Montana congressional delegation, the board of livestock, the fish and wildlife commission, and the public regarding results of the programs established in 2-15-3111 through 2-15-3113.
(4) The livestock loss board may sell or auction any carcasses or parts of carcasses from wolves or mountain lions received pursuant to 87-1-217. The proceeds, minus the costs of the sale including the preparation of the carcass or part of the carcass for sale, must be deposited into the livestock loss reduction and mitigation special revenue account established in 81-1-110 and used for the purposes of 215-3111 through 2-15-3114."

81-1-110. Livestock loss reduction and mitigation accounts

(1) There are livestock loss reduction and mitigation special revenue accounts administered by the department within the state special revenue fund and the federal special revenue fund established in 17-2-102.
(2)(a) All state proceeds allocated or budgeted for the purposes of 2-15-3110 through 2-15-3114, 81-1-110, and 81-1-111, except those transferred to the account provided for in 81-1-112 [or 81-1-113] or appropriated to the department of livestock, must be deposited in the state special revenue account provided for in subsection (1) of this section.
(b) Money received by the state in the form of gifts, grants, reimbursements, or allocations from any source intended to be used for the purposes of 2-15-3111 through 2-15-3113 must be deposited in the appropriate account provided for in subsection (1) of this section.
(c) All federal funds awarded to the state for compensation for wolf, mountain lion, or grizzly bear depredations on livestock must be deposited in the federal special revenue

account provided for in subsection (1) for the purposes of 2-15-3112.
(3) The livestock loss board may spend funds in the accounts only to carry out the provisions of 2-15-3111 through 2-15-3113.

87-1-201. Powers And Duties

(1) Except as provided in subsection (11), the department shall supervise all the wildlife, fish, game, game and nongame birds, waterfowl, and the game and fur-bearing animals of the state and may implement voluntary programs that encourage hunting access on private lands and that promote harmonious relations between landowners and the hunting public. The department possesses all powers necessary to fulfill the duties prescribed by law and to bring actions in the proper courts of this state for the enforcement of the fish and game laws and the rules adopted by the department.
(2) Except as provided in subsection (11), the department shall enforce all the laws of the state regarding the protection, preservation, management, and propagation of fish, game, fur-bearing animals, and game and nongame birds within the state.
(3) The department has the exclusive power to spend for the protection, preservation, management, and propagation of fish, game, fur-bearing animals, and game and nongame birds all state funds collected or acquired for that purpose, whether arising from state appropriation, licenses, fines, gifts, or otherwise. Money collected or received from the sale of hunting and fishing licenses or permits, from the sale of seized game or hides, from fines or damages collected for violations of the fish and game laws, or from appropriations or received by the department from any other sources is under the control of the department and is available for appropriation to the department.
(4) The department may discharge any appointee or employee of the department for cause at any time.
(5) The department may dispose of all property owned by the state used for the protection, preservation, management, and propagation of fish, game, fur-bearing animals, and game and nongame birds that is of no further value or use to the state and shall turn over the proceeds from the sale to the state treasurer to be credited to the fish and game account in the state special revenue fund.
(6) The department may not issue permits to carry firearms within this state to anyone except regularly appointed officers or wardens.
(7) Except as provided in subsection (11), the department is authorized to make, promulgate, and enforce reasonable rules and regulations not inconsistent with the provisions of Title 87, chapter 2, that in its judgment will accomplish the purpose of chapter 2.
(8) The department is authorized to promulgate rules relative to tagging, possession, or transportation of bear within or outside of the state.
(9) (a) The department shall implement programs that:
(i) manage wildlife, fish, game, and nongame animals in a manner that prevents the need for listing under 87-5-107 or under the federal Endangered Species Act, 16 U.S.C. 1531, et seq.;
(ii) manage listed species, sensitive species, or a species that is a potential candidate for listing under 87-5-107 or under the federal Endangered Species Act, 16 U.S.C. 1531, et seq., in a manner that assists in the maintenance or recovery of those species;
(iii) manage elk, deer, and antelope populations based on habitat estimates determined as provided in 87-1-322 and maintain elk, deer, and antelope population numbers at or below population estimates as provided in 87-1-323. In implementing an elk management plan, the department shall, as necessary to achieve harvest and population objectives, request that land management agencies open public lands and public roads to public access during the big game hunting season.
(iv) in accordance with the forest management plan required by 87-1-622, address fire mitigation, pine beetle infestation, and wildlife habitat enhancement giving priority to forested lands in excess of 50 contiguous acres in any state park, fishing access site, or wildlife management area under the department's jurisdiction.
(b) In maintaining or recovering a listed species, a sensitive species, or a species that is a potential candidate for listing, the department shall seek, to the fullest extent possible, to balance maintenance or recovery of those species with the social and economic impacts of species maintenance or recovery.
(c) Any management plan developed by the department pursuant to this subsection (9) is subject to the requirements of Title 75, chapter 1, part 1.

(d) This subsection (9) does not affect the ownership or possession, as authorized under law, of a privately held listed species, a sensitive species, or a species that is a potential candidate for listing.
(10) The department shall publish an annual game count, estimating to the department's best ability the numbers of each species of game animal, as defined in 87-2-101, in the hunting districts and administrative regions of the state. In preparing the publication, the department may incorporate field observations, hunter reporting statistics, or any other suitable method of determining game numbers. The publication must include an explanation of the basis used in determining the game count.
(11) The department may not regulate the use or possession of firearms, firearm accessories, or ammunition, including the chemical elements of ammunition used for hunting. This does not prevent:
(a) the restriction of certain hunting seasons to the use of specified hunting arms, such as the establishment of special archery seasons;
(b) for human safety, the restriction of certain areas to the use of only specified hunting arms, including bows and arrows, traditional handguns, and muzzle loading rifles;
(c) the restriction of the use of shotguns for the hunting of deer and elk pursuant to 87-6-401(1)(f);
(d) the regulation of migratory game bird hunting pursuant to 87-3-403; or
(e) the restriction of the use of rifles for bird hunting pursuant to 87-6-401(1)(g) or (1)(h).

87-1-214. Disclosure Of Information - Legislative Finding - Large Predators

(1) Except for information that is required by law to be reported to state or federal officials, the department may not disclose any information that identifies any person who has lawfully taken a large predator as defined in 87-1-217 during a hunt without the written consent of the person affected. Information that may not be disclosed includes but is not limited to a person's name, address, phone number, date of birth, social security number, and driver's license number.
(2) The legislature finds that the prohibition on disclosure of information pursuant to subsection (1) is necessary to protect an individual's privacy, safety, and welfare.

87-1-217. Policy For Management Of Large Predators - Legislative Intent
(1) In managing large predators, the primary goals of the department, in the order of listed priority, are to:
(a) protect humans, livestock, and pets;
(b) preserve and enhance the safety of the public during outdoor recreational and livelihood activities; and
(c) preserve citizens' opportunities to hunt large game species.
(2) With regard to large predators, it is the intent of the legislature that the specific provisions of this section concerning the management of large predators will control the general supervisory authority of the department regarding the management of all wildlife.
(3) For the management of wolves in accordance with the priorities established in subsection (1), the department may use lethal action to take problem wolves that attack livestock if the state objective for breeding pairs has been met. For the purposes of this subsection, "problem wolves" means any individual wolf or pack of wolves with a history of livestock predation.
(4) The department shall work with the livestock loss board and the United States department of agriculture wildlife services to establish the conditions under which carcasses or parts of carcasses from wolves or mountain lions are retrieved during management activities and when those carcasses or parts of carcasses are made available to the livestock loss board for sale or auction pursuant to 2-15-3113.
(5) The department shall ensure that county commissioners and tribal governments in areas that have identifiable populations of large predators have the opportunity for consultation and coordination with state and federal agencies prior to state and federal policy decisions involving large predators and large game species.
(6) As used in this section:
(a) "consultation" means to actively provide information to a county or tribal government regarding proposed policy decisions on matters that may have a harmful effect on agricultural production or livestock operations or that may pose a risk to human health or safety in that county or on those tribal lands and to seek information and advice from counties or tribal governments on these matters;
(b) "large game species" means deer, elk, mountain sheep, moose, antelope, and mountain goats; and

(c) “large predators” means bears, mountain lions, and wolves.

87-1-225. Regulation of Wild Animals Damaging Property - Public Hunting Requirements

(1) Subject to the provisions of subsection (2), a landowner is eligible for game damage assistance under subsection (3) if the landowner:
(a) allows public hunting during established hunting seasons; or
(b) does not significantly reduce public hunting through imposed restrictions.
(2) The department may provide game damage assistance when public hunting on a landowner’s property has been denied because of unique or special circumstances that have rendered public hunting inappropriate.
(3) Within 48 hours after receiving a request or complaint from any landholder or person in possession and having charge of any land in the state that wild animals of the state, protected by the fish and game laws and regulations, are doing damage to the property or crops on the property, the department shall investigate and arrange to study the situation with respect to damage and depredation. The department may then decide to open a special season on the game or, if the special season method is not feasible, the department may destroy the animals causing the damage. The department may authorize and grant the holders of the property permission to kill or destroy a specified number of the animals causing the damage. A wild, ferocious animal damaging property or endangering life is not covered by this section.

87-1-271. Annual Lottery Of Hunting Licenses - Proceeds Dedicated To Hunting Access Enhancement

(1) The commission may issue through a lottery one license each year for each of the following:
(a) deer;
(b) elk;
(c) shiras moose;
(d) mountain sheep;
(e) mountain goat;
(f) wild buffalo or bison;
(g) antelope; and
(h) mountain lion.
(2) The restriction in 87-2-702(4) that a person who receives a moose, mountain goat, or mountain sheep special license is not eligible to receive another license for that species for the next 7 years does not apply to a person who receives a license through a lottery conducted pursuant to this section.
(3) The commission shall establish rules regarding:
(a) the conduct of the lottery authorized in this section;
(b) the use of licenses issued through the lottery; and
(c) the price of lottery tickets.
(4) Except as provided in 87-2-903, all proceeds from a lottery conducted pursuant to this section must be used by the department for hunting access enhancement programs and law enforcement.

87-1-301. Powers Of Commission

(1) Except as provided in subsections (7) and (8), the commission:
(a) shall set the policies for the protection, preservation, management, and propagation of the wildlife, fish, game, furbearers, waterfowl, nongame species, and endangered species of the state and for the fulfillment of all other responsibilities of the department related to fish and wildlife as provided by law;
(b) shall establish the hunting, fishing, and trapping rules of the department;
(c) except as provided in 23-1-111 and 87-1-303(3), shall establish the rules of the department governing the use of lands owned or controlled by the department and waters under the jurisdiction of the department;
(d) must have the power within the department to establish wildlife refuges and bird and game preserves;
(e) shall approve all acquisitions or transfers by the department of interests in land or water, except as provided in 23-1-111 and 87-1-209(2) and (4);
(f) except as provided in 23-1-111, shall review and approve the budget of the department prior to its transmittal to the office of budget and program planning;
(g) except as provided in 23-1-111, shall review and approve construction projects that have an estimated cost of more than $1,000 but less than $5,000;
(h) shall manage elk, deer, and antelope populations based on habitat estimates determined as provided in 87-1-322 and maintain elk, deer, and antelope population numbers at or below population estimates as provided in 87-1-323. In developing or implementing an elk management plan,

the commission shall consider landowner tolerance when deciding whether to restrict elk hunting on surrounding public land in a particular hunting district. As used in this subsection (1)(h), "landowner tolerance" means the written or documented verbal opinion of an affected landowner regarding the impact upon the landowner's property within the particular hunting district where a restriction on elk hunting on public property is proposed.

(i) shall set the policies for the salvage of antelope, deer, elk, or moose pursuant to 87-3-145; and

(j) shall comply with, adopt policies that comply with, and ensure the department implements in each region the provisions of state wildlife management plans adopted following an environmental review conducted pursuant to Title 75, chapter 1, parts 1 through 3.

(2) The commission may adopt rules regarding the use and type of archery equipment that may be employed for hunting and fishing purposes, taking into account applicable standards as technical innovations in archery equipment change.

(3) The commission may adopt rules regarding the establishment of special licenses or permits, seasons, conditions, programs, or other provisions that the commission considers appropriate to promote or enhance hunting by Montana's youth and persons with disabilities.

(4) (a) The commission may adopt rules regarding nonresident big game combination licenses to:

(i) separate deer licenses from nonresident elk combination licenses;

(ii) set the fees for the separated deer combination licenses and the elk combination licenses without the deer tag;

(iii) condition the use of the deer licenses; and

(iv) limit the number of licenses sold.

(b) The commission may exercise the rulemaking authority in subsection (4)(a) when it is necessary and appropriate to regulate the harvest by nonresident big game combination license holders:

(i) for the biologically sound management of big game populations of elk, deer, and antelope;

(ii) to control the impacts of those elk, deer, and antelope populations on uses of private property; and

(iii) to ensure that elk, deer, and antelope populations are at a sustainable level as provided in 87-1-321 through 87-1-325.

(5) (a) Subject to the provisions of 87-2-115, the commission may adopt rules establishing license preference systems to distribute hunting licenses and permits:

(i) giving an applicant who has been unsuccessful for a longer period of time priority over an applicant who has been unsuccessful for a shorter period of time; and

(ii) giving a qualifying landowner a preference in drawings. As used in this subsection (5)(a), "qualifying landowner" means the owner of land that provides some significant habitat benefit for wildlife, as determined by the commission.

(b) The commission shall square the number of points purchased by an applicant per species when conducting drawings for licenses and permits.

(6) (a) The commission may adopt rules to:

(i) limit the number of nonresident mountain lion hunters in designated hunting districts; and

(ii) determine the conditions under which nonresidents may hunt mountain lion in designated hunting districts.

(b) The commission shall consider, but is not limited to consideration of, the following factors:

(i) harvest of lions by resident and nonresident hunters;

(ii) history of quota overruns;

(iii) composition, including age and sex, of the lion harvest;

(iv) historical outfitter use;

(v) conflicts among hunter groups;

(vi) availability of public and private lands; and

(vii) whether restrictions on nonresident hunters are more appropriate than restrictions on all hunters.

(7) The commission may not regulate the use or possession of firearms, firearm accessories, or ammunition, including the chemical elements of ammunition used for hunting. This does not prevent:

(a) the restriction of certain hunting seasons to the use of specified hunting arms, such as the establishment of special archery seasons;

(b) for human safety, the restriction of certain areas to the use of only specified hunting arms, including bows and arrows, traditional handguns, and muzzle loading rifles;

(c) the restriction of the use of shotguns for the hunting of deer and elk pursuant to 87-6-401(1)(f);

(d) the regulation of migratory game bird hunting pursuant to 87-3-403; or

(e) the restriction of the use of rifles for bird hunting pursuant to 87-6-401(1)(g) or (1)(h).

(8) Pursuant to 23-1-111, the commission does not oversee department activities related to the administration of state parks, primitive parks, state recreational areas, public camping grounds, state historic sites, state monuments, and other heritage and recreational resources, land, and water administered pursuant to Title 23, chapter 1, and Title 23, chapter 2, parts 1, 4, and 9.

87-1-304. Fixing Of Seasons And Bag And Possession Limits

(1) Subject to the provisions of 87-5-302 and subsection (7) of this section, the commission may:

(a) fix seasons, bag limits, possession limits, and season limits;

(b) open or close or shorten or lengthen seasons on any species of game, bird, fish, or fur-bearing animal as defined by 87-2-101;

(c) declare areas open to the hunting of deer, antelope, elk, moose, sheep, goat, mountain lion, bear, wild buffalo or bison, and wolf by persons holding an archery stamp and the required license, permit, or tag and designate times when only bows and arrows may be used to hunt deer, antelope, elk, moose, sheep, goat, mountain lion, bear, wild buffalo or bison, and wolf in those areas;

(d) subject to the provisions of 87-1-301(7), restrict areas and species to hunting with only specified hunting arms, including bow and arrow, for the reasons of safety or of providing diverse hunting opportunities and experiences; and

(e) declare areas open to special license holders only and issue special licenses in a limited number when the commission determines, after proper investigation, that a special season is necessary to ensure the maintenance of an adequate supply of game birds, fish, or animals or fur-bearing animals. The commission may declare a special season and issue special licenses when game birds, animals, or fur-bearing animals are causing damage to private property or when a written complaint of damage has been filed with the commission by the owner of that property. In determining to whom special licenses must be issued, the commission may, when more applications are received than the number of animals to be killed, award permits to those chosen under a drawing system. The procedures used for awarding the permits from the drawing system must be determined by the commission.

(2) The commission may adopt rules governing the use of livestock and vehicles by archers during special archery seasons.

(3) Subject to the provisions of 87-5-302 and subsection (7) of this section, the commission may divide the state into fish and game districts and create fish, game, or fur-bearing animal districts throughout the state. The commission may declare a closed season for hunting, fishing, or trapping in any of those districts and later may open those districts to hunting, fishing, or trapping.

(4) The commission may declare a closed season on any species of game, fish, game birds, or fur-bearing animals threatened with undue depletion from any cause. The commission may close any area or district of any stream, public lake, or public water or portions thereof to hunting, trapping, or fishing for limited periods of time when necessary to protect a recently stocked area, district, water, spawning waters, spawn-taking waters, or spawn-taking stations or to prevent the undue depletion of fish, game, fur-bearing animals, game birds, and nongame birds. The commission may open the area or district upon consent of a majority of the property owners affected.

(5) The commission may authorize the director to open or close any special season upon 12 hours' notice to the public.

(6) The commission may declare certain fishing waters closed to fishing except by persons under 15 years of age. The purpose of this subsection is to provide suitable fishing waters for the exclusive use and enjoyment of juveniles under 15 years of age, at times and in areas the commission in its discretion considers advisable and consistent with its policies relating to fishing.

(7) In an area immediately adjacent to a national park, the commission may not:

(a) prohibit the hunting or trapping of wolves; or

(b) close the area to wolf hunting or trapping unless a wolf harvest quota established by the commission for that area has been met.

87-2-101. Definitions

As used in Title 87, chapter 3, and this chapter, unless the context clearly indicates otherwise, the following definitions apply:

(1) "Angling" or "fishing" means to take or the act of a person possessing any instrument, article, or substance for

the purpose of taking fish in any location that a fish might inhabit.
(2) (a) "Bait" means any animal matter, vegetable matter, or natural or artificial scent placed in an area inhabited by wildlife for the purpose of attracting game animals or game birds.
(b) The term does not include:
(i) decoys, silhouettes, or other replicas of wildlife body forms;
(ii) scents used only to mask human odor; or
(iii) types of scents that are approved by the commission for attracting game animals or game birds.
(3) "Fur-bearing animals" means marten or sable, otter, muskrat, fisher, mink, bobcat, lynx, wolverine, northern swift fox, and beaver.
(4) "Game animals" means deer, elk, moose, antelope, caribou, mountain sheep, mountain goat, mountain lion, bear, and wild buffalo.
(5) "Game fish" means all species of the family Salmonidae (chars, trout, salmon, grayling, and whitefish); all species of the genus Sander (sandpike or sauger and walleyed pike or yellowpike perch); all species of the genus Esox (northern pike, pickerel, and muskellunge); all species of the genus Micropterus (bass); all species of the genus Polyodon (paddlefish); all species of the family Acipenseridae (sturgeon); all species of the genus Lota (burbot or ling); the species Perca flavescens (yellow perch); all species of the genus Pomoxis (crappie); and the species Ictalurus punctatus (channel catfish).
(6) "Hunt" means to pursue, shoot, wound, kill, chase, lure, possess, or capture or the act of a person possessing a weapon, as defined in 45-2-101, or using a dog or a bird of prey for the purpose of shooting, wounding, killing, possessing, or capturing wildlife protected by the laws of this state in any location that wildlife may inhabit, whether or not the wildlife is then or subsequently taken. The term includes an attempt to take by any means, including but not limited to pursuing, shooting, wounding, killing, chasing, luring, possessing, or capturing.
(7) "Migratory game birds" means waterfowl, including wild ducks, wild geese, brant, and swans; cranes, including little brown and sandhill; rails, including coots; Wilson's snipes or jacksnipes; and mourning doves.
(8) "Nongame wildlife" means any wild mammal, bird, amphibian, reptile, fish, mollusk, crustacean, or other animal not otherwise legally classified by statute or regulation of this state.
(9) "Open season" means the time during which game birds, game fish, game animals, and fur-bearing animals may be lawfully taken.
(10) "Person" means an individual, association, partnership, or corporation.
(11) "Predatory animals" means coyote, weasel, skunk, and civet cat.
(12) "Trap" means to take or participate in the taking of any wildlife protected by the laws of the state by setting or placing any mechanical device, snare, deadfall, pit, or device intended to take wildlife or to remove wildlife from any of these devices.
(13) "Upland game birds" means sharp-tailed grouse, blue grouse, spruce (Franklin) grouse, prairie chicken, sage hen or sage grouse, ruffed grouse, ring-necked pheasant, Hungarian partridge, ptarmigan, wild turkey, and chukar partridge.
(14) "Wild buffalo" means buffalo or bison that have not been reduced to captivity.

87-2-506. Restrictions On Hunting Licenses

Restrictions on hunting licenses. (1) The department may prescribe by rule the number of hunting licenses to be issued. Any license sold may be restricted to a specific administrative region, hunting district, or other designated area and may specify the species, age, and sex to be taken and the time period for which the license is valid.
(2) When the number of valid resident applications for big game licenses or permits of a single class or type exceeds the number of licenses or permits the department desires to issue in an administrative region, hunting district, or other designated area, then the number of big game licenses or permits issued to nonresident license or permit holders in the region, district, or area may not exceed 10% of the total issued.
(3) Disabled veterans who meet the qualifying criteria provided in 87-2-817(1) must be provided a total of 50 Class A-3 deer A tags, 50 Class A-4 deer B tags, 50 Class B-7 deer A tags, 50 Class B-8 deer B tags, and 50 special antelope licenses annually, which may be used within the administrative region, hunting district, or other designated area of the disabled veteran's choice, except in a region, district, or area where the number of licenses are less than

the number of applicants, in which case qualifying disabled veterans are eligible for no more than 10% of the total licenses for that region, district, or area.

87-2-507. Class D-1-Nonresident Mountain Lion License

Except as otherwise provided in this chapter, a person who is not a resident, as defined in 87-2-102, but who is 12 years of age or older or who will turn 12 years old before or during the season for which the license is issued may, upon payment of a fee of $320, receive a Class D-1 license that entitles a holder who is 12 years of age or older to hunt mountain lion and possess the carcass of the mountain lion as authorized by department rules.

87-2-508. Class D-2-Resident Mountain Lion License

Except as otherwise provided in this chapter, a person who is a resident, as defined in 87-2-102, and who is 12 years of age or older or who will turn 12 years old before or during the season for which the license is issued may, upon payment of a fee of $19, receive a Class D-2 license that entitles a holder who is 12 years of age or older to hunt mountain lion and possess the carcass of the mountain lion as authorized by department rules.

87-2-521. Class D-3-Resident Hound Training License

A person who is a resident, as defined in 87-2-102, and who is 12 years of age or older or who will turn 12 years old before or during the season for which the license is issued, upon payment of a fee of $5, may receive a Class D-3 hound training license that entitles the holder to use a dog or dogs to aid in pursuing mountain lions or bobcats during the training season established in 87-6-404(4).

87-2-702. Restrictions On Special Licenses - Availability Of Bear And Mountain Lion Licenses

(1) A person who has killed or taken any game animal, except a deer, an elk, or an antelope, during the current license year is not permitted to receive a special license under this chapter to hunt or kill a second game animal of the same species.

(2) The commission may require applicants for special permits authorized by this chapter to obtain a valid big game license for that species for the current year prior to applying for a special permit.

(3) Except as provided in 87-2-815, a person may take only one grizzly bear in Montana with a license authorized by 87-2-701.

(4) (a) Except as provided in 87-1-271(2) and 87-2-815, a person who receives a moose, mountain goat, or limited mountain sheep license, as authorized by 87-2-701, with the exception of an antlerless moose or an adult ewe game management license issued under 87-2-104, is not eligible to receive another special license for that species for the next 7 years. For the purposes of this subsection (4)(a), "limited mountain sheep license" means a license that is valid for an area in which the number of licenses issued is restricted.

(b) Except as provided in 87-1-271(2) and 87-2-815, a person who takes a mountain sheep using an unlimited mountain sheep license, with the exception of a mountain sheep taken pursuant to an adult ewe license, as authorized by 87-2-701, is not eligible to receive another special license for that species for the next 7 years. For the purposes of this subsection (4)(b), "unlimited mountain sheep license" means a license that is valid for an area in which the number of licenses issued is not restricted.

(5) An application for a wild buffalo or bison license must be made on the same form and is subject to the same license application deadline as the special license for moose, mountain goat, and mountain sheep.

(6) (a) Licenses for spring bear hunts must be available for purchase at department offices after April 15 of any license year. However, a person who purchases a license for a spring bear hunt after April 15 of any license year may not use the license until 24 hours after the license is issued.

(b) Licenses for fall bear hunts must be available for purchase at department offices after August 31 of any license year. However, a person who purchases a license for a fall bear hunt after August 31 of any license year may not use the license until 24 hours after the license is issued.

(7) Licenses for mountain lion hunts must be available for purchase at department offices after August 31 of any license year. However, a person who purchases a license for a mountain lion hunt after August 31 of any license year may not use the license until 5 days after the license is issued.

87-2-806. Taking Fish Or Game For Scientific Purposes

(1) An accredited representative of an accredited school, college, university, or other institution of learning or

of any governmental agency or an individual who is investigating a scientific subject for which collection is necessary, may take, kill, capture, and possess for that purpose any birds, fish, or animals protected by Montana law or department or commission rule if a permit to collect is authorized by the department. Under the provisions of this section, a permittee may take, kill, and capture protected or unprotected birds, fish, or animals in any way that is approved by the department, except by the use of explosives. A permittee may not take, kill, or capture more birds, fish, or animals than are necessary for the investigation. A collection permit may not be given for a species for which a taking is prohibited by statute or rule.
(2) A person who desires to engage in the scientific investigation shall apply to the department for a permit. The department may require the applicant to submit a plan of operations that includes the purpose for the collection, collection methodology to be employed, and the qualifications of the person who will be doing the collecting. The department may set qualifications for persons to whom permits are issued and may place special authorizations or special requirements and limitations on any permit. If the department is satisfied of the good faith and qualifications of the applicant and that the collecting is necessary for a valid purpose, the department:
(a) may issue a permit that must place a time limit on the collections and may place a restriction on the number of birds, fish, or animals to be taken; and
(b) shall require a report of the numbers and species of animals taken by collection areas.
(3) The department may deny a permit if:
(a) the applicant is not qualified to make the scientific investigation;
(b) the proposed collecting is not necessary for the proposed scientific investigation;
(c) the method of collecting is not appropriate;
(d) the proposed collecting may threaten the viability of the species; or
(e) there is no valid reason or need for the proposed scientific investigation.
(4) By December 31 of each year, a permittee shall submit a report to the department that lists the species and numbers of individuals of the species taken and locations from which collections were taken. A permittee who fails to file a required report may not be issued another permit.
(5) The permittee shall pay $50 for the permit, except that a permittee who is a representative of an accredited school, college, university, or other institution of learning or of any governmental agency is exempt from payment of the fee.
(6) The permittee may not take, have, or capture any other or greater number of birds, fish, or animals than are allowed in the permit.
(7) A representative of an accredited school, college, university, or other institution of learning or an individual permittee who may have various students or associates assisting throughout the year may apply to have a permit issued that includes the individual and the students or associates. The department shall approve the qualifications of a student or an associate and the level of supervision required by the primary permittee. The students or associates, when carrying a copy of the permit, have the same authorizations and restrictions as the primary applicant. The primary applicant shall keep a record of all students or associates listed on the permit and of the dates when each student or associate conducts a collection under the permit. The primary applicant is responsible for the students' or associates' use of the permit or copies of the permit.

87-3-127. Taking Of Stock-killing Animals

(1) Livestock owners, their agents, or employees of the department or a federal agency may use dogs in pursuit of stock-killing black bears, stock-killing mountain lions, and stock-killing bobcats. Other means of taking stock-killing black bears, stock-killing mountain lions, and stock-killing bobcats may be used, except the deadfall.
(2) Traps used in capturing bears must be inspected twice each day with the inspections 12 hours apart.

87-3-128. Exceptions - Department Personnel

The provisions of this chapter relating to methods of herding, driving, capturing, taking, locating, or concentrating of fish, game animals, game birds, or fur-bearing animals do not apply to the department or to any employee thereof while acting within the scope and course of the powers and duties of the department.

87-5-713. Control Of Wildlife Species Permitted To Be Transplanted Or Introduced

Any wildlife species listed in 87-5-714 or approved by the commission for introduction or transplantation may be introduced or transplanted only subject to a plan developed by the department to assure that the population can be controlled if any unforeseen harm should occur.

87-5-725. Notification Of Transplantation Or Introduction Of Wildlife

Notification of transplantation or introduction of wildlife.
(1) When the decision to introduce or transplant a wolf, bear, or mountain lion is made pursuant to this part, the department shall:
(a) provide public notice on its website and, when practical, by personal contact in the general area where the animal is released; and
(b) notify the public through print and broadcast media of the availability of release information on the department's website.
(2) Prior permission from the landowner is required before any animal may be transplanted onto private property.

87-6-106. Lawful Taking To Protect Livestock Or Person

(1) This chapter may not be construed to impose, by implication or otherwise, criminal liability for the taking of wildlife protected by this title if the wildlife is attacking, killing, or threatening to kill a person or livestock. However, for purposes of protecting livestock, a person may not kill or attempt to kill a grizzly bear unless the grizzly bear is in the act of attacking or killing livestock.
(2) A person may kill or attempt to kill a wolf or mountain lion that is in the act of attacking or killing a domestic dog.
(3) A person who, under this section, takes wildlife protected by this title shall notify the department within 72 hours and shall surrender or arrange to surrender the wildlife to the department.

87-6-404. Unlawful Use Of Dog While Hunting

(1) Except as provided in subsections (3) through (6), a person may not:
(a) chase any game animal or fur-bearing animal with a dog; or
(b) purposely, knowingly, or negligently permit a dog to chase, stalk, pursue, attack, or kill a hooved game animal. If the dog is not under the control of an adult at the time of the violation, the owner of the dog is personally responsible. A defense that the dog was allowed to run at large by another person is not allowable unless it is shown that at the time of the violation, the dog was running at large without the consent of the owner and that the owner took reasonable precautions to prevent the dog from running at large.
(2) Except as provided in subsection (3)(d), a peace officer, game warden, or other person authorized to enforce the Montana fish and game laws who witnesses a dog chasing, stalking, pursuing, attacking, or killing a hooved game animal may destroy that dog on public land or on private land at the request of the landowner without criminal or civil liability.
(3) A person may:
(a) take game birds during the appropriate open season with the aid of a dog;
(b) hunt mountain lions during the winter open season, as established by the commission, with the aid of a dog or dogs;
(c) hunt bobcats during the trapping season, as established by the commission, with the aid of a dog or dogs; and
(d) use trained or controlled dogs to chase or herd away game animals or fur-bearing animals to protect humans, lawns, gardens, livestock, or agricultural products, including growing crops and stored hay and grain. The dog may not be destroyed pursuant to subsection (2).
(4) A resident who possesses a Class D-3 resident hound training license may pursue mountain lions and bobcats with a dog or dogs during a training season from December 2 of each year to April 14 of the following year.
(5) (a) A person with a valid hunting license issued pursuant to Title 87, chapter 2, may use a dog to track a wounded game animal during an appropriate open season. Any person using a dog in this manner:
(i) shall maintain physical control of the dog at all times by means of a maximum 50-foot lead attached to the dog's collar or harness;
(ii) during the general season, whether handling or accompanying the dog, shall wear hunter orange material pursuant to 87-6-414;
(iii) may carry any weapon allowed by law;
(iv) may dispose of the wounded game animal using any weapon allowed by the valid hunting license; and
(v) shall tag an animal that has been reduced to possession in accordance with 87-6-411.

(b) Dog handlers tracking a wounded game animal with a dog are exempt from licensing requirements under Title 87, chapter 2, as long as they are accompanied by the licensed hunter who wounded the game animal.
(6) Any person or association organized for the protection of game may run field trials at any time upon obtaining written permission from the director.
(7) A person who is convicted of or who forfeits bond or bail after being charged with a violation of this section shall be fined not less than $50 or more than $1,000 or be imprisoned in the county detention center for not more than 6 months, or both. In addition, the person, upon conviction or forfeiture of bond or bail, may be subject to forfeiture of any current hunting, fishing, or trapping license issued by this state and the privilege to hunt, fish, and trap in this state or to use state lands, as defined in 77-1-101, for recreational purposes for a period of time set by the court.
(8) A violation of this section may also result in an order to pay restitution pursuant to 87-6-905 through 87-6-907.

87-6-701. Failure To Report Or Tattoo

Failure to report or tattoo. (1) Any bear, wolf, tiger, mountain lion, or coyote that is captured alive to be released later or that is held in captivity for any purpose must be reported to the department within 3 days of the capture or commencement of captivity.
(2) Each animal reported as required in subsection (1) must be permanently tattooed or otherwise permanently identified in a manner that will provide positive individual identification of the animal. No tattoo is required if the animal is subject to a permanent, individual identification process by another state or federal agency.
(3) Any person holding a bear, wolf, tiger, mountain lion, or coyote in captivity shall immediately report to the department any death, escape, release, transfer of custody, or other disposition of the animal.
(4) A person convicted of a violation of this section shall be fined not less than $50 or more than $1,000 or be imprisoned in the county detention center for not more than 6 months, or both. In addition, the person, upon conviction or forfeiture of bond or bail, may be subject to forfeiture of any current hunting, fishing, or trapping license issued by this state and the privilege to hunt, fish, or trap in this state or to use state lands, as defined in 77-1-101, for recreational purposes for a period of time set by the court.

ADMINISTRATIVE RULES OF MONTANA

12.3.105 Limitation On Number Of Hunting Licenses

(1) When the department sets a limitation or quota for the number of hunting licenses to be issued in any hunting district or other designated area, resident applicants shall receive at least 90% of the total hunting licenses to be issued for that game species in that district. When the number of resident applicants totals less than 90% of the quota for that district, all resident applicants shall receive a hunting license for that game species.
(2) The remaining licenses will be issued to the nonresident applicants for that district by drawing.
(3) Any thereafter remaining licenses for that district shall be issued in such manner as the director determines.

12.3.111. License/Permit Prerequisites

(1) Deer. All valid resident conservation license holders and all valid nonresident big game (class B-10) and deer combination (class B-11) license holders may apply for deer permits. However, a holder of a B-11 license obtained through a landowner sponsor can only apply for a deer permit where the permitted area includes the landowner sponsor's property and can only use the permit for hunting on the landowner sponsor's property. All valid conservation license holders may apply for deer B licenses. All nonresident conservation license holders who do not possess a B-10 or B-11 license may apply for a nonresident deer A (B-7) license, if available.
(2) Elk. Only persons who possess a valid resident A-5 elk license or a valid nonresident class B-10 license may apply for a special elk permit or A-7 license.
(3) All valid conservation license holders may apply for moose, sheep, goat, deer B, antelope, black bear, grizzly bear, buffalo, swan, and mountain lion licenses, and turkey permits/licenses. Resident sportsman and nonresident big game combination license holders may not apply for a black bear license if the black bear license is included as part of the combination license.
(4) A nonresident who uses a class B-11 landowner sponsored license in conjunction with a deer permit or a wild turkey license may hunt only on the landowner

sponsor's property. A nonresident who possesses a class B-1 landowner sponsored license and who hunts turkey off the landowner sponsor's property must also hold a class B-1, nonresident bird license valid statewide which is different than the restrictive B-1 license contained in the B-11 license. A nonresident holding both the class B-11 license and the class B-1 license valid statewide may purchase only the number of wild turkey licenses specified on the annual regulations for that season.

12.3.116 Moose, Sheep, And Goat Licenses

(1) The department shall issue moose, sheep, and goat licenses as described in sections 87-2-701 and 87-2-506 , MCA according to the following policy and procedures:

(a) Applicants for moose and goat must specify one choice for a hunting district. However, for bighorn sheep, an applicant may specify a second choice.

(b) Application for unlimited sheep must be postmarked no later than May 1. The deadline may be extended by the department if necessary to provide adequate time for the applicants to apply.

(2) The following procedure will be used when allocating 10% license opportunities for nonresidents in moose, sheep and goat drawings:

(a) The total regional license quota, by species and region, will be used to determine 10% nonresident quota.

(b) Nonresident license allocations will be applied to those hunting districts and season types with a quota of ten or more in the tentative regulations.

(c) Any remaining license allocation will be put, on a rotating basis, in those districts and season types with a quota of less than ten of the tentative regulations.

(d) If no district in a region has a quota of ten or more licenses on the tentative regulations, all of the nonresident license authority will be allocated as described in (c).

(e) If a region has a total quota of less than ten, no nonresident license allocations will be made for that region.

12.3.140 Application For Drawings

(1) The deadline date for the moose, sheep, and goat special drawings is on or before May 1. The deadline date for elk, deer and antelope special drawings is on or before June 1. All applications for participation in any special permit/license drawing, except drawings under ARM 12.9.801 (damage hunts) provided for by these regulations must be postmarked by the U.S. Postal Service on or before the deadline date of the current license year, or delivered by private mail service on or before the deadline date; or if personally delivered, received in the Helena Fish, Wildlife and Parks office by 5:00 p.m., on the deadline date of the current license year. If the deadline date for application for any license or drawings, as set by the department, falls on a Sunday or state holiday, that date shall be automatically extended to 5:00 p.m. of the next full work day. The deadline may be extended by the department if necessary to provide adequate time for the applicants to apply.

(2) The department shall reject an application for any permit/license drawing or for surplus, mountain lion, black bear, trapping, buffalo, or grizzly bear licenses if:

(a) application is not made on the current year's form provided by the department;

(b) applicant fails to provide mandatory information on the form;

(c) applicant fails to sign the application; or

(d) applicant fails to submit the proper fee. The department will not accept personal checks from nonresidents for nonresident license applications and drawing fees.

(3) Submittal of more than one application for any one drawing by an individual will disqualify that individual's applications from the drawing for which the multiple applications were submitted.

(4) No corrections or changes may be made after the department has received the drawing application, except those types that can be made without contacting the applicant. These include:

(a) adding hunter safety numbers;

(b) moving valid district choices up to replace invalid choices;

(c) eliminating species choices on those applications that are short money when the shortfall is the amount for that species; and

(d) adjusting party applications to insure party consistency.

(5) Any category of correction made by the department must be applied to all applications. In addition, the department will accept corrections on the applications of those seeking landowner preference. Unless otherwise provided by these rules, all drawings will take place in Helena.

(6) All applications for participation in buffalo, spring grizzly bear, swan and turkey drawings must be

postmarked by the U.S. Postal Service by the advertised deadline date, or delivered by private mail service on or before the date to the address indicated for the particular drawing which is being applied for.

(7) If an application for any species is rejected by the department pursuant to this rule:

(a) the application must not be included in the procedure for awarding the permits/licenses applied for;

(b) the applicant must not be awarded a bonus point for that drawing for that species; and

(c) the drawing fee, and any bonus point fee, once the application is entered into the drawing, will be retained by the department. Applications not processed in the drawing because of errors will be returned to the applicant with all fees.

12.3.185. Super-tag Hunting Licenses

(1) The department will issue one deer, one elk, one shiras moose, one mountain sheep, one mountain goat, one wild buffalo or bison, one antelope, and one mountain lion hunting license each year through a lottery. These hunting licenses are known as “super-tags.”

(2) For each species, an unlimited number of chances to draw a super-tag will be sold at $5 per chance. Chances will be sold by license agents as defined in ARM 12.3.201A or through the department authorized web site on the internet. License agents will receive a commission of $0.50 for each super-tag transaction for a species. A transaction in this case means the purchase of one or more super-tag chances of the same species at one time. Individuals purchasing a ticket through the internet shall pay a convenience fee in accordance with the current internet provider contract.

(3) After the completion of the special license drawing for a species, the department will conduct a computerized drawing selecting randomly the super-tag winner for that species. The department shall issue the appropriate super-tag to the lottery winner.

(4) Only a person legally able to be licensed under current Montana statutes may purchase chances to draw a super-tag or use a super-tag. A person must possess a valid conservation license to be eligible to purchase a chance to draw a super-tag.

(5) The super-tag is valid for the taking of one animal of the species for which it is issued and is valid only for the current license year. A super-tag may be used in any legally described hunting district open for hunting of that species. A super-tag may be used only during the legal hunting season for the species for which it is issued. The person using the super-tag may use it only during a hunting district’s open season and is subject to all hunting regulations, including special weapons regulations, that apply to a hunting district. However, if a hunting district requires a permit to hunt that species in that district, a super-tag can be used without the special permit.

(6) In the event that a person who drew a license or purchased a license is also drawn for the super-tag for the same species, the person must surrender the license to the department before receiving the super-tag. The department will refund the license fee paid by the winner of the super-tag. The person winning the super-tag shall retain any accumulated bonus points for that species.

(7) The super-tag is a nontransferable license.

