FINAL REPORT

Federal Aid in Wildlife Restoration Project W-131-R

A STUDY OF BLACK BEAR ECOLOGY IN NEW MEXICO WITH MODELS FOR POPULATION DYNAMICS AND HABITAT SUITABILITY

Cecily M. Costello
Hornocker Wildlife Institute and
New Mexico Cooperative Fish and Wildlife Research Unit

Donald E. Jones
New Mexico Department of Game and Fish

Katherine A. Green Hammond
Ecosystem Modeling

Robert M. Inman
Kristine H. Inman
Hornocker Wildlife Institute and
New Mexico Cooperative Fish and Wildlife Research Unit

Bruce C. Thompson
U.S. Geological Survey
New Mexico Cooperative Fish and Wildlife Research Unit

Robert A. Deitner
New Mexico Cooperative Fish and Wildlife Research Unit

Howard B. Quigley
Hornocker Wildlife Institute

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EXECUTIVE SUMMARY

During the late 1980's and the early 1990's, interpretation of New Mexico black bear (*Ursus americana*) harvest data was stymied by the realization that increasing, stable, and decreasing population trend were all plausible explanations for observed changes in harvest data. Various interest groups, favoring different interpretations of population trend, argued for liberalizing or limiting hunting regulations as justified by the data. Clearly, additional information was needed to interpret these data and to determine the status of New Mexico bear populations.

In 1991, responding to this need for more scientific information, the New Mexico State Game Commission instructed the New Mexico Department of Game and Fish (NMDGF) to conduct a black bear study with funding from the NMDGF and the Federal Aid in Wildlife Restoration program. Research was initiated in 1992 with an overall goal to study the ecology and population dynamics of black bears for developing methods and analytical tools to help estimate and predict trends in population size and structure in New Mexico, as influenced by human-caused mortality and environmental variation.

The study involved 2 related efforts: field investigations and population modeling including harvest data evaluation. The first component was an 8-year, field-based investigation of bear ecology within 2 distinct study areas situated in prime bear habitat. To specifically address the effect of hunting on population dynamics, 1 study area was closed to hunting for the majority of the study period. Primary objectives of the field study were to estimate black bear reproductive and survival rates, especially as related to mast production and human-caused mortality. Another primary objective was to validate the cementum annuli method for aging bears in New Mexico. Secondary objectives were to examine patterns of denning, home range, movements, habitat use, and population density between study areas and among sex-age categories. Combining all relevant data, the final objective was to extrapolate study area characteristics to identify suitable habitat across New Mexico using a Geographic Information System.

The second component involved analyses of existing NMDGF harvest data and development of an analytical tool for understanding bear population dynamics. Primary objectives were to determine relationships between the harvest sample and the sex-age composition of study populations, and to determine relationships among weather variables, mast production, and bear population characteristics. Using all relevant information, the final objective was to develop a population/environmental/hunt model and to integrate the model into management application.

This report chronicles results of this 8-year study, which represents the first concerted effort to understand New Mexico black bear ecology. We also discuss applications of the existing tools and the new tools based on this research to black bear management in New Mexico.

We conducted field investigations on 2 study areas. The Northern Study Area (NSA) was located in the Sangre de Cristo Mountains of northern New Mexico. The NSA was approximately 310 km^2 and was comprised of private and state lands. It was adjacent to the towns of Eagle Nest and Ute Park, and about 6 km from Cimarron. The Southern Study Area (SSA) was located in the Mogollon Mountains of west-central New Mexico. The SSA was approximately 423 km^2 and was encompassed within the Gila National Forest. It was remote, with the closest towns of Reserve, Glenwood, and Mogollon, located 3-16 km away.

Field data were collected using capture, den investigation, and radio-telemetry techniques. We captured bears using foot snares or culvert traps and chemically immobilized most individuals. Approximate age of bears was estimated from dental characteristics and size. A vestigial premolar tooth was extracted from bears ≥1 year old for age determination using cementum annuli counts. We marked each bear with numbered, colored eartags and tattooed the same number on an inner, upper lip. We placed radio-transmitters on all females, on adult males as needed to maintain a sample of about 10 individuals, and on younger bears as needed for assessing population attributes. We monitored radio-transmittered bears from fixed-wing aircraft on a 14-day schedule during the active season. We visited dens of radio-transmittered bears to ascertain their reproductive status and change or refit collars as necessary. Weights and other measurements were obtained from all bears when possible.

Between September 1992 and June 2000, we captured 300 bears (103 females, 195 males, 2 unknown sex) 517 times, and observed 339 bears in dens (178 females, 137 males, 24 unknown sex) on 680 occasions. We placed 409 radio-transmitters on 316 bears (181 females, 135 males), and obtained 5,723 radio-telemetry locations.

Reproductive data were obtained during 268 den investigations of 80 female bears 4-27 years old. The minimum observed age of first litter production was 4 years old. Mean age at production of the first litter was 5.7 years and most females (73%) produced their first litter either at age 5 or 6 years. Natality of female bears ≥4 years old was 0.77 cubs/female/year and percent of females with cubs was 43%. Among previously reproductive females, natality was 1.4 cubs/female/year and percent of females with cubs was 77% (*n* = 112). Litter size ranged from 1-3 cubs and mean litter size was 1.8 cubs (*n* = 115). Observed litter interval ranged from 1-3 years and mean litter interval was 1.8 years (*n* = 69). Overall cub survival rate for 148 individual cubs from 82 litters was 55%. Recruitment of females ≥5 years old was 0.40 yearlings/female/year and percent of females with yearlings was 27% (*n* = 232). Recruitment of previously reproductive females was 0.53 yearlings/female/year and percent of females with yearlings was 35% (*n* = 175).

Reproductive success was evaluated on the basis of mast production by 10 surveyed species. Acorn (*Quercus* spp.) crop failure had the greatest influence on reproduction and juniper (*Juniperus* spp.) berry failure had a secondary effect. Mast failure was associated with decreased natality, cub survival, and recruitment. Neither natality nor recruitment varied following poor to good mast production, suggesting only a minimum threshold of quality food is needed for successful reproduction. Documenting annual mast production, especially the occurrence and frequency of oak failures, may be an effective index to bear reproductive success. During 1999-2000, NMDGF officers subjectively evaluated mast production statewide. Evaluations were highly correlated with our survey results, indicating subjective criteria were adequate to distinguish variation in mast production.