APPENDIX 7

MONTANA MOUNTAIN LION IPM MODEL CODE

The Montana Mountain Lion Integrated Population Model was constructed using the statistical programming language R (R Development Core Team 2013).

```
model{
     #  Naming
     #  Parameter names begin with a capitalized letter
     #  Data are all lower case
     #  Indexing always follows - DAU, Year, Age, Sex
     #  If fewer indices are needed they follow the same order despite
     #   omissions

     #  Priors
     #  Pregnancy rates - [age, sex, mean:tau]
     Preg[1] ~ dnorm(preg[3,1,1], preg[3,1,2])T(0,1)
     Preg[2] ~ dnorm(preg[4,1,1], preg[4,1,2])T(0,1)

     #  Fetus Counts - [age, sex, mean:tau]
     FC[1] ~ dnorm(fc[3,1,1], fc[3,1,2])T(0,3)
     FC[2] ~ dnorm(fc[4,1,1], fc[4,1,2])T(0,3)

     #  Survival
     #  Priors on survival - First age class, not available for harvest, so
     #   survival is the only parameter
     #  Informative prior stored as probability
     yS_mu ~ dnorm(means[1,1,1], means[1,1,2])T(0,1)

     #  Transform probability back to real scale and use as the intercept
     for(u in 1:ndau){
       for(yr in 1:nyr){
         for(s in 1:2){
           logit(S[u,yr, 1, s]) <- log(yS_mu/(1 - yS_mu))
           H[u,yr,1,s] <- 0
           O[u,yr,1,s] <- 0
         }
       }
     }

     #  Priors on survival - Juveniles - two sexes, cause specific mortality
     for(s in 1:2){
       #  Informative priors are stored as probabilities
       jS_tmp[1,s] ~ dnorm(means[2,s,1], means[2,s,2])T(0, 1)
       jS_tmp[2,s] ~ dnorm(meanh[2,s,1], meanh[2,s,2])T(0, 1)
       jS_tmp[3,s] ~ dnorm(meano[2,s,1], meano[2,s,2])T(0, 1)

       #  Transform probability to real scale
       for(i in 1:3){
         jS_mu[i,s] <- log(jS_tmp[i,s]/jS_tmp[3,s])
       }

       #  Describe rate as function of linear predictor and define link
       #   function
       for(u in 1:ndau){
         for(yr in 1:nyr){
           log(jS_log[u,yr,s]) <- jS_mu[1,s]
           log(jH_log[u,yr,s]) <- jS_mu[2,s]
```

```
      log(jO_log[u,yr,s]) <- 0
      jSums[u,yr,s] <- jS_log[u,yr,s] + jH_log[u,yr,s] + jO_log[u,yr,s]
      S[u,yr,2,s] <- jS_log[u,yr,s]/jSums[u,yr,s]
      H[u,yr,2,s] <- jH_log[u,yr,s]/jSums[u,yr,s]
      O[u,yr,2,s] <- jO_log[u,yr,s]/jSums[u,yr,s]
    }
  }
}

#  Priors on survival - SubAdults - two sexes, cause specific mortality
for(s in 1:2){
  #  Informative priors are stored as probabilities
  sS_tmp[1,s] ~ dnorm(means[3,s,1], means[3,s,2])T(0, 1)
  sS_tmp[2,s] ~ dnorm(meanh[3,s,1], meanh[3,s,2])T(0, 1)
  sS_tmp[3,s] ~ dnorm(meano[3,s,1], meano[3,s,2])T(0, 1)

  #  Transform probability to real scale
  for(i in 1:3){
    sS_mu[i,s] <- log(sS_tmp[i,s]/sS_tmp[3,s])
  }

  #  Describe rate as function of linear predictor and define link
  #   function
  for(u in 1:ndau){
    for(yr in 1:nyr){
      log(sS_log[u,yr,s]) <- sS_mu[1,s]
      log(sH_log[u,yr,s]) <- sS_mu[2,s]
      log(sO_log[u,yr,s]) <- 0
      sSums[u,yr,s] <- sS_log[u,yr,s] + sH_log[u,yr,s] + sO_log[u,yr,s]
      S[u,yr,3,s] <- sS_log[u,yr,s]/sSums[u,yr,s]
      H[u,yr,3,s] <- sH_log[u,yr,s]/sSums[u,yr,s]
      O[u,yr,3,s] <- sO_log[u,yr,s]/sSums[u,yr,s]
    }
  }
}

#  Priors on survival - Adults, two sexes, cause specific mortality
for(s in 1:2){
  #  Informative priors are stored as probabilities
  aS_tmp[1,s] ~ dnorm(means[4,s,1], means[4,s,2])T(0, 1)
  aS_tmp[2,s] ~ dnorm(meanh[4,s,1], meanh[4,s,2])T(0, 1)
  aS_tmp[3,s] ~ dnorm(meano[4,s,1], meano[4,s,2])T(0, 1)

  #  Transform probability to real scale
  for(i in 1:3){
    aS_mu[i,s] <- log(aS_tmp[i,s]/aS_tmp[3,s])
  }


  #  Describe rate as function of linear predictor and define link
  #   function
  for(u in 1:ndau){
    for(yr in 1:nyr){
      log(aS_log[u,yr,s]) <- aS_mu[1,s]
      log(aH_log[u,yr,s]) <- aS_mu[2,s]
      log(aO_log[u,yr,s]) <- 0
      aSums[u,yr,s] <- aS_log[u,yr,s] + aH_log[u,yr,s] + aO_log[u,yr,s]
      S[u,yr,4,s] <- aS_log[u,yr,s]/aSums[u,yr,s]
      H[u,yr,4,s] <- aH_log[u,yr,s]/aSums[u,yr,s]
      O[u,yr,4,s] <- aO_log[u,yr,s]/aSums[u,yr,s]
    }
  }
}

###  Prior on first year population size
#  Indexing - Year, Age, Sex
for(u in 1:ndau){
  N[u,1,1,1] ~ dnorm(n1[1,2], 1/n1[1,2])T(0,)
```

```
  N[u,1,1,2] <- N[u,1,1,1]

  for(a in 2:nage){
    for(s in 1:2){
      N[u,1,a,s] ~ dnorm(n1[a,s+1], 1/n1[a,s+1])T(0,)
    }
  }

  yN[u,1] <- N[u,1,1,1] + N[u,1,1,2]
  fN[u,1] <- N[u,1,2,1] + N[u,1,3,1] + N[u,1,4,1]
  mN[u,1] <- N[u,1,2,2] + N[u,1,3,2] + N[u,1,4,2]
  totN[u,1] <- yN[u,1] + fN[u,1] + mN[u,1]
}

###  Process model - 4 ages, 2 sex
#  Using normal approximation because it is fast and mixes well
#  Sex = 1 is a female
#  Indexing follows - DAU, Year, Age, Sex
for(u in 1:ndau){
  for(yr in 2:nyr){
    #  Kittens
    #  Normal approximation of Poisson
    nMu[u,yr,1,1] <-
      ((N[u,yr,3,1] * 0.5 * FC[1] * Preg[1]) +
        (N[u,yr,4,1] * 0.5 * FC[2] * Preg[2])) *
        S[u,yr-1,1,1]
    nMu[u,yr,1,2] <- nMu[u,yr,1,1]

    N[u,yr,1,1] ~ dnorm(nMu[u,yr,1,1], 1/(nMu[u,yr,1,1]))
    N[u,yr,1,2] <- N[u,yr,1,1]

    for(s in 1:2){
      #  Juveniles
      #  Normal approximation of Binomial
      nMu[u,yr,2,s] <-
        (1 - O[u,yr-1,2,s]) * (N[u,yr-1,1,s] - harv[u,yr-1,2,s])

      nTau[u,yr,2,s] <- 1/((N[u,yr-1,1,s] - harv[u,yr-1,2,s]) *
        (O[u,yr-1,2,s]) * (1 - O[u,yr-1,2,s]))

      N[u,yr,2,s] ~ dnorm(nMu[u,yr,2,s], nTau[u,yr,2,s])

      #  SubAdults
      #  Normal approximation of Binomial
      nMu[u,yr,3,s] <-
        (1 - O[u,yr-1,3,s]) * (N[u,yr-1,2,s] - harv[u,yr-1,3,s])

      nTau[u,yr,3,s] <- 1/((N[u,yr-1,2,s] - harv[u,yr-1,3,s]) *
        (O[u,yr-1,3,s]) * (1 - O[u,yr-1,3,s]))

      N[u,yr,3,s] ~ dnorm(nMu[u,yr,3,s], nTau[u,yr,3,s])


      #  Adults
      #  Normal approximation of Binomial
      #  Female Other Mortality shared between the sexes
      nMu[u,yr,4,s] <-

        (N[u,yr-1,3,s] + N[u,yr-1,4,s] - harv[u,yr-1,4,s]) *
          (1 - O[u,yr-1,4,s])

      nTau[u,yr,4,s] <-
        1/((N[u,yr-1,3,s] + N[u,yr-1,4,s] - harv[u,yr-1,4,s]) *
        (O[u,yr-1,4,s]) * (1 - O[u,yr-1,4,s]))


      N[u,yr,4,s] ~ dnorm(nMu[u,yr,4,s], nTau[u,yr,4,s])
```

```
      }

    #  Totals in each year
    yN[u,yr] <- N[u,yr,1,1] + N[u,yr,1,2]
    fN[u,yr] <- N[u,yr,2,1] + N[u,yr,3,1] + N[u,yr,4,1]
    mN[u,yr] <- N[u,yr,2,2] + N[u,yr,3,2] + N[u,yr,4,2]
    totN[u,yr] <- yN[u,yr] + fN[u,yr] + mN[u,yr]
    }
  }

  ####################  Observation Models
  #  Indexing/columns always follows
  #    1    2     3    4    5    6
  #  DAU, Year, Age, Sex, Mean, Tau

  #  Abundance Observation - [dau, yr]
  for(i in 1:nn){
    ndat[i,5] ~ dnorm(totN[1,ndat[i,2]], ndat[i,6])T(0,)
  }

  #  Harvest Observations - [dau,yr,a,s]
  for(u in 1:ndau){
    for(yr in 1:nobs_yr){
      for(a in 1:nage){
        for(s in 1:2){
          harv[u,yr,a,s] ~ dbinom(H[u,yr,a,s], round(N[u,yr,a,s]))
        }
      }
    }
  }

  #  Survival Observations
  for(i in 1:ns){
    sdat[i,5] ~ dnorm(S[1, sdat[i,2], sdat[i,3], sdat[i,4]], sdat[i,6])T(0, 1)
  }
  #  Harvest Mortality Rate Observations
  for(i in 1:nhm){
    hmdat[i,5] ~ dnorm(H[1, hmdat[i,2], hmdat[i,3], hmdat[i,4]], hmdat[i,6])T(0, 1)
  }
  #  Other (Non-Harvest) Mortality Rate Observations
  for(i in 1:nom){
    omdat[i,5] ~ dnorm(O[1, omdat[i,2], omdat[i,3], omdat[i,4]], omdat[i,6])T(0, 1)
  }

  #  Derived - the constant is added to avoid division by 0
  for(u in 1:ndau){
    for(yr in 1:nyr){

      mf[u,yr] <- (mN[u,yr] + 0.001)/(fN[u,yr] + 0.001)
    }
  }

  #  Incomplete vectors cannot be monitored, so aribitrary value is given
  #  to the first year
  #  Same constant trick is used here for the division
  #  Using the log and exp handles 0 gracefully, recall that
  #  log(x) + log(y) = log(xy), so the geometric mean is calculated using
  #  an algebraic rearrangment that is more robust to 0's
  for(u in 1:ndau){
    lambda[u,1] <- 1
    for(yr in 2:nyr){
      lambda[u,yr] <- (totN[u,yr] + 0.001)/(totN[u,yr-1] + 0.001)
      logla[u,yr] <- log(lambda[u,yr])
    }
    geoLambda[u] <- exp((1/(nyr-1))*sum(logla[u,2:(nyr)]))
  }
}
```

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Hound baying treed mountain lion near Missoula, Montana, O. Smith

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Utah Cougar Management Plan V.3

2015-2025

Photo Credit: Tom Becker, Utah Division of Wildlife Resources

Utah Division of Wildlife Resources

and the

Cougar Advisory Group

DWR Publication No. 15-28

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* These members of the Cougar Advisory Group support the majority of the plan but are *of the opinion* that the approved targets allow for the possibility of excessive cougar harvest as judged from the standpoint of the best available science.

Utah Cougar Management Plan V. 3
2015 – 2025

PLAN GOAL: Maintain a healthy cougar population within their current distribution while considering human safety, economic concerns, other wildlife species, and maintaining hunting traditions through 2025.

Definition: A healthy cougar population is one that maintains: 1) a reasonable proportion of older age animals; 2) breeding females; 3) healthy individuals; 4) balance with its natural prey; 5) and genetic variability.

Introduction

The purpose of the Utah Cougar Management Plan is to direct the management of cougars (*Puma concolor*) in accordance with the mission of the Utah Division of Wildlife Resources (Division or DWR) through 2025. An internal review of the plan will be completed 5 years after implementation to ensure that established targets, goals, and objectives meet both management and social needs.

The mission of DWR is:

Serve the people of Utah as trustee and guardian of the state's wildlife

In 1997, the DWR initiated a process to obtain public input on issues and concerns with cougar management. Individuals representing many diverse points of view were invited to form a Cougar Advisory Group. The mission of this group was to aid the Division in preparing a cougar management plan that would gain agreement from diverse groups.

The first version of the Utah Cougar Management Plan (UDWR 1999) resulted from these meetings and was used to direct cougar management efforts from 1999 to 2009. In 2009, the DWR reformed the Cougar Advisory Group to review and update the plan. The group met 8 times between December and May 2010 which resulted in Version 2 (UDWR 2010). After approval of this version several social and management issues led to an emergency meeting of the Wildlife Board. The outcome of the meeting was Version 2.1 of the Utah Cougar Management Plan (UDWR 2011). Subsequently, this version did not fully address the concerns of the public or wildlife managers and the Wildlife Board directed the Division to reform the Cougar Advisory Group with the goal of simplifying the cougar management plan.

This document is version 3 of the Utah Cougar Management Plan which seeks to simplify cougar management and address social and management issues created through previous versions of the plan. The Cougar Advisory Group met 5 times between December and April 2015. The first meeting of the group focused on developing a list of issues and concerns that the group could focus on and address in this document (see Attachment D. Issues and Concerns).

The natural history and ecology of cougars is not included or described in this document because more detailed information on cougar ecology can be found in “Managing Cougars in North America” (WAFWA 2011).

Management History

Cougars were persecuted as vermin in Utah from the time of European settlement in 1847 until 1966. In 1967 the Utah State Legislature changed the status of cougars to that of *protected wildlife,* and since that time they have been considered a game species with established hunting regulations. The first Utah Cougar Management Plan (UDWR 1999) guided cougar management through 2009. Consequently, two additional versions of the plan were adopted by the Wildlife Board to guide cougar management between 2010 and 2014 (UDWR 2010, 2011).

Cougars use very broad and diverse areas in Utah. The large scale dynamics and interconnectivity of the states cougar populations have been demonstrated through multiple telemetry and GPS radio collar studies (Stoner et al. 2006; 2008: 2013b). Evaluation of the genetic relatedness of cougars in Utah also provides evidence that gene flow occurs over large geographic areas (Sinclair et al. 2001). Cougar harvest has traditionally been controlled in specific geographic areas or hunting units. Version 2 of the management plan sought to tie smaller hunting units to larger home ranges or eco-regions to account for the large spatial scale and source-sink population dynamics (Stoner et al. 2013b; cougar management areas; Figure 1). However, implementation of the eco-region concept limited the ability of the Division to distribute hunters adequately which resulted in heavy hunting pressure and high harvest in easily accessible areas and low to no harvest in areas with limited access.

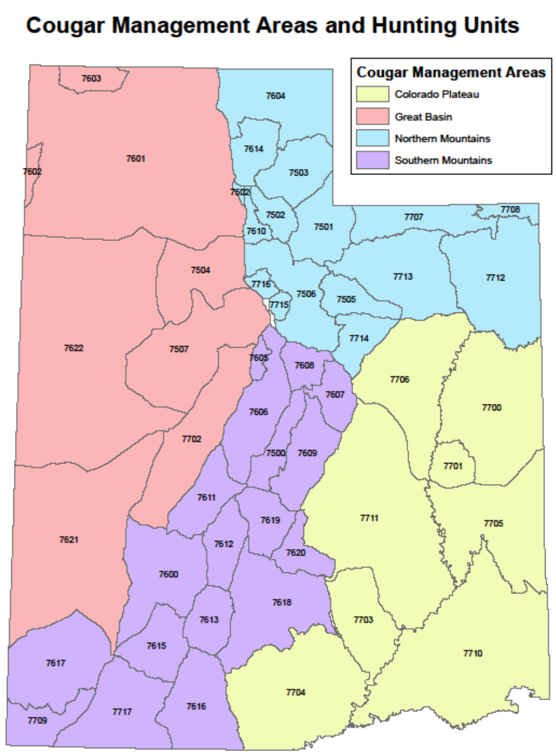

Figure 1. Cougar Management Areas and Hunting Units

Cougar harvest in Utah has been accomplished using three harvest strategies: harvest objective (quota), limited entry and split (limited entry followed by harvest objective). Under the *harvest objective strategy*, managers prescribe a quota, or number of cougars to be harvested on the unit. An unlimited number of licensed hunters are allowed to hunt during a season which closes as soon as the quota is filled or when the season end date is reached. Hunters are required to check daily to ensure the quota has not been filled. Under the *limited entry strategy*, harvest is managed by limiting the number of hunters on a unit. The number of hunters is determined based upon an expectation of hunting success and the desired harvest size. Individuals are usually selected for hunting on the unit through a random drawing process. Under the *split strategy*, units start the season under the limited entry strategy and then transition to a harvest objective strategy on a set date using the number of limited entry permits that remained unfilled at the time of the transition as the quota for the remaining weeks of the season.

Predator-Prey Relationships

Mule deer are known to be the preferred prey species of cougars (Seidensticker et al. 1973, Ackerman 1982, Mitchell 2013), and in Utah both deer and elk have been identified as primary prey species. In areas where both deer and elk co-exist cougars will usually select deer (Lindzey et al. 1989, Mitchell 2013). Other prey species include lagomorphs, turkey, skunk, fox, porcupines, rodents, bighorn sheep, feral horses, domestic sheep, cattle, bobcat and coyote (Russell 1978, Ackerman et al.1982, Knopf 2010, Mitchell 2013).

Cougar populations may be limited by prey abundance, availability, and vulnerability (Pierce et al 2000*b*, Logan and Sweanor 2001), and the relationship between predator and prey is very complex. Much controversy surrounds whether cougar predation can restrict or limit population growth of prey species; the majority of evidence is circumstantial, revolving around observations that deer are preferred prey, high cougar densities, and/or prey populations are declining. Most research indicates that cougars and predation alone are not a major limiting factor of prey species abundance (Hornocker 1970, Russell 1978, Lindzey et al. 1994, Logan et al. 1996, Pierce et al. 2012). Ballard et al. (2001) reviewed a total of 17 published studies and concluded that deer-predator relationships are confounded by many factors including the relationship of deer to available habitat and carrying capacity. For example in New Mexico, Logan et al. (1996) found that cougar predation was the major cause of mortality in mule deer but that habitat quality was the critical limiting factor. Conversely, when habitat quality was good and the deer population was below carrying capacity, cougar predation did not prevent the deer population from increasing. In Idaho, Hurley et al. (2011) examined mule deer survival in response to removal of both coyote and cougars. Their data indicated that winter severity had the largest influence on population growth rate and predator removal only resulted in slight prey population increases for short term periods.

In contrast, predator-prey dynamics between cougar and bighorn sheep are less ambiguous because most bighorn sheep populations are small in number and isolated in space. Cougar predation on bighorn sheep typically occurs randomly and most often when one individual learns to specialize on bighorn sheep (Logan et al. 1996, Ross et al. 1997, Ernst et al. 2002, Sawyer and Lindzey 2002, Festa-Bianchet. et al. 2006). In a population of desert bighorn sheep radio collared in southeastern Utah, cougar predation was responsible for 53% of radio collared adult mortalities (UDWR unpublished data). In California and Arizona, cougars were implicated in the decline of bighorn sheep populations (Hayes et al. 2000, Schaefer et al. 2000, Kamler et al. 2002), and in Alberta, a single cougar was responsible for killing 9% of the early-winter bighorn sheep population including 26% of the lambs (Ross et al. 1997). Targeted removal of cougar that learn to specialize on bighorn sheep can be beneficial for both cougar and sheep populations (Ernest et al 2002).

The availability and abundance of different prey species in an area as well as the presence of other predators are also factors that may influence prey populations. In some cases a “predator pit” effect can occur when the primary prey experiences a reduction in numbers but an alternate prey source is available to the predator. This helps artificially keep predator populations high because the predator can switch to other prey, and their population size does not decrease in response to lower availability or preferred prey. The predator can then keep the primary prey species from recovering (Dale et al. 1994, Gassaway 1992).

In 1996 the Utah Wildlife Board approved a Predator Management Policy (DWR Policy No. W1AG-4, last updated in 2006) that authorizes the Division to increase cougar harvest on management units where big game populations are depressed, or where big game has recently been released to establish or supplement new populations. The policy acts under the assumption that predators can slow recovery of prey populations when they are depressed or that a prey population can be kept at a lower density due to predation (Cougar Management Guidelines Working Group 2005). Predator management plans are reviewed by regional staff, the Mammals Program Coordinator, and approved by both the Wildlife Section Chief and DWR Director.

Most predator management plans that affect cougars have been designed to benefit mule deer and/or bighorn sheep. Cougar harvest has been liberalized where mule deer or bighorn sheep are below population management objective, and adult survival is lower than normal under the assumption that large harvests will reduce cougar numbers and hence predation rates, therefore encouraging growth of populations by improving survival. However, drought, habitat alteration and loss and predation all substantially impact big game populations making the effectiveness of predator management plans difficult to evaluate.

This version of the cougar management plan differs from previous versions in that aspects of the Divisions predator management policy are being incorporated into the plan. Mule deer and bighorn sheep population abundance and survival estimates will be used to help determine annual cougar harvest recommendations. This was one of the key social and management issues with previous versions of the Cougar

Management Plan identified through both the public recommendations process and by the Cougar Advisory Group.

In 1999, UDWR implemented a Nuisance Cougar Complaints policy (DWR Policy No. W5WLD-5, last updated in 2006) to provide guidance for reducing damage to private property, reducing public safety concerns, and direction to Division personnel responding to cougar depredation, nuisance, and human safety situations. Any cougar that poses a threat to human safety or preys upon livestock or pets is euthanized, as are sick or injured adult cougars and kittens that are unable to care for themselves in the wild. The Division does not rehabilitate cougars. The only cougars that are captured and translocated are healthy adults and subadults that wander into urban or suburban areas in situations where they have not been aggressive toward humans, pets, or livestock.

Harvest Information

The Division began managing cougar harvests through statewide limited entry hunting in 1990 and increased numbers of permits through 1995-1996. In 1996-1997, additional harvest pressure was added by switching some management units to the harvest objective (quota) system and a record high of 1,496 Permits were sold (Table 1).

Utah's cougar population is monitored through mandatory reporting of all hunter-harvested cougars, cougars that are killed on highways or in accidents and those taken as a result of livestock depredation. Location of kill, sex and age (through a premolar for age estimation) are recorded for every cougar killed and provide the data used to assess management performance in relation to established target values that serve as indicators of population status. Since 1990 cougar mortality in Utah has ranged from 275 (1990) to 666 (1996) and has averaged 421 animals (Figure 2).

	Limited Entry Permits				Harvest Objective Permits			Total Permits	Pursuit Permits
Year	Resident	Nonresident	Conservation / Expo	Total	Resident	Nonresident	Total		
1989-90	385	142		527				527	355
1990-91	383	142		525				525	364
1991-92	383	142		525				525	524
1992-93	431	160		591				591	570
1993-94	479	180		659				659	552
1994-95	559	232		791				791	505
1995-96	611	261		872				872	627
1996-97	425	170		595			901	1,496	638
1997-98	381	128		509	472	199	671	1,180	635
1998-99	337	109		446	386	189	575	1,021	630
1999-00	259	84		343	374	170	544	887	545
2000-01	206	66		272	880	290	1,170	1,442	692
2001-02	228	30	8	266	897	300	1,197	1,463	681
2002-03	326	36	12	374	685	266	951	1,325	703
2003-04	215	29	20	264	533	209	742	1,006	772
2004-05	233	30	10	273	841	290	1,131	1,404	703
2005-06	356	38	12	406	464	222	686	1,092	730
2006-07	313	35	18	366	600	245	845	1,211	714
2007-08	283	34	20	337	587	238	825	1,162	880
2008-09	271	34	18	323	543	220	763	1,086	855
2009-10	263	32	18	313	566	192	758	1,071	900
2010-11	330	38	15	383	595	190	785	1,168	909
2011-12	312	36	16	364	613	202	815	1,178	777
2012-13	312	36	17	365	564	226	790	1,096	769
Total	**8,281**	**2,224**	**184**	**10,689**	**9,600**	**3,648**	**14,149**	**24,778**	**16,030**
Mean	**345**	**93**	**15**	**445**	**600**	**228**	**832**	**1,032**	**668**

Table 1. Utah Cougar Permits 1990-2013.

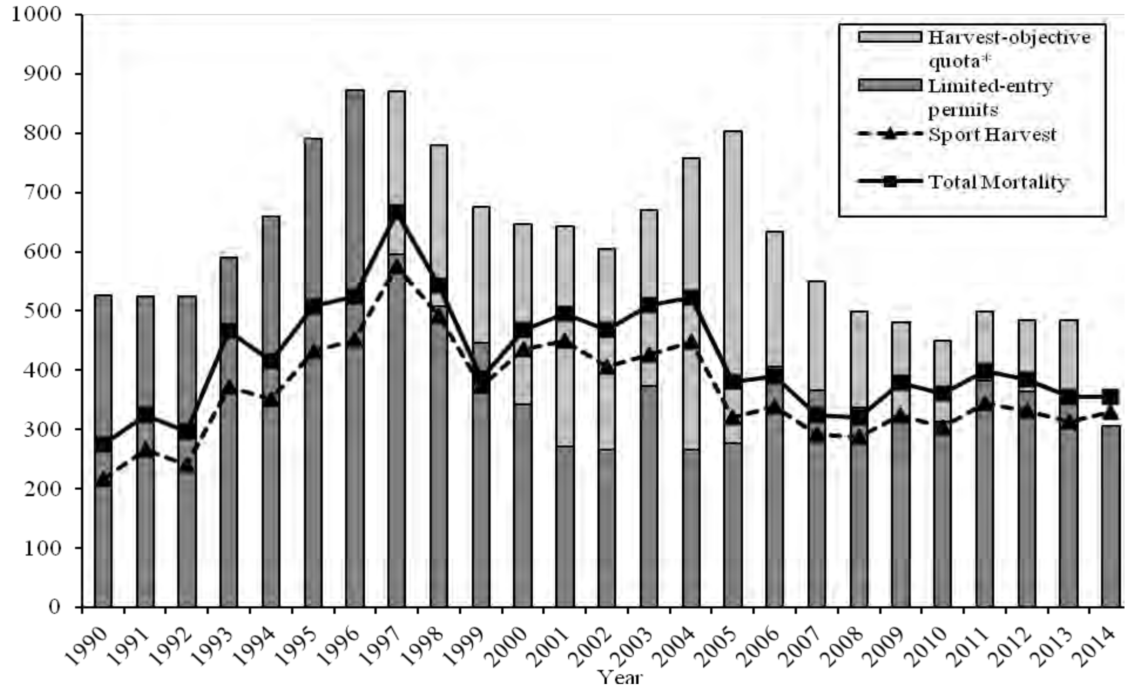

Figure 2. Cougar Mortality1990-2014

Nearly all cougars harvested in Utah are taken with the aid of dogs. An individual hunter is restricted to holding either a limited entry permit or a harvest objective permit per season, and must wait 3 years to reapply once they acquire a limited entry permit. The bag limit is 1 cougar per season. Kittens and females accompanied by young are protected from harvest. The cougar hunting season runs from late November through early June on both limited entry and most harvest objective units. Some units are open year round and some have earlier or later opening dates. Because harvest objective units close as soon as the objective (quota) is reached, hunters must call a toll-free number or check the Division website daily to ensure that the unit they plan to hunt is still open.

Pursuit (chase or no-kill) seasons provide additional recreational opportunities over most of the state. The pursuit season generally follows the hunt season, but specific units have year round pursuit, and a few units are closed to pursuit.

A valuable way to assess cougar population response to hunting is to follow the trend of age structure in harvest over time. The effect hunting has on cougar populations depends on the level of harvest and the sex and age of cougars that are removed. In general transient males are most susceptible to harvest (Barnhurst 1996). Under more intensive harvest pressures fewer juveniles tend to be harvested, followed by a decrease in adult males, and then finally a steady increase in adult females. The longer and more intensive the harvest pressure the more young females will occur in the harvest. This happens because older age animals and males are not available in the population. Likewise, relatively light harvest allows hunters to be more selective and tends to produce more males and older animals (WAFWA 2011).

Most cougar populations can sustain harvest rates of 20-30% of the adult population depending on the age and sex composition of the harvest (Beck et al. 2005). However, recent work in Washington state suggests the natural rate of increase is approximately 12-14% per year (Beausoleil et al. 2013). Large and well connected cougar populations can recover rapidly from over-exploitation (Cougar Management Guidelines 2005) given relaxation from hunting pressure and an adequate influx of immigrants. Cougar populations are most sensitive to the survival or removal of adult females (Martorello and Beusoleil 2003) which may slow or reduce population growth and may eventually lead to population decline (Stoner et al. 2006, Robinson et al. 2008, Cooley et al. 2009*a*; 2009*b*). For example, evaluation of cougar harvest for two different hunting regimes in Utah demonstrated negative impacts on fecundity, density, and age structures when the annual harvest consisted of >30% of the adult population with ≥42% females for periods greater than 3 years (Stoner 2004). Harvest and population data from southern Wyoming indicates that cougar populations can maintain themselves with a harvest comprised of 10-15% adult females (Anderson and Lindzey 2005). For these reasons most states limit female hunting mortality to <50% of the total harvest.

Distribution and Abundance

In Utah cougars occupy 92,696 km^2 (35,790 mi^2) of habitat. Cougars are distributed throughout all available eco-regions (Figure 3) and exhibit a broad habitat tolerance occurring from the semi-arid low-elevation pinion-juniper belt, to the mesic, aspen and conifer dominated forests of the higher mountains and plateaus. Habitat quality varies by ecoregion with the Colorado Plateau and Great Basin containing smaller, naturally fragmented habitats with lower cougar densities, and the mountain ecoregions comprised of relatively large, mesic patches (Stoner et al. 2013a). Residential and commercial development is incrementally reducing cougar distribution through habitat alteration and destruction, particularly along the western border of the Wasatch Mountains in northern and central Utah.

The last statewide cougar population estimates were developed in conjunction with the Utah Cougar Management Plan in 1999 (UDWR 1999). These estimates used extrapolations of cougar densities from published studies in the southwestern United States to: 1) the total area within all management units that comprise cougar range, and 2) the total amount of occupied cougar habitat within Utah. The habitat quality within each management unit was classified as either high, medium or low based on vegetative characteristics, terrain ruggedness (Riley 1998) and prey density. Cougar densities derived from research within Utah, California and New Mexico were associated with each habitat quality level. High quality habitat was assigned a density range of 2.5-3.9 cougars/100 km^2, medium quality habitat was assigned a density of 1.7-2.5 cougars/100 km^2 and a density of 0.26-0.52 cougar/100 km^2 was assigned to low quality habitat. The first statewide population estimate of 2,528-3,936 cougars resulted from summing unit population estimates.

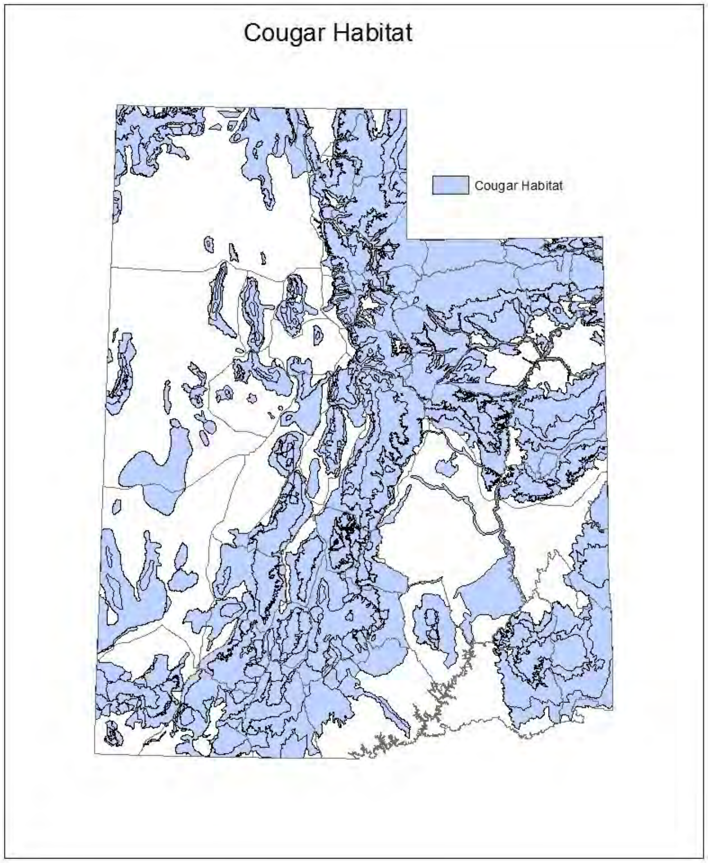

Figure 3. Cougar Habitat in Utah

For comparison, a second estimate of 2,927 cougars statewide was generated based upon mean cougar densities and total occupied cougar habitat within the state. Each management unit's cougar population was estimated by extrapolating the mean cougar density assigned to the unit (based on the respective range indicated above) to the amount of occupied cougar habitat within the unit, and unit estimates were summed to obtain the statewide figure. The two methods produced population estimates that show considerable agreement, but they should be only viewed as general approximations of the statewide cougar population.

Research

Beginning with the observational work of Connolly (1949), up through current investigations of cougar-coyote-mule deer interactions by Julie Young and colleagues, Utah has a rich history of research on cougar ecology and management. Two topics dominate the literature on the species: predation effects on big game species, and population estimation techniques. In Utah and most western states cougars are often managed from conflicting standpoints. As a predator of mule deer, elk, and bighorn sheep, cougars can be managed as a pest, in which measureable changes in density are desired in order to evaluate the numerical responses of prey. However, when prey survival is not a concern, cougars may be managed as a trophy game species, in which harvest can be fairly conservative. Under both conditions, the ability to estimate and track changes in local abundance is central to effective management.

Cougar research can be subdivided into a few broad topics; natural history, foraging habits and predation, habitat use, and population dynamics. The latter category has received the most attention and involves estimation of abundance, reproduction, and survival rates. In order for management to be effective, a solid understanding of these life history characteristics is essential. The earliest work in Utah was conducted by houndsman and district Predatory Animal and Rodent Control agent, Edward Connolly, who used snow tracking to evaluate predation rates and prey selection in the Wasatch Mountains. These efforts were followed in the 1950s by W. L. Robinette who made further evaluations of food habits by examining the stomach contents of harvested cougars (Robinette et al. 1959). Similarly, these authors used necropsy of females removed through harvest and depredation control to evaluate pregnancy rates, litter size, and breeding seasons (Robinette et al. 1961). Other investigations elaborated on causes of natural mortality (Gashwiler and Robinette 1957). Robinette et al (1977) summarized their findings about cougars and their role in mule deer population dynamics in their study, *The Oak Creek Mule Deer Herd in Utah*. Because of the large sample sizes and relatively simple analyses, some of these papers are still relevant as more recent efforts have only reinforced early findings.

The advent of radio-telemetry in the 1960’s facilitated a detailed view of cougar behavior. This tool removed much of the speculation from field work by providing investigators a means of tracking animals in real time. Telemetry allowed for rigorous measures of home range size, sociality, movement behavior, and predation rates. The work of Lindzey et al. (1989) was the first use of radio-telemetry on cougars in the state. This project was conducted on the Boulder Plateau and adjacent Henry Mountains in southern Utah from 1978 to 1989. By the time this study was initiated, cougars had been classified as a big game species for over a decade, and many of the uncertainties associated with managing a secretive carnivore were apparent. Lindzey focused on applied questions related to cougar predation impacts on deer, elk, and livestock (Ackerman et al. 1984, 1986), population dynamics (Hemker et al. 1984, 1986; Lindzey et al. 1988, 1994), and survey techniques (Van Dyke et al. 1986; Van Sickle and Lindzey 1991, 1992). During the latter years of the study, Lindzey and his students evaluated cougar demographic responses to typical harvesting regimes (Barnhurst and Lindzey 1989; Lindzey et al.1992; Laing and Lindzey 1993). In 1991 Lindzey published a brief paper on recommendations for future research. Due largely to an inability to accurately census cougars and an increasing concern over human/cougar conflicts the development of reliable survey techniques and evaluation of cougar behaviors in and around urban settings were top among managers concerns.

As the human population in the west have increased and became progressively more urban, societal values have evolved. Along with these changes restructuring of wildlife management policy has changed to include greater public input. Wildlife commissions and advisory boards are the avenue for public input in most western states. Continued debate over abundance, reactions to hunting pressure, and the burgeoning issue of cougars living near people prompted the initiation of Utah's second radio-telemetry effort to examine cougars. This project was led by Dr. Michael Wolfe at Utah State University, and Clint Mecham, a veteran from Lindzey's fieldwork on the Boulder. This new project involved two study areas; one in central Utah on the Fishlake National Forest (Monroe Mountain), and the other due west of the rapidly expanding Salt Lake metro area in the Oquirrh Mountains. The primary difference between these sites was the pattern of land ownership. The Monroe Mountain site was public land and open to hunting whereas the Oquirrh Mountain site was a patchwork of private properties with restricted access, including large holdings by the Utah Army National Guard and the Kennecott Copper Company. This created a vast region of un-hunted habitat on the edge of an expanding metro area.

Wolfe's study had three central objectives: 1) evaluating cougar enumeration techniques under differing densities, 2) assessing the demographic effects of sustained harvest on cougar demographics, and 3) assessing cougar movement behavior and resource use in an urban-wildland setting. This project ran from 1996 to 2013 and represents the longest comparative study ever conducted on the species. Unlike many diurnally active, herding, or numerically abundant species, there are no robust and widely accepted techniques for cougar enumeration (Choate et al. 2006) and findings from this study underscored the severe limitations imposed by cougar behavior on the development and use of robust survey techniques. Stubbornly small sample sizes, the inherently open nature of cougar populations, and wide dispersal tendencies mean that classic mark-recapture techniques are of limited utility at scales relevant to management (Sinclair et al. 2001, Stoner et al. 2008).

During his Boulder Plateau study, Lindzey addressed the question of harvest effects, but it was an experiment in time on a single study area (before-after). The second objective Wolfe's project was an attempt to replicate the Boulder study in space. The effort here was the first to employ a Before-After-Control-Impact study design in which two populations were monitored simultaneously while varying harvest levels on one site. The Monroe-Oquirrh study lasted 12 years and demonstrated notable demographic differences between populations subjected to different management regimes. Based on these results and combined with the uncertainty of local abundance, Wolfe et al. (2004) recommended statewide implementation of a source-sink type management structure in which known behavioral tendencies, such as male-biased dispersal are used to backfill territories left vacant following harvest. This idea was developed further by Stoner et al.

(2013*a*, 2013*b*), who parameterized cougar dispersal and identified a series of *de facto* refugia, i.e. areas of suitable habitat that exhibit low levels of hunting.

The third objective of this study was pursued by Rieth (2009), Stoner (2011) and Mitchell (2013). These authors looked at habitat use, movement patterns, and predation behavior in the Oquirrh Mountains- a region that encompassed military training, industrial activities, and suburban land-use. Rieth (2009) demonstrated a shift in cougar habitat selection by behavior, which is correlated with time-of-day. Notably, cougars are farthest from human activity during diurnal hours when human activity is highest, and nearest at night when actively hunting. Subsequently, Stoner (2011) found cougars generally avoided areas of predictable human activity, but that aversion was not absolute and some individuals, particularly males and older females with dependent kittens passed occasionally used human dominated landscapes. Mitchell (2013) followed on this work and noted that despite proximity to urban and mixed-use landscapes, cougar depredation on pets and hobby livestock were rare, and that most livestock depredations were on free-ranging cattle in wilderness parts of the study area.

The capstone of the Monroe-Oquirrh cougar project were the evaluations by Wolfe et al. (2015, in review) of commonly used cougar performance measures with respect to known demographics, and an assessment of the degree to which harvest mortality acts in an additive or compensatory manner in cougar populations. These analyses used radio-telemetry data to calibrate catch-per-unit-effort, survival rates, and percent females in the harvest as an index of population performance. Following these efforts the project moved into a second phase in which the Oquirrh Mountain site was closed and remaining resources were directed to a new study objective on the Monroe site. This segment of the project was lead by Julie Young of the National Wildlife Research Center at Utah State University and changed focus from population demographics to the interaction between coyotes, cougars and mule deer. Results are forthcoming.

Objective, Strategies and Management Systems

<u>Outreach and Education</u>

Objective 1:

Increase awareness and appreciation within the general public for the role of cougars in Utah's ecosystems.

Strategy:

1. Determine (survey) the general public's knowledge and attitudes toward the role of cougars in Utah's ecosystems.
2. Implement the new Wild Aware Utah program; an effort generated by the Conservation Outreach Section.

Objective 2:

Educate and increase awareness of the public that utilize cougar habitat about cougar safety.

Strategy:

1. Implement the Wild Aware Utah program.

Objective 3:

Provide educational opportunities to the big game hunting public about the relationship between cougar and prey populations.

Strategies:

1. Develop an educational presentation highlighting cougar-prey interactions geared toward hunting/conservation organizations such as Sportsmen for Fish and Wildlife, Mule Deer Foundation, Rocky Mountain Elk Foundation, Utah Bowman's Association and others.
2. Write articles addressing cougar prey interactions for publication in sportsmen magazines/news letters published by hunting/conservation organizations such as: Sportsmen for Fish

and Wildlife, Mule Deer Foundation, Rocky Mountain Elk Foundation, Utah Bowman's Association and others

3. Explain cougar-prey interactions through radio, television and print media.
4. Periodically assess big game hunter opinions about the effect of cougars on big game populations.

Objective 4:

Educate all cougar hunters on how to determine the age/sex of cougars to increase harvest selectivity and continue to educate Division employees tagging cougars.

Strategies:

1. Continue to publish information about sex and age identification techniques in the Cougar Guidebook and online.
2. Evaluate the effectiveness of the voluntary online orientation course to determine if desired results are being obtained.
3. Modify the harvest reporting form to gather data on effectiveness of orientation course.
4. Survey unsuccessful cougar hunters to gather data on the effectiveness of orientation course.
5. Obtain high quality digital photographs of cougars for sex and age identification education purposes. Examples: treed cougars, lactating females and track and paw sizes for sex and age differentiation.
6. Explore ways to reward hunters for selective harvest.
7. Train Division employees responsible for tagging cougars at least biannually.

Objective 5:

Increase and develop educational opportunities for sportsmen and other user groups prior to the RAC and Board process

Strategy:

1. Hold informational meetings on recommendations prior to taking them through the public process.

Population Management

Objective 1

Maintain cougar populations within their current statewide distribution in a manner that: 1) recognizes the large geographic and temporal scales at which cougar populations operate, 2) stresses the importance of social structure for long-term viability, 3) directs hunter pressure on a management unit or subunit basis, and 4) manages cougar abundance with respect to their ungulate prey species.

Performance Targets:

- **Primary Target** - Proportion of all females in the harvest < 40% (within a management unit averaged over 3 years)
- **Secondary Target** – Proportion of cougars ≥5 years old in harvest between 15-20% (within a management unit averaged over 3 years)

Strategies (See Attachment A: Cougar Management Tree):

1. Implement the management system based on data for the previous 3 years for all units that mule deer and bighorn sheep triggers are not met as follows:

a. Select limited entry, harvest objective, or split strategy based on the needs of the unit and what type of hunting pressure is appropriate.

b. If proportion of all females in the harvest <40% then:

   1). Proportion of cougars ≥5 years old in harvest ≥ 20 % then permits/quota may increase.

   2). Proportion of cougars ≥5 years old in harvest =15-20% then permits/quota may be maintained or decrease/increase at biologist discretion.

   3) Proportion of cougars ≥5 years old in harvest <15% then permits/quota may decrease.

   4) Small sample sizes may bias both sex and age data. In these instances the biologist may increase, decrease or maintain permits at their discretion.

c. If proportion of all females in the harvest ≥40% then:

   1). Decrease permits/quota

Objective 2:

Be responsive to prey population objectives. Manage cougar populations to reduce predation on big game herds that are below objective when cougar predation is considered a potential limiting factor for herd growth or recovery. Consider development of a predator management plan and implement according to UDWR policy W1AG-4 if annual recommendations are not meeting the needs of the unit.