Observed annual survival rates for adult and subadult females were above 90%, and rates of adult and subadult males were above 80% (*n* = 591 bear-years). Most mortality of adults and subadults was human-caused, including hunter kills, depredation kills, illegal kills, and automobile kills. Observed yearling survival was variable, ranging from 75%-97% by sex and study area (*n* = 72). Among yearlings, most mortality was from natural causes, but human-caused mortality also was observed.

Among 179 bears observed on both study areas, observed den entrance dates ranged from 25 September-7 February. The majority of bears entered dens between mid October and mid November. Mean entrance date of pregnant females was 29 October, while that of all other bears was 6 November. Among 177 bears, observed den emergence dates ranged from 21 March-5 June. Adult males emerged earliest (mean date = 18 April); females with yearlings, lone females, and subadult males emerged next (mean date = 28 April); and females with cubs emerged the latest (mean date = 7 May). Comparing study areas, the schedule of denning dates was approximately 2 weeks earlier for den entrance and 2 weeks later for emergence on the NSA than the SSA.

Bear home range and movement patterns differed by sex, age class, season, and annual mast production. Males bears had significantly larger home ranges and activity radii than female bears. For both sexes, mean activity radii and percent of long-range movements increased during the mast season, when foraging for acorns and other mast dominated activity. During years of oak failure, mean activity radii were larger than during other years. Dispersal away from natal areas was observed for 4 males monitored until age 4, but none was observed for 8 females. Nuisance and depredation activity was associated with availability of human-related foods, especially garbage. Monitoring of translocated nuisance bears indicated subadult bears, particularly males, were less likely to exhibit homing behavior than adult bears.

Bear density appeared to be higher on the NSA (17.0/100km^2) than the SSA (9.4/100km^2), but the sex-age composition was very similar for the 2 study areas. Adult females constituted approximately 30% of study populations and adult males accounted for 15-19%. Annually, relative proportions of yearlings and subadult males appeared to vary the most.

Using the habitat model, we predicted suitable black bear habitat across approximately 58,939 km^2 (14.6 million acres), of which 75% was comprised of primary cover types. Nearly 50% of the predicted suitable bear habitat was managed by the U. S. Forest Service, 33% was under private ownership, and tribal lands comprised about 10% of the area. Statewide, 17% of predicted bear habitat was within 5 km of human-populated areas. Although currently based on relatively coarse data, the model was constructed so that future, more resolved information can be easily incorporated to update model predictions.

Extrapolating observed density estimates to areas of primary habitat yielded a statewide population estimate of 5,947 bears ≥1 year old. This estimate was similar to the independent estimate of 5,200 derived from population modeling for the state (excluding the Zuni, Mt. Taylor, Sandia/Manzano, and Chuska regions). These estimates refute the previous estimate of 3,000 bears used by the NMDGF, however they do not suggest a doubling of the bear population in the past decade. Rather, these estimates are based on better information and, as such, are more reliable.

Analyses of harvest data from 1985-1999 indicated bear hunters in New Mexico consistently harvested more males than females. The female proportion of annual statewide harvest ranged from 29 to 46%. Total annual bear kill by hunters was affected by many factors including season timing, hunter effort, hunter method, and mast production, as well as underlying population composition. Hunters aided with dogs had higher success rates and harvested 4 times as many female bears per hunter as those not using dogs. Later fall seasons were associated with lower total harvest and lower proportions of females in the harvest, compared to earlier fall seasons and spring seasons. Failures in oak production were associated with increases in hunter effort, hunter success, and the proportion of females in the kill.

Accuracy and consistency of the cementum annuli aging technique appeared adequate for assessing the age composition of annual hunter-killed bears and reporting of sex appeared to be accurate. However, analyses indicated harvest data were incomplete, underestimating the annual bear kill by as much as 7%.

The bear population model was designed to simulate a black bear population through time, with biological realism, hunting, and environmental influences. Using observed reproductive and survival rates, modeling indicated study populations were either stable or slightly increasing. Future utility of the model will depend on continued input of data in the form of annual harvest records and annual surveys of mast production. Use of the model will allow for interpretation of recent demographic trends in New Mexico bear populations, a timely indication of potential overharvest, and predictive scenarios useful for selecting from several management options.

The outcomes of this research will significantly improve understanding of black bear ecology and management in New Mexico. Using the new tools provided by this study, as well as the existing tools, managers can evaluate the results and consequences of numerous management alternatives and assess past, current, and future trends in bear populations. The existing tools consist of hunter-kill records and the hunter mail-in survey. The validity of those tools has been verified to supply useful input to hunt regulation assessment and regional management decisions. The new tools include the bear population model, the model to predict suitable bear habitat, a simple annual mast survey, and the research report as a compilation and archive of these tools.

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PREFACE

In the early part of the 20th century, the science of wildlife management was in its infancy, but public and government interest in this discipline intensified as the need for protection of wildlife species became apparent. Across North America, unregulated hunting had reduced or eliminated wildlife populations once plentiful. In 1914, the last passenger pigeon died, bringing the extinction of a species, once so numerous as to blacken the skies with their multitudes. In the Southwest, Merriam's elk were eradicated, and several carnivore species, including black bears, grizzly bears, cougars, and Mexican wolves, were facing unprecedented mortality from predator control programs.

Amidst these extraordinary events, New Mexico joined only a handful of other states in granting game status to black bears and grizzly bears in 1927. Conservation measures came too late for grizzly bears, but black bear populations rebounded. Today, evidence indicates black bears inhabit the same range in New Mexico as they did prior to European settlement. They tread the same mountains, consume the same foods, and possibly slumber in the very dens used by their ancestors for thousands of years.

How did these historic events come about? The answer is as relevant today as it was in 1927. The decision to protect bear populations, by setting legal hunting regulations, arose from participation of the public, the legislature, and the New Mexico Department of Game and Fish. Without involvement from each of these 3 entities, conservation of black bears might also have come too late. With this in mind, it seems fitting that the black bear was selected as the symbol of the Department of Game and Fish. Black bears may well have been the first wildlife management success story in New Mexico.

As human populations increase in the 21st century, management of black bears will only become more challenging. Creative solutions to bear-human conflict will be necessary, as well as sensible management strategies for hunting and habitat quality. But with continued public involvement and sound management based on science, existence of black bears in New Mexico can continue to be a success story for generations to come.

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Permits to capture bears and use immobilizing chemicals were obtained from NMDGF or bears were captured in cooperation with NMDGF personnel. Further permits for use of controlled substances for immobilizing bears were obtained from New Mexico Board of Pharmacy and U.S. Drug Enforcement Agency. Fieldwork during 1999-2000 was approved under the NMSU Institutional Animal Care and Use Committee.

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Use of brand or trade names throughout this report acknowledges the product's application to our research but does not constitute agency or cooperator endorsement of those products.

Photo credits for the cover are: Cecily Costello for Gambel oak acorns, F506 yearling in tree, F536 in den, and Baldy Meadows in fall; Robert Inman for Southern Study Area (Gila) ridges from airplane, and Gerry Lamarre for black bear on rock.

CHAPTER 1

INTRODUCTION

RATIONALE FOR STUDY

The black bear (*Ursus americanus*) is an important species in New Mexico, valued both as a big game animal and an embodiment of the southwestern wilderness. Throughout history, bears have been both revered and scorned by humankind. Management of this species must balance the positive aspects of bear-human interactions, including wildlife viewing and hunting, with negative aspects, such as nuisance problems, crop and livestock depredation, and bear-inflicted human injuries. With expanding human populations, management of these bear-human interactions will only become more challenging.

The New Mexico Department of Game and Fish (NMDGF) is responsible for managing the wildlife and fish populations of New Mexico, including black bears. Their mission 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, and conservation; and for their use as a public recreation and food supply." The NMDGF primarily manages bear populations through hunting regulations and resolution of nuisance and depredation problems.

Wildlife management is essentially governed by knowledge of the status and trend of populations. However, monitoring black bear population status is a difficult job. The solitary nature of bears, coupled with the dense habitats they generally use, prevent use of survey methods commonly used for other big game species such as elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), or pronghorn antelope (*Antilocapra americana*). As in many states, the primary foundation for black bear management in New Mexico is information obtained from hunter-killed bears. Since 1978, the NMDGF has collected annual records of harvested bears through a mandatory reporting program. Beginning in 1985, utility of these data was improved with the requirement of proof of sex and collection of a premolar tooth for aging with the cementum annuli method. Since 1986, the NMDGF also has conducted hunter surveys to obtain data on hunter effort and methods to be used in conjunction with harvest records.

Managers often make inferences about status and trend of populations based on the sex and age composition of harvested bears. However, harvest data are not necessarily representative of actual bear populations because of differences in vulnerability and hunter selectivity between sex and age groups (Miller 1990, Garshelis 1991). One common circumstance, subject to misinterpretation, is an observed increase in the percentage of young bears in the harvest sample. Is this increase due to previous overharvest of mature individuals or an increase in reproductive success?

During the late 1980's and the early 1990's, interpretation of New Mexico black bear harvest data was stymied by these very circumstances. Increasing, stable, and decreasing population trend were all plausible explanations for the observed changes in the harvest data. The lack of conclusive evidence for any trend did little to alleviate the growing controversy over future hunting regulations. Many guides, outfitters, and hunters favored the interpretation of an increasing trend, arguing that hunting regulations could be less restrictive. But other hunters and environmental groups defended the interpretation of a declining trend, and advocated more conservative hunting regulations. Clearly, additional information was necessary to interpret these data and to determine the true status and trend of New Mexico bear populations.

In 1991, responding to this need for more scientific information, members of the New Mexico State Game Commission instructed the NMDGF to conduct a black bear study. With funding from the NMDGF and the Federal Aid in Wildlife Restoration program (U. S. Fish and Wildlife Service) research was initiated in 1992. This 8-year study involved the NMDGF and three contracting organizations: Hornocker Wildlife Institute (HWI), Ecosystem Modeling (EM), and the New Mexico Cooperative Fish and Wildlife Research Unit (NMCFWRU) at New Mexico State University. The overall goal was to study the ecology and population dynamics of black bears for developing methods and analytic tools to help estimate and predict trends in population size and structure in New Mexico, as influenced by human-caused mortality and environmental variation.

STUDY OBJECTIVES

The study involved 2 related efforts. The first job was an 8-year, field-based investigation of bear ecology. Research was conducted within 2 distinct study areas situated in prime bear habitat. To specifically address the effect of hunting on population dynamics, 1 study area was closed to hunting for the majority of the study period. Research involved use of radio-telemetry transmitters on free-ranging bears, and although our primary objectives were related to population characteristics, use of telemetry permitted investigation of other ecological questions. Objectives of the field study were:

1. To document black bear population characteristics and dynamics, focusing on natality; cub survival; yearling survival; and adult/subadult survival relative to human-caused mortality.

2. To document black bear foraging habits and identify key foods, especially mast-producing species.

3. To quantify annual variation in production of important mast species for evaluation of its influence on reproductive success and survival.

4. To validate the premolar cementum annuli aging technique for New Mexico bears.

5. To document den entrance and emergence dates for comparison among sex/age categories and between study areas.

6. To investigate den site selection and use of elevation and habitat by denning bears.

7. To document home range characteristics, seasonal patterns of movement, subadult dispersal, and general habitat use.

8. To determine density and sex-age composition of study populations annually and with all years combined.

9. To extrapolate study area habitat characteristics to identify suitable bear habitat across the state using a Geographic Information System (GIS).

A second job involved analyses of NMDGF harvest and hunter survey data and development of a black bear population model using data collected during the field study. Primary objectives were:

1. To determine relationships between the harvest sample and the sex-age composition of study populations.

2. To determine relationships among weather variables, mast production, and bear population characteristics.

3. To develop a population/environmental/hunt model based on existing knowledge, and refined by rates observed in the field study.