Performance Targets for units where mule deer or bighorn sheep triggers are met (See Attachment B: Predator Management Tree – Mule Deer):

- **Primary Target -** Proportion of female cougars in the harvest ≥ 40% (within a management area averaged over 3 years)

  Strategies:

  1. Implement the management system based on data for the previous 3 years for all units that mule deer and bighorn sheep triggers are met as follows:

     a. Select limited entry, harvest objective, or split strategy based on the needs of the unit and what type of hunting pressure is appropriate.

     b. If mule deer populations are <90% of unit or subunit objective <u>and</u> conditions listed in 1) <u>or</u> 2) below are met:

        1). Adult deer survival on the representative unit <84% for 2 of the past 3 years and the herd unit is demonstrating a declining population trend (lambda is <1) or;

        2). Adult deer survival on the representative unit is <80% in the previous year and the herd unit is demonstrating a declining population trend (lambda is <1).

           i. Proportion of all females in the harvest <40% then permits/quota may be increased and may not exceed +100% of the previous years permits/quota.

           ii. Proportion of all females in the harvest ≥40% then permits/quota may be maintained at the current level.

c. If mule deer populations are <65% of unit or subunit objective in the previous year.

1). Proportion of all females in the harvest <40% then permits/quota may be increased and may not exceed +100% of the previous years permits/quota.

2). Proportion of all females in the harvest ≥40% then quota/permits should be maintained at the current level.

d. Bighorn sheep populations where any of the following conditions are met (See Attachment C: Predator Management Bighorn Sheep and Transplants):

1). Population is <90% of unit or subunit objective or;

2). Bighorn sheep population is below viable levels of <125 animals.

i. Proportion of all females in the harvest <40% then permits/quota may be increased and may not exceed +100% of the previous years permits/quota.

ii. Proportion of all females in the harvest ≥40% then quota/permits may remain the same.

e. When a bighorn sheep, mountain goat, or mule deer transplant or reintroduction will occur in the next year then (See Attachment C: Predator Management Bighorn Sheep and Transplants):

i. Proportion of all females in the harvest <40% then permits/quota may be increased and may not exceed +100% of the previous years permits/quota.

ii. Proportion of all females in the harvest ≥40% then quota/permits may be maintained.

f. Evaluate ungulate population response annually (based on 3 year average) to determine the need to continue or discontinue predator management direction.

g. When a split unit transitions from limited entry to harvest objective the quota will equal the number of limited entry permits that were not filled during the limited entry season.

h. Bighorn sheep only management areas are management units that don't have an appreciable deer population. On these units the cougar prey base consists primarily of bighorn sheep. These units consist of low elevation primarily snow-free habitat and as a result too few cougars are harvested to analyze relative to performance targets. No quota is assigned to these management units (San Rafael, Kaiparowits, Book Cliffs-Rattlesnake).

i. Offer multiple permits or allow harvest of up to 2 cougars on units/subunits where harvest and access is limited.

j. In special circumstances where it is determined that a cougar may be preying on bighorn sheep the Division may use DWR employees, contract with USDA Wildlife Services (WS), or hire/authorize a contractor outside of the agency to remove the offending animal. The director may authorize removal of depredating cougars as needed.

Chronic Depredation Criteria:

- The depredation is occurring on private land and;
- The depredation has occurred in the same area for 3 consecutive years or 4 out of 5 years and;

- WS has attempted to remove the offending animal(s) but has been unsuccessful.

Strategies:

1. WS increase efforts and/or bring cougar specialists in from other areas to help resolve chronic depredation problems – option to implement after 2 years.
2. Division request that WS continue efforts to remove the offending animal after livestock have left the area, or before they have arrived to resolve chronic depredation problems – option to implement after 2 years.
3. The Division may authorize the livestock owner, an immediate family member or an employee of the owner (not someone specifically hired to take cougar) to remove the offending animal beyond the 72hr period stipulated in Utah Admin Code R657-10-21.

   Conditions to the authorization to remove a cougar(s) should include:

   i. The time period during which the cougar(s) can be removed;
   ii. A description of the geographic area from which a cougar(s) can be removed;
   iii. A description of the cougar(s) authorized to be removed (i.e. male, female……)
   iv. Other relevant conditions

   Any cougars removed are considered depredating cougars and are subject to the reporting and possession requirements in the Utah Administrative Code R657-10-21.

4. DWR and WS will work with the houndsmen community to develop a list of houndsmen willing to volunteer their time to help livestock owners resolve chronic depredation issues.

Cougar Research

Objective:

Increase base understanding through continued research designed to address questions relative to cougar management in Utah. Potential research projects are listed below in order of priority.

High Cost Research Priorities (> $100,000 / Year)

1. Investigate alternative population estimation techniques for cougars using the relationships between primary productions, ungulate abundance, and cougar home range size.
2. Radio collar cougars in bellwether units to obtain adult survival estimates to monitor population trends. Consider using bellwether mule deer units to evaluate efficacy of predator control on mule deer survival.
3. Prey switching in cougars. In multi-prey systems, do cougars switch to alternative prey (e.g. livestock, elk, or feral horses) when mule deer numbers decline? To what extent is cougar predation additive to other sources of mule deer mortality?
4. Cougar habitat use and predation behavior in multi-prey communities (bighorn sheep, mule deer, elk, feral horses). Can we predict bighorn vulnerability to cougar predation in space?
5. Indirect effects of predation risk on foraging behavior of livestock.

Low to Moderate Cost Research Priorities (< $100,000 / Year)

1. Examining DWR livestock depredation records to evaluate the influence or efficacy of cougar removal on depredation rates. Does cougar removal affect depredation losses in subsequent years? How does depredation risk vary in space, i.e. are there depredation hotspots? What are the demographic patterns in cougar depredation of livestock – cattle vs sheep vs. pets?

2. Examine DWR pet depredation and public safety complaints with respect to cougar management in adjacent units. Are conflicts predicatable in time and space? What are management regimes in units defined by high and low complaints?
3. To what extent can we manipulate the cougar-deer relationship through habitat manipulation? For example can we use prescribed fire to simultaneously increase forage and reduce stalking cover?
4. Evaluate cougar occupancy of military lands, national parks, and other de facto refugia during winter.
5. Modeling the long-term data set to examine cougar population ecology and demographics; population persistence; possible PhD student interested in population models.

Strategies:

1. Continue collaborative research efforts to maximize knowledge base, funding sources and available resources.
2. Explore new funding sources and ways to leverage those resources.
3. Whenever possible use Division employees enrolled in the educational assistance program to conduct research.
4. Work closely with the big game program, and where possible, develop research projects that improve knowledge and understanding of mule deer and cougar.

Re-visit prioritized list every 5 years after implementation to determine if research direction or funding change or new opportunities become available.

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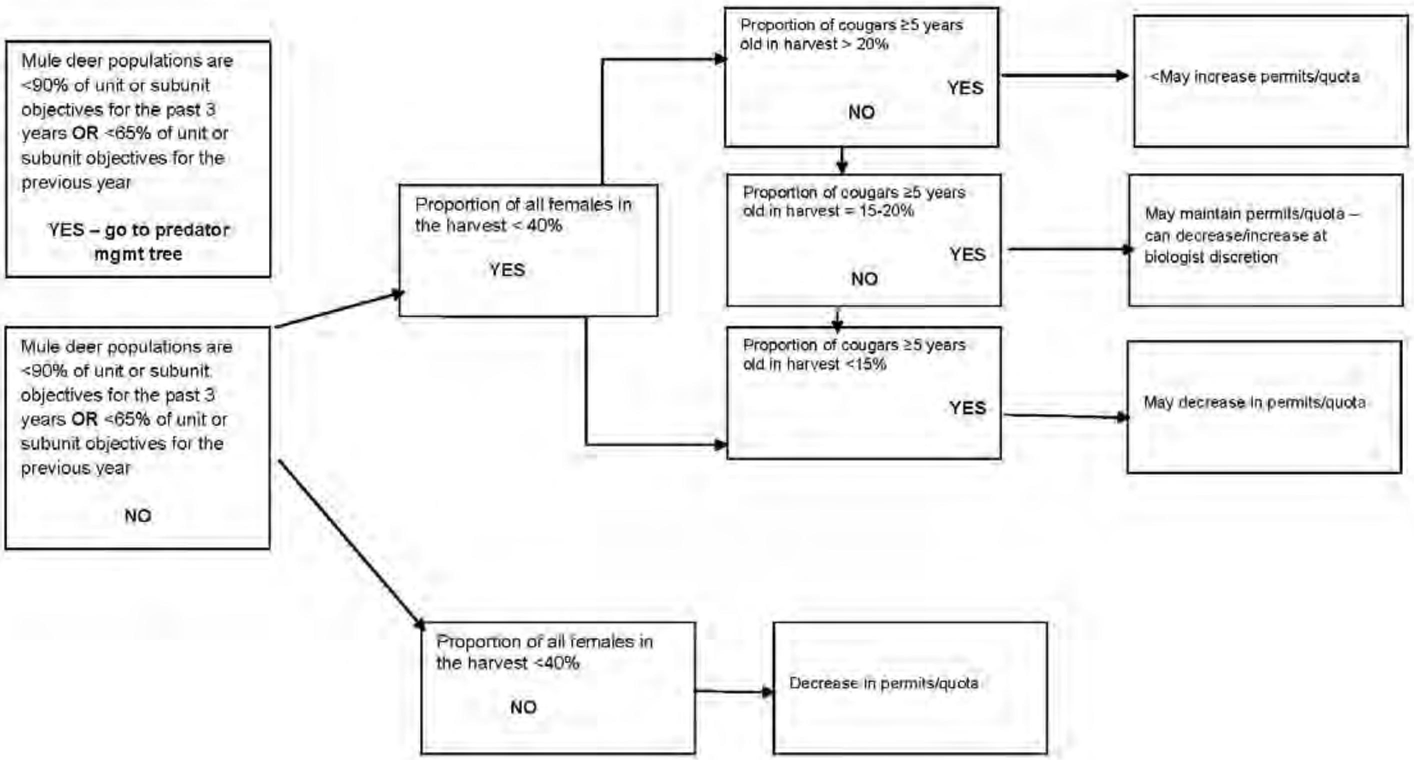
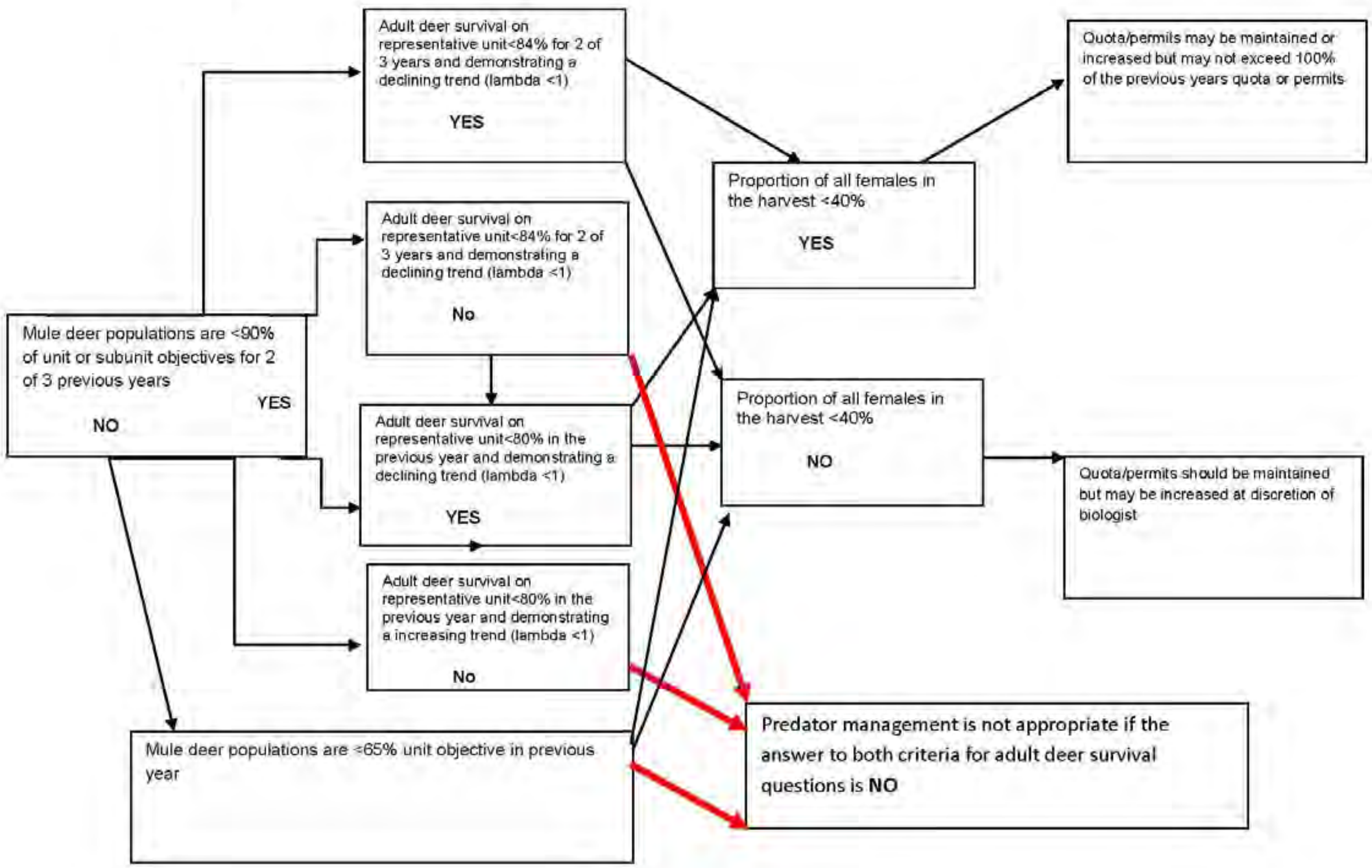
Attachment A: Cougar Management Tree

- **Primary Target** - Proportion of all females in the harvest < 40% (within a management area averaged over 3 years)
- **Secondary Target** – Proportion of cougars ≥5 years old in harvest between 15-20% (within a management area averaged over 3 years)



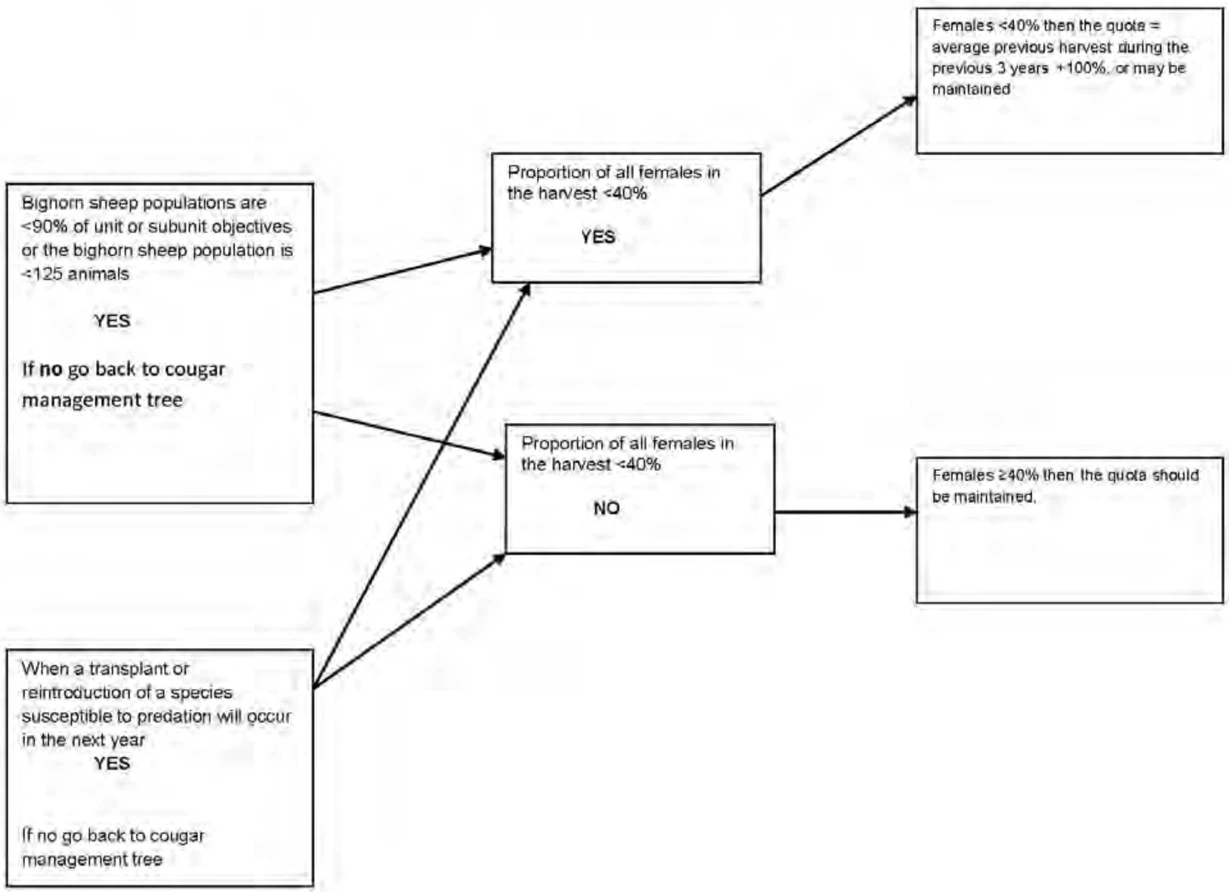
Attachment B: Predator Management Tree - Mule Deer

- **Primary Target -** Proportion of cougar females in the harvest ≥ 40% (within a management area averaged over 3 years)



Attachment C: Predator Management Tree Bighorn Sheep and Transplants

- **Primary Target -** Proportion of cougar females in the harvest > 40% (within a management area averaged over 3 years)



Attachment D: Issues and Concerns

During the meetings of the Cougar Advisory Group the following list of issues and concerns were established by the group members. Subsequent meetings focused on discussion, perceptions, and developing, objectives, strategies and management systems to address issues and concerns.

Outreach / Education

- Need to educate the public about the relationship between cougar and prey populations and the need to integrate management of both predator and prey.
- Need to educate hunters on sex/age identification to help protect females and kittens.
- Need to educate the general public about cougars and cougar safety. Especially in communities situated along the urban-wildland interface.
- Need to improve efforts to educate sportsmen and interest groups on our decision making and recommendations process – need more education prior to RAC and Wildlife Board meetings.

Population Management / Harvest Management

- Need tools to solve non-resident issues (pursuit permits, commercial vs recreational).
- Three year plan and recommendation process was too inflexible and didn't allow for responsiveness to depredation, nuisance or population concern responses .
- Need to simplify the management criteria (performance targets).
- Revisit performance criteria.
- Need tools designed to protect all females.
- Female performance targets in previous plan made it difficult to address livestock damage and nuisance using sport harvest .
- Ecoregion/cougar management areas were too broad for hunter management.

- Eco-region/cougar management area quotas shut down entire units too quickly and didn't allow for targeted harvest to address problem areas.
- Need to harvest more females in some situations – female subquota reduces ability to manage in balance with prey.
- Need to recognize the importance of adult males in the social demographic .
- Need to recognize social structure as a predictor of population.
- Need more knowledge and information on source-sink populations.
- Does transition on split units from limited entry to harvest objective lead to over harvest.
- Does harvest objective hunting lead to over harvest of females.
- Hard to encourage harvest in areas that are difficult to hunt.
- Belief that population estimates are too high – need to reevaluate population estimates.
- Would like to require GPS location on all cougar harvests.

Predator Management

- Need to integrate cougar and prey (mule deer and bighorn sheep) management .
- Need to move away from predator management plans.
- Need for evaluation of predator management plans and their effectiveness.
- Need to reduce units under predator management and find a way to balance prey populations with predator populations.
- Need for triggers to be related to livestock depredation, deer survival and populations.

Livestock Depredation

- Need to identify the sex of depredating cougars.
- Develop a way to deal with chronic depredation problems.
- Triggers need to be to related to livestock depredation and deer survival.

Research

- Compare ungulate and cougar populations
  - Develop monitoring system to measure deer herd response to variation in cougar abundance on units under predator management
- Explore mark recapture population estimates (DNA sampling).
- Explore cougar survival estimates for population management in relation to representative deer survival units.
- Need more robust population estimates.
- Identify limiting factors for predator management units.

WYOMING GAME & FISH DEPARTMENT

Mountain Lion Management Plan

Prepared By: Trophy Game Section (Management/Research Branch), Wyoming Game & Fish Department, Lander, Wyoming

Sept. 7, 2006

TABLE OF CONTENTS

EXECUTIVE SUMMARY

- The goal of mountain lion management in Wyoming is to sustain mountain lion populations throughout core habitat at varying densities depending on management objectives to provide for recreational/hunting opportunity, maintain ungulate populations at established objectives or in line with current habitat conditions, and minimize mountain lion depredation to pets and livestock and reduce the potential for human injury.

- The intent of this document is to provide guidelines to direct future management efforts for mountain lion populations in Wyoming and not to specifically address local management issues throughout the state; a process that occurs during the 3 year season setting process, when hunt area specific data are presented in the annual mountain lion mortality summaries. The management approach addressed in this document favors an adaptive management process where management objectives are established based on local biological and social conditions and modified/adapted over time relative to management criteria suggesting whether or not objectives have been met, to achieve balance between predator and prey populations, and address changing social factors related to depredation incidents and human-mountain lion interactions.

- Core occupied habitats for adult mountain lions during the winter will be delineated statewide to evaluate impacts from the density of human-caused mountain lion mortalities and to evaluate potential impacts from future development projects. Local (by hunt area) and regional (by Mountain Lion Management Unit-LMU) management objectives will be developed and evaluated based on harvest data. A source-stable-sink adaptive management approach will be applied evaluating (1) density of human-caused mortalities, (2) sex-age composition of mountain lion harvest focusing on relative proportion of adult female harvest, and (3) the relative age of harvested adult females.

- Hunt area management objectives will be based on Regional desires to meet localized situations relative to maintaining low population densities (sink), stable population densities, or to maintain areas with low mountain lion mortality to serve as source areas for mountain lion dispersal into areas experiencing negative population growth (sink areas). Sink management will be applied to maintain low mountain lion densities in areas experiencing high nuisance incidents (livestock depredation, human-lion interactions) and areas where ungulate populations are believed to be depressed primarily due to mountain lion predation; stable management objectives will be implemented to sustain long term hunting opportunity; and source management objectives will be applied to areas where nuisance incidents and predation impacts to prey populations are not an issue. Management objectives at the LMU level will strive for a combination of source, stable, and sink management that will allow for the department to sustain mountain lion populations throughout core habitat at varying densities depending on management objectives.

- Status of representative source areas will be periodically evaluated to verify that these areas are functioning as source areas for mountain lion dispersal using monitoring techniques that can be reasonably applied relative to Department budget constraints. Success of sink management to address nuisance incidents or predation pressures on ungulate populations will be evaluated over time following the adaptive management process outlined in this plan. Similarly, mountain lion population monitoring criteria will be evaluated and modified as information becomes available addressing the utility of the proposed criteria in defining source, stable, or sink mountain lion habitats.

- Hunting season structure will be based on mountain lion mortality quotas. Mortality quotas will be established for each hunt area, and the hunting season will be closed when the quota has been met. Most of the hunting seasons will run from September 1 through March 31, with the exception of a few hunt areas with chronic livestock depredations. Hunting with hounds will continue to be allowed. Hunters shall present the pelt and skull of harvested mountain lions to Department personnel within 72 hours of harvest so specific data can be recorded. These data will be used to determine the management status, age and sex structure of harvested mountain lions, distribution of mortalities, hunter effort, hunter success, and to account for and set future mortality quotas. Mortality quotas will be established every 3 years to allow sufficient time to reach management objectives and to permit adequate analysis of potential impacts of specific harvest quotas. The process by which these 3-year mortality quotas are set includes annual data analyses and summary by the Trophy Game Section, internal review and recommendations at the regional level, public review of the recommendations, and final approval by the Commission.

- The Department will continue to use a variety of options ranging from no action to lethal removal, which will be assessed on a case-by-case basis, to address mountain lion depredation on domestic livestock and pets and mountain lion/human interactions. All management actions and responses will be documented for future evaluation.

- Adaptive management will be implemented to address short and long-term management needs where appropriate, and additional research efforts will be conducted to address other management priorities as funds become available relative to other Department priorities.

- A previous draft of this management plan was revised based on comments received from 4 peer reviewers and 73 separate public comments. We thank Brad Compton, Idaho Department of Fish and Game, Fred Lindzey, Wyoming Cooperative Fish & Wildlife Research Unit-retired, Ken Logan, Colorado Division of Wildlife, Dale Strickland, Western Ecosystems Technology, Inc, Cheyenne, WY, and members of the public submitting comments for suggestions on improving this management plan. Comments from peer reviewers were evaluated and most have been addressed throughout the revised document. Comments concerning various aspects of the proposed plan (e.g. surveying all mountain lion license holders for hunter effort data, educating hunters about sexing lions in the field, including all human-caused mortality towards quotas, oppose sink management every 3 years, balance source-sink management and reducing the reporting period for harvested lions to 48 hours) were addressed and included in the plan for consideration by the Commission.

- The Department will continue to update and expand, where feasible, information and education efforts across the state including development of a website to educate hunters on sexing mountain lions in the field, and periodically conducting public attitude surveys of Wyoming residents.

- The Department will begin to survey all mountain license holders to enhance the management database.

- All human caused mountain lion mortalities will be counted towards quotas.

MOUNTAIN LION LIFE HISTORY AND ECOLOGY

Distribution

The historic range of the mountain lion was the largest of any terrestrial mammal in the western Hemisphere, with the exception of humans (Logan and Sweanor 2001). The mountain lion continues to range from the southern tip of South America to northern British Columbia (Logan and Sweanor 2001), but were apparently extirpated from the eastern US and Canada, with the exception of southern Florida, by the late 1800s to early 1900s. Between the mid 1960s and the early 1990s, mountain lion populations increased in many western states and they expanded their distribution into some of the mid-western states including Nebraska, South Dakota, and North Dakota likely due to reclassifying mountain lions from unregulated predator status to game animals and the restricted use of predicides since the early 1970s. Similarly, mountain lions in Wyoming have increased in abundance and distribution and currently occupy most timbered and tall-shrub covered regions statewide. In the early part of the 20th century, efforts to remove mountain lions from many areas of Wyoming caused local extirpations. However, robust populations are currently found in the Black Hills of northeastern Wyoming, the pinyon-juniper country of southwestern Wyoming, and all major mountain ranges throughout the state. This reestablishment of mountain lions throughout Wyoming (and likely throughout much of their former range) is likely due to a shift in management practices and policies that favored increases in numbers and distribution (see Appendix I for mountain lion management history in Wyoming) and habitat conditions favoring increases in some prey abundance (e.g., elk, *Cervus elaphus*, white-tailed deer, *Odocoileus virginianus*).

Dispersal patterns and genetic evidence suggest mountain lion populations throughout most of the western US are well connected (Culver et al. 2000, Sinclair et al. 2001, Anderson et al. 2004). Movements of male mountain lions in excess of 1,000 km have been documented (Thompson and Jenks 2005). These long-range movements provide a very effective means of genetic transfer and population maintenance to mountain lion populations in distant regions. In addition, much of Wyoming's mountain lion habitats are extensions of mountain ranges in other states. This provides excellent connectivity to other habitats, and hence, other mountain lion populations. Overall, gene flow among mountain lion populations in the Central Rocky Mountains suggests this region exists as one large mountain lion population with rapid genetic exchange among suitable habitat patches throughout the region (Anderson et al. 2004).

Habitat Use

The broad geographic distribution of the mountain lion in North America attests to its ability to persist anywhere that provides adequate prey and cover [Cougar Management Guidelines Working Group (CMGWG) 2005]. Previous mountain lion habitat studies in the western US suggest mountain lions select conifer, deciduous timber, riparian, and tall shrub habitat types at mid-high elevations in steep or rugged terrain (Logan and Irwin 1985, Laing 1988, Koehler and Hornocker 1991, Williams et al. 1995, Dickson and Beier 2002). Tall vegetation or rugged terrain sufficient for concealment provides the necessary hiding and stalking cover for securing prey and raising young (CMGWG 2005). Mountain lions may be found in climates ranging from arid regions of desert environments to temperate rainforests of the Pacific Coast. Besides prey availability, the only biophysical limitations for mountain lions are vast, open areas with little hiding cover and severely cold winter temperatures of northern climates (Pierce and Bleich 2003).

Despite the mountain lions broad distribution and adaptability, human impacts from development and habitat fragmentation can negatively impact mountain lion populations (Beier 1993). Increased construction of roads and homes in mountain lion habitat not only reduces the amount and quality of habitat available to mountain lions and their prey [e.g., deer (*Odocoileus* spp.) and elk (*Cervus* spp.)], but also increases human presence in these areas. Increased human activity ultimately leads to increases in mountain lion/human interactions and mountain lion deaths (CMGWG 2005). Even in sparsely human populated states like Wyoming, where most mountain lion range is still relatively contiguous, subdivisions, new road construction, and oil and gas development may negatively impact mountain lion habitats.

Mountain Lion Social Structure and Reproduction

Social behavior of mountain lions likely evolved to maximize individual survival and reproductive success (Logan and Sweanor 2001). Mountain lions are solitary carnivores exhibiting a polygynous breeding strategy where dominant males typically breed with females that reside within their home range (Murphy 1998). Resident males aggressively defend their territories against male intruders, whereas females allow more overlap, but express mutual avoidance (Lindzey et al. 1989, Ross and Jalkotzy 1992, Logan and Sweanor 2001). Size of female home ranges tend to be large enough to provide sufficient prey for themselves and their young (~50-100 km^2, 20-40 mi^2), while male home ranges tend to be larger (~150-300 km^2, 60-120 mi^2), overlapping several females, apparently to maximize their reproductive success (Murphy 1998). Young females commonly express philopatric behavior (remain in their natal range) upon independence, but males typically disperse from their natal range (Anderson et al. 1992, Ross and Jalkotzy 1992, Lindzey et al. 1994, Logan and Sweanor 2001). Partially due to their solitary and territorial nature and ultimately limited by prey abundance, mountain lion densities are low relative to other large mammals ranging from about 10 independent (>1 year old and self sufficient) mountain lions/1,000 km^2 (386 mi^2) in arid climates (e.g., southern Utah, Lindzey et al. 1989) to about 35 independent mountain lions/1,000 km^2 in more mesic areas (e.g., the Diablo Range, California, Hopkins 1989, southwest Alberta, Ross and Jalkotzy 1992).

Female mountain lions typically produce their first litter at 2-3 years old (Anderson 1983, Ashman et al. 1983, Logan and Sweanor 2001) and may breed at any time of the year, but exhibit seasonal birth pulses. Data from 7 mountain lion studies in western North America indicate May through October are the peak months for mountain lion parturition (CMGWG 2005). Gestation lasts 82-96 days and mountain lions typically produce 2 to 4 young. The average size of 53 nursling litters documented in New Mexico was 3.0, with 13 (26%) 2-kitten litters, 26 (49%) 3-kitten litters, and 14 (26%) 4-kitten litters (Logan and Sweanor 2001). Other studies reported average litter sizes <6 months old, ranging from 2.2 in Alberta (Ross and Jalkotzy 1992) to 2.9 in Wyoming (Logan et al. 1986). Kittens are usually weaned at 2–3 months and typically remain with the female for 12–18 months before becoming independent (Pierce and Bleich 2003).

Food Habits and Prey Relationships

Mountain lion diets consist primarily of large vertebrate prey species. In much of North America, deer comprise the majority of mountain lion diets (Pierce and Bleich 2003), but other large ungulates such as elk, bighorn sheep (*Ovis canadensis*), moose (*Alces alces*), and pronghorn (*Antilocapra americana*) may also be consumed (Ross and Jalkotzy 1996, Ross et al. 1997, Murphy 1998, Anderson and Lindzey 2003). Although mountain lions primarily subsist on large ungulates, small mammals including porcupines (*Erethizon dorsatum*), lagomorphs (hares and rabbits), ground squirrels (*Spermophilus* spp.), and beavers (*Castor canadensis*) may also supplement mountain lion diets. Mountain lions also occasionally prey on domestic livestock and pets. Sheep and goats are the most commonly killed domestic livestock, but mountain lions also kill cattle, horses, and pets including dogs, and cats (CMGWG 2005).

The mountain lion can be an influential predator on some ungulate populations. Mountain lions were an important source of predation on a bighorn sheep population in Alberta (Ross et al. 1997), and were implicated in the decline of another bighorn population by causing avoidance of high quality forage (Wehausan 1996). Logan and Sweanor (2001) reported that mountain lion predation was the strongest proximate cause limiting a New Mexico mule deer (*O. hemionus*) population by slowing the rate of growth during a population increase phase, and hastening the decline of the population during drought conditions that degraded forage quantity and quality. Mountain lions have annually removed an estimated 15-20% of a mule deer population on the Kaibab Plateau, Arizona (Shaw 1980), 8-12% of a mule deer population on the Uncompahgre Plateau, Colorado (Anderson et al. 1992), and 2-3% of elk and 3-5% of mule deer in the northern Yellowstone Ecosystem (Murphy 1998). Mountain lion predation, however, does not necessarily indicate suppression or regulation of the prey population. Regulation is more likely in systems with multiple prey and multiple predator species. In these situations, predator populations that would normally decrease as their prey populations are reduced, are supported by other, more numerous prey populations (Pierce and Bleich 2003).

The potential impacts of mountain lions on prey populations are largely dependent on the condition of the prey and their habitat. In areas where prey habitat is in good condition, prey body condition will also be greater. Thus, most individuals in the prey population are likely to survive in the absence of predation. In prey populations where individuals are in poor condition due to poor forage quality, however, those individuals are more likely to die regardless of predation. Therefore, mountain lion predation on ungulates in good physical condition is more likely to be *additive* to other causes of mortality. Conversely, mountain lion predation on ungulates in poor physical condition is more likely to be *compensatory* (Logan and Sweanor 2001). In addition, healthy prey populations likely exhibit higher reproductive rates and are more likely to offset predatory regulation by producing more young than are consumed by predators. Ungulate populations exhibiting the characteristics of limitation by predation (Table 1) may benefit from increased mountain lion harvest. Populations limited mainly by habitat conditions will not likely benefit from increases in local mountain lion harvest except during the initial phases of habitat recovery allowing more rapid response of the prey population to improved forage conditions. Additionally, in situations where alternative prey species are lacking, a decline in mountain lion numbers will naturally follow the decrease in the ungulate population regardless of mountain lion harvest levels (CMGWG 2005).

Table 1. Characteristics of ungulate-prey populations regulated by predation and populations regulated by forage conditions (from the Cougar Management Guidelines 2005, page 15).

Life history characteristic	Population size mainly affected by predation[b]	Population size mainly affected by forage
Physical condition of adult females	better	poorer
Pregnancy rate of adult females	higher	lower
Pause in annual production by adult females	less likely	more likely
Yearlings pregnant[a]	usually	seldom
Corpora lutea counts of adult females[a]	higher	lower
Litter size[a]	higher	lower
Age at first reproduction for females	younger	older
Weight of neonates	heavier	lighter
Mortality of young	additive	compensatory
Age at extensive tooth wear	older	younger
Diet quality	higher	lower

[a]Some species of ungulates may show limited variability in these characteristics.
[b]These traits will be evident in *any* population far below carrying capacity, even if it experiences *no* predation. The manager should have evidence that predation is a limiting factor before concluding that reducing predation would increase ungulate recruitment.

TRADITIONAL MOUNTAIN LION MANAGEMENT IN WYOMING

Mountain lion management in Wyoming (and throughout its range) has traditionally consisted of more art than science largely due to the secretive nature and naturally low densities typical of this solitary large carnivore and the rugged terrain it typically inhabits. Agencies charged with mountain lion management attempt to address the public's desires, where values vary and sometimes compete between maintaining abundant populations, providing hunting opportunity, and minimizing human conflicts by addressing depredation incidents and potential for mountain lion-human interactions. The goal of mountain lion management in Wyoming is to sustain mountain lion populations throughout suitable mountain lion habitat at varying densities depending on management objectives, and to provide for recreation/hunting opportunity, maintain ungulate populations at established objectives or in line with current habitat conditions, and minimize mountain lion depredation and potential for human injury resulting from mountain lion-human encounters.

Although population estimates have traditionally been lacking, evidence based on professional experience and opinion (i.e., local wildlife biologists, game wardens), increasing mountain lion harvest levels (Appendix II, Fig. II-1), hunter observations, sightings, and nonharvest-human caused mortalities (Appendix II, Fig. II-3) indicate mountain lion populations have increased in Wyoming over the past 30 years. In response to perceived increases in mountain lion numbers, harvest quotas were increased annually during the mid to late 1990s (Appendix II, Fig. II-1). Approaches to how we manage mountain lion populations have changed gradually since 1974 when regulated hunting was first established in Wyoming, including establishment of fall-winter hunting seasons, developing management units and hunt areas to address local management issues, requiring mandatory inspection of harvested mountain lions for annual data collection, and developing total and female harvest quotas to address hunt area management objectives (Appendix I). Traditionally, mountain lion harvest quotas were set based on perceived densities and the history of or potential for human conflicts (e.g., mountain lion-human interactions, depredation incidents, potential impacts to big game species) and adjusted based on perceived mountain population trends relative to annual harvest data, and how quickly quotas were filled each year loosely reflecting hunter effort. Although mountain lion populations in Wyoming increased under this management scheme, this general approach to mountain lion management provided managers with limited ability to determine whether or not management objectives were achieved. The previous Draft Wyoming Mountain Lion Management Plan (1997) identified the lack of data necessary to identify whether or not management objectives have been met and supported research investigating potential methods to adequately monitor mountain lion population responses to varying management prescriptions. Subsequently, mountain lion research was conducted from 1997-2003 (Anderson 2003) to investigate potential approaches for evaluating mountain lion management.

Local and Regional Mountain Lion Management and Annual Data Collection

Wyoming is currently divided into 5 Mountain Lion Management Units (LMU), which are further divided into 29 mountain lion hunt areas (Appendix III). Due to the large size of the West LMU, covering several connected mountain ranges and associated foothill winter mountain lion habitats, the West LMU is divided into 3 separate Data Analysis Units (DAUs) called the Absaroka (hunt areas 19 and 20), Wyoming Range (hunt areas 2, 14, 17, 26, and 29) and Wind River (hunt areas 3, 4, 18 and 28) DAUs (Appendix III). This subdivision provides managers improved capability to monitor the effects of harvest strategies designed to meet potentially different management objectives among these 3 regions.

Mountain lion management units primarily represent connected regions of contiguous mountain lion habitat (i.e., geographic populations), and the smaller hunt areas allow managers to address local management issues while maintaining the overall management objective for the regional population (i.e., within the LMU). The Cougar Management Guidelines Working Group (2005) recently suggested managing mountain lion populations with respect to source-sink dynamics, where source areas would be managed for positive growth and sustain sink areas where management objectives call for reducing mountain lion densities. The current hunt area and management unit structure in Wyoming lends itself well to this concept, where hunt areas within management units can be managed as source and sink subpopulations, depending on local management issues, and can continue to support desired mountain lion population densities at landscape levels.

Mountain lion management objectives shall be based on ecological data and social conditions to ensure management strategies benefit both the species of concern and the people who are impacted by mountain lion conflicts. Mountain lion mortality data in Wyoming include information obtained annually from harvest or other documented forms of mortality [e.g., natural causes, damage removals, road kills; Appendix II]. Since 1974, hunters have been required to present the pelt and skull of harvested mountain lions to a district game warden, biologist, or a Wyoming Game and Fish Department regional office for registration. Information collected include: harvest date, location (legal description, Universal Transverse Mercator location, and hunt area), sex, lactation history (whether or not females have ever produced young from nipple characteristics; Anderson and Lindzey 2000), estimated age from tooth wear and degree of staining, and collection of teeth for cementum annuli aging, number of days spent hunting, hunting method, and number of mountain lions and mountain lion tracks observed while hunting (Appendix IV). Trainer and Golly (1992) reported 76% agreement ≤1 year of annuli ages compared using blind tests of 2 premolars from the same mountain lion ($n = 426$; 92% agreement for lions <4 years old), and annuli age comparisons of known age mountain lions were 95% accurate (within 1 year; Trainer and Golly 1992:14/15, Anderson 2003:6/6). In addition to mortality data, the Wyoming Game & Fish Department compiles data on mountain lion observations, sign, depredations, human interactions and gauges social concerns through public meetings, hunter surveys, public attitude surveys, and contacts with the public.

Mountain lion mortality data are used to assess: (1) population status, (2) age and sex structure of harvested mountain lions, (3) distribution of mountain lion mortalities, (4) effort expended per mountain lion harvested (Appendix II, Fig. II-2), and (5) to account for and set mortality quotas. Sex and age composition of mountain lion harvests are useful to assess mountain lion population trends (Anderson and Lindzey 2005), and the age of reproductive females can be useful to examine the reproductive potential of mountain lion populations (Stoner 2004, Anderson and Lindzey 2005); populations maintaining older-age females have higher reproductive potential, and thus resiliency, than populations where female survival is reduced. Recording distribution of mountain lion harvest and other human-caused mortalities allows assessment of potential source areas where little or no mountain lion mortality occurs, and sink areas where mountain lion mortalities may be relatively high. Changes in hunter effort may indicate changes in mountain lion densities, assuming the time required to harvest a mountain lion is related to the number of mountain lions in an area. This information is used to establish total and/or female mortality quotas by hunt area every 3 years. Setting mountain lion seasons every 3 years allows sufficient time for management reductions in areas with sufficient hunter access (Anderson and Lindzey 2005) and recovery for previously suppressed populations (Logan and Sweanor 2001, Anderson and Lindzey 2005). The process by which these 3-year mortality quotas are set include (1) annual data analyses and summary by the Trophy Game Section, (2) internal regional review and recommendations provided by each of the 7 Wyoming Game and Fish regions, (3) a public input process, and (4) final hunting season regulations submitted from the regions for action to the Wyoming Game and Fish Commission.

Mountain Lion Hunting Season Structure

Regulation of sport hunting for mountain lions in the western states typically follows 1 of 3 harvest strategies including general seasons, limited entry, and harvest quota systems (CMGWG 2005). General seasons allow unlimited hunting of mountain lions of either sex, and the only restrictions include the number of licenses issued per hunter (typically 1 per season) and timing and length of the hunting season. General seasons provide the highest hunting opportunity, but likely result in uneven hunting pressure (i.e., accessible areas are heavily hunted and inaccessible areas are not) limiting control over harvest level, composition of the harvest, and distribution of the harvest. Limited entry programs limit the number of hunters per hunt area through limited license allocation, using either first come first serve or lottery license sales. This approach is most limiting in terms of hunter opportunity, but can be useful to disperse hunting pressure, control harvest levels, and may increase the opportunity for hunters to be selective (increasing male harvest) in areas where hunting pressure is low. Harvest quota management requires setting a limit on the total harvest and/or number of female mountain lions harvested from an area. The hunting season is closed in an area once the harvest quota has been met. Hunters are required to monitor status of the hunting season by calling a harvest quota hotline. Advantages to the quota management approach are that hunting opportunity remains high and harvest distribution and level can be regulated. Female sub quotas can be used to support a management objective of sustaining harvest levels with reduced impact on the mountain lion population. Potential disadvantages of harvest quota management include the number of hunters per hunt area is unlimited until quotas are filled and harvest quotas may be exceeded if more than 1 mountain lion is harvested the same day the quotas is filled. Harvest quota management has traditionally been used in Wyoming for mountain lion management.