4. To integrate the model into management application.

This report chronicles the results of this 8-year study, which represents the first concerted effort to understand New Mexico black bear ecology. Prior to 1992, only 2 research efforts had been conducted on New Mexico black bears. With funding from the NMDGF, Zager and Beecham (1982) conducted a preliminary investigation of food habits and habitat ecology in north-central, west-central, and southeast New Mexico. In 1988, a radio-telemetry study was initiated by a NMDGF District Officer to investigate bear-human conflicts, particularly on Philmont Scout Ranch (Jones 1991). That investigation acted as a springboard for establishment of the Northern Study Area for this study.

Further, this study and the resulting report supplements NMDGF data on hunter-killed black bears with information on vital rates, relationships with annual environmental variation, live population structure, and habitat use. The population model will provide managers with a tool for integrating harvest data with biological and environmental information to make inferences about bear population status consistent with all available information. Although uncertainty about black bear population resources will remain a challenge to bear management, the knowledge available to managers has been significantly improved.

CHAPTER 2

LIFE HISTORY AND MANAGEMENT HISTORY IN NEW MEXICO

This chapter describes the general ecology of black bears. It provides background for understanding the design, implementation, outcomes, and interpretations of this research.

TAXONOMY

Bears are members of the Family Ursidae, in the Order Carnivora, in the Class Mammalia. Other families found within the Carnivora include the Canidae (dogs), Felidae (cats), Mustelidae (weasels), and Procyonidae (raccoons). The Ursidae family is of recent origin, believed to have diverged from the Canidae approximately 20-25 million years ago (McLellan and Reiner 1994). Black bears are 1 of 8 ursid species worldwide.

At least 2 million years ago, after radiating to North America from Asia, a small forest-adapted ancestor (probably *Ursus abstrusus*) gave rise to the modern American black bear (Stirling and Derocher 1989). Despite climatic changes and competition with various species, the black bear adapted to survive to the present day virtually unchanged from 1 million years ago (Stirling and Derocher 1989). Within their evolutionary history, black bears have coexisted with several other ursid species, including the extinct short-faced bear (*Arctodus simus*) and the extinct North American spectacled bear (*Tremarctos floridanus*). The brown bear (*Ursus arctos*), which coexists with black bears in northwestern regions today, radiated into North America only about 100,000 years ago, and probably reached the Southwest about 13,000 years ago. Since then, black and grizzly bears inhabited New Mexico and probably shared similar distributions. However, grizzly bears were extirpated from New Mexico by the late 1930's.

DISTRIBUTION AND STATUS

Throughout their evolutionary history, the distribution of black bears has been basically defined by the extent of forested habitat in North America. Black bears have inhabited eastern deciduous forests from Florida to Maine, boreal forests from Newfoundland to Alaska, and montane forests from Alberta to Mexico. Fossil evidence indicates black bears were never commonly found in open habitats, such as the Great Plains, the Great Basin, or the arctic tundra, possibly due to competition with larger ursids, such as short-faced bears and brown bears (Stirling and Derocher 1989).

During modern times, black bear distribution has been most affected by deforestation, unlimited hunting, and use of poisons following European settlement of North America. Beginning in the 19th century, black bears were eliminated or greatly reduced in several U.S. states, including Illinois, Ohio, Kentucky, Florida, Alabama, Louisiana, Arkansas, Missouri, and Texas (Servheen 1989). However, during the last century, reforestation, legal limits on hunting, and restrictions on the use of poisons have allowed population recovery in many regions. The bear population in Arkansas, and subsequently Missouri and Louisiana, also were augmented with bears transplanted from Minnesota in the 1950’s. Today, black bear distribution is expanding and is known to include 32 U.S. states, 11 Canadian provinces or territories, and 6 Mexican states (Servheen 1989, Carrera 1993). Throughout their current distribution, bears are variously protected by game, threatened, or endangered status.

In New Mexico, evidence indicates black bear populations were greatly reduced by the early 1900’s due to unlimited hunting and use of poisons (NMDGF 1926, Bailey 1932, Brown 1985). Much of the mortality was the result of government sponsored anti-predator programs, aimed at eliminating loss of livestock to grizzly bears, black bear, wolves, and other carnivores (Brown 1985). In 1924, the U. S. Forest Service (USFS) estimated only 1,500 black bears inhabiting the national forests of New Mexico, Arizona, southern Colorado, and southern Utah, combined (Brown 1985). In 1925, the New Mexico population estimate was 660 black bears (NMDGF 1926). Responding to public and legislative support for protection of bears, the NMDGF classified the black bear as a big game species in 1927, and set a bag limit of 1 bear/season (10-31 October). Black bear, deer (*Odocoileus* spp.), and turkey (*Meleagris gallopavo*) were included in a single big game license and this regulation remained until 1981. This protection had significant results, and the bear population appeared to rebound by the 1940's. In 1941, more than 3,500 bears were estimated to reside in the national forests of the southwest (Brown 1985). By 1967, the black bear population in New Mexico was estimated at 3,000 and stable (Lee 1967). In 1971, a regulation was adopted prohibiting the harvest of young less than 1 year of age or females accompanied by young. In 1978, a mandatory hide-tagging program was instituted and 2 further requirements were added in 1985: proof of sex and collection of premolar teeth for cementum aging. In 1982, facilitated by the separate black bear hunting license, the NMDGF initiated a survey of randomly selected license holders.

Since the first bear hunting seasons were set in 1927, timing and duration of seasons have varied. By the late 1970’s, bear seasons encompassed 7-8 months each year, including parts of April, May, June, August, September, October, November, December, and January. In 1992, due to concerns about potential overharvest, NMDGF eliminated the spring bear season and reduced the fall season to 1 September-31 October. The fall season was again changed to 15 October-15 December in 1998 and 1 October-15 December in 1999.

Current distribution of black bears in New Mexico is associated with the forested mountain ranges. Bears inhabit areas ranging from the low elevation pinyon-juniper woodland and oak scrub habitats to the high elevation mixed conifer and spruce-fir forests (See Chapter 11).

LIFE HISTORY

Although taxonomically carnivores, black bears are, in fact, omnivorous. Throughout North America, diets of black bears are dominated by plant matter (Hatler 1972, Beeman and Pelton 1980, Graber and White 1983, MacHutcheon 1989, Raine and Kansas 1990). Diets of black bears in New Mexico also are dominated by plant material (see Chapter 5).

To an herbivorous black bear incapable of digesting cellulose, winter represents a time of food shortage, especially in northern regions. It is believed bear hibernation evolved primarily as a response to this seasonal scarcity of food (Pelton 1982). In most regions of North America, hibernation is a central component of the annual cycle of black bear activity, and the timing and duration of all other activities might be viewed as evolutionary consequences of this unique process. Although different from hibernation among smaller mammals, the physiological state attained by bears is generally considered true hibernation (Folk et al. 1976, Hellgren 1998), and some argue it is the most refined response to starvation of any mammal (Nelson 1980). For periods up to 7 months, a hibernating bear does not eat, drink, defecate, or urinate (Folk et al. 1976, Nelson 1980, Hellgren 1998). In all hibernators, metabolic activity is generated from energy stored in the form of fat, but small hibernators must arouse periodically to feed. Bears are capable of recycling the waste products of fat metabolism into lean body mass, while other hibernators must arouse and eliminate wastes through urination or suffer toxemia (Nelson et al. 1973, Hellgren 1980). Bears, like other hibernators, achieve energy savings by reducing their heart rate from 40-50 beats per minute (bpm) to 8-10 bpm, and lowering their metabolic rate by 27-50% (Hellgren 1998). However, concurrent with these other declines, black bear body temperature drops from 37-38^{o}C to only 31-35^{o}C compared to temperatures less than 10^{o}C in other hibernators (Hellgren 1998). Bears can achieve energy savings equal to small hibernators without dramatic changes in body temperature, because of their lower surface-area to volume ratio. This maintenance of near normal body temperature also allows bears to arouse quickly in response to disturbance.

Female black bears give birth in winter dens, and in addition to their own metabolic requirements must fulfill the energetic demands of gestation and lactation during the hibernating phase. Timing of breeding season may be tied to hibernation. Although mating occurs during spring or summer, fetal development does not begin until late fall, due to the process of delayed implantation. Following fertilization, eggs divide until the blastocyst stage (about 300 cells) and remain within the fallopian tubes for several months. In late fall, the blastocyst migrates down the fallopian tubes and implants in the uterine wall, at which time gestation begins (Wimsatt 1963). Actual gestation length is approximately 30-90 days and cubs generally are born during late January or early February (Alt 1983, Hellgren et al. 1991). Black bear litter sizes are known to range from 1-5, but litter sizes observed during this study ranged only from 1-3 (see Chapter 6).

Delayed implantation may be adaptive in bears for 2 primary reasons. First, it allows breeding to occur early in the active season when it would not interfere with the prolonged fall foraging necessary to build up fat stores for hibernation. Secondly, even after mating occurs, it is postulated that delayed implantation may allow females, with fat stores insufficient for gestation and lactation, to forego reproduction by not implanting the blastocyst. No hard evidence of this process had been found, however lack of litter production has been linked to poor nutritional status (Kolenosky 1990, Noyce and Garshelis 1994, Samson and Huot 1995).

Like most other members of the Carnivora, black bears can be classified as k-selected species, characterized by slow maturation, low reproductive potential, and long life spans (Caughley 1977). Throughout North America, female black bears reach reproductive maturity and mate at ages ranging from 1-5 years, with most over 3 years. In New Mexico, the youngest females observed in estrus were 3 years old, and the youngest females observed to give birth were 4 years old (see Chapter 6).

Breeding season typically ranges from May to September with peaks in June or July. Evidence from New Mexico indicates the peak of breeding occurs in June. Prolonged dependence of offspring on their mother sets the minimum successful birth interval at 2 years. Bears have been observed to give birth in the presence of yearlings (Alt 1981) and to give birth to newborn cubs after fall separation from the previous year's cubs (LeCount 1983). Nonetheless, these events appear to be extremely rare, and we found no evidence of their occurrence in New Mexico.

Cubs remain with their mothers for approximately 16-18 months, denning with them during their second winter. Following den emergence in the spring, yearling bears generally become independent between May and July, at which time the female is usually receptive to mating. Despite independence, occasional socialization between mothers and offspring probably occurs for several months to years. Numerous studies, including this one, have documented temporary reuniting of mothers and offspring. Bear species exhibit a high degree of female philopatry. Subadult female bears often remain in the vicinity of their mother's home range and establish their own home range adjacent to their mother. Conversely, most male offspring disperse away from natal areas at ages ranging from 1-3 years old. Finding of this study concur with these general trends (see Chapter 9).

Natural life expectancy of black bears probably varies regionally, but bears living in excess of 20 years are common. During this study, the oldest female bear age documented using cemetum annuli counts was 27 years and the oldest male was 23 years. The highest age recorded for litter production was 22 years and was observed for 2 bears.

CHAPTER 3

STUDY AREAS

Research was conducted on 2 study areas in New Mexico. The Northern Study Area (NSA) was located in the Sangre de Cristo Mountains of northern New Mexico (Figure 3-1). The study area was approximately 310 km^2 and was bounded by U.S. Highway 64 to the south and Moreno Valley to the west. The area encompassed private and state lands, including Philmont Scout Ranch, the Colin Neblett State Wildlife Area (CNWA) and the Elliot Barker State Wildlife Area (EBWA), Cimarron Canyon State Park, and several private ranches. It was adjacent to the towns of Eagle Nest and Ute Park, and about 6 km from Cimarron. It was bordered by a 2-lane highway, which received fairly high use year-round. It also enclosed numerous gravel roads, dirt roads, and trails. During the study period, recreation and cattle ranching were the primary land uses. Philmont Scout Ranch hosted up to 20,000 scouts during 3 months each summer. Access to private lands was limited and vehicular access to the CNWA was restricted to the highway.

In addition to presence of highways and towns, the primary human influences on the landscape included excavation, logging, and construction of dirt tanks. Scattered mines and dredge tailings remained from gold and copper mining activities that lasted from the late 19th to the mid 20th century. Most forests within the study area were second-growth, following selective logging, clearing for pasture, and forest fires. During the 1960's, an elaborate network of dirt roads was constructed on the CNWA to provide access for selective logging. Public driving access to the roads was restricted, allowing most roads to become overgrown. Occasional man-made dirt tanks were scattered within the area, primarily on private lands.