Methods of Mountain Lion Hunting

Mountain lion hunting in Wyoming is accomplished using various hunting methods including opportunistic harvest (spot and stalk) during big game (e.g., elk and deer) seasons, calling mountain lions using predator calls, and tracking and baying mountain lions using trained hunting dogs (i.e., hunting with hounds). The majority of mountain lions harvested annually in Wyoming are taken by hunting with hounds (typically >90%).

Some groups and individuals, both nationally and locally (Gasson and Moody 1995), are concerned about the use of dogs as a hunting method for mountain lions, and some states have recently banned hunting with hounds (e.g., Oregon, Washington). In states where hunting with hounds is not allowed, opportunistic mountain lion hunting (during big game seasons, predator calling) appears comparably successful based on harvest levels observed in Washington and South Dakota. Results from Washington (Martorello and Beausoleil 2003) suggest opportunistic mountain lion hunting is less selective than hunting with hounds and/or female mountain lions are more vulnerable to opportunistic hunting; relative female harvest levels increased from 42% to 59% when hunting with hounds was banned in Washington (mean annual harvest before hound hunting ban = 157 and after hound hunting ban = 199, but harvest rates were not significantly different due to annual harvest variability).

Mountain lion harvest data from Wyoming the past 5 years suggest an average of 32% of successful hound hunters (range = 25-44%; mean total lion harvest from hunting with hounds = 176/year) report being selective while mountain lion hunting and averaged 1.8 days longer in the field than unselective hunters (4.8 days versus 3.0 days). Harvest comparisons indicate on average 49% of unselective and 32% of selective hunters harvest females each year (mean total female harvest = 44%), averaging 9 fewer females and 9 additional males harvested by selective hound hunters in Wyoming annually. Although selectivity reduces female mountain lion harvest, it does not completely explain differences observed between Washington and Wyoming. These differences likely also relate to differences in mountain lion vulnerability between hunting methods.

Anderson (2003) observed that nightly movement distances from Global Positioning System (GPS) data averaged over 3 times longer for male mountain lions than for females (mean end-point distance = 4.6 km versus 1.5 km, 2.9 mi versus 0.9 mi). These longer distance movements expose males more than females to hunting methods where tracking is involved (i.e., hunting with hounds). Opportunistic hunters who do not track mountain lions while hunting are also more likely to harvest the less mobile and more abundant sex (typically females, CMGWG 2005:40) because relative abundance rather than movement patterns drive harvest vulnerability when mountain lions are hunted opportunistically. In addition, hunters with hounds have an increased ability to avoid family groups by detecting young while tracking mountain lions, whereas opportunistic hunters have limited opportunity to determine if young are present.

Potential for Orphaning Young

Because mountain lions can breed and reproduce any time of the year, orphaning of young can result from the harvest of female mountain lions with young. This issue draws emotionally negative responses from some segments of the public and deserves formal appraisal of the potential biological consequences of orphaning young from the harvest of adult female mountain lions. Wyoming law prohibits the harvest of mountain lions accompanied by young, but females may not be accompanied by young while searching for prey (Barnhurst and Lindzey 1989), and therefore may mistakenly be harvested by mountain lion hunters.

Number of mountain lion litters orphaned from hunting can be estimated if data are collected addressing the number of adult females harvested annually. All mountain lions harvested in Wyoming are subjected to mandatory inspection where sex, age, and lactation history data (from nipple characteristics; Anderson and Lindzey 2000) are collected to determine the number of subadult (estimated age <4 years old and have never nursed young) and adult females (nipple characteristics suggest previous lactation and/or estimated age >3 years old) harvested each year. Logan and Sweanor (2001) reported that on average 50% of adult females reproduce and 75% were with dependent young each year. Thus, about 25% of adult females are without young and 25% are with yearlings. Because young may become independent as early as 12 months old or earlier and average dispersal age is about 14-15 months (Anderson et al. 1992, Sweanor et al. 2000), it is unlikely yearling survival is influenced by death of their mother, but survival of young ≤12 months old is likely reduced. Applying these assumptions, timing of female mountain lion harvest, and estimates of monthly birthing rates we can estimate the number of litters orphaned each year due to hunting. Two Wyoming mountain lion studies identified birth month for 31 litters in north central (*n* = 10, Logan 1983) and southeast Wyoming (*n* = 21, Anderson 2003) and provide estimates of monthly birth rates for Wyoming mountain lions (Table 2). Female harvest of both age classes (non-reproducing subadults, reproductive adults) averaged 88 the past 5 years (fall 2000-spring 2005) and averaged 32 adult females (Table 3). Assuming 50% of reproductive females produce young each year, we estimated about 16 litters ≤12 months old may be orphaned in Wyoming annually due to harvest of adult female mountain lions (Table 3).

Table 2. Monthly birth rate from 2 Wyoming mountain lion studies.

	Number of litters			
Birth month	North-central, Wyo.[a]	Southeast, Wyo.[b]	Total	Monthly birth rate
January	0	1	1	0.032
February	0	1	1	0.032
March	0	0	0	0
April	0	1	1	0.032
May	2	1	3	0.097
June	0	4	4	0.129
July	0	3	3	0.097
August	2	5	7	0.226
September	2	1	3	0.097
October	0	1	1	0.032
November	3	2	5	0.161
December	1	1	2	0.065

[a]From Logan 1983.
[b]From data collected by Anderson 2003.

This annual estimate of the number of mountain lion litters orphaned in Wyoming may be high (i.e., assumes 50% of adult females are with young when harvested) because our approach ignores the possibility of hunters detecting and passing females with young while hunting, therefore shifting the harvest toward barren females, which likely occurs at some level when mountain lion tracks are followed in the snow while hunting with hounds. To investigate the estimate, we compared the average number of lactating females harvested the past 5 years (mean = 2.6, range 1-3/year) to that expected when compared to data from Tables 2 and 3. Assuming juvenile mountain lions quit nursing at 2-3 months of age (Pierce and Bleich 2003), we would expect annual harvest of lactating females to range somewhere between 2.8 and 4.7. Whether the lower than expected harvest of lactating females is due more to hunter selectivity or reduced vulnerability resulting from the more sedentary nature of young family groups is unknown but further indicates that some degree of harvest selectivity is occurring.

Based on the estimate of orphaned litters from average adult female mountain lion harvest in Wyoming the past 5 years, 8.7 litters <6 months old and 7.5 litters 6-12 months old (Table 3) would be orphaned in a given year. Survival of orphaned young <6 months old is unlikely, but survival of orphaned young 6-12 months has been documented during at least 3 mountain lion studies (Lindzey et al. 1989, Logan and Sweanor 2001, Anderson 2003) suggesting about 71% survival for this age group; total sample size from the 3 studies was small, resulting in 5 of 7 young orphaned at 6-10 months old surviving. If we assume on average 2 kittens/litter survive to independence (Logan and Sweanor 2001), orphaned young <6 months do not survive, and about 71% of orphaned young 6-12 months old survive, the estimated biological impact to Wyoming mountain lion populations would be an average loss of about 22 juvenile mountain lions annually [$2 \times 8.7 = 17.4$ young <6 months old, $(2 \times 7.5) \times 0.29 = 4.4$ young 6-12 months old]. Based on mountain lion occupancy throughout most timbered and shrub-covered habitats statewide, this level of loss is biologically insignificant, but is still a concern to some segments of the public. If opportunistic hunting increased and hunting with hounds were reduced, we would expect the actual number of young being orphaned to increase because of the apparent increased vulnerability and the higher proportion of females harvested when compared to hunting with hounds (Martorello and Beausoleil 2003).

Table 3. Monthly female mountain lion harvest in Wyoming (recent 5 year average), and estimated number of litters orphaned (<6 months old, 6-12 months old) from adult female harvest.

Month	Mean total female harvest	Mean adult female harvest	Est. mean No. of females w/young[a]	Est. mean No. orphaned litters <6 moths old[b]	Est. mean No. orphaned litters 6-12 months old[c]
Sept.	1.4	0.4	0.2	0.12	0.08
Oct.	6.0	2.4	1.2	0.77	0.43
Nov.	17.2	6.0	3.0	1.74	1.26
Dec.	26.4	8.6	4.3	2.64	1.66
Jan.	15.6	6.2	3.1	1.80	1.30
Feb.	15.8	5.8	2.9	1.12	1.78
Mar.	6.0	3.0	1.5	0.48	1.02
Total	88.4	32.4	16.2	8.67	7.53

[a]Assumes 50% of adult females reproduce annually (Logan and Sweanor 2001).
[b]Estimated number of females w/young × sum of previous 5-month birth rate from Table 2.
[c]Estimated number of females w/young – estimated number of litters <6 months old.

Mountain Lion Habitat Management

Mountain lions are habitat generalists evident in their broad geographic distribution ranging throughout a variety of habitat types in much of the western hemisphere. The primary habitat component necessary for mountain lion survival includes some form of hiding cover for securing large prey (e.g., ungulates) and raising young. Although open vegetative communities are rarely used, mountain lions are found in virtually all other vegetation types including coniferous and deciduous forests, woodlands, swamps, savannahs, chaparral, riparian forests, desert canyons and mountains, and semi-arid shrub lands (Hansen 1992). In Wyoming, Logan and Irwin (1985) reported that mountain lions preferred mixed conifer-curlleaf mountain mahogany (*Cercocarpus ledifolius*) habitats in rugged terrain, and Anderson et al. (in review) reported mountain lion use of timbered and tall-shrub covered regions occurring near the base of mountain ranges during winter.

Mountain lions, depend on healthy prey populations (e.g., deer, elk), therefore, habitats supporting abundant prey are also important to mountain lion populations. Habitat protection and improvement projects are currently in place for ungulate populations in Wyoming (Wyoming Game & Fish Department 2001), which will undoubtedly benefit mountain lion populations. In addition, Anderson et al. (in review) recently developed a mountain lion habitat model and efforts are currently in place to delineate core winter mountain lion habitat statewide (Fig. 1). Current habitat projects for mountain lion prey species and application of the mountain lion habitat model allow evaluation of potential impacts of proposed development projects to habitats supporting mountain lions and their prey.

Mountain Lion Population Monitoring

Monitoring Mountain Lion Population Trend: Although mountain lion populations have previously been monitored with intensive capture efforts over relatively small areas, reliable and affordable techniques to monitor mountain lion populations for large-scale management programs are lacking. Mountain lion management has traditionally employed harvest strategies with little understanding of the quantitative effect differing harvest levels have on mountain lion population demographics. Sex and age classes of mountain lions exhibit different and relatively predictable movement patterns, where males move longer distances than females and subadults (1-2.5 years old) generally move longer distances than adults (Barnhurst 1986, Anderson 2003). Conceptually, the likelihood of a specific sex or age class of mountain lion being harvested would reflect its relative abundance in the population and its relative vulnerability based on daily movement patterns. In areas where dogs are used to track mountain lions, those mountain lions that typically move longer distances would most likely be detected first (males/subadults). The least vulnerable individuals (adult females) should become prominent in the harvest only after the population has been reduced in size by removal of more vulnerable/available mountain lions. Anderson and Lindzey (2005) tested these predictions applying varying levels of hunter harvest and found harvest composition to be predominantly subadults for a high-density population with low harvest levels, shift to adult males as harvest levels increased, and then a shift from adult males to adult females with continued high harvest as the population declined. When harvest levels were reduced, composition of the harvest returned to primarily subadults. The male segment of the reduced population recovered within 2 years primarily due to male immigration

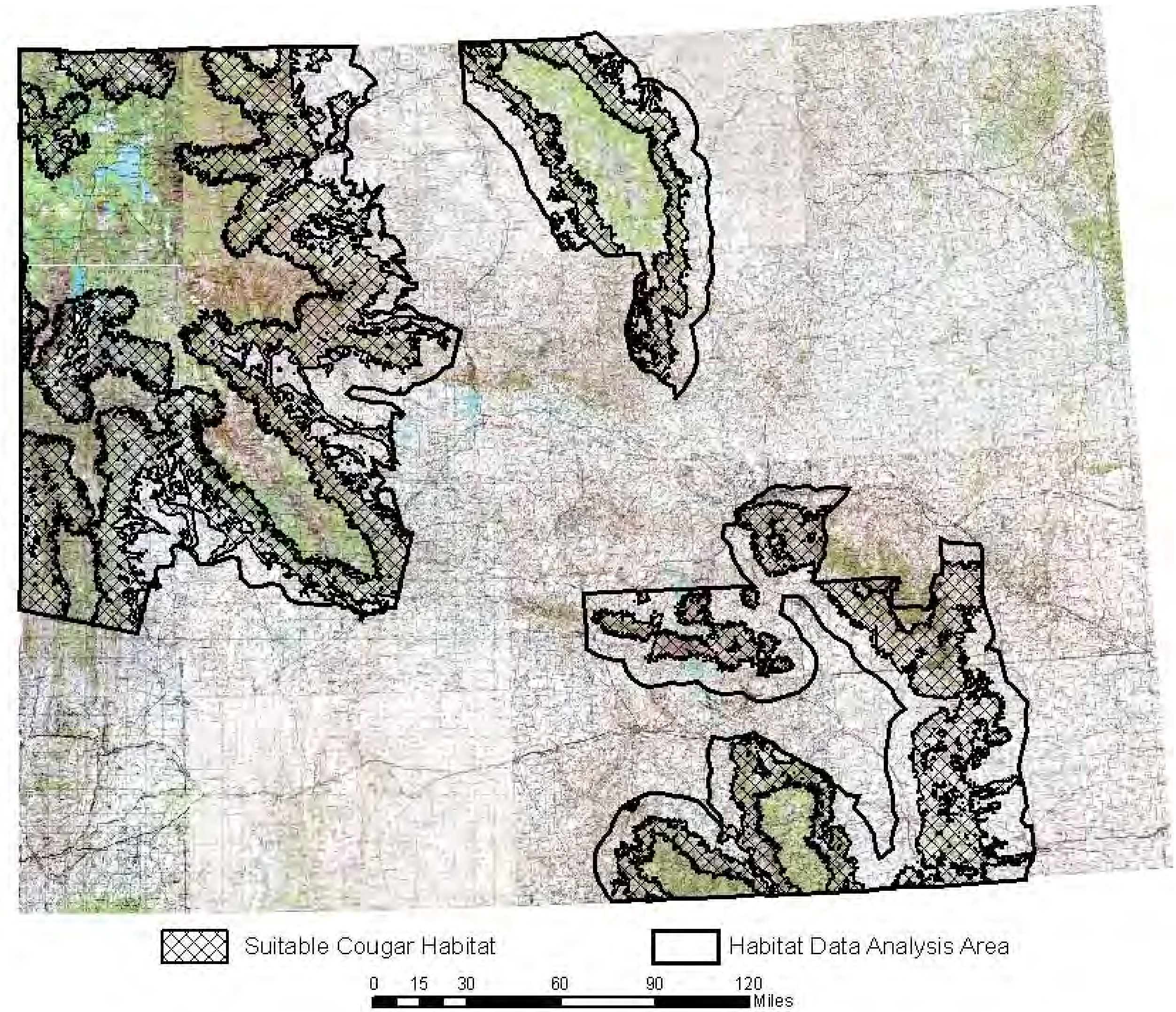


Figure 1. Wyoming mountain lion winter habitat based on model predictions for those portions of Wyoming with suitable vegetation data available for analyses (Anderson et al. in review). Winter mountain lion habitat represents areas suitable for resident adult mountain lions and not necessarily transient subadults (i.e., core mountain lion habitat). Background represents USGS 1:250,000 scale maps. Mountain lion habitat analyses will be completed for areas outside the habitat data analysis area (e.g., northeast and southwest Wyoming) when sufficient vegetation data layers are developed for those regions of the state.

from other populations and the female segment within 3 years from an increased number of females producing young within the population (Anderson and Lindzey 2005).

We compared harvest composition and age of harvested adult females from the Snowy Range (Fig. 2; Anderson and Lindzey 2005) to 2 other areas in Wyoming (Fig. 3; Star Valley and the Laramie Range) where management objectives called for increasing harvest levels to reduce mountain lion populations (i.e., where comparable data were available). We then applied the

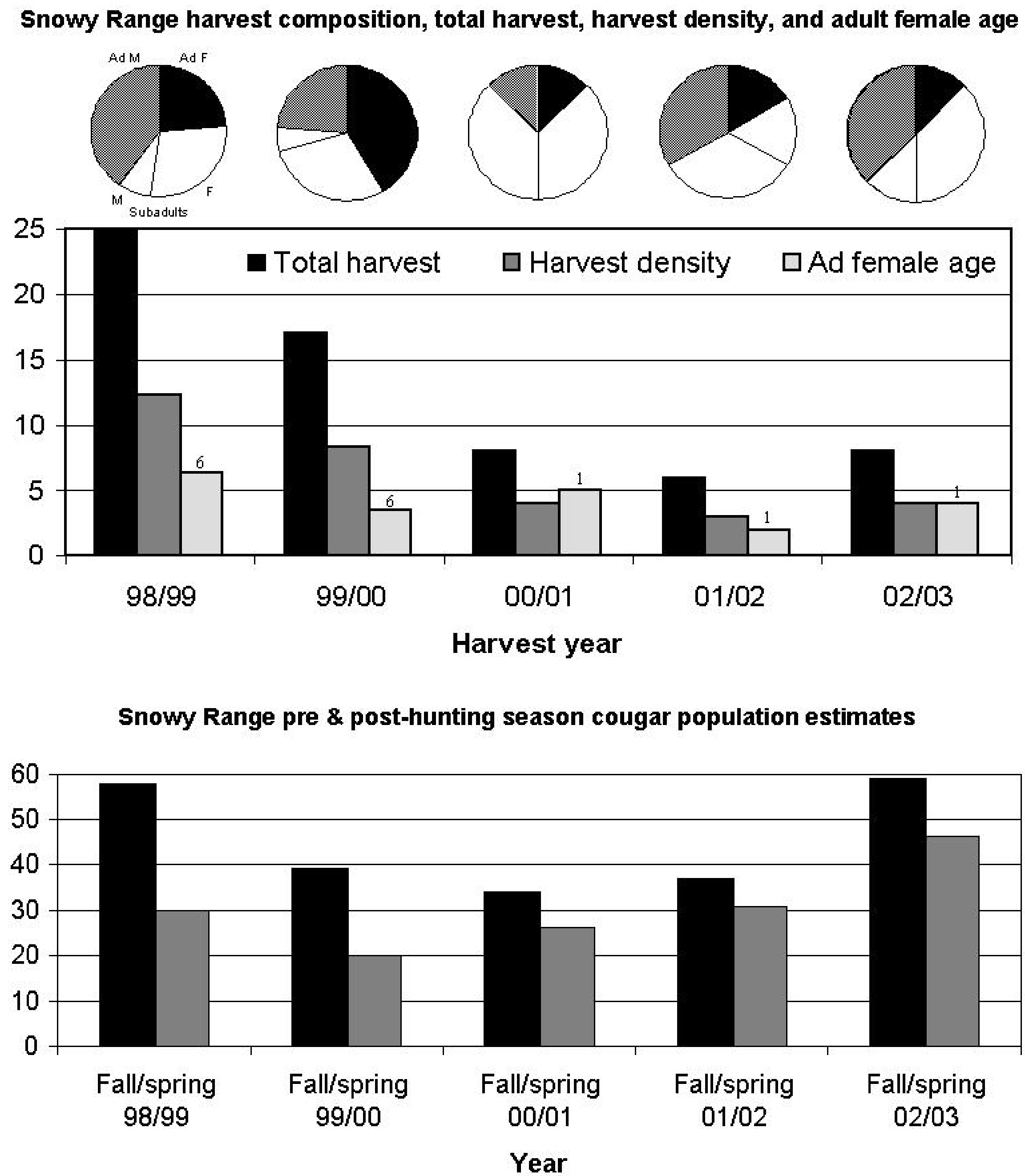
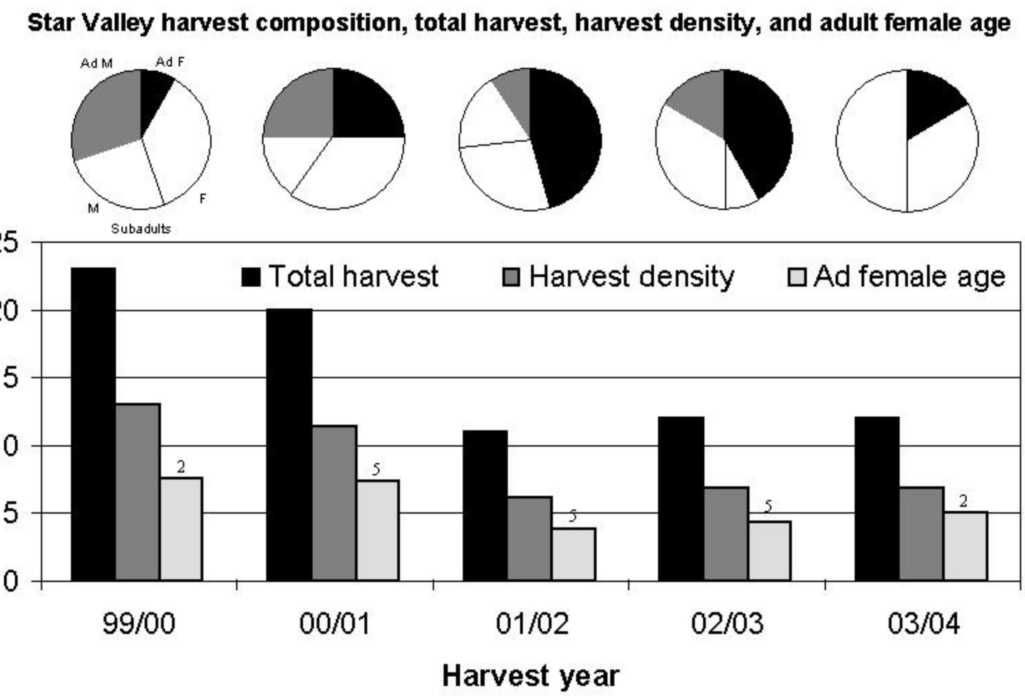


Figure 2. Sex/age composition of mountain lion harvest (pie charts), total harvest, harvest density (mountain lions/1,000 km^2), and mean annuli age of adult females (top bar graph) and pre and post-hunting season mountain lion population estimates (bottom bar graph; Anderson and Lindzey 2005) from the Snowy Range, Wyoming, 1998-2003. Numbers above adult female age represent sample size. Note initial high harvest density (>12 mountain lions/1,000 km^2), decline in adult male harvest, increase in adult female harvest, and decline in age of harvested adult females as the population decreased in size. Also note low harvest densities (<5 mountain lions/1,000 km^2) and low adult female harvest levels during population increase.



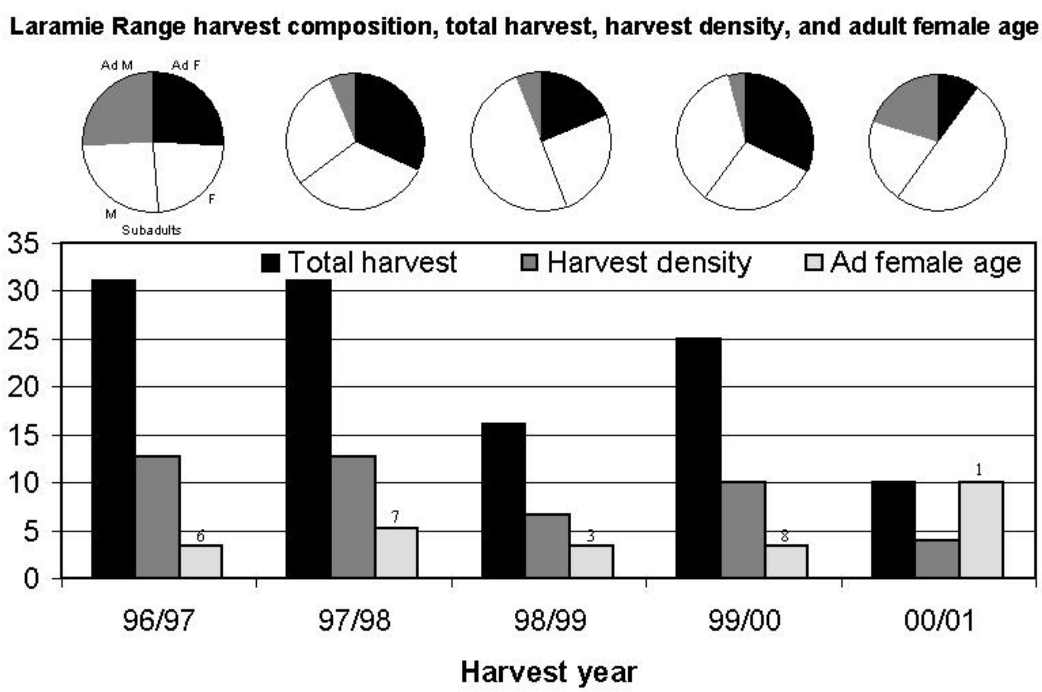


Figure 3. Sex/age composition of mountain lion harvest (pie charts), total harvest, harvest density (mountain lions/1,000 km^2), and mean age of adult females harvested from Star Valley (hunt area 26), Wyoming, 1999-2004 (top bar graph) and from the Laramie Range (hunt areas 6 and 27), Wyoming, 1996-2001 (bottom bar graph). Numbers above adult female age represent sample size. Mountain lion harvest was increased >40% during the first harvest year in each area to achieve the management objective of reducing mountain lion populations.

Wyoming mountain lion habitat model (Anderson et al. in review; Fig. 1) to evaluate harvest densities among areas. The Snowy Range mountain lion population declined about 33% (fall population estimates) following a harvest density of 12.3 mountain lions/1,000 km^2 (386 mi^2; 1998/99 harvest year) and continued to decline another 13% following a harvest density of 8.4 mountain lions/1,000 km^2 (386 mi^2; 1999/00 harvest year). Harvest composition shifted from primarily adult males to adult females and mean annuli age of harvested adult females declined from 6.3 to 3.6 years old as the population declined (Fig. 2). The Snowy Range mountain lion population recovered to previous levels following a 3-year period where harvest densities were between 3.0-4.0 mountain lions/1,000 km^2 (386 mi^2) and harvest composition consisted primarily of subadults, buffering the adult female segment of the population during recovery (2000/01-2002/03 harvest years; Fig. 2). We noted similar progressions in harvest density, harvest composition, and mean age of harvested adult females for Star Valley and the Laramie Range (Fig. 3), except that harvest composition shifting from adult males to adult females was more gradual in Star Valley. Harvest densities remained moderate (typically between 6-7 mountain lions/1,000 km^2) following initial high harvest densities (>10/1,000 km^2) in both areas, and older age females (>5 years old) were not evident in the harvest until the second year of high harvest density in the Laramie Range. The more gradual increase in adult female harvest for Star Valley is likely due to this area being more connected to adjacent mountain lion habitat than the Snowy or Laramie ranges (i.e., more resilient to mountain lion harvest allowing animals from adjacent areas to replace harvested animals). Based on relatively high adult female harvest and intermediate harvest densities (Fig. 3), Star Valley and Laramie Range mountain lion populations were likely maintained at low-moderate densities during the periods examined.

Population Estimation Methods: Obtaining accurate and precise estimates of mountain lion population size for each managed population can be logistically and financially challenging, limiting application of estimation methods to relatively small areas every several years. Methods that have been evaluated or hold promise for estimating mountain lion populations for large-scale management programs include ground-based track surveys, sampling mountain lion tracks during helicopter surveys (i.e., helicopter probability sampling; Van Sickle and Lindzey 1991), and DNA or camera-based mark-recapture efforts. Application of DNA or camera-based mark-recapture methods to estimate mountain lion populations is currently limited because there does not appear to be a reliable attractant for luring mountain lions into hair collection or photo detection sites and individual identification of mountain lions from photos appears unreliable for the camera approach. Until these methods are further developed for mountain lions, track surveys and helicopter probability sampling mountain lion tracks appear most promising in estimating mountain lion populations for management application.

Track surveys have been used to monitor mountain lion populations in California (Smallwood 1994, Smallwood and Fitzhugh 1995) and Arizona (Cunningham et al. 1995). This method requires transect sampling areas where mountain lion tracks are detectable and provides presence-absence data with confidence interval estimates. Beier and Cunningham (1996) reported that sampling 140 and 110 8-km-long transects would be required to detect 30% and 50% population declines, respectively (80% power, $\alpha = 0.05$). The difficulty in implementing track surveys is ensuring transects are well distributed throughout the population in areas where access may be limited and the unpredictability of favorable tracking conditions. The level of effort required to detect useful population changes likely limits application of this method to once every few to several years.

Becker (1991) and Becker et al. (1998) addressed helicopter probability sampling of snow tracks to estimate lynx and wolf population size in Alaska. This method requires sampling animal tracks during helicopter surveys and then following tracks from beginning to end to estimate the probability of detection for each track observed during surveys, and therefore requires consistent snow conditions for the duration of the survey. Helicopter probability sampling provides population and confidence interval estimates derived from the inverse of the detection probabilities for tracks in the sample. Van Sickle and Lindzey (1991) applied this method to a low-density Utah mountain lion population of known size and obtained an accurate but imprecise (high variance) population estimate. Anderson et al. (2003) investigated this method further using computer simulations of mountain lion GPS data (≤6 locations/night) to simulate mountain lion tracks and reported that mountain lion population changes of 15-30% could be detected (90% probability) for medium-high density mountain lion populations (23-35 independent mountain lions/1,000 km^2 or 386 mi^2) depending on sampling effort (transects spaced 2 to 3 km apart). Both Becker (1991) and Anderson et al. (2003) noted the logistical difficulty and added expense of completely following tracks during surveys and suggested using telemetry data from radiocollared animals in the population or GPS movement data from similar habitat types during similar seasons to estimate track lengths. Anderson et al. (2003) noted that an area of about 2,000 km^2 (771 mi^2) could be surveyed in 2 helicopter days for about $8,000-$10,000. Thus, helicopter probability sampling mountain lion populations would be limited to relatively small areas and likely only affordable to management agencies every few to several years.

ADAPTIVE MOUNTAIN LION MANAGEMENT APROACH FOR WYOMING

Mountain Lion Hunting Season Structure, Hunting Methods, and Hunter Effort Indices: Since 1980, mountain lion harvest in Wyoming has been controlled using harvest quota management. Harvest quota management maximizes management flexibility by maintaining high hunting opportunity and controlling harvest by assigning total and sometimes female subquotas by hunt area depending on local management objectives. Rarely are harvest quotas exceeded in Wyoming, but heavily roaded areas are more prone to multiple hunters harvesting mountain lions at the end of the season thereby exceeding harvest quotas. If exceeding harvest quotas becomes a recurring problem, limited entry seasons could be established in those areas or quotas could be adjusted anticipating additional harvest similar to past seasons.

Mountain lion hunting seasons in Wyoming typically occur from September 1 through March 31 lasting 212 days. Year round seasons are established in 2 areas with high depredation incidents to provide opportunity for licensed hunters to take depredating mountain lions as a substitute for removal by agency personnel. Most mountain lion harvest (>90% annually) occurs during the winter months (November-March) when snow cover provides optimal tracking conditions. Although few mountain lions are harvested during September and October, this period provides hunting opportunity for hunters opportunistically during big game seasons or using predator calls.

Although some individuals and groups criticize the use of hounds for hunting mountain lions, this hunting method is an efficient management tool, which allows optimal dispersal of hunting pressure and minimizes harvest of adult females primarily due to vulnerability differences between hunting methods. Tracking mountain lions while hunting with hounds also increases the opportunity for hunters to detect and avoid family groups.

Currently, hunting information is only recorded from successful hunters when registering harvested mountain lions during the mandatory inspection process. Catch-per-unit-effort indices can be useful to monitor impacts to hunted populations assuming there is an identifiable relationship between hunter effort and the number of animals in the area hunted. Hunter effort data from only successful hunters has changed little the past 20 years has not proved useful in assessing mountain lion population trends (Appendix II, Fig. II-2). Additional information from unsuccessful hunters may prove more useful in evaluating these indices and knowledge about the number of unsuccessful and successful hunters hunting an area may explain changes in harvest level in cases where other information does not (i.e., due to changes in the number of hunters hunting an area). Regardless, data from unsuccessful hunters will enhance the management database and likely contribute to other harvest data currently collected.

Mountain Lion Habitat Management: Anderson et al. (in review) developed a winter mountain lion habitat model from GPS data collected in the Snowy Range, Wyoming, and validated model predictions using historic harvest locations 1996-2005 from the Bighorn, Sierra Madre, and Snowy Mountain Ranges. Habitat modeling efforts by Anderson et al. (in review) focused on the winter period (November-May) because this is the period when mountain lion activity is most limited due to deep snow at higher elevations resulting in ungulate concentrations on low elevation winter ranges, human development projects are vastly more common on low elevation winter ranges than on higher elevation summer ranges, and the vast majority of human-caused mountain lion mortality occurs during this period (>90% annually). The winter mountain lion habitat model is currently being used to delineate core winter mountain lion habitat statewide (Figs. 1 and 5). Thus far, most contiguous core mountain lion habitat in Wyoming has been delineated with the exception of the Southwest LMU, Northeast LMU, and hunt areas 14, 22, 25 and the Converse County portion of hunt area 6 (refer to Appendix III). Habitat maps for the other areas will be completed when detailed vegetation data layers are mapped and ground verified (e.g., Landsat Enhanced Thematic Mapper data at 30 m resolution); efforts are currently in place to complete vegetation data layers statewide.

Our intent for the mountain lion habitat model is to delineate suitable winter mountain lion habitat for resident adults (i.e., core mountain lion habitat) and exclude marginal habitats used as transition areas by transient subadults. Delineating core mountain lion habitat allows assessment of potential impacts from proposed development projects and application of mountain lion mortality densities to be used in development and assessment of management objectives (see next section below). Based on evaluations using historic harvest distribution (Fig. 4), the model appears to work well in most regions of Wyoming. Final acceptance of mountain lion habitat model predictions is pending regional review based on local knowledge of mountain lion habitat use during winter.

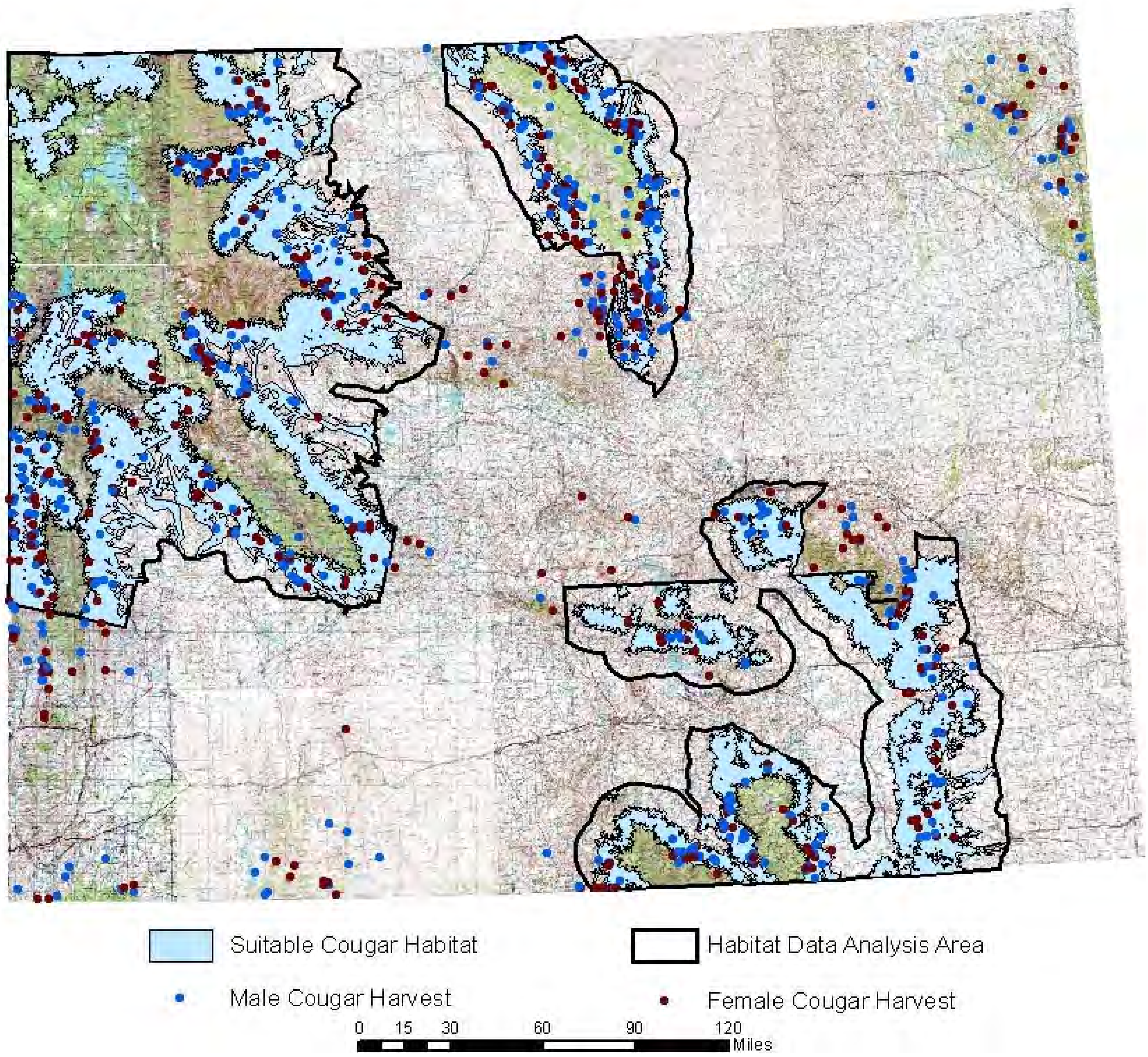


Figure 4. Winter mountain lion habitat model predictions relative to mountain lion harvest locations by sex, fall 2000-spring 2005. Winter mountain lion habitat represents core habitat of resident adult mountain lions and excludes marginal habitats occasionally used as transition areas by transient subadult mountain lions.

Habitat management efforts should include conserving large tracts of connected habitats that have the characteristics preferred by mountain lions and their prey. The Department's efforts to maintain high quality ungulate habitat should benefit mountain lion populations, and application of the mountain lion habitat model will provide opportunity to evaluate potential impacts from proposed development projects.

Management Criteria for Establishing Mountain Lion Management Objectives: The Cougar Management Guidelines Working Group (2005) suggested managing mountain lion populations by managing source and sink subpopulations. As stated previously, the hunt area and management unit approach currently used in Wyoming lends itself well to this concept and has likely, by default, maintained source-sink mountain lion population dynamics since the early 1970s by maintaining relatively high lion densities in some portions of the state (i.e., source areas) which support recruitment of young lions into other areas managed at low population densities (i.e., sink areas); maintaining source mountain lion habitats allow persistence of mountain lions in other habitats experiencing high mortality rates. The CMGWG did not provide specific guidelines on how to delineate source and sink mountain lion habitats other than to establish large-unhunted refuge areas to offset population sinks that experience high human-caused mortality. However, refining this approach by applying sex-age composition of harvest and annuli age of harvested adult females addressed by Anderson and Lindzey (2005) and applying the Wyoming mountain lion habitat model (Anderson et al. in review) to evaluate density of human-caused mortality provides criteria to establish source and sink mountain lion management. Based on Anderson and Lindzey (2005) and evaluation of harvest densities presented here for mountain lion population decline (Figs. 2 and 3) and increase (Fig. 2), the following criteria appear appropriate for establishing source-stable-sink mountain lion management:

Hunt area management objectives:

1. Sink management: reduce mountain lion densities
    a) Maintain density of human-caused mortality >8 mountain lions/1,000 km^2 (386 mi^2).
    b) Achieve adult female harvest >25% of total harvest for 2 of 3 seasons.
    c) Progression in mean age of harvested adult females should decline to <5 years old.

2. Source management: maintain human-caused mortality levels that allow mountain lion population growth or maintenance of relatively high mountain lion densities.

    a) Maintain density of human-caused mortality <5 mountain lions/1,000 km^2 (386 mi^2)
    b) Maintain adult female harvest <20% of total harvest.
    c) Maintain older-age adult females in the population (>5 years old). This will be difficult to identify without additional sampling due to low sample size from harvest, but would be expected for lightly hunted populations.

3. Manage for stable mountain lion populations: maximize long-term hunting opportunity.

    a) Maintain human-caused mortality density between 5-8 mountain lions/1,000 km^2 (386 mi^2)
    b) Adult female harvest should not exceed 20% of total harvest for more than 1 season.

c) Maintain intermediate aged adult females (mean ≅ 4-6 years old) in the harvest. Adequate age evaluation may require averaging age data over time to achieve meaningful sample sizes.

LMU management objectives:

- The LMU management objective should attempt to achieve the criteria above for source, stable, or sink mountain lion management at the LMU level. The objectives chosen by managers will be based on the adjacent management priorities, size of the LMU, maintaining recreational opportunity, maintaining source mountain lion populations, as well as depredations and other factors to achieve the overall management goal of sustaining mountain lion populations throughout core habitat at varying densities depending on management objectives.

- Coordinating management efforts with adjacent states would be most desirable for the smaller LMUs (i.e., Northeast and Southwest LMUs) where the majority of connected mountain lion habitat extends beyond Wyoming. Source or stable management could be maintained without interagency coordination, but sink management could also be implemented when sufficient source habitat has been identified in adjacent areas.

Acknowledging managers rarely, if ever, have precise information to measure success of management objectives, that mountain lion densities vary regionally, and the criteria proposed here are general guidelines, these guidelines should be compared to one another and applied adaptively to assess success of management prescriptions. For example, an area managed with the objective of stability and receiving a mountain lion removal density of 7 mountain lions/1,000 km^2 (386 mi^2), but relative adult female harvest exceeds 25% and harvested adult female annuli ages have declined below 5 years old likely suggests mountain lion population decline rather than stability. Conversely, an area managed with the objective of sink and receiving harvest densities of 10 mountain lions/1,000 km^2 (386 mi^2), but relative adult female harvest remains below 20% and older-age females (>5 years old) are consistently harvested suggests population stability (e.g., hunt area 23 in Table 4). Applying management objectives in an adaptive management framework, where density of human-caused mortality, harvest composition, and age of harvested adult females are monitored relative to expectations (criteria above) allows assessment of whether or not management objectives are being achieved and if management strategies should be modified to produce the desired outcome. Based on mountain lion management criteria averaged over the past 5 years for single or combined hunt areas of at least 1,000 km^2 of core mountain lion habitat (Table 4), 9 regions (1 to 3 hunt areas each) currently qualify as source areas, 7 as stable areas, and 1 as a sink area; 2 regions appear intermediate between source and stable and 2 regions intermediate between stable and sink (Fig. 5).

In implementing and evaluating mountain lion management objectives based on human-caused mortality density, proportion of total harvest comprised of adult females, and mean age of harvested adult females, it may be necessary to maintain consistent harvest objectives and combine data spatially or temporally to obtain meaningful information. Examples include hunt

Table 4. Annual 5-year average (fall 2001-spring 2006) of human-caused mountain lion mortality density (mountain lions/1,000 km^2), proportion of adult females in the total harvest, adult female annuli age (*n* = sample size), management status (source, stable, or sink), and area of core winter mountain lion habitat for Wyoming mountain lion hunt areas[a] and management units (LMU).