Topography and vegetation were diverse. Elevations range from 2,073 m (6,800 ft) on the east side of the study area to 3,793 m (12,441 ft) on Baldy Mountain. At the lower elevations, dominant habitat types included pinyon-juniper (*Pinus edulis-Juniperus* spp.) woodlands, and oak-mountain mahogany (*Quercus* spp.-*Cercocarpus* spp.) scrub. Middle elevations were dominated by ponderosa pine (*Pinus ponderosa*), mixed conifer (*Pseudotsuga menziesii-Abies concolor*), and aspen (*Populus tremuloides*) forests. Meadows of fescue (*Festuca* spp.), mountain muhly (*Muhlenbergia Montana*), grama (*Bouteloua* spp.), and bluegrass (*Poa* spp.) existed throughout the wooded habitats at lower and mid elevations. Spruce-fir (*Picea engelmannii-Abies lasiocarpa*), and bristlecone pine-limber pine (*Pinus aristata-Pinus flexilis*) forests dominated the higher elevations. An alpine tundra community, consisting of sedge (*Carex* spp.), alpine avens (*Geum rossii*), mountain current (*Ribes montigenum*), shrubby cinquefoil (*Potentilla fruticosa*), and grounsel (*Senecio* spp.) surrounded the scree and talus slopes at the highest elevations. Further description of these vegetation communities is provided by Dick-Peddie (1993).

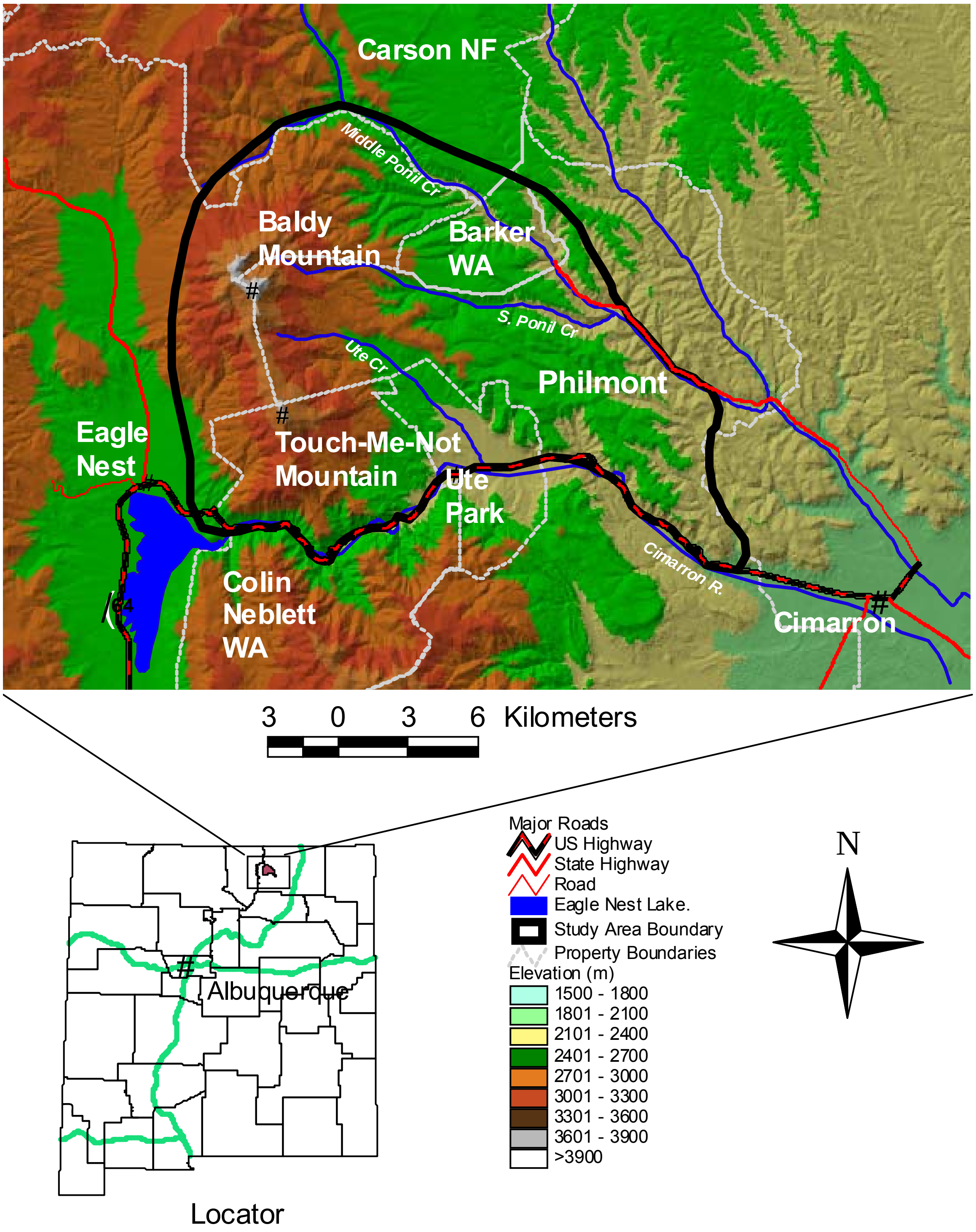


Figure 3-1. Location of the Northern Study Area of the Black Bear Study in New Mexico showing relationship to major roads, towns, and terrain.

The area included numerous permanent streams draining into the Cimarron River, including Willow Creek, California Creek, Ute Creek, Dean Creek, and Ponil Creek. Most of the smaller streams draining into these larger streams also were permanent.

Climate varied by elevation within the study area (Table 3-1). Mean January temperatures were at or below freezing and snowfall was high in the upper elevations. July temperatures were generally mild with most rainfall occurring during July-August.

Table 3-1. Climate variables recorded at weather stations close to the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1939-2000.

	NSA		SSA	
Parameter	Eagle Nest (2506 m[a])	Cimarron (1939 m)	Beaverhead (2023 m)	Glenwood (1432 m)
Mean Jan temperature (^{0}C)	-7	0	-1	5
Mean Jul temperature(^{0}C)	16	21	19	24
Frost -free season (days)	70-120	145-190	110-155	180-230
Annual precipitation (cm)	37.8	41.4	37.6	40.4
Monthly snowfall Dec-Mar (cm)	25.4	15.0	10.5	4.0
Monthly rainfall Jul-Aug (cm)	6.9	7.0	6.6	6.8

[a] Elevation of weather station

The area was located in Game Management Unit (GMU) 55. Prior to the study, bear hunting intensity varied within the study area. The CNWA and EBWA were closed to bear hunting since the late 1980's. Levels of bear hunting varied on private land, but were probably moderate to high throughout the area. With cooperation of private landowners, the area was closed to bear hunting so population dynamics could be studied in the absence of hunting. This closure was in effect from 1992 until 1998 when hunting was reestablished on some private land within the study area.

The Southern Study Area (SSA) was located in the Mogollon Mountains of west-central New Mexico (Figure 3-2). The area was approximately 423 km^2 and was bounded by U. S. Forest Service Road 141 to the north and Mineral Creek to the south. The area was encompassed within the Gila National Forest (Reserve Ranger District), but included some private parcels. It was remote, with the closest towns of Reserve, Glenwood, and Mogollon, located 3-16 km away. A 2-lane, partially paved loop road provided the main access into the study area. Numerous gravel roads, dirt roads, and trails were found on the study area, and access was usually unrestricted.

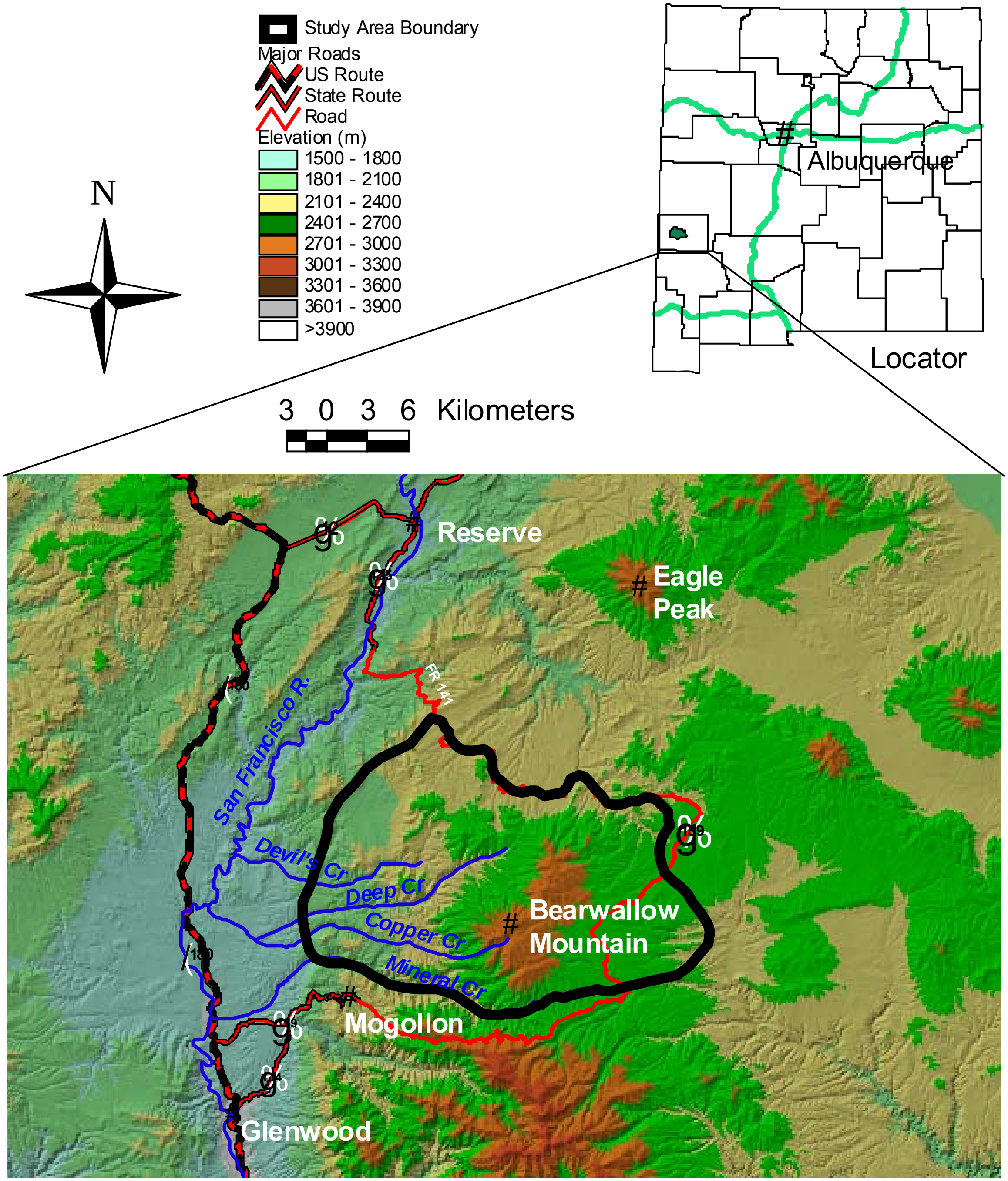


Figure 3-2. Location of the Southern Study Area of the Black Bear Study in New Mexico showing relationship to major roads, towns, and terrain.

During the study period, cattle grazing and recreation were the primary land uses. Historically, logging was also a dominant land use in this area, but during the 1990’s, timber harvest was very limited within the study area. It consisted of 1 commercial timber sale on Corner Mountain and limited firewood cutting. Prior to the 1990’s, much of the forested area was selectively logged or cleared for pasture, therefore most forests were second-growth. Some old-growth forests persisted, especially in steeper canyons. Numerous constructed dirt tanks were found within the area, providing permanent or seasonal water for cattle and wildlife.

Topography was diverse on the SSA, but elevations were lower than the NSA. Elevations ranged from approximately 1,750 m (5,740 ft) on the west side of the study area to 3,035 m (9,954 ft) on Bearwallow Mountain. Dominant habitat types coincided with those described for the NSA, with some variation in species composition. The high elevation bristlecone pine-limber pine forest and alpine community of the NSA were not present on the SSA.