LMU Hunt area	Density of human caused mortalities	Proportion of total harvest including adult females	*n*/Annuli age[b]	Management status[c]	Core habitat (km^2)
Northeast					
1 & 24[d]	a	0.13	5/4.4	source/stable[e]	Undetermined
Southeast					
5 & 25[d]	1.9	0.26	3/7.0	Source/stable[e]	2,889[f]
7	6.2	0.20	8/4.1	Stable to stable/sink[e]	2,185
8 & 16[d]	2.9	0.08	3/5.3	Source	1,475[f]
9 & 10[d]	6.3	0.12	3/5.0	Stable	1,138
6 & 27[d]	5.6	0.13	6/4.2	Stable	2,480[f]
Southwest					
11, 12 & 13[d]	a	0.06	2/4.0	Source	Undetermined
North central					
15	15.4	0.11	8/4.4	Sink	1,221
21	9.6	0.14	6/4.8	Sink to stable[e]	1,295
22	a	0.19	8/3.4	stable to stable/sink	Undetermined
23	11.2	0.12	7/6.6	Stable	1,377
West					
Absoraka DAU					
19	4.6	0.13	8/6.8	Source	3,905
20	2.8	0.15	4/6.3	Stable to source[e]	3,045
Wind River DAU					
18	6.8	0.16	5/6.4	Stable	1,235
28	0.5	0.00	0/-	Source	1,720
4	4.5	0.16	3/4.3	Source	1,023
3	3.4	0.14	3/7.0	Source	2,151

Continued

Table 4. Continued.

LMU Hunt area	Density of human caused mortalities	Proportion of total harvest including adult females	n/Annuli age[b]	Management status[c]	Core habitat (km^2)
West (cont.)					
Wyoming Range DAU					
2 & 29[d]	3.2	0.23	12/6.4	Source	3,372
26	6.2	0.27	13/4.3	Sink to stable[e]	1,762
17	2.0	0.09	1/2.0	Source	1,838
14	a	0.22	10/5.5	Stable	Undetermined

[a]Insufficient vegetative data for hunt areas 1, 11-14, 16, 22, and 24-25 to calculate core mountain lion habitat and mortality density.

[b]Annuli age estimated from the number of rings evident after cross sectioning of the first premolar. Mean annuli ages from small sample sizes ($n < 5$) should be interpreted with caution.

[c]Status assigned based on the majority of the 3 criteria examined. Status criteria: source = mortality density <5 mountain lions/1,000 km^2, <20% of total harvest includes adult females, mean adult female annuli age >5 years old; stable = mortality density of 5-8 mountain lions/1,000 km^2, proportion of harvested adult females should not exceed 25% of total harvest for more than 1 year, mean annuli age of adult females should be intermediate to source and sink areas (e.g., 4-6 years old); sink = mortality density >8 mountain lions/1,000 km^2, >25% of total harvest includes adult females for 2 years, mean adult female annuli age declines to <5 years old.

[d]Hunt areas with <1,000 km^2 of core mountain lion habitat were combined with adjacent hunt areas within the same mountain range.

[e]Criteria separated with " / " indicate intermediate management status. Management criteria separated with "to" indicate a transition in management status over the 5-year period based on trends in annual data.

[f]Amount of core mountain lion habitat subject to change in hunt areas 5 and 6 following completion of improved habitat data layers and Regional review. Lack of vegetative data for hunt areas 16 and 25 precludes core habitat delineation and mortality density calculations for these hunt areas.

areas receiving low harvest levels or hunt areas of small geographic size. Small hunt areas can be combined with adjacent hunt areas and information from lightly hunted areas can be averaged over time to improve sample sizes (e.g., Table 4). Evaluating annual changes in management criteria are also important to determine if the population may be changing due to annual shifts in mortality density, harvest sex/age composition, and/or age of adult females, especially in areas experiencing moderate to high harvest levels; averaging management criteria over time may mask shifts in management status that are otherwise evident from annual changes in management criteria (e.g., hunt areas 7, 21, 22, 20, 2 & 29, and 26; Table 4). For example, mountain lion population reduction can be achieved in a short time period (>50% reduction; Logan and Sweanor 2001, Anderson and Lindzey 2005) in areas that are accessible to hunters where high harvest densities, increase in adult female harvest, and decline in age of adult females occurs within 2-3 years and subsequent management criteria suggest stability following the initial reduction (Fig. 3).

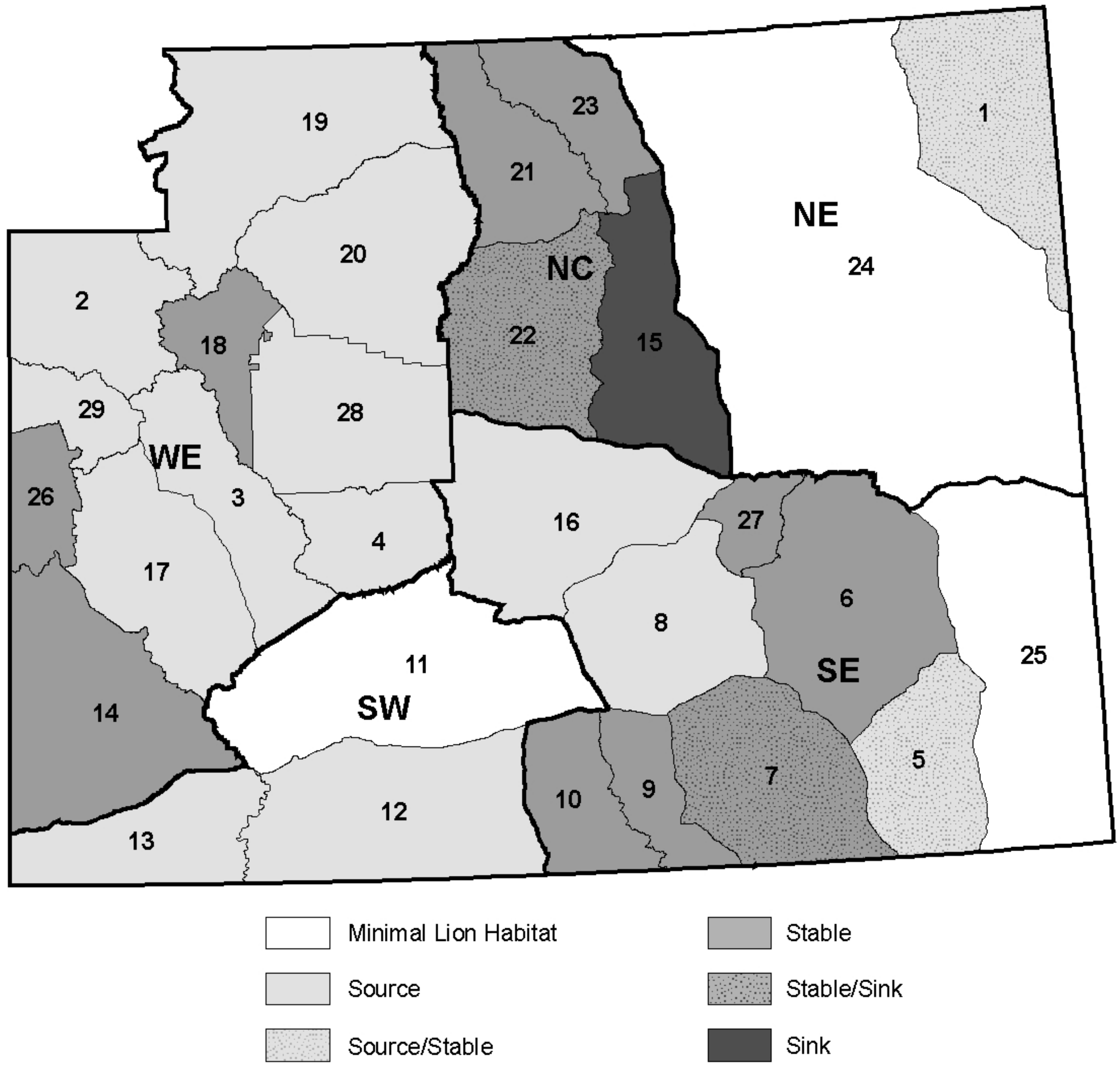


Figure 5. Current Wyoming mountain lion management status by hunt areas (numbered) within mountain lion management units (WE = west, NC = north central, NE = northeast, SE = southeast, SW = southwest). Status assigned based on the majority of the 3 criteria examined: source = human caused mortality density <5 mountain lions/1,000 km^2, <20% of total harvest includes adult females, mean adult female annuli age >5 years old; stable = human caused mortality density of 5-8 mountain lions/1,000 km^2, proportion of harvested adult females should not exceed 25% of total harvest for more than 1 year, mean annuli age of adult females should be intermediate to source and sink areas (e.g., 4-6 years old); sink = human caused mortality density >8 mountain lions/1,000 km^2, >25% of total harvest includes adult females for 2 years, mean adult female annuli age declines to <5 years old (Table 4). Unable to calculate mortality density for hunt areas 1, 12, 13, 14, 16, and 22 due to incomplete habitat data. White areas represent primarily open vegetative types and contain low-density mountain lion habitats.

Other factors to consider are the similarity in harvest composition for high and low-density populations and the duration for establishing source management areas. Anderson and Lindzey (2005) observed that harvest composition progressed from primarily subadults, to adult males, and finally to adult females with mountain lion population decline, but observed similar harvest composition to a high-density population, composed primarily of subadults, when the population was at low density. Harvest composition composed primarily of subadults may suggest a high density population where the less vulnerable adults have not yet been greatly exposed to harvest or conversely that the population is actually at low density where the majority of the adult segment of the population has previously been removed (via disease, past harvest levels, etc.) and most of the individuals in the population are immigrants from other populations. Approaches to determining whether high subadult harvest/low adult harvest suggests high or low mountain lion densities include comparing other harvest criteria, evaluating changes in harvest data over time (e.g., Table 4), and evaluating relative harvest of subadult females. Based on the current season setting structure in Wyoming where management objectives are established every 3 years, we suggest monitoring management criteria for the previous 2 management cycles (6 years) to adequately determine whether populations may be increasing, decreasing, or remaining stable. Low density of human-caused mortalities (<5/1,000 km^2) for a 6-year period would indicate a high-density population, as would a majority of females in the subadult harvest suggesting numerous adult females producing young within the population. Ideally, source management areas should be maintained over time. If changes in social or biological conditions warrant shifting from source to sink management, 3 years should be sufficient to reduce mountain lion densities assuming sufficient access, but returning to source status will likely take longer. Numerical recovery can occur within 3 years (Logan and Sweanor 2001, Anderson and Lindzey 2005), but returning to the older age structure consistent with a functioning source population will benefit from source management for 2 management cycles (i.e., 6 years).

Another issue relative to source-stable-sink mountain lion management that should be addressed is the size at which an area may serve as a source subpopulation and the relative area and juxtaposition of source-sink mountain lion habitat necessary to sustain mountain lion populations at landscape levels. This issue has not been well addressed at this time, but work by Beier (1993) may offer some guidance. Beier (1993) suggested areas as small as 600-1,600 km^2 (231-617 mi^2) would likely sustain viable mountain lion populations assuming 4 immigrants every 10 years, and higher levels of immigration would allow even smaller areas to support mountain lions. Genetic evidence suggests Wyoming mountain lion populations are well connected, with the estimated number of migrants per generation ranging from 6-30 among geographically distinct regions (i.e., LMUs; Anderson et al. 2004). Thus, areas of at least 1,000 km^2 (386 mi^2) would appear sufficient to serve as source areas in Wyoming. The amount and juxtaposition of source mountain lion habitat relative to sink habitat necessary to sustain mountain lion populations at landscape levels, however, is still unresolved. Past mountain lion management and recent management status (Table 4, Fig. 5) suggests the current amount of source mountain lion habitat has been sufficient to sustain mountain lion populations statewide. In addition, maintaining source or stable management objectives at the LMU level should support large-scale mountain lion population persistence and this approach may preclude the need to specifically delineate the ratio of source:sink mountain lion habitat relative to hunt area management objectives.

In addition to assessing mountain lion population trends for stable or sink management areas, periodic mountain lion population monitoring will also be useful to confirm the status of source populations. Harvest data may be sufficient to reasonably evaluate trends for areas managed as stable or sink populations, but likely insufficient to adequately evaluate status of source populations. Confirming the status of areas intended to support mountain lions at landscape scales will be a useful component in source-stable-sink management of mountain lion populations in Wyoming. Population estimation methods (e.g., track surveys, helicopter probability sampling, mark-recapture methods if they become applicable for estimating mountain lion populations) should be applied every 3-5 years (e.g., 1 hunt area/LMU) to confirm mountain lion densities are consistent with populations that are at or near carrying capacity. Ability to formally survey source areas, however, will be dependent on Department budget constraints. If budget constraints do not allow formal surveys of source areas, other approaches should be investigated to confirm the status of source populations (e.g., less intensive track surveys, hunter interviews, etc.).

Mountain lion management objectives should be based on local and regional biological and social considerations. Management objectives to reduce mountain lion densities should be proposed when the expected outcome will result in (1) reduced human conflicts (e.g., human-mountain lion encounters, mountain lion incidents near human development), (2) reduced depredation incidents, or (3) to alleviate predation pressures on ungulate populations that are below the ungulate population management objective primarily due to mountain lion predation rather than habitat conditions. Success of management actions should be monitored to determine if reducing mountain lion densities achieve the desired outcome by recording changes in human conflict levels, depredation incidents, or ungulate population parameters (e.g., changes in female:young ratios). In the case of predation impacts to ungulate populations, additional data collection may be necessary to determine if reducing mountain lion numbers has resulted in increased ungulate numbers, and will depend on the availability of additional funding to monitor the ungulate population response. Changing management strategies over time, while monitoring the effects will provide an adaptive management approach to evaluate the success of mountain lion management prescriptions.

In areas where human conflicts and depredation incidents are not an issue and ungulate populations do not appear to be strongly influenced by predation, stable or source management objectives should be implemented. Managing areas for stable mountain lion populations should maximize long-term hunting opportunity, and source population management should offset reduction in other areas managed as sink populations. In areas of Wyoming where hunter access is limited (National Parks, refuges, ungulate winter range closures, private lands), sink (e.g., hunt area 2) or even stable management at lower densities (e.g., hunt area 28) may not be possible. These areas have served and will continue to serve as source mountain lion populations as long as access remains limited.

NUISANCE MOUNTAIN LION MANAGEMENT

Livestock Depredations

Mountain lions will kill most species of domestic livestock, although sheep and cattle tend to dominate depredation records (Lindzey 1987). In Arizona, Shaw (1983) reported that 93% of mountain lion-killed cattle examined were calves (typically <300 lbs.), and although all age classes of sheep were killed, lambs were preferred. Cattle losses to mountain lions are rare in Wyoming (Fig. 6) primarily due to calves being born away from mountain lion habitat compared to other areas of the southwestern U.S. where calves are born in mountain lion habitat (e.g., the desert southwest; Shaw 1977, Cunningham et al. 1995). Mountain lion depredations of horses, llamas, goats, poultry, pigs, and other types of livestock have also been documented (Tully 1991). Data from Wyoming, 2000-2005, indicate approximately 97% of the damage claims submitted for reimbursement were for sheep, primarily lambs and ewes (Fig. 6; Wyoming Game & Fish Department 2005). Other livestock occasionally killed include horses, cattle, goats, and pigs. The loss of domestic pets near residential areas is also on the increase in urban areas, primarily due to human development into occupied mountain lion habitat (Davies 1991).

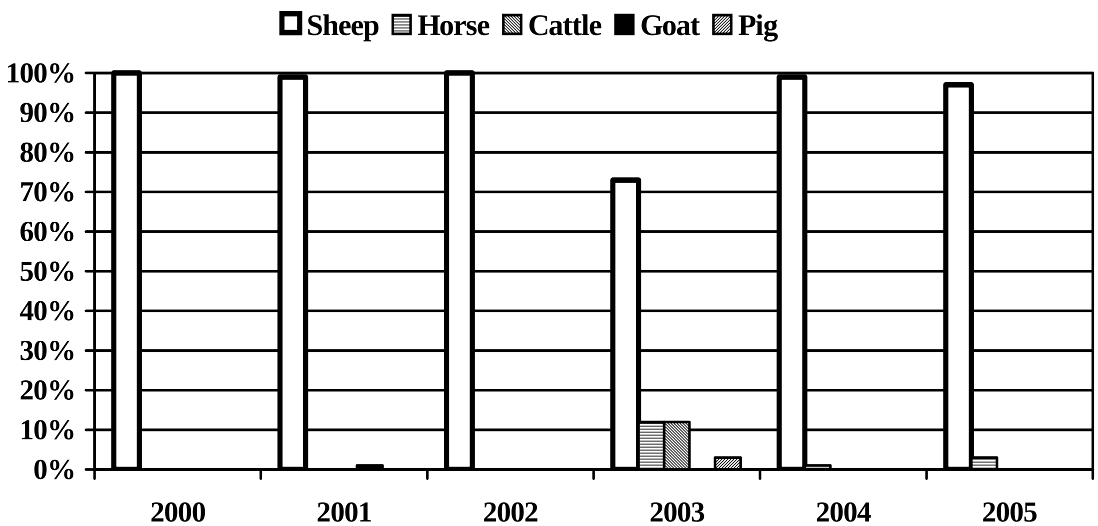


Figure 6. Percentage of mountain lion damage compensation in Wyoming by type, fiscal year 2000-2005.

Wyoming Statute §23-1-901 provides for monetary compensation of damage to livestock caused by mountain lions, and W.S. §§23-3-115 allows property owners or their employees and lessees to kill mountain lions damaging private property, given they immediately notify the nearest game warden of the incident. They may keep the pelt and skull if they purchase a Wyoming game tag. Because of this statute, Wyoming obtains annual information on the number of reported conflicts between mountain lions and domestic livestock and provides compensation for those losses. The number of damage claims submitted to the Department has varied between 1980 and 2005, ranging from under 5 to over 40 (Fig. 7). During that same time period, compensation paid to livestock producers ranged from just over $7,400 to just under $110,000 (Fig. 8). Compensation does not correspond to the number of claims submitted in all years. For example, in fiscal year 2003, 21 damage claims were submitted for payment and only $10,131 was paid to producers compared to 2005 when only 10 claims were submitted that resulted in $39,000 in compensation. This is due primarily to the loss of expensive livestock, primarily horses, in some years.

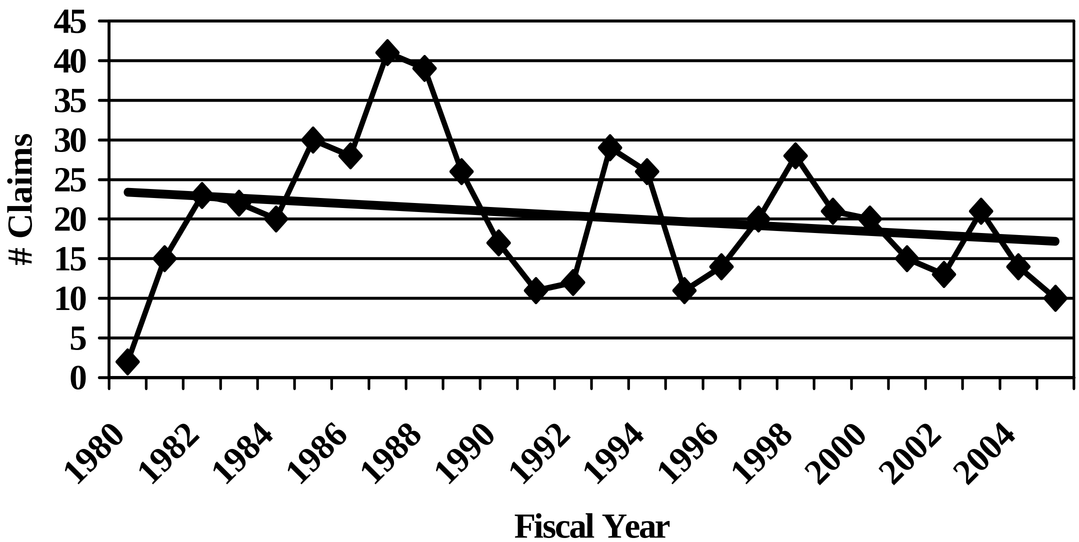


Figure 7. Trend in the number of damage claims submitted for Wyoming mountain lion depredations, fiscal year 1980-2005.

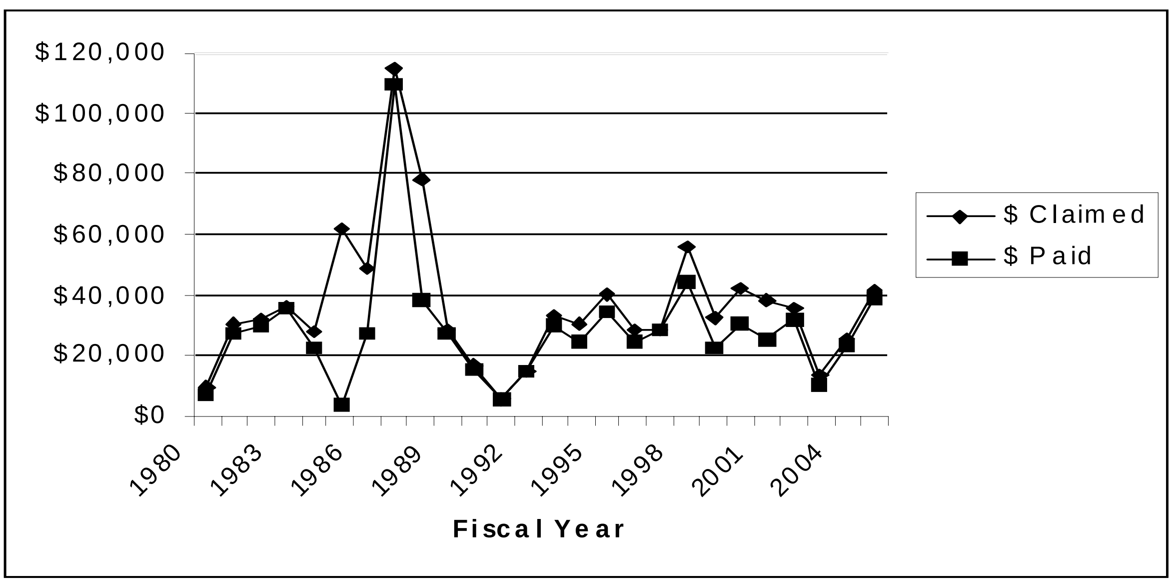


Figure 8. Mountain lion damage claims versus payments to livestock producers in Wyoming, fiscal year 1980-2005.

Although Wyoming Statute allows for the take of mountain lions depredating livestock, mountain lions also have aesthetic value, trophy value, and removal costs that should be considered when making removal decisions (Lindzey 1987). In Wyoming, there are currently 2 approaches to reduce mountain lion damage including (1) remove the offending mountain lion and (2) increase take through sport hunting. Removal of individuals appears to be more accepted by the public than overall population reductions (Gasson and Moody 1995). Killing the offending mountain lion has been successful as a short-term solution, but livestock losses may eventually continue in the future where livestock remain in mountain lion habitat. Conversely, attempting to reduce mountain lion populations also does not appear to entirely resolve the depredation issue because it is usually very difficult to maintain a reduction program that is sufficient to reduce a population to the level required to reduce depredations. Public acceptance of such a program may or may not be maintained over a sustained period of time. We currently do not know the harvest level or length of time required to reduce lion populations to the point that livestock reductions would be reduced, but the adaptive management approach outlined in this plan will allow evaluation of this issue in the future. Therefore the Department will continue to consider all issues, including livestock depredation, to establish harvest quotas. Mountain lion populations have the ability to rebound from this level of reduction fairly quickly. Lindzey et al. (1992) documented that a population of mountain lions in Utah recovered from a reduction of approximately 42% in only 9 months. Similarly, mountain lion populations recovered from comparable reductions in New Mexico and Wyoming in 31 and 36 months, respectively (Logan and Sweanor 2001, Anderson and Lindzey 2005). Licensed hunters are occasionally directed to areas with damage in hopes of removing problem individuals, but agency personnel, either the Department of Agriculture's APHIS-Wildlife Services or the Wyoming Game & Fish Department, do most individual removals.

Management actions that target mountain lions that are a potential threat to human safety or cause livestock damage normally result in the lethal removal of the offending mountain lion. Current protocols provide agency personnel with a variety of options to address conflicts ranging from no action to relocation of the offending animal to lethal removal. Agency personnel respond and resolve incidents based on site-specific conditions. The Department will continue to document incident circumstances and outcomes.

Reducing non-harvest mortality should allow for increased hunter opportunity through season/quota regulations. Nevertheless, in most instances agency removal of specific individuals will be necessary to resolve specific depredation incidents. Striving for removal of only responsible individuals should help minimize losses, increase public acceptance, and maintain hunter opportunity.

Mountain Lion - Human Interactions

Interactions between humans and mountain lions have increased during the last 2 decades throughout most of the western United States and Canada (Beier 1991). Although mountain lion attacks are extremely rare, there were 9 fatal and at least 44 non-fatal attacks reported in North America between 1890 and 1990 (Beier 1991). The majority (66%) of the humans attacked were either unsupervised children or lone adults. Approximately 30% of the attacks occurred within sight of some type of developed area. Fitzhugh et. al. (2003) updated this information through

2003, and determined an additional 7 fatal and 38 non-fatal attacks had occurred since Beier (1991) published his data. The first recorded physical injury resulting from a human-mountain lion encounter in Wyoming occurred in 2006 near Laramie; fortunately, the injuries were minor. It appears younger-aged males, primarily yearlings, accounted for 42% of the attacks on humans (Beier 1991). Increased mountain lion numbers along with increased recreational use and urbanization of mountain lion habitat has created greater opportunity for mountain lion-human encounters. For example, new homes have been built on traditional mule deer winter range in Boulder County, Colorado, resulting in increased mountain lion sightings along with a dramatic increase in mountain lion predation on domestic pets (Sanders and Halfpenny 1991). Typically, when a mountain lion interacts with another animal, including a human, it determines whether the other animal is either prey or non-prey. If the animal is determined to be non-prey, it might become the target of aggressive behavior as the mountain lion may think the animal is a threat. Humans should attempt to maintain eye contact with an aggressive mountain lion and attempt to increase one's potential size by standing erect. It appears that attacks can be reduced if the mountain lion is aware that you are not a typical prey species. If an attack does occur, humans should fight back as aggressively as possible. Several attacks have been broken off due to this type of response (Fitzhugh et al. 2003). If humans have the ability to observe a mountain lion prior to an attack, they can interpret specific mountain lion behavior to assess the level of threat from the mountain lion (Appendix IV).

Not all mountain lion-human interactions can be avoided and, in some cases, humans do have the opportunity to modify their behavior to reduce the chance of an attack. It is much more effective for humans to modify their behavior than it is for people to modify mountain lion behavior. Guidelines that can reduce the chance of an attack are presented in Appendix V.

The Wyoming Game and Fish Department strives to minimize human conflicts with mountain lions while maintaining sustainable mountain lion populations for ecological, recreational, scientific, and aesthetic purposes. Coordination with county planning boards to minimize conflicts in suitable mountain lion habitats (Anderson et al. in review) should help reduce conflicts.

A "Protocol for Managing Aggressive Wildlife/Human Interactions", which includes mountain lions, was completed in 1999 (Moody et al. 1999). Major components of this protocol include procedures for reporting, documenting, and investigating incidents. This document is designed to aid Wyoming Game and Fish Department personnel in conducting investigations and assure appropriate coordination with other State and/or Federal agencies. Accurate reporting and periodic analysis of this information will improve our understanding of the factors that promote conflicts and how to better address them.

PUBLIC INFORMATION AND EDUCATION EFFORTS

As with all large predators, some aspects of mountain lion management are increasingly controversial. The public is much more cognizant of issues associated with mountain lion management compared to the early 1990s. The Department traditionally relied on public contacts, open houses, and public meetings held in conjunction with season setting meetings to gauge constituent attitudes and values about managed species. This process does not appear to provide a forum that all interest groups are comfortable participating in. The Department will consider alternative methods to engage these segments of the public, such as increased involvement in establishing population management objectives.

The Wyoming Game & Fish Department completed an attitude survey of Wyoming residents to assess public values and attitudes that might influence mountain lion management (Gasson and Moody 1995). No attempt was made to calculate confidence intervals around the survey results. As a result, these data are qualitative indicators of public attitudes. The distribution of the sample by county roughly approximated the distribution of Wyoming's population. Approximately 67% of the respondents reported they hunted at some point in their lives, and over 54% presently engaged in some form of hunting. Less than 9% of the respondents hunted mountain lions, and 65% of mountain lion hunters used dogs to pursue mountain lions. Over 71% of the respondents felt that mountain lions were a benefit to Wyoming. Only 11% felt that mountain lions were not a benefit to the state. Approximately 50% agreed or strongly agreed that mountain lion hunting should continue, while 29% of respondents believed mountain lion hunting should be discontinued, and 57% felt hunting with dogs should be eliminated. However, only 51% of the people surveyed were aware mountain lion hunting was legal in Wyoming, suggesting the Wyoming public may be uninformed about the issues surrounding mountain lion management in the state. Sixty percent of the respondents indicated they would benefit from additional information and education about this species.

Based on the results of this survey it was apparent the Wyoming Game and Fish Department should expand its efforts to educate the public on mountain lion management and provide those interested with the information necessary to aid the Wyoming Game and Fish Commission/Department in future management strategies. The Wyoming Game and Fish Commission/Department recognize the importance of keeping the public informed.

To address these concerns, the Department provided additional information to the public about mountain lion biology, management, and how to avoid conflicts with lions beginning in 1996. One specific publication entitled "Living in Lion Country" was developed and distributed to WGFD Regional offices throughout the state. The Department has worked closely with The Center for Wildlife Information to integrate this material into existing programs that have traditionally focused on grizzly bears. Mountain lion information has been included in the Department's "Living in Lion and Bear Country" workshops that are presented every spring around the state. These workshops include information on grizzly bear, black bear, and mountain lion biology and how to reduce conflicts. An updated public attitude survey would be useful to assess the success of additional information and education efforts implemented since the previous survey in 1995.

Although a species management plan provides direction for the responsible agency, it also provides a concise, complete overview of important issues surrounding the species, which can easily be circulated to the public. Thus, wide circulation of this plan will help inform and educate the public about current mountain lion management topics. Issues can change, as well as attitudes, so periodically surveying public opinion will be necessary, along with education updates following completion of surveys. Collectively, adequate ongoing education and information efforts coupled with periodic public surveys will help the Commission optimally manage mountain lions to address the public trust.

The Department will institute new programs. Additional information will be put on the Game and Fish web site to assist hunters in being able to differentiate sex of individuals. Additional and continued training of Department employees will be implemented to assure personnel who field check harvested lions are adequately trained to determine sex and age.

FUTURE RESEARCH AND MANAGEMENT NEEDS

The adaptive management approach outlined in this plan will provide opportunity to evaluate many of the management needs listed below, while other management needs will likely require additional research efforts. Addressing mountain lion management needs that require additional research efforts will be implemented when and if additional funding becomes available with respect to other management priorities for the Wyoming Game & Fish Department.

Short Term Needs:

- Develop or cooperate with other agencies in the development of vegetation data layers sufficient for application of the mountain lion habitat model in regions of the state where data are currently lacking.
- Further evaluation and refinement of population monitoring techniques.
  - Explore the potential for new approaches that are cost effective and logistically feasible for management application.
  - Evaluate track surveys and helicopter probability sampling for periodically monitoring mountain lion subpopulations the size of hunt areas.
  - Investigate the utility of DNA and camera based mark-recapture methods for estimating mountain lion populations. Explore reliability of different attractants for enticing mountain lions into hair collection or photo detection sites, and evaluate ability of photographic technology to differentiate individual mountain lions from digital photographs.
  - Include hunter effort data from unsuccessful hunters to that collected from successful hunters to better evaluate catch-per-unit-effort indices in evaluating mountain lion population trends.
- Test mountain lion habitat model predictions using independent data sets (e.g., GPS locations) as they become available.
- Monitor success of sink management objectives in reducing human conflicts and depredation incidents.
- Conduct placental analyses from harvested females to confirm accuracy of female age class determination.

Long-Term Needs:

- Identify juxtaposition and amount of source mountain lion habitat necessary to sustain mountain lion populations at landscape scales.

- Evaluate the level at which sink management successfully reduces human conflicts, depredation incidents, and predation impacts to prey populations.
- Develop and evaluate application of simulation models to examine vital rates relative to source-sink mountain lion management.
- Improve knowledge of mountain lion-prey relationships.
- Investigate population dynamics of multi predator-prey systems.
- Investigate potential influences of exploitation on mountain lion population dynamics.

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APPENDIX I. History of mountain lion management regulations in Wyoming.

As in other western states, management in Wyoming became increasingly conservative during the mid 1970s through the early 1990s, primarily to control the number and sex of lions harvested. Emphasis was placed on controlling the take of females until sufficient information was available to warrant increased harvest. Harvest quotas have been increased since that time in an effort to limit population increase in specific portions of the state.

From territorial days to 1973, mountain lions received no legal protection. The earliest statutory reference to mountain lions was in 1882 when the Council and House of Representatives of the Territory of Wyoming enacted Chapter 108, Section 1. This legislation authorized county commissioners to encourage the destruction of wolves (*Canis lupus*), wild cats (i.e., bobcats; *Lynx rufus*), lynx (*Lynx canadensis*), bears (*Ursus* spp.), and mountain lions by offering bounty payments. Although property owners, employees, and lessees are still allowed to kill any mountain lion causing damage to private property, bounty payments are no longer authorized. In 1973, the mountain lion was reclassified from a predator to a trophy game animal. Since then, regulations governing the take of mountain lions have become more restrictive with the establishment of shorter seasons, total mortality quotas, and female sub-quotas.

CHRONOLOGICAL SUMMARY OF MOUNTAIN LION MANAGEMENT REGULATIONS IN WYOMING

1882 The Wyoming Territorial Legislature passed a law authorizing County Commissioners to encourage the destruction of wolves, bobcats, lynx, bears, and mountain lions. The County Fund paid $2.50 for each mountain lion killed. This was the first law authorizing bounty payments for mountain lions.

1884 The bounty payment for mountain lions was raised to $5.00.

1890 The bounty payment was raised to $6.00. The Territorial Legislature passed a law prohibiting the killing of mountain lions outside of the Wyoming Territory. Violation of the law resulted in a penalty ranging from $25.00 to $50.00.

1907 Applications for bounty payments had to be accompanied by an affidavit stating that the person presenting the skin, in said county, and within Wyoming, killed the animal. The animal had to be taken after March 1st. Persons could take predators (mountain lions) within State Game Preserves with the permission of the State Game Warden.

1910-1911 It was unlawful to enter the forest reserves of Wyoming for the purpose of chasing or coursing predators with dogs, unless the dogs were licensed. The license was $1.00 per dog, per calendar year. It was permissible to take mountain lions during closed big game seasons on State Game Preserves with a permit from the State Game Warden.

1913-1914 It was lawful to use dogs on predatory species and on State Game Preserves with permit from State Game Warden.

1915-1916 Game animals could not be used as bait for the purpose of trapping predatory animals within Wyoming.

1917-1972 No changes in mountain lion regulations.

1973 The mountain lion was reclassified from a predator to a trophy game animal.

1974 The first mountain lion hunting season established. The hunt area was considered the entire state. The season ran for the entire calendar year, with a bag limit of 1 mountain lion per season. A license and fee was required, and hunters had to present the pelt and skull to the nearest Wyoming Game and Fish District Office within 10 days of harvest. Hunting with dogs was allowed and females with kittens at side and kittens were protected from harvest. The owner, employees, or lessee of said property could take mountain lions damaging private property.

1978 Mountain lion season ran from September 1—December 31 and January 1—March 31.

1980 Wyoming was divided into 22 hunt areas and 5 LMUs. Mortality quotas (total mountain lions) by hunt area were established. The season ran from September 1 - March 31.

1983 Hunt area 15 was divided into hunt areas 15 and 23.

1985 Hunters must report mountain lion kills within 72 hours to nearest Wyoming Game and Fish District Office or game warden.

1993 The pelt and skull were required to be presented in an unfrozen condition to allow extraction of two premolar teeth for aging, and to allow examination of the pelt to determine sex. Female mortality quotas established in some hunt areas.

1994 Hunt area boundaries revised to more closely correspond with known distribution. A total of 27 hunt areas existed.

1999 Hunt area 26 was eliminated from the Southeast LMU. Hunt area 6 was expanded in its place. Regulations revised to allow for the take of 2 mountain lions per person per year in hunt areas 7 and 21 to assist the Snowy Range mountain lion study. Hunters must purchase an additional license ($15 for resident and $75 for non-resident). Hunt Area 25 added to the southeast LMU.

2000 Hunt area 17 split with hunt area 26 being created in the West LMU to separate the Wyoming Range from the Salt River Range in the Jackson Region. Hunt area 27 added to the areas where two mountain lions can be taken in a calendar year. Biological year for analysis of harvest information changed to September 1–August 31. Hunt area 28 created to address potential harvest and damage on fee title lands within the Wind River Reservation. Hunt area 7 was eliminated from those where 2 mountain lions can be harvested annually.

2001 Hunt area 21 eliminated from those where 2 mountain lions can be harvested annually.

2003 Hunt area 2 in the Jackson region split to address hunter pressure issues. Hunt area 29 established in the southern portion of hunt area 2. Quotas set for three-year cycle to address data assessment issues.

Appendix II. Wyoming mountain lion harvest and harvest quotas, hunter effort for successful mountain lion hunters, and nonharvest-human caused mountain lion mortalities.

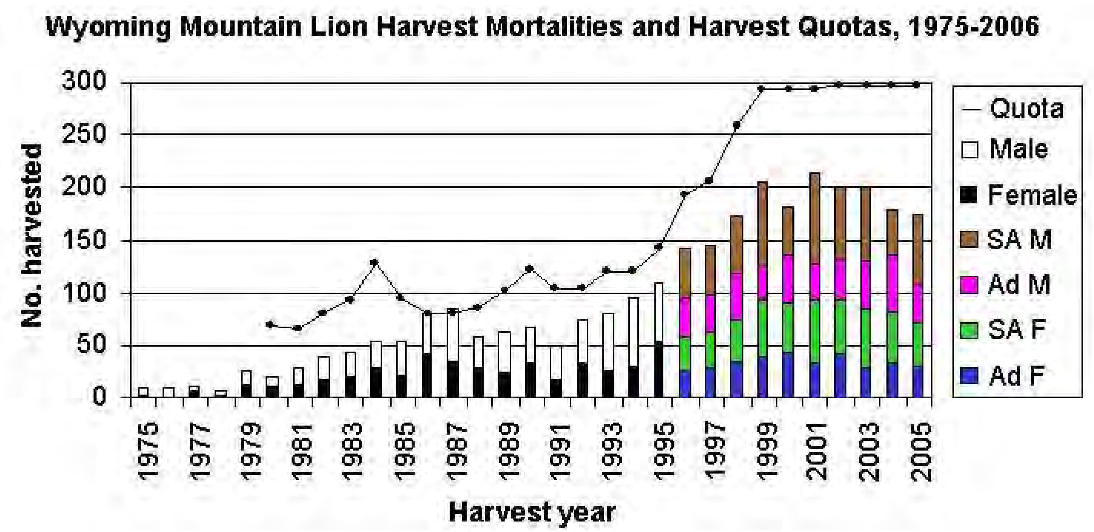


Figure II-1. Wyoming mountain lion harvest mortalities by sex (1975-1995) and age class (subadult = SA, adult = Ad; 1996-2006) and annual harvest quotas (1980-2006). Harvest year represents September of the given year through March of the following year; quotas reported from 1980-1984 were based on calendar year (Jan.-Mar. and Sept.-Dec. of the year reported). No harvest quotas were in place 1975-1979 and for hunt areas 15 and 22 (i.e., the southern Bighorn Mtns.) from 1986-1989.

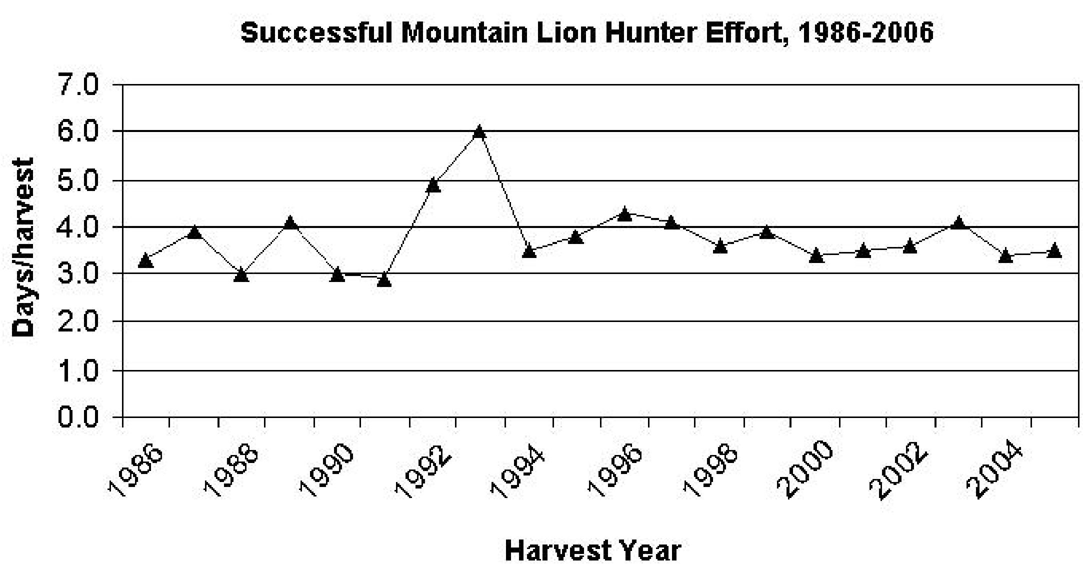


Figure II-2. Hunter effort (average days hunted per harvest) for hunters successfully harvesting a mountain lion, 1986-2006. Harvest year represents September of the given year through March of the following year. Harvest years exceeding 4 days per harvest were primarily due to a single hunter hunting for unusually long periods during the hunting season (e.g., a hunter reported hunting for 90 days in 1993).

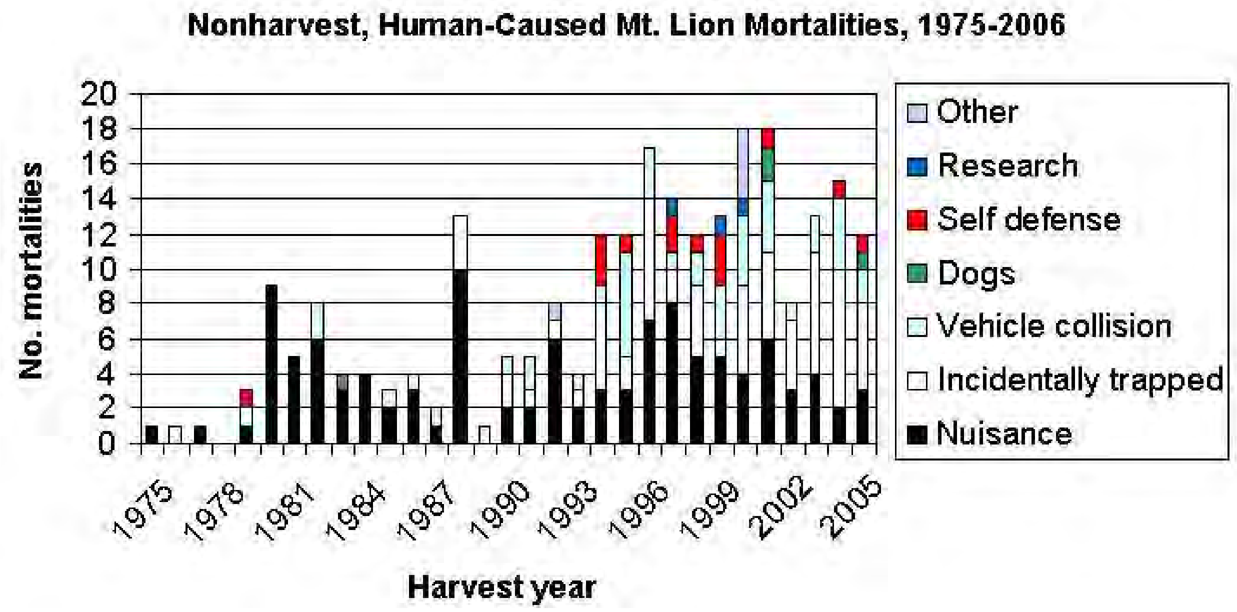
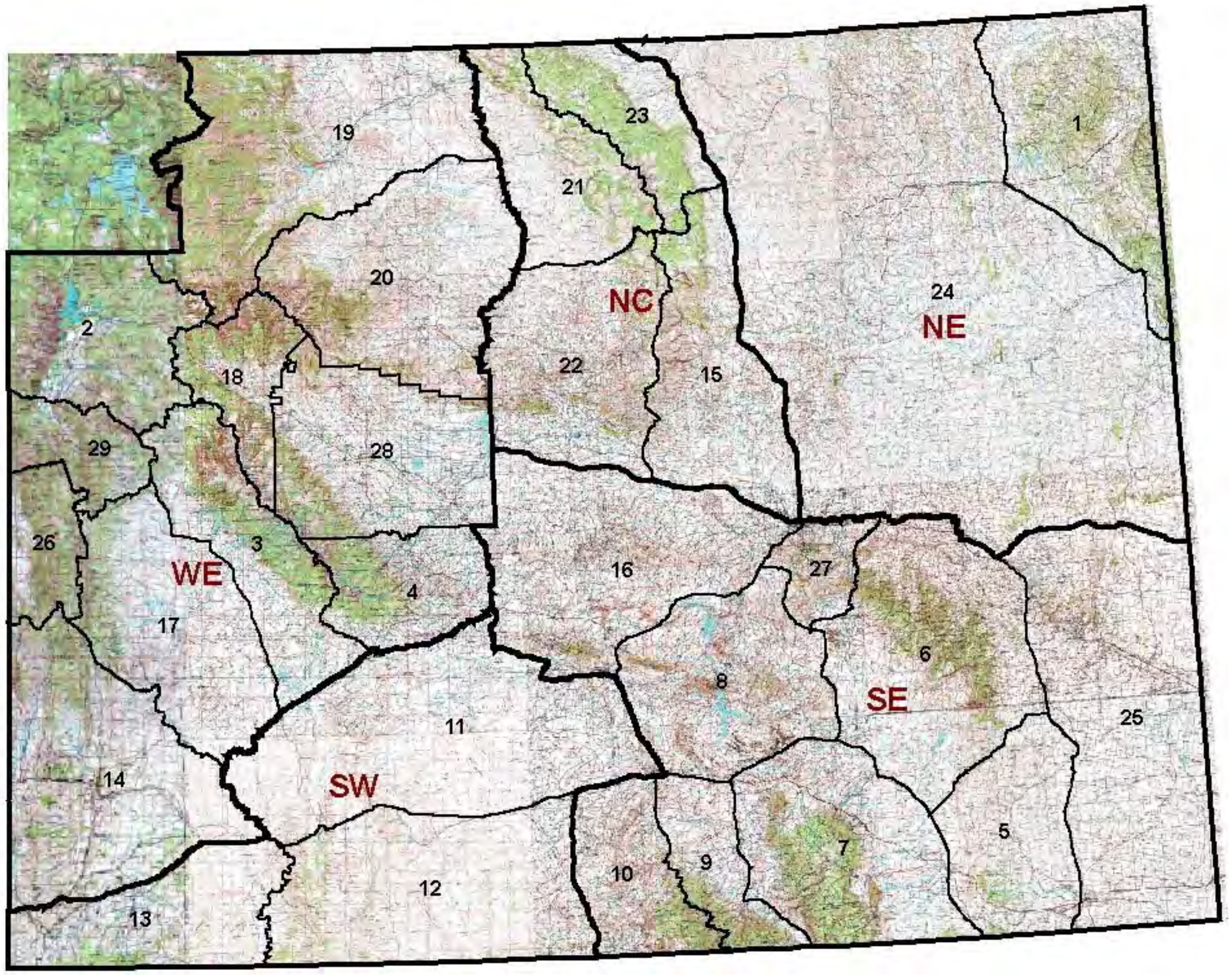


Figure II-3. Nonharvest, human caused mountain lion mortalities by cause reported in Wyoming, 1975-2006. Harvest year represents September of the given year through March of the following year. Other represents an electrocution in 1992 and a family group (1 female with 3 young) illegally poisoned in 2000. Nuisance mortalities include mountain lions depredating livestock or coming into close contact with human residence.



APPENDIX III. Wyoming mountain lion management units and hunt areas (numbered). Mountain lion management units: WE = West, SW = Southwest, SE = Southeast, NE = Northeast, and NC = North central.

APPENDIX IV. Wyoming mountain lion mortality form.

MOUNTAIN LION MORTALITY FORM

Hunt Area ____ Region ____

Date of kill: ______________ TYPE: Legal____; Illegal____; Damage Control____; Other____; Unknown____

If "Other" or "Unknown", probable cause of mortality ______________________________

PERSON WHO HARVESTED LION: Name: ______________________________

Address: ______________________________ City: ______________

State: _____ Zip: ____________ Phone: ______________________ Resident: _____ Nonresident: _____

METHODS/EFFORT: Days hunted: _____ Were dogs used? (Y/N) _____ If not, how was lion harvested? ____________

Was a guide/outfitter used? (Y/N): _____ Name: ____________________ Dog owner: ______________

Number of lions observed: _____ Were you selective while hunting? (Y/N): _____ Number of lions treed and released: _____

Number of lions that were marked: _____ (Ear tag / tattoo / radio collar frequency : ______________________)

Number of fresh tracks not pursued: _____ (How many were single adults?: _____ How many were adults with kittens?: _____)

LOCATION/DRAINAGE: Where was lion harvested? ______________________________

Sec: _____ Twnshp: _____ Rng: _____ UTM Zone: _____ UTM Easting: __________ UTM Northing: ____________

SEX AND AGE: Sex: _____ Est. Age: _____

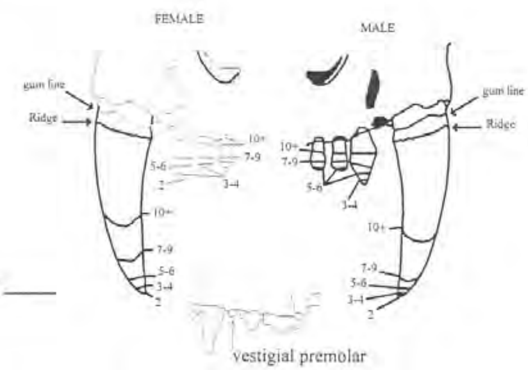
If female, presently lactating? (Y[≥2] / N) _____

Appear to have lactated in past? (Y / N) _____

Canine ridge below gumline? (Y[≥2.5] / N) _____

Any visible spotting on rear legs? (Y[≤3] / N / ?) _____

Visible bars on inside of front legs? (Y[<4] / N / ?) _____



REQUIRED SAMPLES:

Number of teeth collected: 0 1 2 Pictures of teeth (Y/N): _____

Hair/Hide sample (1/2" X 1/2") taken (Y/N): _____

Remarks: ______________________________

Date record was WOFed: ______________ Date Biological Services Called: ______________

I, ______________________ of ______________________

being duly sworn, depose and say that I am the holder of Wyoming Mountain Lion license # ____________,

and lawfully took the above lion on ________ - __________, 20____ in Hunt Area # ________.

Inspected by   Date   Hunter's Signature

Any person who makes a false statement on the registration form regarding the date the mountain lion was taken or the hunt area in which it was taken shall be in violation of this regulation and, such violation shall be punishable as provided by Title 23, Wyoming statutes for violation of Commission regulations.

Note: The person that checked the lion should forward the completed form and all tooth & hair samples to the Regional Office of registration and call Biological Services to update the harvest database. The Regional Office of registration will keep a copy of the completed form and send the original, along with the tooth and hair samples to the Trophy Game Section. Revised 01/04.

Appendix V. Interpretation of mountain lion behaviors arranged in order of increasing risk to a human interacting with the mountain lion. Do not rely solely on these behaviors to assess risk, because mountain lions are ambush predators whose behavior usually is not observed before an attack on a human (from the Cougar Management Guidelines 2005, page 89).

Observation	Interpretation	Human Risk
Opportunistically viewed at distance	Secretive	Low
Flight, hiding	Avoidance	Low
Lack of attention, various movements not directed toward person	Indifference, or actively avoiding inducing aggression	Low
Various body positions, ears up, may be shifting positions, intent attention, following behavior.	Curiosity	Low-provided human response is appropriate
Intense staring, following and hiding behavior	Assessing success of attack	Moderate
Hissing, snarling, vocalization	Defensive behaviors, attack may be imminent	Moderate, depending on distance to animal
Crouching, tail twitching, intense staring, ears flattened like wings, body low to ground, head may be up	Pre-attack	High
Ears flat, fur out, tail twitching, body and head low to ground, rear legs "pumping"	Imminent attack	Very high and immediate

Appendix VI. Some measures, with supporting information, that humans can take during an encounter to prevent injury (from the Cougar Management Guidelines 2005, page 93).

Recommendations	Supporting Information
Keep children under close control, and in view. Pick up small children immediately if you Encounter a mountain lion. Do not hike alone.	60% of victims have been unsupervised children or lone adults.
Do not run.	Running and quick movements may Stimulate chasing and catching response.
Stand. Wave your arms. Raise jacket over your Head. Appear as large as possible. Move to higher ground if nearby. Throw sticks, rocks, or other objects if within reach and accessible without bending to low.	Prey size vulnerability, and "positioning" influences mountain lion response.
Avoid dead animals and never approach kittens. Talk calmly. Back away.	Non-prey may be attacked if viewed as a threat.
Maintain eye contact. Do not look away. But if mountain lion appears agitated use peripheral vision to keep track if its location.	Eye-to-eye contact often restrains large cats. Direct eye contact from prey may inhibit predatory action.
Be alert to your surroundings.	Cats exploit all vantage points/cover when investigating prey.
If attacked, fight back. Humans have successfully deterred attacks by becoming aggressive.	A cat grasps with its teeth only if it meets with no resistance. Violently struggling Prey may be released.
Secure pets and hobby animals in predator proof enclosures between dusk and dawn. Keep pets on leashes and off trails in the backcountry.	Domestic prey animals may sustain mountain lion populations at unnaturally high levels.
Keep garbage under control to avoid attracting raccoons, skunks, etc. Do not feed pets outside and remove extra feed from domestic animal pens. Do not feed wildlife.	Mountain lions may be attracted to concentrations of potential prey.
A mountain lion that treats humans as prey is a public safety threat.	Once a learned behavior develops it may not be possible to modify this behavior.
Mountain lions that enter yards or campsites to kill pets may be candidates for removal. Keep pets under control.	Once a learned behavior develops it may not be modifiable.

Table 1. Annual Cougar Mortality Statistics 2001-2019, New Mexico Department of Game and Fish

	Sport Harvest			Depredation Kill			Bighorn Sheep Protection			Other (road kill, accident, etc.)				
License Year	Fem	Male	Unk[a]	Fem	Male	Unk	Fem	Male	Unk	Fem	Male	Unk	**Total**	**% Female**
2001-02	76	110	0	3	3	1	5	6	0	3	0	2	209	41.2%
2002-03	82	120	1	14	13	1	14	11	0	6	3	2	267	43.4%
2003-04	84	114	0	17	5	0	5	12	0	3	2	0	242	45.0%
2004-05	72	89	0	16	16	1	3	8	0	4	0	0	209	46.3%
2005-06	34	72	0	5	5	0	6	8	0	1	3	0	134	34.8%
2006-07	82	95	0	11	13	1	8	10	0	3	1	0	224	46.7%
2007-08	59	104	0	13	13	0	3	8	0	1	1	0	202	37.6%
2008-09	50	72	0	5	11	0	4	11	0	4	1	0	158	39.9%
2009-10	55	103	0	7	11	0	8	7	0	1	5	0	197	36.0%
2010-11	57	110	1	1	3	0	8	6	0	5	5	0	196	36.2%
2011-12	75	123	0	14	7	0	4	8	0	5	7	0	243	40.2%
2012-13	87	170	0	14	6	0	7	23	0	4	5	1	317	35.3%
2013-14	85	117	1	12	12	0	5	12	0	5	4	0	253	42.4%
2014-15	102	130	0	12	10	1	8	10	0	4	7	0	284	44.8%
2015-16	88	151	0	14	9	0	6	5	1	7	13	0	294	39.1%
2016-17[b]	89	154	1	15	6	0	5	12	0	7	9	2	300	38.7%
2017-18[c]	94	143	1	10	10	0	9	10	0	5	9	1	292	40.4%
2018-19[d]	117	227	0	14	11	0	5	22	0	5	6	2	409	34.5%

[a] Unk – Unknown, sometimes the sex is impossible to determine due to decomposition or physical damage.

[b] Four cougars were lawfully harvested by trapping, on private lands, as sport harvests during the 2016-17 season as allowed under the 2016-2020 Bear and Cougar Rule.

[c] Twenty cougars were lawfully harvested by trapping, on private or state trust lands, as sport harvests during the 2017-18 season as allowed under the 2016-2020 Bear and Cougar Rule.

[d] Thirteen cougars were lawfully harvested by trapping, on private or state trust lands, as sport harvests during the 2018-19 season as allowed under the 2016-17-2019-20 Bear and Cougar Rule.

May 13, 2019

Table 1. Cougar Mortality in New Mexico, 2012-13, New Mexico Department of Game and Fish.

		Sport Harvest			Depredation			Road Kill/Other			Bighorn Sheep Removal			
Zone	**GMUs**	**Fem**	**Male**	**Unk***	**Fem**	**Male**	**Unk**	**Fem.**	**Male**	**Unk**	**Fem**	**Male**	**Unk**	**Totals**
A	2, 7	9	15	0	0	0	0	0	0	0	0	0	0	24
B	5, 50, 51	6	17	0	0	0	0	0	0	0	0	0	0	23
C	43,45,46, 48, 49, 53	13	21	0	3	0	0	0	1	0	0	0	0	38
D	41, 42, 47, 59	4	8	0	1	1	0	1	1	0	0	0	0	16
E	9, 10	0	4	0	0	0	0	0	0	0	0	0	0	4
F	6	11	8	0	0	0	0	1	0	0	0	0	0	20
G	13, 17, 18	4	6	0	0	0	0	0	0	0	1	1	0	12
H	19, 20	0	0	0	0	0	0	0	0	0	3	4	0	7
I	36-38	4	10	0	1	0	0	1	1	0	0	0	0	17
J	15, 16, 21, 25	9	26	0	1	0	0	0	2	0	0	2	0	40
K	22-24	8	9	0	3	5	0	0	0	0	1	11	0	37
L	26, 27	0	2	0	0	0	0	0	0	0	2	4	0	8
M	31-33, 39, 40	5	1	0	0	0	0	0	0	0	0	0	0	6
N	4, 52	4	4	0	0	0	0	0	0	0	0	0	0	8
O	12	1	4	0	0	0	0	0	0	0	0	0	0	5
P	56-58	1	5	0	0	0	0	0	0	0	0	0	0	6
Q	28-30, 34	2	7	0	2	0	0	0	0	0	0	0	0	11
R	54, 55	4	19	0	3	0	0	0	0	1	0	0	0	27
S	8, 14	2	4	0	0	0	0	1	0	0	0	1	0	8
	Totals	87	170	0	14	6	0	4	5	1	7	23	0	317

*Unk – Unknown, sometimes the sex is impossible to determine due to decomposition or physical damage.

Table 2. Cougar Mortality in New Mexico, 2013-14, New Mexico Department of Game and Fish.

		Sport Harvest			Depredation			Road Kill/Other			Bighorn Sheep Removal			
Zone	**GMUs**	**Fem**	**Male**	**Unk***	**Fem**	**Male**	**Unk**	**Fem.**	**Male**	**Unk**	**Fem**	**Male**	**Unk**	**Totals**
A	2, 7	11	8	0	0	0	0	0	0	0	0	0	0	19
B	5, 50, 51	7	10	0	2	0	0	0	0	0	0	0	0	19
C	43,45,46, 48, 49, 53	7	17	1	0	0	0	1	1	0	0	0	0	27
D	41, 42, 47, 59	4	8	0	2	3	0	0	0	0	0	0	0	17
E	9, 10	5	2	0	1	0	0	0	1	0	0	0	0	9
F	6	4	5	0	0	0	0	1	0	0	0	0	0	10
G	13, 17, 18	5	3	0	0	0	0	0	0	0	1	2	0	11
H	19, 20	0	0	0	0	0	0	0	0	0	1	0	0	1
I	36-38	7	10	0	1	2	0	1	0	0	0	0	0	21
J	15, 16, 21, 25	12	15	0	1	0	0	1	0	0	0	0	0	29
K	22-24	3	9	0	1	5	0	1	0	0	2	1	0	22
L	26, 27	1	4	0	0	0	0	0	0	0	1	5	0	11
M	31-33, 39, 40	0	1	0	2	1	0	0	0	0	0	0	0	4
N	4, 52	4	1	0	0	0	0	0	1	0	0	0	0	6
O	12	0	1	0	0	0	0	0	0	0	0	0	0	1
P	56-58	3	7	0	1	1	0	0	1	0	0	0	0	12
Q	28-30, 34	8	6	0	1	0	0	0	0	0	0	0	0	15
R	54, 55	2	8	0	0	0	0	0	0	0	0	0	0	10
S	8, 14	2	2	0	0	0	0	0	0	0	0	4	0	8
	Totals	85	117	1	12	12	0	5	4	0	5	12	0	253

Table 3. Cougar Mortality in New Mexico, 2014-15, New Mexico Department of Game and Fish.

		Sport Harvest			Depredation			Road Kill/Other			Bighorn Sheep Removal			
Zone	**GMUs**	**Fem**	**Male**	**Unk***	**Fem**	**Male**	**Unk**	**Fem.**	**Male**	**Unk**	**Fem**	**Male**	**Unk**	**Totals**
A	2, 7	7	7	0	0	0	0	0	0	0	0	0	0	14
B	5, 50, 51	6	19	0	1	0	0	0	0	0	0	0	0	26
C	43,45,46, 48, 49, 53	17	18	0	1	1	0	0	1	0	0	0	0	38
D	41, 42, 47, 59	3	7	0	0	2	0	0	0	0	0	0	0	12
E	9, 10	4	5	0	1	1	0	0	0	0	0	0	0	11
F	6	4	4	0	0	0	0	1	0	0	0	0	0	9
G	13, 17, 18	6	6	0	0	0	0	0	0	0	1	1	0	14
H	19, 20	0	0	0	0	0	0	0	0	0	1	3	0	4
I	36-38	13	8	0	2	2	0	2	0	0	0	0	0	27
J	15, 16, 21, 25	9	11	0	2	0	0	0	0	0	1	0	0	23
K	22-24	6	13	0	4	1	0	1	1	0	1	4	0	31
L	26, 27	0	1	0	0	0	0	0	0	0	3	1	0	5
M	31-33, 39, 40	1	0	0	0	0	0	0	0	0	0	0	0	1
N	4, 52	0	5	0	0	1	0	0	0	0	0	0	0	6
O	12	1	2	0	0	0	0	0	0	0	0	0	0	3
P	56-58	7	1	0	0	0	0	0	1	0	0	0	0	9
Q	28-30, 34	10	5	0	1	2	1	0	2	0	0	0	0	21
R	54, 55	4	16	0	0	0	0	0	2	0	0	0	0	22
S	8, 14	4	2	0	0	0	0	0	0	0	1	1	0	8
	Totals	102	130	0	12	10	1	4	7	0	8	10	0	284

Table 4. Cougar Mortality in New Mexico, 2015-16, New Mexico Department of Game and Fish.

		Sport Harvest			Depredation			Road Kill/Other			Bighorn Sheep Removal			
Zone	**GMUs**	**Fem**	**Male**	**Unk***	**Fem**	**Male**	**Unk**	**Fem.**	**Male**	**Unk**	**Fem**	**Male**	**Unk**	**Totals**
A	2, 7	10	10	0	0	1	0	1	0	0	0	0	0	22
B	5, 50, 51	2	10	0	0	0	0	0	0	0	0	0	0	12
C	43,45,46, 48, 49, 53	14	14	0	1	0	0	2	0	0	0	0	0	31
D	41, 42, 47, 59	1	4	0	0	2	0	0	0	0	0	0	0	7
E	9, 10	2	6	0	11	1	0	0	0	1	0	0	0	21
F	6	4	6	0	0	0	0	0	0	0	0	0	0	10
G	13, 17, 18	5	12	0	0	1	0	1	0	0	5	4	0	28
H	19, 20	2	1	0	0	1	0	0	1	0	0	5	0	10
I	36-38	8	15	0	0	0	0	0	1	0	0	0	0	24
J	15, 16, 21, 25	12	23	0	0	0	0	0	0	0	0	0	0	35
K	22-24	8	15	0	0	0	0	0	1	0	0	0	0	24
L	26, 27	1	1	0	0	0	0	0	0	0	2	4	0	8
M	31-33, 39, 40	1	3	0	0	1	0	0	0	0	0	0	0	5
N	4, 52	2	4	0	0	0	0	0	0	0	0	0	0	6
O	12	1	3	0	0	0	0	0	0	0	0	0	0	4
P	56-58	3	8	0	1	0	0	0	1	0	0	0	0	13
Q	28-30, 34	9	8	0	0	1	0	0	0	0	0	0	0	18
R	54, 55	1	7	0	1	0	0	2	1	0	0	0	0	12
S	8, 14	2	1	0	1	0	0	0	0	0	0	0	0	4
	Totals	88	151	0	14	9	0	6	5	1	7	13	0	294

Table 5. Cougar Mortality in New Mexico, 2016-17, New Mexico Department of Game and Fish.

		Sport Harvest			Depredation			Road Kill/Other			Bighorn Sheep Removal			
Zone	**GMUs**	**Fem**	**Male**	**Unk***	**Fem**	**Male**	**Unk**	**Fem.**	**Male**	**Unk**	**Fem**	**Male**	**Unk**	**Totals**
A	2, 7	3	9	0	0	0	0	0	0	0	0	0	0	12
B	5, 50, 51	8	14	0	0	0	0	0	0	0	0	0	0	22
C	43,45,46, 48, 49, 53	5	20	0	3	0	0	0	3	0	0	0	0	31
D	41, 42, 47, 59	1	4	0	1	0	0	0	0	0	0	0	0	6
E	9, 10	1	0	0	0	1	0	0	1	0	0	0	0	3
F	6	2	9	0	1	0	0	1	0	0	0	0	0	13
G	13, 17, 18	7	6	0	1	0	0	1	0	0	2	3	0	20
H	19, 20	0	0	0	0	0	0	0	0	0	0	3	0	3
I	36-38	3	11	0	1	1	0	0	1	0	0	0	0	17
J	15, 16, 21, 25	19	29	1	0	1	0	0	0	0	0	0	0	50
K	22-24	15	9	0	1	2	0	0	0	0	0	3	0	30
L	26, 27	2	3	0	0	0	0	0	0	0	3	3	0	11
M	31-33, 39, 40	0	2	0	0	0	0	1	0	0	0	0	0	3
N	4, 52	5	5	0	0	0	0	0	1	1	0	0	0	12
O	12	2	3	0	1	1	0	0	0	0	0	0	0	7
P	56-58	2	11	0	2	0	0	1	0	1	0	0	0	17
Q	28-30, 34	5	8	0	3	0	0	1	0	0	0	0	0	17
R	54, 55	6	10	0	1	0	0	1	2	0	0	0	0	20
S	8, 14	3	1	0	0	0	0	1	1	0	0	0	0	6
	Totals	89	154	1	15	6	0	7	9	2	5	12	0	300

Table 6. Cougar Mortality in New Mexico, 2017-18, New Mexico Department of Game and Fish.

		Sport Harvest			**Depredation**			**Road Kill/Other**			**Bighorn Sheep Removal**			
Zone	**GMUs**	**Fem**	**Male**	**Unk***	**Fem**	**Male**	**Unk**	**Fem.**	**Male**	**Unk**	**Fem**	**Male**	**Unk**	**Totals**
A	2, 7	7	7	0	1	0	0	0	0	0	0	0	0	15
B	5, 50, 51	5	15	0	0	0	0	0	0	0	0	0	0	20
C	43,45,46, 48, 49, 53	8	16	0	0	0	0	1	3	0	0	0	0	28
D	41, 42, 47, 59	6	5	0	0	0	0	0	0	0	0	0	0	11
E	9, 10	2	1	0	0	0	0	0	0	0	0	0	0	3
F	6	4	12	0	1	0	0	0	2	0	0	0	0	19
G	13, 17, 18	3	8	0	0	0	0	0	0	0	3	1	0	15
H	19, 20	2	2	0	0	0	0	0	0	0	2	1	0	7
I	36-38	7	4	0	1	0	0	0	0	0	0	0	0	12
J	15, 16, 21, 25	9	30	0	0	1	0	0	0	0	0	0	0	40
K	22-24	13	12	0	5	5	0	0	1	0	0	4	0	40
L	26, 27	1	2	0	0	0	0	0	0	0	4	4	0	11
M	31-33, 39, 40	3	1	0	0	0	0	0	0	1	0	0	0	5
N	4, 52	3	7	0	0	0	0	1	0	0	0	0	0	11
O	12	1	0	0	0	0	0	0	0	0	0	0	0	1
P	56-58	10	5	0	1	0	0	1	1	0	0	0	0	18
Q	28-30, 34	2	5	0	0	1	0	0	1	0	0	0	0	9
R	54, 55	7	10	0	2	2	0	1	1	0	0	0	0	23
S	8, 14	1	1	1	0	0	0	0	0	0	0	0	0	3
	Totals	94	143	1	10	10	0	5	9	1	9	10	0	292

Table 7. Cougar Mortality in New Mexico, 2018-19, New Mexico Department of Game and Fish.

		Sport Harvest			Depredation			Road Kill/Other			Bighorn Sheep Removal			
Zone	**GMUs**	**Fem**	**Male**	**Unk***	**Fem**	**Male**	**Unk**	**Fem.**	**Male**	**Unk**	**Fem**	**Male**	**Unk**	**Totals**
A	2, 7	9	12	0	0	1	0	0	0	0	0	0	0	22
B	5, 50, 51	10	17	0	0	0	0	0	0	0	0	0	0	27
C	43,45,46, 48, 49, 53	14	33	0	1	1	0	2	0	0	0	0	0	51
D	41, 42, 47, 59	3	5	0	0	0	0	0	1	0	0	0	0	9
E	9, 10	4	3	0	2	0	0	0	0	0	0	0	0	9
F	6	4	16	0	0	0	0	0	1	1	0	0	0	22
G	13, 17, 18	6	21	0	0	1	0	0	0	0	2	9	0	39
H	19, 20	2	1	0	0	0	0	0	0	0	0	2	0	5
I	36-38	7	12	0	0	0	0	0	0	0	0	0	0	19
J	15, 16, 21, 25	22	52	0	0	1	0	0	1	0	0	0	0	76
K	22-24	9	16	0	2	1	0	0	0	0	1	2	0	31
L	26, 27	2	2	0	0	2	0	0	0	0	0	3	0	9
M	31-33, 39, 40	2	2	0	2	0	0	0	0	0	0	0	0	6
N	4, 52	6	4	0	0	0	0	1	0	0	0	0	0	11
O	12	2	3	0	0	0	0	0	0	0	0	0	0	5
P	56-58	5	8	0	2	2	0	0	2	0	0	0	0	19
Q	28-30, 34	4	5	0	0	0	0	0	1	0	2	6	0	18
R	54, 55	5	12	0	4	2	0	2	0	1	0	0	0	26
S	8, 14	1	3	0	1	0	0	0	0	0	0	0	0	5
	Totals	117	227	0	14	11	0	5	6	2	5	22	0	409

10/24/16 – Amended 3/26/18

Cougar Population and Harvest Management Matrix (2016-17 through 2019-20).

Zone	Game Management Units	Estimated Cougar Habitat (km^2)[a]	Cougar Population Point Estimate[b]	Cougar Population Management Objectives 2016-2020[c]	2016-20 Total Mortality Limit [d]	2016-20 Female Sub-Limit
A	2, 7	13,728	207-285	Manage for stable cougar populations	42	13
B	5, 50, 51	6,526	142-192		28	8
C	43,45,46, 48, 49, 53	11,482	289-387		85	43
E	9, 10	13,674	251-341		50	15
I	36-38	7,138	121-165		24	7
J	15, 16, 21, 25	22,714	445-603		89	27
M	31-33, 39, 40	21,394	146-215		31	9
N	4, 52	2,801	76-102		15	5
O	12	6,663	103-141		21	6
Q	28, 29, 30, 34	11,752	170-235		35	11
R	54, 55	4,557	131-175		26	8
D	41, 42, 47, 59	6,468	76-106	Manage for decreasing cougar populations	23	12
F[e]	6	6,659	156-209		37	19
G	13, 17	14,422	247-338		73	37
H	18-20	11,878	140-197		42	21
K	22-24	11,299	225-305		66	33
L	26, 27	6,456	64-91		19	10
P	56-58	2,700	49-66		14	7
S	8, 14	4,661	85-116		25	13
Totals:		**186,972**	**3,123-4,269**		749	303

[a]The quantity of the habitat was derived from a model designed by G&F and T. Perry, PhD. The habitat is classed as Excellent, Good, Moderate, and Fair; Excellent has a density of 3.0-4.0/100km2, Good has a density of 1.2-1.7/100km2, Moderate has a density of 0.6-0.9/100km2 and Fair has a density of 0.4-0.5/100km2 adult cougars. Densities derived from studies conducted in New Mexico. 64% of the state is considered cougar habitat, 5% is tribal jurisdiction.

[b]The point estimate total cougar population is used, management objectives and removal/harvest level calculations and may not reflect the true value for the population. The population estimated is that of independent cougars, ≥18 months of age.

[c] Stable = harvest ≤ 17% of total estimated population w/max of 30% female; Stable to decrease = harvest ≤ 25% of total estimated population with ≤ 50% females.

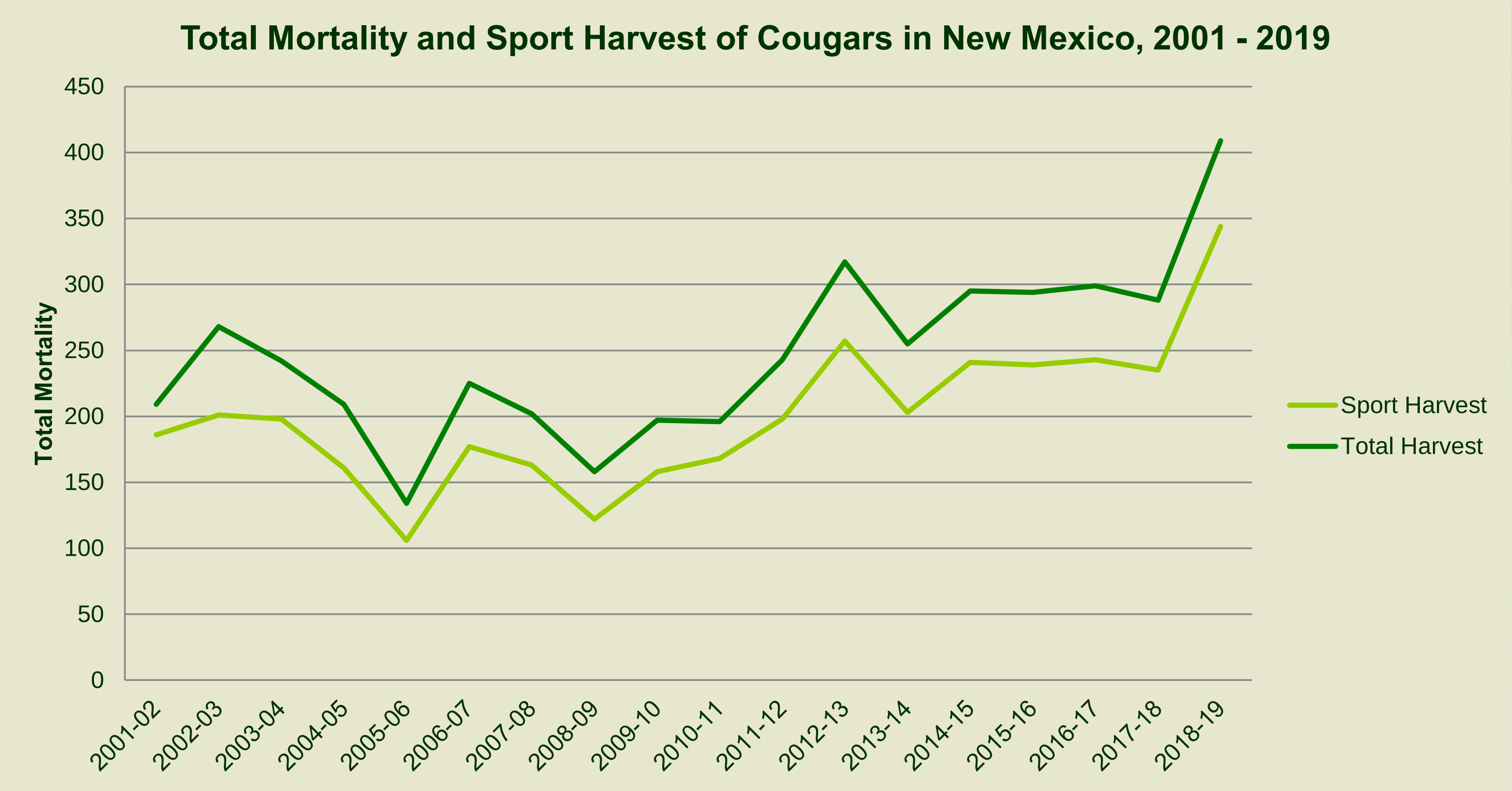
[d] 90% of Total mortality limit and/or female sub-limit will close harvest in any zone, whichever occurs first.

[e] Amended March 26, 2018 in Cougar Management Zone F from 46/23 to 37/19, a 20% reduction based on new research.

Cougar Zone Closures

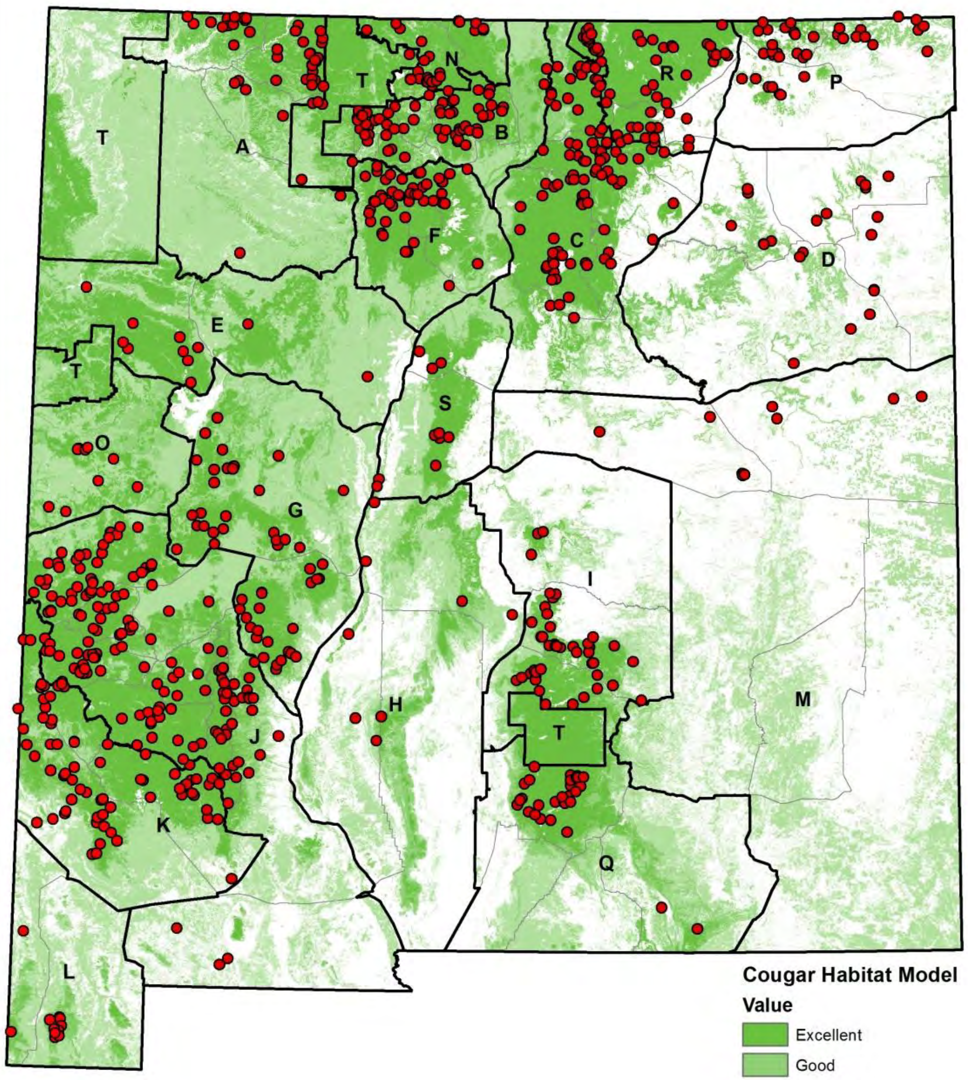
	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
A		Mar 17		No zones			
B		Jan 6	Jan 29	Closed		Feb 22	Jan 2
C				this			
D				season			
E							
F							
G							
H							
I			Jan 5			Jan 24	Dec 31
J							
K							
L							
M							
N	Feb 15	Dec 17			Jan 17	Feb 22	Dec 17
O							
P			Dec 29		Jan 13	Feb 13	Jan 4
Q			Feb 15				
R						Mar 9	
S							

Cougar Harvest



Wildlife Management Division

Cougar Harvest 2016 - 2019



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Cougar Sport Harvest Limits

	Max	2016	2017	2018
A	*42*	12	14	21
B	*28*	22	20	27
C	*85*	25	24	47
D	*23*	5	11	8
E	*50*	1	3	7
F	*46*	11	16	20*
G	*73*	13	11	27
H	*37*	0	4	3
I	*24*	14	11	19
J	*89*	49	39	74
K	*66*	24	25	25
L	*19*	5	3	4
M	*31*	2	4	4
N	*15*	10	10	10
O	*21*	5	1	5
P	*14*	13	15	13
Q	*35*	13	7	9
R	*26*	16	17	17
S	*25*	4	3	4

*2018 CMZ F limit was reduced to 37

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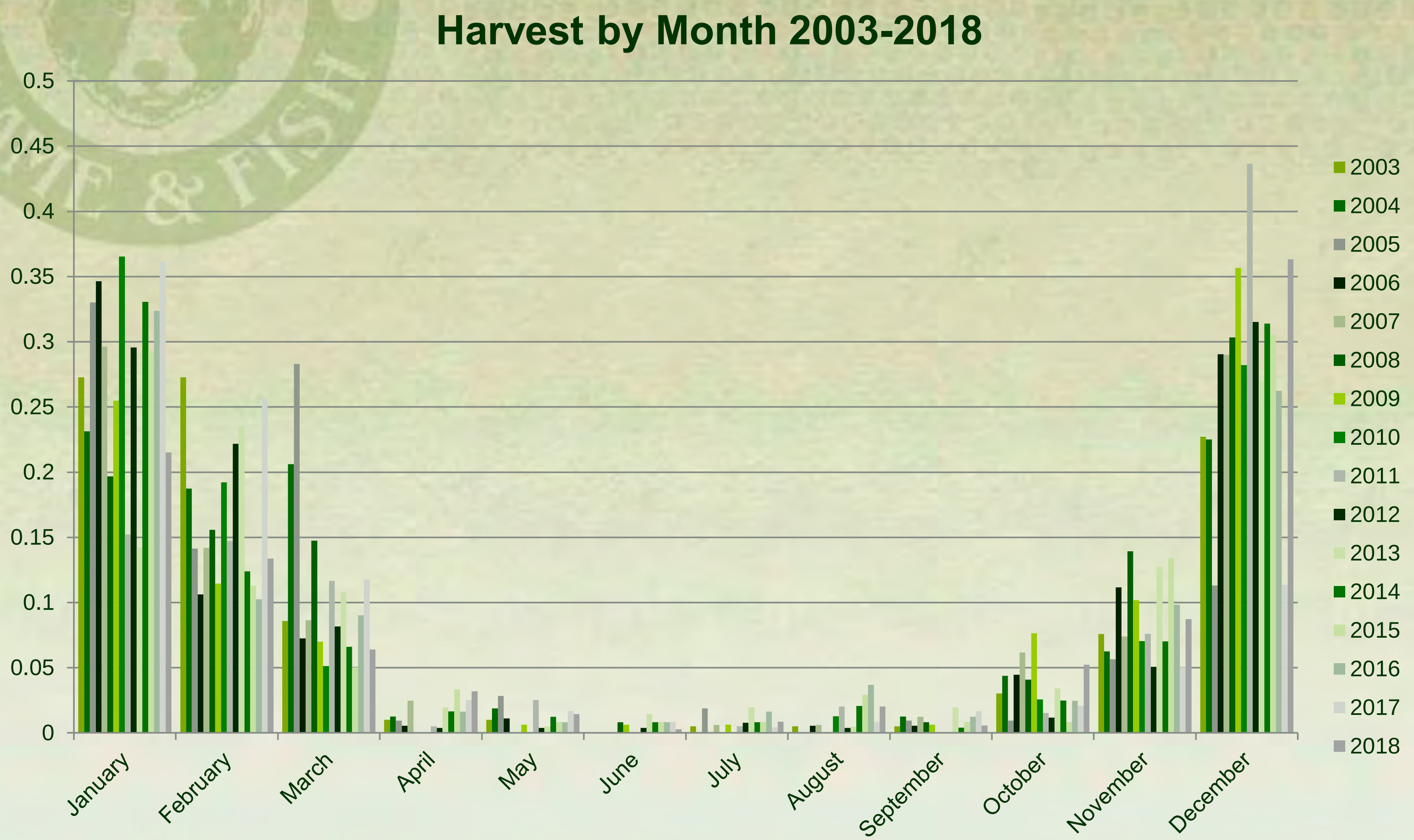
Cougar Harvest by Month



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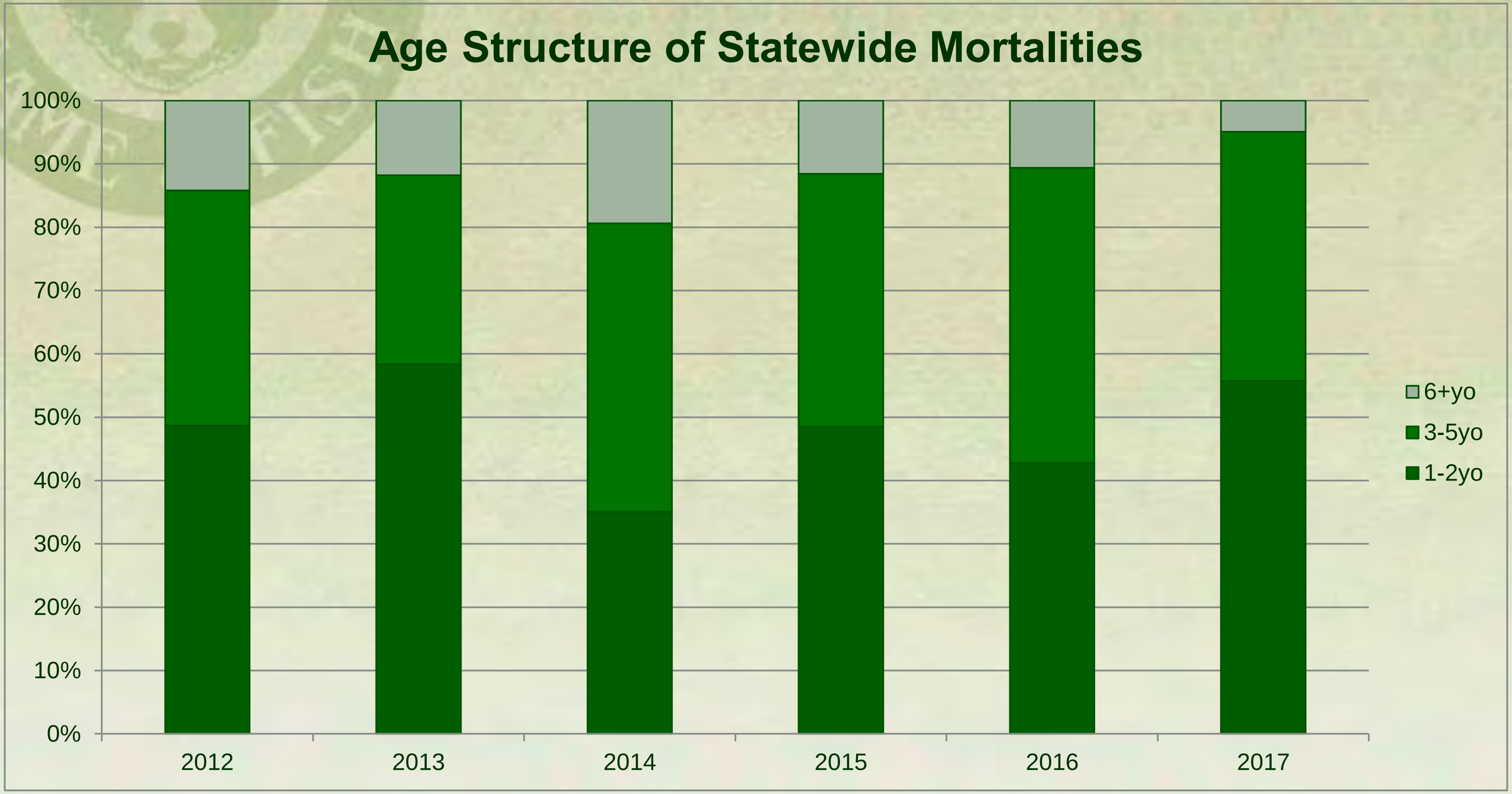
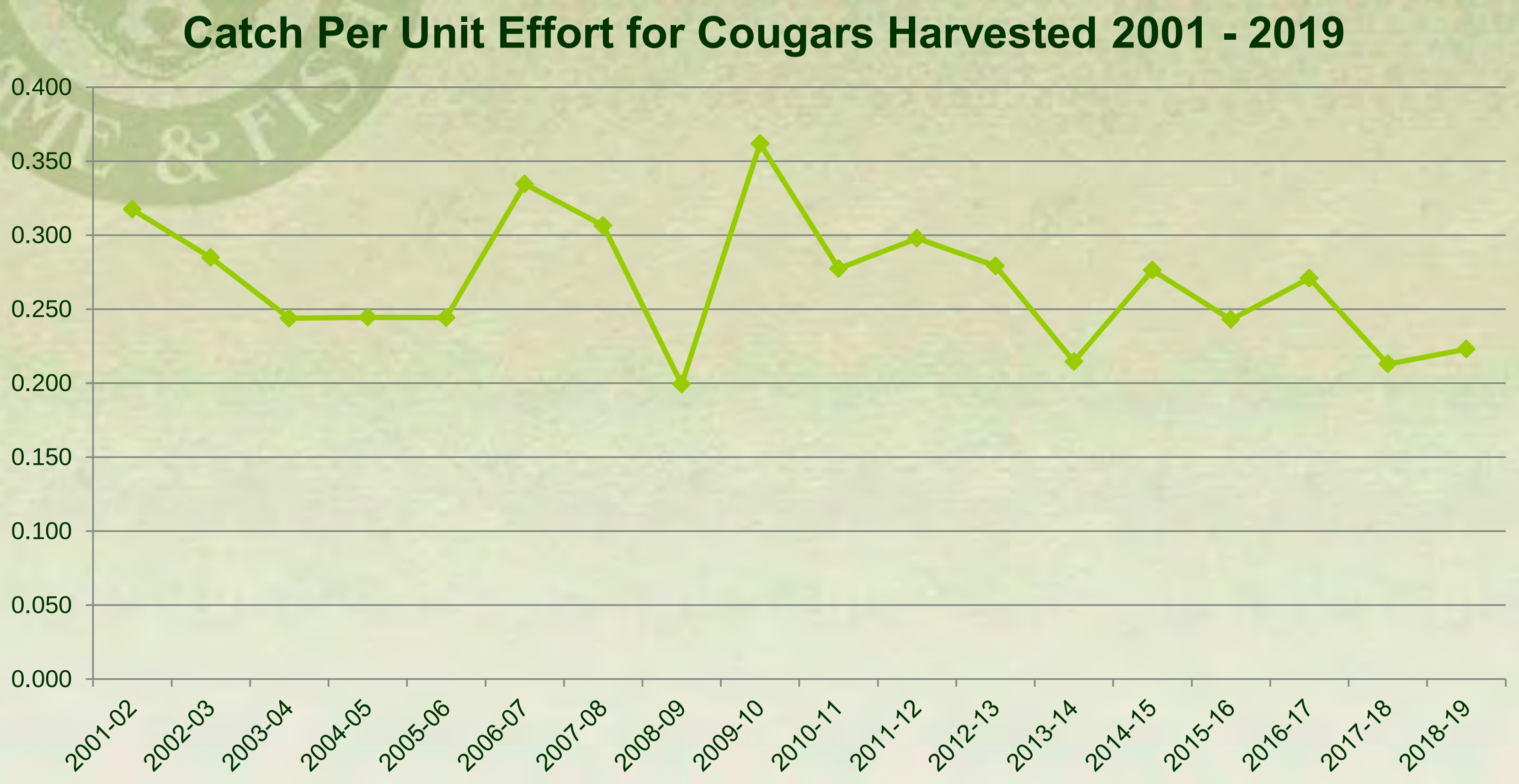
Cougar Population Age Structure



Cougar: Catch Per Unit Effort



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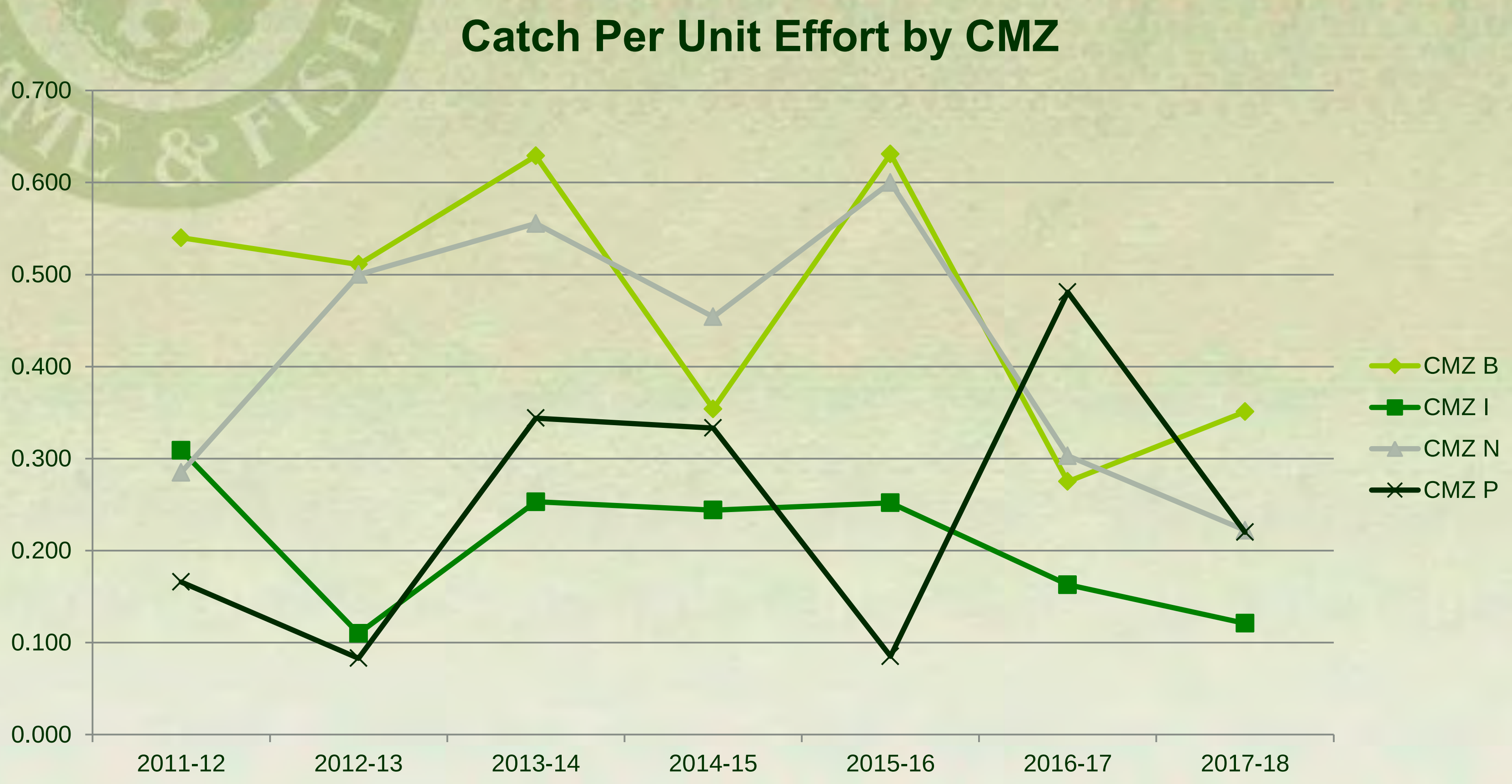
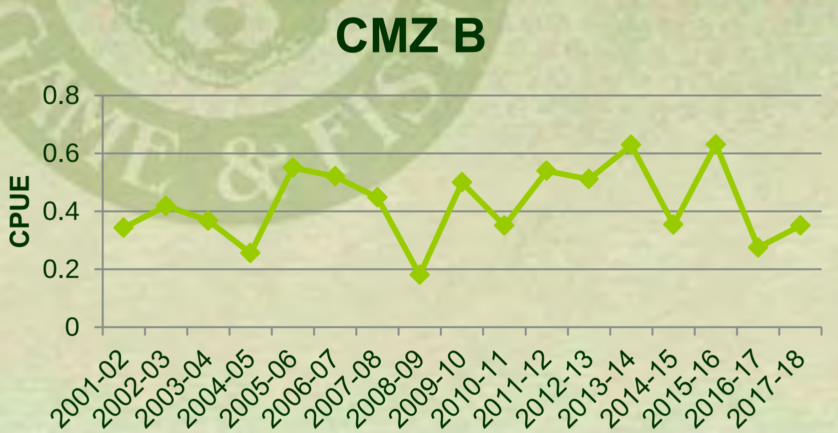
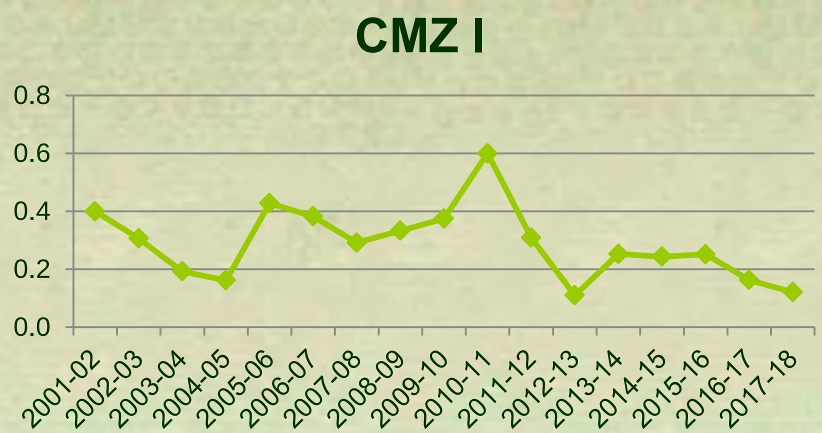
Cougar – CPUE in Zones that Close

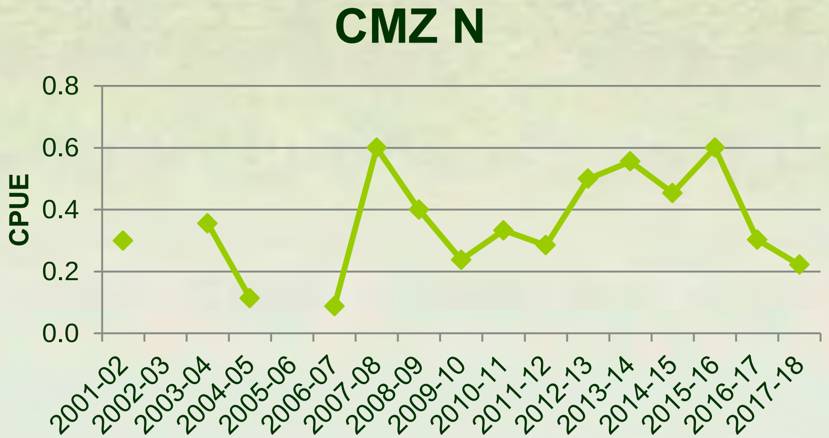


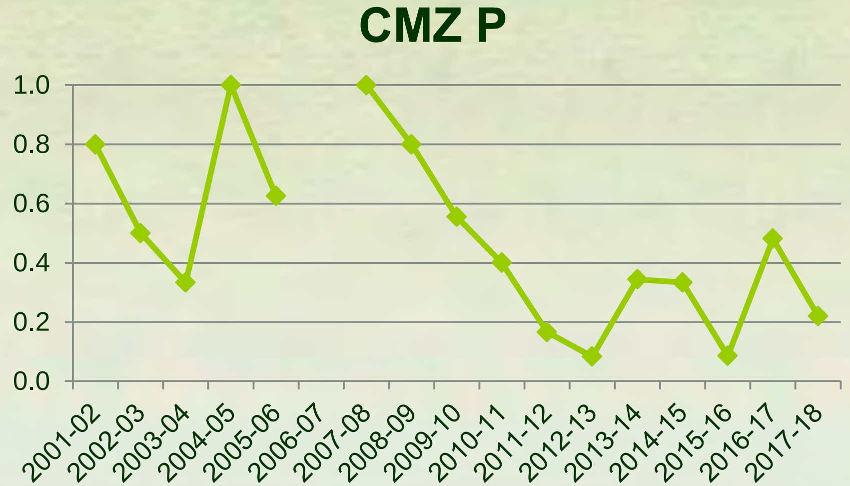
Wildlife Management Division

Cougar – CPUE in Zones that Close









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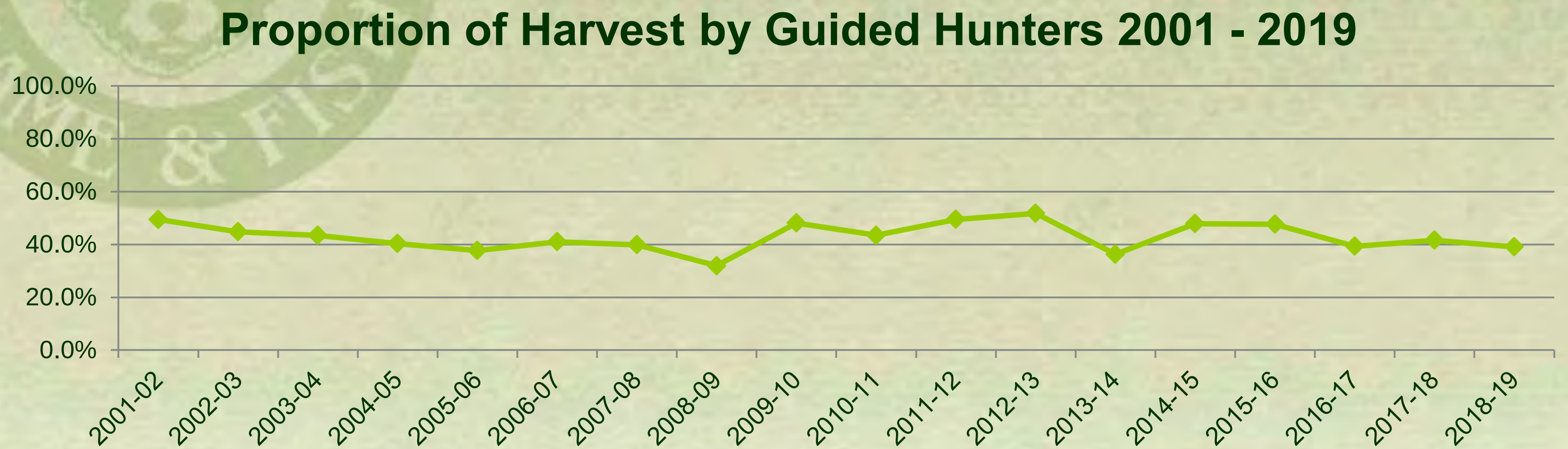
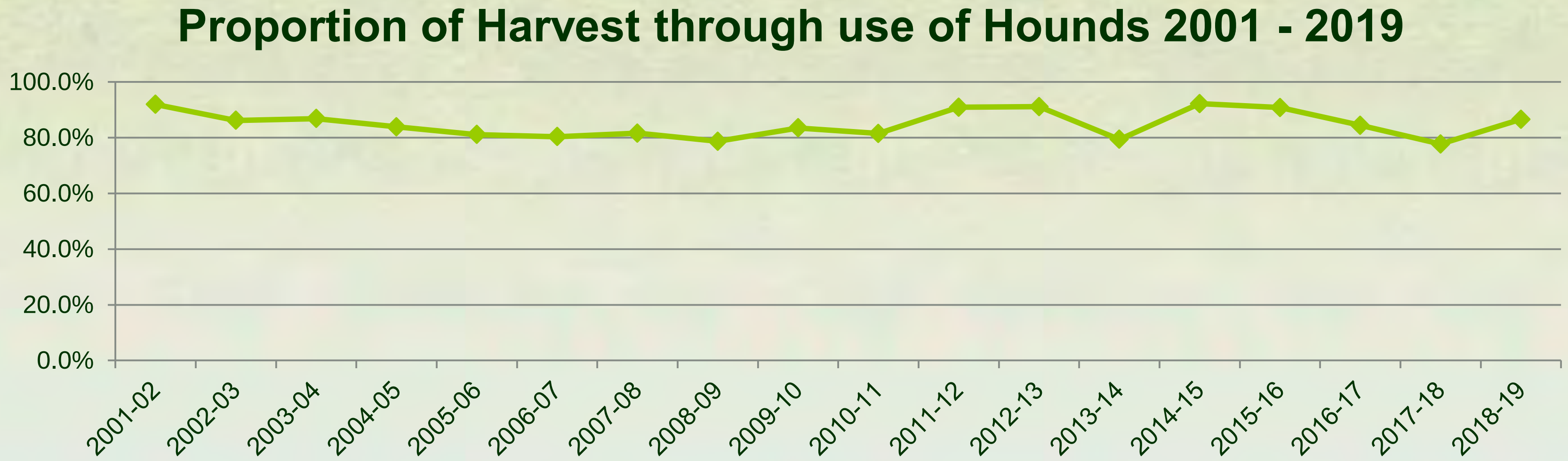
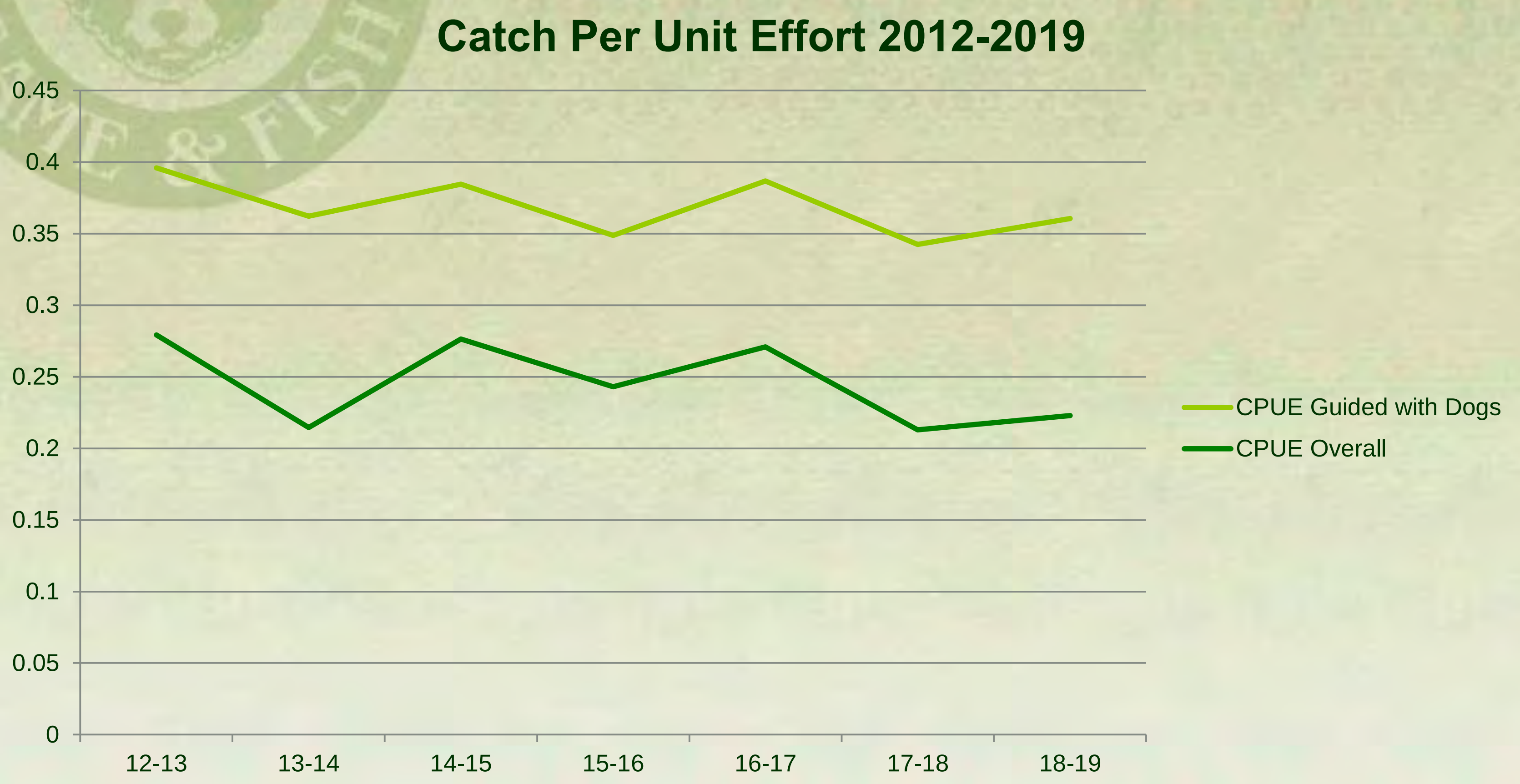
Cougar – Guided and/or with dogs





Wildlife Management Division

Cougar – Catch Per Unit Effort with Guide and Dogs



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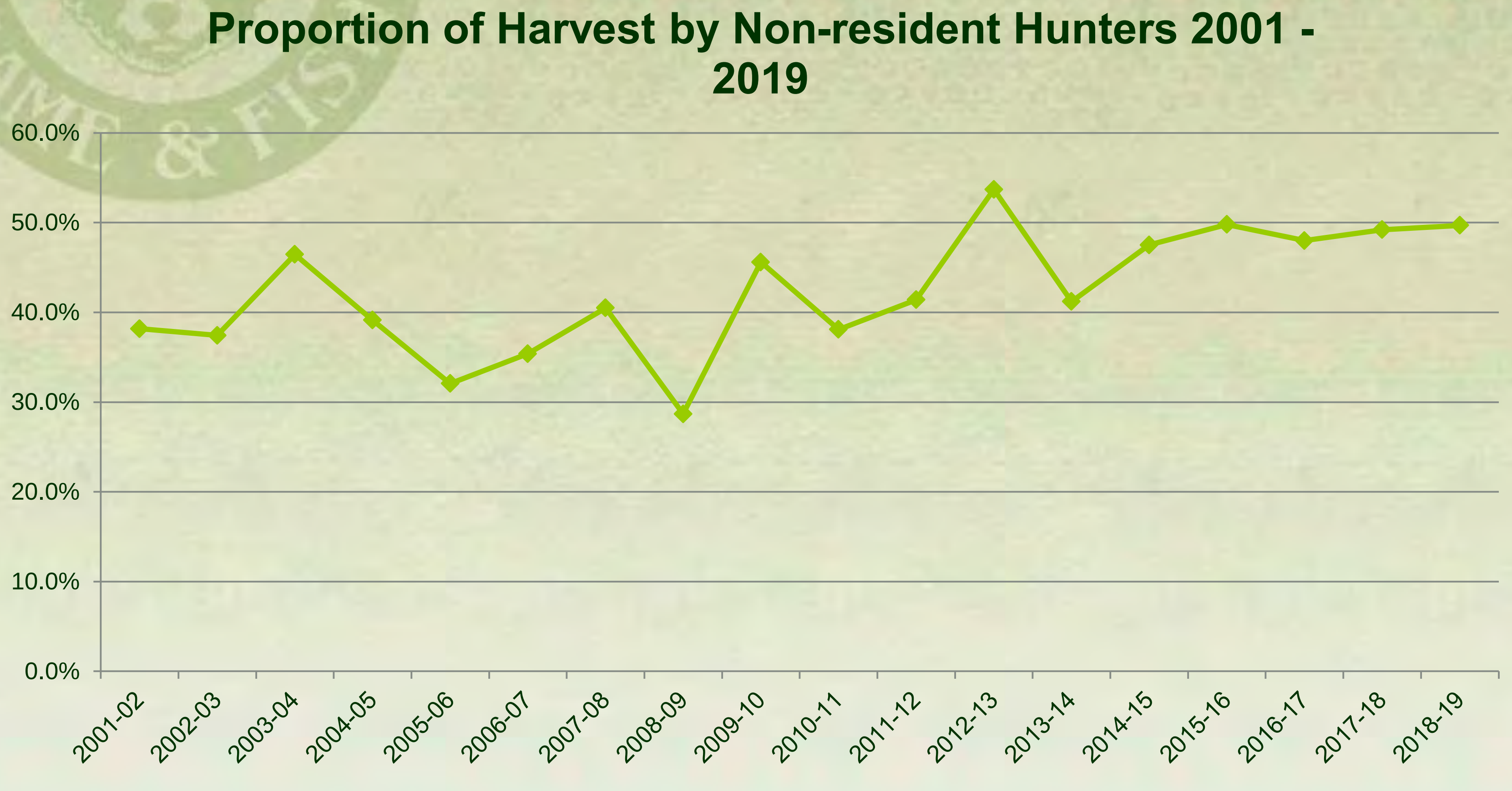
Cougar – Harvest by Non-Residents

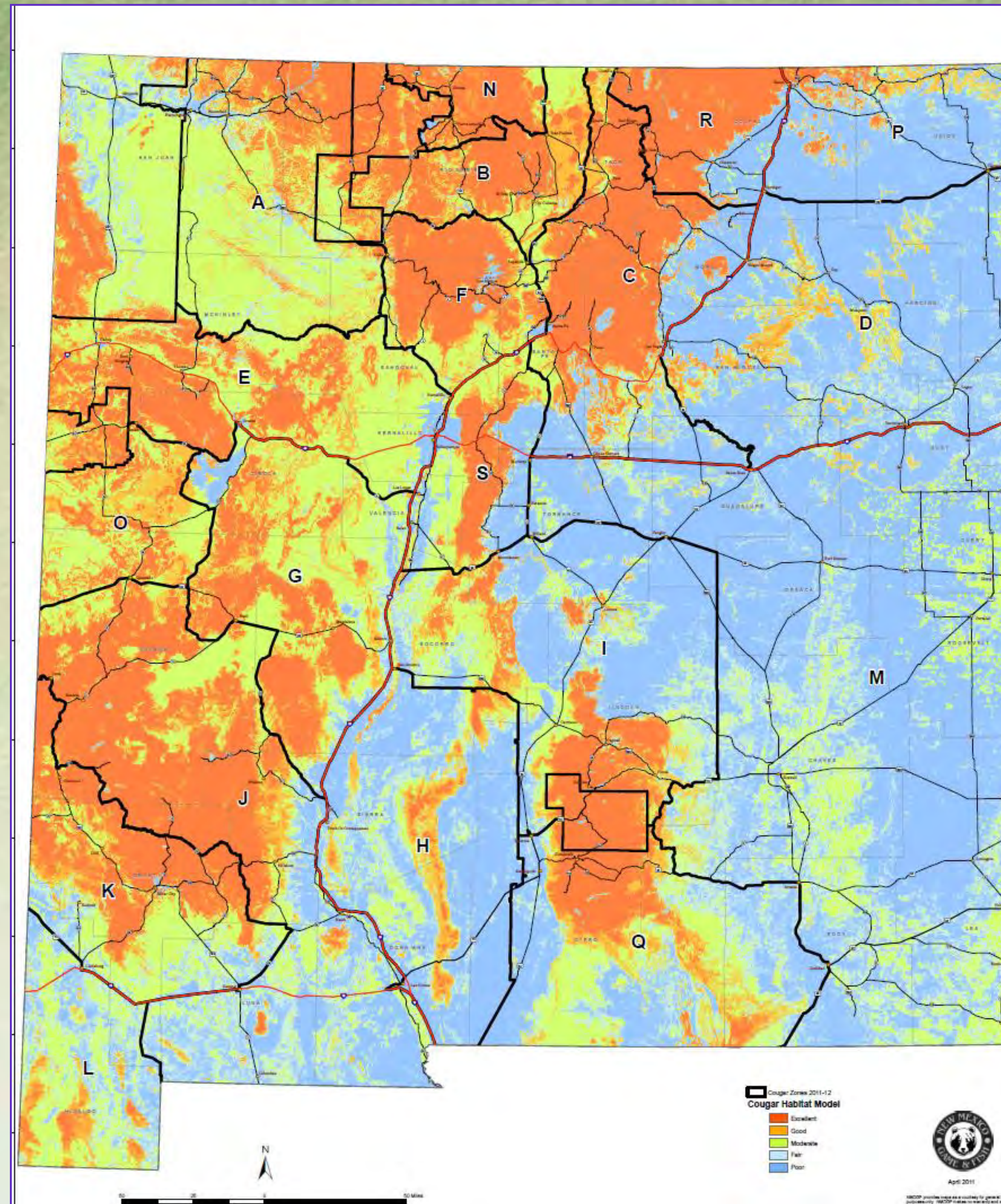


Wildlife Management Division

Cougar – Harvest both tags or additional tags

	2016	2017	2018
Harvested 2	13	22	23
Harvested > 2	2	1	4

Cougar Habitat Map



Wildlife Management Division

PERFORMANCE REPORT

State: New Mexico **Grant Number**: W-93-R-56

Grant Title: Big Game Surveys, Inventories, and Management

Grant Period: From: July 1, 2015 to: June 30, 2016

Grant Objective: To survey New Mexico's big game populations and their hunters and to manage these big game species according to the mission, goals, and plans of the New Mexico State Game Commission and the Department of Game and Fish.

Project Number: 1 **Project Title**: Grant Administration and Coordination

Project Objective: To provide administrative support and coordination for New Mexico's Big Game Surveys, Inventories, and Management Grant.

I. Job Objectives and Summary of Progress:

Cougar (*Puma concolor*). The sustainability of hunter harvest programs was examined in the context of the quality, quantity, and distribution of habitats for this large carnivore. Data were used to amend the Bear and Cougar Rule. The Cougar Population Assessment and Harvest Management Matrix was modified to better track mortalities from all causes, to identify sport harvest limits, estimate population densities, habitat, and management goals. Research is ongoing to determine the effect of cougar predation on ungulate populations and to estimate cougar population densities statewide. A new research project was implemented in collaboration with NMSU to estimate cougar densities in different habitat qualities to develop density estimates statewide and in individual Cougar Management Zones.

PERFORMANCE REPORT

State: New Mexico **Grant Number**: W-93-R-56

Grant Title: Big Game Surveys, Inventories, and Management

Grant Period: **From**: July 1, 2015 **to:** June 30, 2016

Grant Objective: To survey New Mexico's big game populations and their hunters and to manage these big game species according to the mission, goals, and plans of the New Mexico State Game Commission and the Department of Game and Fish.

Project Number: 2 **Sections 2.A.1. and 2.2** **Project Title**: Population and Harvest Surveys, Inventories, and Big Game Management

Objective: To survey New Mexico big game populations and their hunters to develop hunt season recommendations, restore big game populations where biological, ecological and sociological information indicates it is feasible and ascertain health status of big game populations, identify the nature and extent of any disease affecting big game and understand the disease process.

2.A.1. and 2.2. Estimate big game population size and/or trend, sex and age composition, and geographical distribution. Evaluate survey techniques and develop new methods where appropriate.

Cougar. Sport harvest has slowly increased over the last 16 years primarily due to increased opportunity and interest. The female proportion of the harvest has averaged ~40%. Licenses sold since 2000 have stabilized at ~2000 licenses annually. The harvest is primarily dependent on weather, particularly snowfall which allows for better tracking conditions, while depredation kills, road kill and bighorn sheep protection kills have fluctuated annually. Non-resident harvest and license sales are a distinct factor in cougar harvest as non-residents generally hire guides using hounds and have a higher success rate.

Cougar population estimates and sustainable harvest levels were derived from a combination of habitat and average density from the New Mexico cougar study (1996), mortality and harvest data, recent research in New Mexico, and cougar research in the western states (Table 2.A.26). Research has continued on cougar predation effects on the Gallinas Mountains deer population. A second research project was initiated estimating statewide cougar populations using non-invasive genetic and camera-trapping techniques.

Table 2.A.26. Cougar Population Estimates and Mortality Limits by Zones, NMDGF.

Zone	GMUs	Population Estimate	Total Mortality Limit	Female 25%Sub-limit
A	2, 7	207-285	42	13
B	5, 50, 51	142-192	28	8
C	43-46, 48, 49, 53-55	289-387	85	43
D	41, 42, 47, 59	76-106	23	12
E	9, 10	251-341	50	15
F	6	156-209	46	23
G	13 and 17	247-338	73	37
H	18, 19, 20	140-197	42	21
I	36-38	121-165	24	7
J	15, 16, 21, 25	445-603	89	27
K	22 and 24	225-305	66	33
L	26 and 27	64-91	19	10
M	31-33, 39, 40	146-215	31	9
N	4 and 52	76-102	15	5
O	12	103-141	21	6

P	56-58	49-66	14	7
Q	28-30 and 34	170-235	35	11
R	45 and 55	131-175	26	8
S	8 and 14	85-116	25	13
Totals:		3,123-4,269	749	303

PERFORMANCE REPORT

State: New Mexico **Grant Number**: W-93-R-56

Grant Title: Big Game Surveys, Inventories, and Management

Grant Period: **From**: July 1, 2015 **to:** June 30, 2016

Grant Objective: To survey New Mexico's big game populations and their hunters and to manage these big game species according to the mission, goals, and plans of the New Mexico State Game Commission and the Department of Game and Fish.

Project Number: 2 **Sections 2.B.1. and 2.3-2.10** **Project Title**: Population and Harvest Surveys, Inventories, and Big Game Management

Objective: To survey New Mexico big game populations and their hunters to develop hunt season recommendations, restore big game populations where biological, ecological and sociological information indicates it is feasible and ascertain health status of big game populations, identify the nature and extent of any disease affecting big game and understand the disease process.

II. Job Objectives and Summary of Progress:

2.1.B Estimate hunter numbers, harvest, effort, and success rates.

Cougar. Harvest continued to be managed by the hunter harvest/total sustainable mortality system. During the hunting season, each zone remained open to mountain lion hunting from April 1 until March 31 or when the total number of hunter kills (as determined by mandatory check-in for successful hunters) equaled the total sustainable mortality limit for that zone, or the female sub-limit had been met, whichever came first. Only 30% of the harvest may be female in cougar management zones where the long term goal is stable cougar population, and only 50% in cougar management zones where the goal is population reduction. Cougar harvest has been slowly increasing over the past 3 years (Table 2.B.5).

Table 2.B.5. Annual Cougar Mortality Statistics 2001/02 - 2015/16, NMDGF.

	Sport Harvest				Depredation Kill				Bighorn Sheep Protection				Other (road kill, accident, etc.)					
Cougar	Fem.	Male	Unk.*	**Total Sport**	Fem.	Male	Unk.	**Total Depred.**	Fem.	Male	Unk.	**Total BHS**	Fem.	Male	Unk.	**Total Other**	**Total**	% Female
2001-02	76	110	0	**286**	3	3	1	**7**	5	6	0	**11**	3	0	2	**5**	**209**	41.2%
2002-03	82	120	1	**203**	14	13	1	**28**	14	11	0	**25**	6	3	2	**11**	**267**	43.4%
2003-04	84	114	0	**198**	17	5	0	**22**	5	12	0	**17**	3	2	0	**5**	**242**	45.0%
2004-05	72	89	0	**161**	16	16	1	**33**	3	8	0	**11**	4	0	0	**4**	**209**	46.3%
2005-06	34	72	0	**106**	5	5	0	**10**	6	8	0	**14**	1	3	0	**4**	**134**	34.8%
2006-07	82	95	0	**177**	11	13	1	**25**	8	10	0	**18**	3	1	0	**4**	**224**	46.7%
2007-08	59	104	0	**163**	13	13	0	**26**	3	8	0	**11**	1	1	0	**2**	**202**	37.6%
2008-09	50	72	0	**122**	5	11	0	**16**	4	11	0	**15**	4	1	0	**5**	**158**	39.9%
2009-10	55	103	0	**158**	7	11	0	**18**	8	7	0	**15**	1	5	0	**6**	**197**	36.0%
2010-11	57	110	1	**167**	1	3	0	**4**	8	6	0	**14**	5	5	0	**10**	**196**	36.2%
2011-12	75	123	0	**198**	14	7	0	**21**	4	8	0	**12**	5	7	0	**12**	**243**	40.2%
2012-13	87	170	0	**257**	14	6	0	**20**	7	23	0	**30**	4	5	1	**10**	**317**	35.3%
2013-14	85	117	1	**203**	12	12	0	**24**	5	12	0	**17**	5	4	0	**9**	**253**	42.4%
2014-15	102	130	0	**232**	12	10	1	**23**	8	10	0	**18**	4	7	0	**11**	**284**	44.8%
2015-16	88	151	0	**239**	14	9	0	**23**	7	13	0	**20**	6	5	1	**12**	**294**	39.1%

*Unk – Unknown, sometimes the sex is impossible to determine due to decomposition or physical damage.

2.5. Cougar density estimation.

The goal of this study is to provide relevant population and density data that will contribute to developing harvest management strategies and directing other cougar management activities in New Mexico. The objectives of this study are to: 1) estimate cougar abundance and density in replicated survey areas across New Mexico to provide data for the development of data-based harvest objectives and limits; 2) compare data-derived density estimates to those used in the habitat model currently employed by NMDGF to develop harvest limits; and 3) test a remote camera-based method for estimating cougar abundance and density in the absence of marked individuals. Below is a summary of our work to date:

- Implement noninvasive sampling using scat detection dogs, genetic analysis, and mark-recapture techniques to estimate cougar abundance within each of 15, 225 km^2 study areas.
- During 2016, we completed surveys of 4 study areas using scat detection dogs.
- Two of the four study areas completed with scat detection dogs were also sampled using a remote camera array.
- Scat samples are being prepared for genetic analysis to be conducted at the University of Idaho.
- Camera data is being pre-processed and photos organized.

PERFORMANCE REPORT

State: New Mexico **Grant Number**: W-93-R-57

Grant Title: Big Game Surveys, Inventories, and Management

Grant Period: From: July 1, 2016 to: June 30, 2017

Grant Objective: To survey New Mexico's big game populations and their hunters and to manage these big game species according to the mission, goals, and plans of the New Mexico State Game Commission and the Department of Game and Fish.

Project Number: 1 **Project Title**: Grant Administration and Coordination

Project Objective: To provide administrative support and coordination for New Mexico's Big Game Surveys, Inventories, and Management Grant.

I. Job Objectives and Summary of Progress:

Cougar (*Puma concolor*). Annual harvest statistics were compiled and analyzed for trends over the most recent 10 years to inform management. A camera trapping survey in a spatial mark-resight framework was developed to estimate density, abundance, home range size, and resource selection.

PERFORMANCE REPORT

State: New Mexico **Grant Number**: W-93-R-57

Grant Title: Big Game Surveys, Inventories, and Management

Grant Period: **From**: July 1, 2016 **to:** June 30, 2017

Grant Objective: To survey New Mexico's big game populations and their hunters and to manage these big game species according to the mission, goals, and plans of the New Mexico State Game Commission and the Department of Game and Fish.

Project Number: 2 **Sections 2.A.1. and 2.2** **Project Title**: Population and Harvest Surveys, Inventories, and Big Game Management

Objective: To survey New Mexico big game populations and their hunters to develop hunt season recommendations, restore big game populations where biological, ecological and sociological information indicates it is feasible and ascertain health status of big game populations, identify the nature and extent of any disease affecting big game and understand the disease process.

II. Job Objectives and Summary of Progress:

2.A.1. and 2.2. Estimate big game population size and/or trend, sex and age composition, and geographical distribution. Evaluate survey techniques and develop new methods where appropriate.

Cougar. Cougar population estimates and sustainable harvest levels were derived from a combination of available habitat, density extrapolated from a 1996 New Mexico cougar study and from other western states, and existing mortality and harvest data (Table 2.A.27). Two studies were initiated to evaluate non-invasive genetic and camera-trapping survey methods and spatial capture-recapture and spatial mark-resight models for estimating density and abundance of cougars in New Mexico.

Table 2.A.27. Cougar Population Estimates and Mortality Limits by Zones, NMDGF.

Zone	GMUs	Population Estimate	Total Mortality Limit	Female 25%Sub-limit
A	2, 7	207-285	42	13
B	5, 50, 51	142-192	28	8
C	43-46, 48, 49, 53-55	289-387	85	43
D	41, 42, 47, 59	76-106	23	12
E	9, 10	251-341	50	15
F	6	156-209	46	23
G	13 and 17	247-338	73	37
H	18, 19, 20	140-197	42	21
I	36-38	121-165	24	7
J	15, 16, 21, 25	445-603	89	27
K	22, 23, 24	225-305	66	33
L	26 and 27	64-91	19	10
M	31-33, 39, 40	146-215	31	9
N	4 and 52	76-102	15	5
O	12	103-141	21	6
P	56-58	49-66	14	7
Q	28-30 and 34	170-235	35	11
R	45 and 55	131-175	26	8
S	8 and 14	85-116	25	13
Totals:		3,123-4,269	749	303

PERFORMANCE REPORT

State: New Mexico **Grant Number**: W-93-R-56

Grant Title: Big Game Surveys, Inventories, and Management

Grant Period: **From**: July 1, 2015 **to:** June 30, 2016

Grant Objective: To survey New Mexico's big game populations and their hunters and to manage these big game species according to the mission, goals, and plans of the New Mexico State Game Commission and the Department of Game and Fish.

Project Number: 2 **Sections 2.B.1. and 2.3-2.10** **Project Title**: Population and Harvest Surveys, Inventories, and Big Game Management

Objective: To survey New Mexico big game populations and their hunters to develop hunt season recommendations, restore big game populations where biological, ecological and sociological information indicates it is feasible and ascertain health status of big game populations, identify the nature and extent of any disease affecting big game and understand the disease process.

II. Job Objectives and Summary of Progress:

2.1.B Estimate hunter numbers, harvest, effort, and success rates.

Cougar. Harvest continued to be managed by the hunter harvest/total sustainable mortality system. During the hunting season, each zone remained open to mountain lion hunting from April 1 until March 31 or when the total number of hunter kills (as determined by mandatory check-in for successful hunters) equaled the total sustainable mortality limit for that zone, or the female sub-limit had been met, whichever came first. Only 30% of the harvest may be female in cougar management zones where the long term goal is stable cougar population, and 50% in cougar management zones where the goal is population reduction. Cougar harvest has remained relatively stable for the past 3 years (Table 2.B.5).

Table 2.B.5. Annual Cougar Mortality Statistics 2001-2016/17, NMDG

	Sport Harvest				Depredation Kill				Bighorn Sheep Protection				Other (road kill, accident, etc.)				TOTALS	
Cougar	Fem.	Male	Unk.*	**Total Sport**	Fem.	Male	Unk.	**Total Depred.**	Fem.	Male	Unk.	**Total BHS**	Fem.	Male	Unk.	**Total Other**	**Total**	% Female
2001-02	76	110	0	**186**	3	3	1	**7**	5	6	0	**11**	3	0	2	**5**	**209**	41.6%
2002-03	82	118	1	**201**	14	14	1	**29**	14	11	0	**25**	6	5	2	**13**	**268**	43.3%
2003-04	84	114	0	**198**	17	5	0	**22**	5	12	0	**17**	3	2	0	**5**	**242**	45.0%
2004-05	72	89	0	**161**	16	16	1	**33**	3	8	0	**11**	4	0	0	**4**	**209**	45.5%
2005-06	34	72	0	**106**	5	5	0	**10**	6	8	0	**14**	1	3	0	**4**	**134**	34.3%
2006-07	82	95	0	**177**	12	13	1	**26**	8	10	0	**18**	3	1	0	**4**	**225**	46.7%
2007-08	59	104	0	**163**	13	13	0	**26**	3	8	0	**11**	1	1	0	**2**	**202**	37.6%
2008-09	50	72	0	**122**	5	11	0	**16**	4	11	0	**15**	4	1	0	**5**	**158**	39.9%
2009-10	55	103	0	**158**	7	11	0	**18**	8	7	0	**15**	1	5	0	**6**	**197**	36.0%
2010-11	57	110	1	**168**	1	3	0	**4**	8	6	0	**14**	5	5	0	**10**	**196**	36.2%
2011-12	75	123	0	**198**	14	7	0	**21**	4	8	0	**12**	5	7	0	**12**	**243**	40.3%
2012-13	87	170	0	**257**	14	6	0	**20**	7	23	0	**30**	4	5	1	**10**	**317**	35.3%
2013-14	84	117	2	**203**	12	12	0	**24**	5	12	0	**17**	5	4	0	**9**	**255**	42.4%
2014-15	107	134	0	**241**	13	11	1	**25**	8	10	0	**18**	4	7	0	**11**	**295**	44.7%
2015-16	88	151	0	**239**	14	9	0	**23**	7	13	0	**20**	6	5	1	**12**	**294**	39.1%
2016-17	90	154	1	**245**	16	6	0	**22**	5	12	0	**17**	7	9	2	**18**	**302**	39.1%

*Unk – Unknown, sometimes the sex is impossible to determine due to decomposition or physical damage

2.5. Cougar Demographics Research

Project #1: The goal of this study is to provide cougar demographic information to assist with directing cougar management in New Mexico. The objectives are to: 1) estimate cougar abundance and density in replicated 225 km^2 survey areas across habitat quality types; 2) compare density estimates to those used in the habitat model currently employed by NMDGF to develop harvest limits; and 3) test a remote camera-based method for estimating cougar abundance and density in the absence of marked individuals.

During the reporting period, from January through June 2017, 6 study areas were sampled using scat detection dogs; cougars were detected on 5 of those areas. A total of 70 scats were collected that were identified in the field as cougar; 88% (n = 62) were collected on the 3 areas predicted to have the highest quality habitat. An additional 77 samples were collected that were identified in the field as possible cougar samples. These scat samples were shipped to the University of Idaho for genetics analysis, the first stage of which is to test all samples for species identification. Camera photos collected during 2016 are in the final stages of preparation for data analysis. The sampling period was extended from six to eight weeks in 2017. One camera grid has been surveyed in 2017 during this segment (Appendix 2).

Project #2: The goal of this study is to provide cougar demographic and ecological information to inform cougar management in New Mexico, and is being implemented in concert with Project #1. The objectives are to: 1) develop a logistically feasible and cost-efficient survey design for estimating cougar density, abundance, and resource selection at a scale that population dynamics occur; 2) develop novel generalized spatial mark-resight models that incorporate multiple data types to improve density and abundance estimate accuracy and precision, and quantify ecological relationships between density and habitat/landscape characteristics; and 3) compare density estimates and resource selection to the habitat model that is currently employed by NMDGF for cougar management.

This project was initiated during the latter part of the reporting period. A total of 15 cougars (11M:4F) were live-captured and GPS-collared to constitute the marked portion of the population in the ~7,000 km^2 Cougar Management Zone F. Simulations were conducted in a spatial capture-recapture framework to develop a clustered camera trapping survey design that would estimate cougar density and abundance with nominal bias (Appendix 4). A total of 60 double camera trap stations (i.e., 120 total cameras) were established in 9 clusters across Zone F during July 2017, which simulations showed would produce unbiased estimates of cougar density (relative bias = 0.03; 95% CI = -0.04–0.10), pessimistically assuming that density is low ($0.001/km^2$), detection probability would be low (0.1), home range size is large ($400\ km^2$), and if the survey is conducted for 12 sampling occasions. Thus, the camera traps will remain deployed through October 2017 to constitute 12 weeks of sampling, with 1 week serving as a sampling occasion.

PERFORMANCE REPORT

State: New Mexico **Grant Number**: W-93-R-56

Grant Title: Big Game Surveys, Inventories, and Management

Grant Period: **From**: July 1, 2015 **to:** June 30, 2016

Grant Objective: To survey New Mexico's big game populations and their hunters and to manage these big game species according to the mission, goals, and plans of the New Mexico State Game Commission and the Department of Game and Fish.

Cougar (*Puma concolor*). Annual harvest statistics and other human-caused mortality were compiled and analyzed for trends over the most recent 10 years to inform management. A camera trapping survey in a spatial mark-resight framework was developed to estimate density, abundance, home range size, and resource selection. A pilot study was conducted during this segment to determine appropriate sampling design in regards camera placement to most accurately estimate density.

II. Job Objectives and Summary of Progress:

2.A.1. and 2.2. Estimate big game population size and/or trend, sex and age composition, and geographical distribution. Evaluate survey techniques and develop new methods where appropriate.

Cougar. Cougar population estimates and sustainable harvest levels were derived from a combination of available habitat, density extrapolated from a 1996 New Mexico cougar study and from other western states, and existing mortality and harvest data (Table 2.A.27). Two studies were initiated to evaluate non-invasive genetic and camera-trapping survey methods and spatial capture-recapture and spatial mark-resight models for estimating density and abundance of cougars in New Mexico. It was determined that deploying GPS collars on cougars, combined with camera trap data, provides more accurate and precise population estimates than using scat detector dogs because the latter was not able to accrue enough data to run the models.

Table 2.A.27. Cougar Population Estimates and Mortality Limits by Zones, NMDGF.

Zone	GMUs	Population Estimate	Total Mortality Limit	Female 25%Sub-limit
A	2, 7	207-285	42	13
B	5, 50, 51	142-192	28	8
C	43-46, 48, 49, 53-55	289-387	85	43
D	41, 42, 47, 59	76-106	23	12
E	9, 10	251-341	50	15
F	6	156-209	46	23
G	13 and 17	247-338	73	37
H	18, 19, 20	140-197	42	21
I	36-38	121-165	24	7
J	15, 16, 21, 25	445-603	89	27
K	22, 23, 24	225-305	66	33
L	26 and 27	64-91	19	10
M	31-33, 39, 40	146-215	31	9
N	4 and 52	76-102	15	5
O	12	103-141	21	6
P	56-58	49-66	14	7
Q	28-30 and 34	170-235	35	11
R	45 and 55	131-175	26	8
S	8 and 14	85-116	25	13
Totals:		3,123-4,269	749	303

II. Job Objectives and Summary of Progress:

2.1.B Estimate hunter numbers, harvest, effort, and success rates.

Cougar. Harvest continues to be managed by the hunter harvest/total sustainable mortality system. During the hunting season, each zone remained open to mountain lion hunting from April 1 until March 31 or when the total number of hunter kills (as determined by mandatory check-in for successful hunters) equaled the total sustainable mortality limit for that zone, or the female sub-limit had been met, whichever came first. Only 30% of the harvest may be female in cougar management zones where the long term goal is stable cougar population, and 50% in cougar management zones where the goal is population reduction. Cougar harvest has remained relatively stable for the past 3 years (Table 2.B.5).

Table 2.B.5. Annual Cougar Mortality Statistics 2001-2017/18, NMDG

	Sport Harvest				Depredation Kill				Bighorn Sheep Protection				Other (road kill, accident, etc.)			
Cougar	Fem.	Male	Unk. *	**Total Sport**	Fem.	Male	Un k.	**Total Depred.**	Fem.	Mal e	Un k.	**Total BHS**	Fem.	Male	Unk.	**Total Other**
2001-02	76	110	0	**186**	3	3	1	**7**	5	6	0	**11**	3	0	2	**5**
2002-03	82	118	1	**201**	14	14	1	**29**	14	11	0	**25**	6	5	2	**13**
2003-04	84	114	0	**198**	17	5	0	**22**	5	12	0	**17**	3	2	0	**5**
2004-05	72	89	0	**161**	16	16	1	**33**	3	8	0	**11**	4	0	0	**4**
2005-06	34	72	0	**106**	5	5	0	**10**	6	8	0	**14**	1	3	0	**4**
2006-07	82	95	0	**177**	12	13	1	**26**	8	10	0	**18**	3	1	0	**4**
2007-08	59	104	0	**163**	13	13	0	**26**	3	8	0	**11**	1	1	0	**2**
2008-09	50	72	0	**122**	5	11	0	**16**	4	11	0	**15**	4	1	0	**5**
2009-10	55	103	0	**158**	7	11	0	**18**	8	7	0	**15**	1	5	0	**6**
2010-11	57	110	1	**168**	1	3	0	**4**	8	6	0	**14**	5	5	0	**10**
2011-12	75	123	0	**198**	14	7	0	**21**	4	8	0	**12**	5	7	0	**12**
2012-13	87	170	0	**257**	14	6	0	**20**	7	23	0	**30**	4	5	1	**10**
2013-14	84	117	2	**203**	12	12	0	**24**	5	12	0	**17**	5	4	0	**9**
2014-15	107	134	0	**241**	13	11	1	**25**	8	10	0	**18**	4	7	0	**11**
2015-16	88	151	0	**239**	14	9	0	**23**	7	13	0	**20**	6	5	1	**12**
2016-17	90	154	1	**245**	16	6	0	**22**	5	12	0	**17**	7	9	2	**18**
2017-18	93	141	1	**235**	10	10	0	**20**	9	9	0	**18**	5	9	1	**15**

*Unk – Unknown, sometimes the sex is impossible to determine due to decomposition or physical damage

2.5. Cougar Demographics Research

Project #1: The goal of this study was to provide cougar demographic information using scat detector dogs to assist with directing cougar management in New Mexico. **During the previous reporting period** six study areas were sampled using scat detection dogs. Lab work performed during the current grant segment period revealed that cougars were detected on five of those areas. Of the 746 scat samples collected, only 65 of those were confirmed to be cougar by mitochondrial DNA amplification. Of those 65 cougar samples, only 30 amplified at enough microsatellite markers to identify individual cougars. Due to the low number (30/746) of scats identified to individual cougar, further analyses of individual detections and estimates of population numbers were not possible. Therefore, we chose to discontinue this method and focus resources on Project #2.

Project #2: The goal of this study is to provide cougar demographic and ecological information to inform cougar management in New Mexico using GPS collars and camera trap data. A total of 68 double camera trap stations (i.e., 136 total cameras) were established in nine clusters across Cougar Management Zone (CMZ) F during July 2017 and were maintained through October

2017 to constitute 17 weeks of sampling, with one week comprising a sampling occasion. Sufficient data were collected from the combination of GPS collaring and remote camera captures during this sampling period to produce a cougar density estimate of 1.02 cougars/100km2 (95% CI = 0.64─1.56). This camera trap configuration was maintained throughout the winter, until May 2018, and data will be reanalyzed for the extended sampling period.

In January 2018, the scope of this project was extended to include CMZs B and N, for a total survey area of ~16,500 km2. Five additional cougars (4M:1F) were live-captured and GPS-collared from January – March 2018. We will continue with the study during the next grant period.

GRANT STATEMENT

STATE: **New Mexico** **GRANT NUMBER:** W-93-R **SEGMENT NUMBER:** 59

GRANT TITLE: Big Game Surveys, Inventories and Management

GRANT PERIOD: July 1, 2018 to June 30 2019

A. **Need**: This grant is crucial in meeting Department mission and goals and to insure compliance with state and federal mandates. Through the Commission, the Department has the responsibility, mandated by statute, to protect New Mexico's game while providing and maintaining an adequate supply for recreational use. This includes developing recommendations for hunter opportunity, engaging landowners in big game management, conducting population surveys, and restoring populations when feasible.

B. **Purpose:** The information gathered under this grant will be used to prepare annual recommendations for big game and habitat management in accordance with the mission, goals and plans of the Commission and Department. This information may also be used by land management and other agencies and to provide the public with background biological information for their use.

OBJECTIVES:

Objective 5:
Conduct 15 investigations by June 30, 2019.
Activity Tag 1
Fish and wildlife species data acquisition and analysis
Unit of Measure: 15 investigations
Target Species : Deer, Elk, Pronghorn, Bear, Cougar, Bighorn, Oryx, Ibex

Approach

a. Collect, analyze, interpret, and report big game population and harvest data. Plan, prepare, and conduct surveys of big game populations and their hunters (Appendix I). These include composition, sightability, trend, and census surveys. Some of the specific techniques to be used are: ground population surveys, scat/scrapping transects, and mark-resight. This activity also includes surveys specific to young of the year (lamb, calf, fawn) and collecting (pulling) teeth for age determination. The data will be used to estimate big game population size and/or trend, sex and age composition, and geographical distribution. Methods are described in New Mexico Survey Standards and Guidelines.

Cougar. Harvest continues to be managed by the hunter harvest/total sustainable mortality system. During the hunting season, each zone remained open to mountain lion hunting from April 1 until March 31 or when the total number of hunter kills (as determined by mandatory check-in for successful hunters) equaled the total sustainable mortality limit for that zone, or the female sub-limit had been met, whichever came first. Only 30% of the harvest may be female in cougar management zones where the long term goal is stable cougar population, and 50% in cougar management zones where the goal is population reduction. Cougar harvest and total mortality increased by over 25% during this grant period (Table 2.B.5). The primary reason for this increase was excellent snow conditions statewide that allowed harvest of cougars in areas that are usually difficult to harvest from because there is little snow there. Snow conditions and presence make it easier for hounds/houndsmen to locate and tree cougars, thereby making them available for harvest.

Table 4. Annual Cougar Mortality Statistics 2001-2017/18, NMDG

	Sport Harvest				**Depredation Kill**				**Bighorn Sheep Protection**				**Other (road kill, accident, etc.)**			
Cougar	Fem.	Male	Unk. *	**Total Sport**	Fem.	Male	Unk.	**Total Depred.**	Fem.	Male	Unk.	**Total BHS**	Fem.	Male	Unk.	**Total Other**
2001-02	76	110	0	**186**	3	3	1	**7**	5	6	0	**11**	3	0	2	**5**
2002-03	82	118	1	**201**	14	14	1	**29**	14	11	0	**25**	6	5	2	**13**
2003-04	84	114	0	**198**	17	5	0	**22**	5	12	0	**17**	3	2	0	**5**
2004-05	72	89	0	**161**	16	16	1	**33**	3	8	0	**11**	4	0	0	**4**
2005-06	34	72	0	**106**	5	5	0	**10**	6	8	0	**14**	1	3	0	**4**
2006-07	82	95	0	**177**	12	13	1	**26**	8	10	0	**18**	3	1	0	**4**
2007-08	59	104	0	**163**	13	13	0	**26**	3	8	0	**11**	1	1	0	**2**
2008-09	50	72	0	**122**	5	11	0	**16**	4	11	0	**15**	4	1	0	**5**
2009-10	55	103	0	**158**	7	11	0	**18**	8	7	0	**15**	1	5	0	**6**
2010-11	57	110	1	**168**	1	3	0	**4**	8	6	0	**14**	5	5	0	**10**
2011-12	75	123	0	**198**	14	7	0	**21**	4	8	0	**12**	5	7	0	**12**
2012-13	87	170	0	**257**	14	6	0	**20**	7	23	0	**30**	4	5	1	**10**
2013-14	84	117	2	**203**	12	12	0	**24**	5	12	0	**17**	5	4	0	**9**
2014-15	107	134	0	**241**	13	11	1	**25**	8	10	0	**18**	4	7	0	**11**
2015-16	88	151	0	**239**	14	9	0	**23**	7	13	0	**20**	6	5	1	**12**
2016-17	90	154	1	**245**	16	6	0	**22**	5	12	0	**17**	7	9	2	**18**
2017-18	93	141	1	**235**	10	10	0	**20**	9	9	0	**18**	5	9	1	**15**
2018-19	117	227	0	**344**	14	11	0	**25**	5	22	0	**27**	5	6	2	**13**

Survey Data

b. Cougar density estimation: Includes planning, implementing and assessment of a statewide cougar density estimation study

RESULTS:
The goal of this survey is to provide cougar demographic and ecological information to inform cougar management in New Mexico using GPS collars and camera trap data. A total of 128 double camera trap stations (i.e., 256 total cameras) were established in clusters across Cougar Management Zones (CMZ) B, F and N during July 2018 and were maintained through November 2018 to constitute 18 weeks of sampling, with one week comprising a sampling occasion. A total of 14 individual cougars fitted with GPS collars were included in the study. We detected cougars a total of 156 times across 48 sites, including 38 detections of previously marked cougars. Data collected from the combination of GPS collaring and remote camera captures during this sampling period are currently being analyzed to produce a cougar density estimate.

In November 2018, the scope of this project was extended to CMZ Q, a survey area of ~17,800 km2. Seven cougars (3M:4F) were live-captured and GPS-collared from January – June 2019. A total of 101 double camera trap stations (i.e., 202 total cameras) were established in clusters across Cougar Management Zone Q during January 2019. We will continue with the survey during the next grant period to produce a population estimate.

NEW MEXICO STATE GAME COMMISSION MEETING

April 30, 2020

Virtual Meeting

PRESENT:

Sharon Salazar Hickey, Chair
Roberta Salazar-Henry, Vice Chair
Jeremy Vesbach, Commissioner
Jimmy Bates, Commissioner
Gail Cramer, Commissioner
Tirzio Lopez, Commissioner
David Soules, Commissioner
Michael Sloane, Director
James Comins, III, Assistant Director
Lance Cherry, Information and Education Chief
Stewart Liley, Wildlife Management Division Chief
Valerie Joe, Assistant Attorney General

MS. SALAZAR HICKEY: Very nice. Good morning, everyone. Welcome to the New Mexico State Game Commission Meeting. Today it's Thursday, April 30th. We are not in Silver City, New Mexico; I wish we were. I think Silver City today has a temperature of about 67 degrees, and it's a beautiful community in New Mexico with about 10,000 people.

So I want to say welcome to all of the game commissioners. We're going to get started with the roll call from our department director from the Game and Fish, Michael Sloane.

MR. SLOANE: Thank you.

Commissioner Vesbach?

MR. VESBACH: I am here.

MR. SLOANE: Commissioner Soules?

MR. SOULES: Here.

MR. SLOANE: Commissioner Lopez?

MR. LOPEZ: Here.

MR. SLOANE: Commissioner Cramer?

MS. CRAMER: Here.

MR. SLOANE: Commissioner Bates?

MR. BATES: Here.

MR. SLOANE: Vice Chair Salazar-Henry?

MS. SALAZAR-HENRY: Present.

MR. SLOANE: Chair Salazar Hickey?

MS. SALAZAR HICKEY: Here.
MR. SLOANE: We have a quorum.
Madam Chair, just as a reminder, because we're doing the video, all the votes today will have to be by roll call.
MS. SALAZAR HICKEY: Absolutely. Thank you, sir. Thank you for that reminder.
And thank you again, commissioners; and thank you to the State of New Mexico.
We have an agenda that's posted on the Department of Game and Fish website, and I hope many of you can see that agenda from your homes and from your computers. I believe that there should be some discussion on this agenda, which I'm going to start, and I'll open it up to the other commissioners.
First and foremost, I want to acknowledge that the time frame on page 1 says 9 to 5. I don't think we will be in our meeting until 5 p.m. today. We are starting promptly at 9, but I do believe a number of these agenda items will move rather quickly.
Do I have any other comments or discussion about the agenda?
MS. SALAZAR-HENRY: Madam Chair?
MS. SALAZAR HICKEY: Thank you, Vice Chair. Yes?
MS. SALAZAR-HENRY: On our agenda our two separate

agenda items or breakdown in our executive session and the part, 4B, I believe, where we are meeting with the Attorney General staff, we need to just let everybody know that we need to be a little flexible about the timing on that. They're working from home and we're going to accommodate their schedule today, which I believe, they would like to meet with us on that section at noon. So regardless of where we are we need to break so that we, you know, if we're not done and at that point we need to break and go straight there first, at noon.

MS. SALAZAR HICKEY: Thank you, Vice Chair. I see that we have the assistant attorney general, Valley -- Valerie Joe present. And I think that's a very good comment about whether or not the executive session agenda item 8B --

MS. JOE: 8B.

MS. SALAZAR HICKEY: -- must -- 8B -- must be at a particular time. Or if the commission is moving rather quickly, can we just immediately log in to the separate call that we will be having for that executive session? So that is for our assistant attorney general, Valerie Joe. That's a question.

MS. JOE: Thank you, Chair. Thank you, Vice Chair, and commissioners.

I just wanted to let you know that as far as I have been made aware, there's no particular time frame. I will alert them when we do go into the first executive session so and then when it looks like we're starting to wrap up, I will send them another email so that they will be alerted. I had not heard of a specific time, but I'm sure if they want to let me know that they'll, you know, inform me.

MS. SALAZAR HICKEY: Very good. Thank you, Assistant Attorney General Valerie Joe.

Vice Chair, do you have any other questions or comments about the agenda?

MS. SALAZAR-HENRY: I don't, but I'd like to make a motion to prove the agenda.

MR. LOPEZ: Second.

MS. SALAZAR HICKEY: Well -- I'm sorry?

MR. BATES: I think there was a motion by Vice Chair Salazar Henry, and a second by Commissioner Lopez.

MS. SALAZAR HICKEY: Beautiful. Okay. Let's take a vote.

Director Michael Sloane?

MR. SLOANE: Commissioner Vesbach?

MR. VESBACH: Yes.

MR. SLOANE: Commissioner Soules?

MR. SOULES: Yes.

MR. SLOANE: Commissioner Lopez?

MR. LOPEZ: Yes.

MR. SLOANE: Commissioner Cramer?
MS. CRAMER: Yes.
MR. SLOANE: Commissioner Bates?
MR. BATES: Yes.
MR. SLOANE: Vice Chair Salazar-Henry?
MS. SALAZAR-HENRY: Yes.
MR. SLOANE: Chair Salazar Hickey?
MS. SALAZAR HICKEY: Yes.
MR. SLOANE: Passes unanimously.
MS. SALAZAR HICKEY: Thank you, Director Michael Sloane and commissioners.
So now that we have our agenda, let's move forward with item number 4, which is the Consent Agenda. All of the commissioners have received the read-ahead material, which include item 4A, the Approval of Minutes of April 20th, the special meeting that was held virtually online and streamed; and item 4B, the Approval of License Revocations.
Do I have any questions, comments, concerns? Very good. Well, I see a moment of silence, and I see some shaking of heads. If I have a motion, we can proceed with that action item of approving the Consent Agenda item 4A and 4B.
Do I have a motion?
MR. LOPEZ: Motion.

MS. SALAZAR HICKEY: A second?

MS. SALAZAR-HENRY: Second.

MS. SALAZAR HICKEY: Thank you, Commissioner Tirzio as a motion, and a second from Vice Chair Roberta.

Director Sloane, can you please take a roll call?

MR. SLOANE: Yes.

Commissioner Vesbach?

MR. VESBACH: Yes.

MR. SLOANE: Commissioner Soules?

MR. SOULES: Yes.

MR. SLOANE: Commissioner Lopez?

MR. LOPEZ: Yes.

MR. SLOANE: Commissioner Cramer?

MR. CRAMER: Yes.

MR. SLOANE: Commissioner Bates?

MR. BATES: Yes.

MR. SLOANE: Vice Chair Salazar-Henry?

MS. SALAZAR-HENRY: Yes.

MR. SLOANE: Chair Salazar Hickey?

MS. SALAZAR HICKEY: Yes.

MR. SLOANE: Passes unanimously.

MS. SALAZAR HICKEY: Thank you, Director Sloane and commissioners.

With that, we are ready to proceed to agenda item number 5. Agenda item number 5 is a rulemaking hearing on amendments to the Hunting and Fishing Manner and Method Rule 19.31.10.

For this portion it's very important because this is a hearing. To protect the record, I am going to ask that one person speak at a time. And if a gesture is made on the record, I will record and say yes or no if the person not make that motion or that speech. I want to make sure that each person that is identifying the Board identifies him or herself for the record each time the person addresses the Board. This is a very open transparent, very collaborative meeting, and I hope that all persons coming forward continue to display that respect and openness in the -- in this hearing. So that said, I think we are ready to proceed.

I will begin opening the hearing. As the Chair of the New Mexico State Game Commission, I am the hearing officer, and my name is Sharon Salazar Hickey. I will be serving as the hearing officer and will be advised by the Commissions Counsel from the Office of Attorney General.

The purpose of this hearing is for consideration and final adoption of the following proposed rule amendment by the Commission. Hunting and Fishing Manner and Method of Taking Rule, Title 19, Chapter 31, Part 10 of the New Mexico Administrative Code.

These hearings are being conducted in accordance with the provisions of the Game and Fish Act and the New Mexico State Rules Act. These hearings are being audiotaped and videorecorded. Anyone interested in a copy of the audiotape or video recording should contact Tristanna Bickford with the New Mexico Department of Game and Fish.

Public notice of this hearing was advertised in the New Mexico Register, the New Mexico Sunshine Portal, and on the New Mexico Department of Game and Fish website. Copies of the proposed new rules have been available on the Department's website.

Those wishing to comment here today must have been registered to submit public comments on the Zoom webinar platform that we are currently on. Now, that said, I will continue these rule hearings in the following manner. They will be conducted in the following manner.

First, the staff will present pre-filled exhibit -- or pre-filed exhibits. Exhibits admitted into evidence are available for review by the public on the Department's website. After all exhibits are entered, we will proceed to the presentation of the proposed rule. After which, testimony will be taken from the audience.

Participants are asked to raise their hand in the Zoom webinar platform and wait until they are called to speak. In order to ensure that the hearing is accurately recorded, only one person at a time shall be allowed to speak and they will need permission by me. Any person recognized to speak is asked to first identify themselves by name and who you are affiliated with for the record each time you are recognized. And secondly, speak loudly and clearly to accurately record your comments.

After a person has offered comment, they will stand for questions from me, the hearing officer, and the commissioners. The audience may also ask questions of anyone offering comments after being recognized by me.

The hearings are not subject to judicial rules of evidence. However, in the interest of efficiency, I reserve the right to limit any testimony deemed irrelevant, redundant, or unduly repetitious.

The commission may discuss the proposed amendment after the public comment portion of the hearing. The final commission action, including adoption of the amendment, may occur after the conclusion of the presentation and public comment period of each hearing.

Okay. This hearing is now open. Are there any exhibits or proposed new rule 19.31.10 for the record?

MR. LILEY: Madam Chair, this is Stewart Liley, Chief Wildlife of New Mexico Game of Fish. I'd like to enter four exhibits into the record. Those exhibits will be with Director Sloane.

Exhibit 1 is the notice of the rulemaking that was posted on the Department's website, as well as the modified rulemaking notice to accommodate the Zoom meeting for the hearing today.

Exhibit 2, the initial proposed rule -- the amendment that we're proposing -- that was also posted on the Department's website for the -- approximately the last month and a half.

Exhibit 3 will be the copy of the presentation that I'll be giving to you all today.

And Exhibit 4 was the technical information that we relied upon to build the Bear and Cougar Rule that specifically addresses this one amended item that we need in the Manner and Method.

We normally would have Exhibit 5, public comments received. During the roughly month, month and a half of posting on the website, the Department did not receive any public comments through the website or through the email address so there are no public comments to enter into the record today. And that would be all the --

MS. SALAZAR HICKEY: Thank you.

MR. LILEY: -- information I have.

MS. SALAZAR HICKEY: Thank you, Stewart.

Let the record reflect that Exhibits 1 through 4, as described by Stewart, are hereby admitted into the record.

Stewart, can you please introduce the proposed new rule for 19.31.10?

MR. LILEY: Madam Chair, you should all be able to see the proposal in front of you -- or the PowerPoint. Please let me know if you do see that now.

MS. SALAZAR HICKEY: I do see that.

Commissioners, do you see the Manner and Method Rule amendment screen?

IN UNISON: Yes.

MR. LILEY: All right. Madam Chair, commissioners, as we discussed at the last commission meeting we held in March, one of the necessary amendments we need to make to the Manner and Method Rule coincides with some changes that were made with the Bear and Cougar Rule that you all made in November of 2019.

You finalized that rule, like I said, November of 2019. In that Bear and Cougar Rule specifically, it no longer allowed traps as a method of sport harvest for cougars. Because of that, we also need to strike two subsections in Manner and Method -- subsection DD and EE of 19.31.10.12 to conform to those changes that's -- that you all adopted at the November meeting.

During that rule hearing process for Bear and Cougar that lasted approximately five months -- five to six months, you received 277 comments specifically to that Bear and Cougar Rule. A lot revolved around Bear and -- or excuse me, around trapping for cougars, so we incorporated those comments when we made that rule. This is, again, just to align the Bear and Cougar Rule and the Manner and Method Rule. By striking these two sections, you now would align those so the rules match.

And with that, I would take any questions you all may have.

MS. SALAZAR HICKEY: Would anyone like to comment on the new rule, Title 19, Chapter 31, Part 10? Do I have anybody who would like to comment?

Commissioners?

MR. CHERRY: Madam Chair, no one has their hand raised to comment.

MS. SALAZAR HICKEY: Okay. Very good. Well --

MR. VESBACH: Here -- this is Commissioner Vesbach. If I may just -- I'd just underline this is kind of a simple cleanup to deal with an issue we already addressed, so I think if you're ready, I'd be ready to make a motion.

MR. LILEY: Madam Chair, if I could just ask one question. Did we receive any email comment? I know that we had put out that we would accept email comment, and I don't know if we did or did not receive any, so just to make sure we cross that off the list.

MS. SALAZAR HICKEY: Commissioners, would any of you want to comment on that or answer that question?

MS. SALAZAR-HENRY: Madam Chair?

MS. SALAZAR HICKEY: Yes, Vice Chair?

MS. SALAZAR-HENRY: The individual that originally brought this issue up somehow did not make his email (indiscernible) time, so he didn't submit it. So I don't know what happened there but I do want to thank you and the Department and the AG for working on that policy to allow email comments, especially now that we have essential workers that are tied up doing things elsewhere and may want to comment.

MS. SALAZAR HICKEY: Okay. At this time, I think we can proceed. There are no comments that have been presented. There are no exhibits from the public at this time. Therefore, I'm going to proceed to close the hearing. Those that are registered and participating in the hearing will be included in the attendance sheet -- the records that are kept by the Department of Game and Fish.

So at this time, Director Sloane, do we need a motion on this?

MR. SLOANE: We do.

MS. SALAZAR HICKEY: Do I have a motion from one of the commissioners?

MR. VESBACH: Madam Chair, I would move to amend 19.31.10 NMAC as presented by the Department and allow the Department to make minor corrections to comply with filing this rule with the State records and archives.

MS. SALAZAR HICKEY: Thank you, Commissioner Jeremy. Do I have a second?

MS. SALAZAR-HENRY: Second.

MS. SALAZAR HICKEY: Thank you, Vice Chair.

I have a motion from Commissioner Jeremy Vesbach and a second from Vice Chair Roberta.

Director Michael Sloane, can you please take a vote and a roll call?

MR. SLOANE: Commissioner Vesbach?

MR. VESBACH: Yes.

MR. SLOANE: Commissioner Soules?

MS. SOULES: Yes.

MR. SLOANE: Commissioner Lopez?

MR. LOPEZ: Yes.

MR. SLOANE: Commissioner Cramer?

MS. CRAMER: Yes.

MR. SLOANE: Commissioner Bates?

MR. BATES: Yes.

MR. SLOANE: Vice Chair Salazar-Henry?

MS. SALAZAR-HENRY: Yes.

MR. SLOANE: Chair Salazar Hickey?

MS. SALAZAR HICKEY: Yes.

MR. SLOANE: Amendment passes unanimously.

MS. SALAZAR HICKEY: Thank you, commissioners; thank you, Director Michael Sloane.

The comments submitted and testimony heard today during this rule hearing will be reviewed. And I would like to thank by the commission and discussed at the open session of today's meeting. The commission has voted.

I would like to thank everyone present for their participation. Let the record reflect that this rulemaking hearing was adjourned at 9:23 a.m. today on Thursday, April 30th.

Let us move on to the next agenda item, which is now agenda item number 6. It is the subsequent discussion on Migratory Bird Rule for 2020-2021 hunting season. It's a subsequent discussion on the proposed season dates and bag limits for migratory birds for the 2020-2021 license year.

MR. LILEY: Madam Chair, as you discussed, hopefully you all can see that presentation as well. Give me a thumbs up if you can see it. Perfect. Thank you.

So as we discussed at the last meeting, we are in the midst of setting the rule cycle for the 2020-2021 Migratory Bird Rule season. One of the dates that's to get things in the Federal Register because it is a cooperation with the federal government. U.S. Fish and Wildlife Service is today, April 30th, when we all have to determine our season selection. So we are at that stage today and that's why this is in front of you.

C E R T I F I C A T I O N

I, Melinda Friedland, certify that the foregoing transcript is a true and accurate record of the proceedings.

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Melinda Friedland

eScribers

352 Seventh Avenue, Suite #604

New York, NY 10001

Date: May 5, 2020

New Mexico State Game Commission
Virtual Meeting Minutes

Thursday, April 30, 2020

AGENDA ITEM NO. 1: Meeting Called to Order *[09:04:56 AM (00:02:01)]

Called to order by Chairwoman Salazar Hickey at 9:04 a.m.

AGENDA ITEM NO. 2: Roll Call

All present: Chairwoman Salazar Hickey, Vice-chairwoman Salazar-Henry, Commissioner Bates, Commissioner Cramer, Commissioner Lopez, Commissioner Soules and Commissioner Vesbach.

AGENDA ITEM NO. 3: Approval of Agenda

Motion by: Vice-chairwoman Salazar-Henry moved to approve the agenda as written.
Seconded by: Commissioner Lopez
Approved: Roll call vote – Unanimously: Chairwoman Salazar Hickey, Vice-chairwoman Salazar-Henry, Commissioner Cramer, Commissioner Lopez, Commissioner Soules, Commissioner Vesbach, Commissioner Bates.

AGENDA ITEM NO. 4: Consent Agenda

A. **Approval of Minutes**
B. **Approval of License Revocations**

Motion by: Commissioner Lopez moved to approve the consent items as written.
Seconded by: Vice-chairwoman Salazar-Henry
Approved: Roll call vote – Unanimously: Chairwoman Salazar Hickey, Vice-chairwoman Salazar-Henry, Commissioner Cramer, Commissioner Lopez, Commissioner Soules, Commissioner Vesbach, Commissioner Bates.

AGENDA ITEM NO. 5: Rule making Hearing of Amendments to the Hunting and Fishing Manner and Method Rule 19.31.10 *[09:13:26 AM (00:10:32)]

Stewart Liley presented the Department's proposal to delete Subsections DD and EE in the Hunting and Fishing Manner and Method Rule 19.31.10.12 NMAC to prohibit licensed trappers and cougar hunters from using traps and foot snares to harvest cougars. The proposed deletion from the Manner and Method Rule is necessary to align with the recently approved Bear and Cougar Rule 10.31.11 NMAC, which became effective April 1, 2020.

Motion by: Commissioner Vesbach moved to amend rule 19.31.10.12 as presented by the Department.
Seconded by: Vice-chairwoman Salazar-Henry
Approved: Roll call vote – Unanimously: Chairwoman Salazar Hickey, Vice-chairwoman Salazar-Henry, Commissioner Cramer, Commissioner Lopez, Commissioner Soules, Commissioner Vesbach, Commissioner Bates.

AGENDA ITEM NO. 6: Subsequent Discussion on the Migratory Bird Rule for 2020-2021 hunting season *[09:04:56 AM (00:02:01)]

Stewart Liley presented the Department's proposed changes to the Migratory Game Bird Rule (19.31.6 NMAC) based on public comment, the latest information from the United States Fish and Wildlife Service (USFWS), recent survey information and management goals. Season selections and bag limits are determined in conjunction with the USFWS working through the Central and Pacific Flyway Councils.

AGENDA ITEM NO. 7: General Public Comments *[09:47:06 AM (00:44:11)]

AGENDA ITEM NO. 8: Closed Executive Session *[09:56:57 AM (00:54:02)]

Motion: The State Game Commission voted to adjourn into Executive Session closed to the public; pursuant to 10-15-1(H)(2) NMSA 1978, to discuss limited personnel matters relating to complaints and discipline; pursuant to Section 10-15-1(H)(8) NMSA 1978, to discuss property acquisition; and pursuant to Section 10-15-1(H)(7) NMSA 1978, to discuss matters subject to attorney-client privilege relating to threatened or pending litigation.

Moved by: Vice-chairwoman Salazar-Henry

Seconded by: Commissioner Cramer

Approved: Roll call vote - Unanimously: Chairwoman Salazar Hickey, Vice-chairwoman Salazar-Henry, Commissioner Cramer, Commissioner Lopez, Commissioner Soules, Commissioner Vesbach, Commissioner Bates.

AGENDA ITEM NO. 9: Return from Executive Session [12:32:27 PM (01:00:05)]*

Moved by: Commissioner Lopez to move forward with potential land acquisitiation in Rio Arriba county.

Seconded by: Commissioner Bates

Approved: Roll call vote - Unanimously Chairwoman Salazar Hickey, Vice-chairwoman Salazar-Henry, Commissioner Cramer, Commissioner Lopez, Commissioner Soules, Commissioner Vesbach, Commissioner Bates.

AGENDA ITEM NO. 10: Commission Business *[12:38:29 PM (01:06:07)]

A. Strategic Planning: Committees

Finance: Committee Chair - Vice-chairwoman Salazar-Henry and supported by Commissioner Bates and Commissioner Vesbach.

Customer / Stakeholder : Committee Chair - Commissioner Cramer and supported by Commissioner Lopez.

Overarching / Organizational Profile: Committee Chair - Commissioner Soules and supported by other commissioners and committee leads as needed.

Hunt Structure: Committee Chair - Commissioner Vesbach and supported by Commissioner Soules and Vice-chairwoman Salazar-Henry.

Moved by: Chairwoman Salazar Hickey

Seconded by: Vice-chairwoman Salazar-Henry

Approved: Roll call vote - Unanimously Chairwoman Salazar Hickey, Vice-chairwoman Salazar-Henry, Commissioner Cramer, Commissioner Lopez, Commissioner Soules, Commissioner Vesbach, Commissioner Bates.

Past committee work on stream access – Commissioner Vesbach, Commissioner Cramer and Commissioner Lopez – Thanks to these commissioners for working on stream access issues. The commission is in litigation and is not taking any action on that committee work or doing any committee work on the stream access issue.

B. Commission Calendar for remaining calendar year 2020 [01:09:49 PM (01:37:27)]

The Commission opened discussion on future meeting dates and locations. They decided to maintain the previously approved schedule with the stipulation that future meetings will be held virtually as long as needed to be in compliance with COVID-19 public health orders.

Director Michael Sloane reminded the Commission of two pending Non-Navigable Waters applications that pursuant to rule require hearings to occur by May 24 and that rule further requires 21 days notice on the Department's website prior to the hearings. The Director advised the rule would therefore necessitate a Special Meeting on the applications on May 22, 2020.

Chairwoman Sharon Salazar Hickey stated the Commission and the Department are in litigation on the matter and it is likely judicial proceedings may overtake and overcome the need for a Special Meeting. She further stated if such meeting needs to be called, they could do so within the Open Meetings Act, by noticing it three days prior.

Moved by: Vice-chairwoman Salazar-Henry
Seconded by: Commissioner Cramer
Approved: Roll call vote - Unanimously Chairwoman Salazar Hickey, Vice-chairwoman Salazar-Henry, Commissioner Cramer, Commissioner Lopez, Commissioner Soules, Commissioner Vesbach, Commissioner Bates.

AGENDA ITEM NO. 11: Adjourn at 1:17 PM *[01:19:12 PM (01:46:50)]

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