The area included numerous permanent streams draining into the San Francisco River, including Devils Creek, Deep Creek, Copper Creek, and Mineral Creek. Many of the smaller streams on the area were ephemeral, drying out annually or in drought years.

Climate varied by elevation within the study area (Table 3-1). Mean January temperatures were below freezing at upper elevations, but above freezing at lower elevations. Snowfall was lower than that of the NSA. July temperatures were generally mild, but warmer than the NSA. Most rainfall occurred during July-August and rates were similar to the NSA.

The SSA was located within GMU 16A, and was open to bear hunting throughout the study period. Historically, hunting intensity in the region was moderate to high.

CHAPTER 4

CAPTURE OUTCOMES AND PHYSICAL CHARACTERISTICS

The objectives of the field study required us to capture a large sample of black bears and place radio-transmitters on many individuals. As a prelude to later chapters, we report the methods for our field investigations, including trapping efforts, den investigations, and radio-telemetry monitoring. We also include information on physical characteristics of bears obtained during these activities.

METHODS

Throughout the study period, our trapping efforts were primarily focused on the capture of previously unmarked females, to meet a target of 25 radio-transmitter equipped females monitored each year for reproductive success. During later years, much of the trapping effort was aimed at recapture of individuals requiring refitting or removal of their radio-collar.

Throughout the active season (primarily May-October), we captured bears using foot snares and culvert traps. Traps were examined by 1200 hours each day to prevent excessive stress to captured animals. All snared bears and most culvert-trapped bears were chemically immobilized and handled, however some recaptured bears caught in culvert traps were released without handling. Immobilizing drugs were administered using syringe poles. Captured bears were immobilized using 1 of 2 mixtures of immobilizing agents. Most often, we used a 2:1 mixture of ketamine hydrochloride (Ketaset, Fort Dodge Animal Health, Overland Park, Kansas) and xylazine hydrochloride (Rompun, A. H. Robins Co., Richmond, Virginia) at a combined dosage rate of 6.6 mg/kg (3mg/lb) estimated body weight (Addison and Kolenosky 1979). Under some circumstances, we used tiletamine hydrochloride + zolazepam hydrochloride (premixed as Telazol, A. H. Robins Co., Richmond, Virginia) at a dosage rate of 5.5 mg/kg (2.5mg/lb) estimated body weight (Gibeau and Paquet 1991). Use of Telazol was not ideal for our trapping regime because the protracted recovery period, characteristic of this drug, limited our ability to handle multiple bears per day.

We monitored respiration, pulse, and body temperature during immobilization. Ointment was applied to the eyes of bears to inhibit drying. Blindfolds were used and loud sounds were minimized to reduce unnecessary disrupting stimulus. We remained with immobilized bears until recovery was observed.

Sex of captured bears was determined from external genitalia. Black or brown color phase was noted for each bear, based on the color of the guard hairs and the underfur. Coat condition was rated as good or poor/shedding. For all bears, we recorded chest girth, body length, neck circumference, foot pad length/width, and weight (when possible). For female bears, we noted vulval swelling, teat length/width, teat color, occurrence of lactation, evidence of suckling (swollen teats or hair matting), and presence of offspring.

Approximate age of bears was estimated from tooth eruption/wear (Jonkel 1993) and size. A vestigial premolar tooth was extracted from bears ≥1 year old for age determination using cementum annuli counts (Stoneberg and Jonkel 1966, Willey 1974). Age class was assigned as follows: cub (<1 year), yearling (1 year), subadult (2-4 years), and adult (≥5 years).

We marked each bear with numbered, colored eartags (Allflex USA, Dallas, TX) and we tattooed the same number on an inner, upper lip. We placed radio-transmitters on all females captured, except during 1999-2000 when our target sample size of 25 had been met. We placed radio-transmitters on adult males as needed to maintain a sample of approximately 10 individuals each year. During the first year of the study, most subadult males were also given radio-transmitters. The practice of collaring captured subadult males was terminated after 1993, in favor of placing transmitters on yearling males and females in the den. Adult-sized collars (mod-500 or mod-505, Telonics, Tempe, Arizona) were placed on bears weighing over 23 kg (50 lbs). Bears weighing less than 23 kg were fitted with Telonics mod-400 collars, expandable subadult collars (Ursus Technologies, Williamsburg, Virginia), or ear-tag transmitters (Advanced Telemetry Systems, Isanti, Minnesota). Collars were fitted to allow for growth and cotton spacers were attached to ensure collars would fall off in the event of transmitter failure (Hellgren et al. 1988).

We visited dens of radio-transmittered adult females each year to ascertain their reproductive status. If offspring were present, we attempted to handle all bears in the den, however inaccessibility sometimes prevented it. If offspring were not present, females were usually handled only if necessary to change or refit collars. Dens of males and subadult females were visited annually or biannually to change or refit collars as necessary. Adult, subadult, and yearling bears requiring handling were immobilized using Telazol. We elected to use Telazol for den work because of its reduced tendency to depress heart rate and respiration compared to Ketaset/Rompun. Cubs were handled without immobilization. Typically, we did not remove adult bears from dens, unless it was necessary to reach their head or to reach offspring, however yearlings and cubs were removed from dens for handling. Weights and other measurements were obtained from all bears when possible. Den investigations were conducted between January and April, however we limited handling of cubs to March and April when our handling would have negligible impact on their survival.

We monitored radio-collared bears from fixed-wing aircraft on a 14-day schedule during the active season (weather permitting). During fall and spring months, we attempted to increase the flight schedule to 7-10 days for obtaining den entrance and den emergence data. During winter months, monitoring of bears was reduced while the bears remained in their dens. We recorded locations using Universal Transverse Mercator (UTM) grid coordinates to the nearest 0.1km, on United States Geological Survey (USGS) 7.5-minute maps. We estimated aerial telemetry error by comparing locations obtained by telemetry to actual locations verified by ground investigation. These locations included those of shed transmitters, bear mortalities, and blind tests.

RESULTS AND DISCUSSION

Trapping Success, Den Investigations, and Monitoring

Between September 1992 and June 2000, we captured 300 bears (103 females, 195 males, 2 unknown sex) 517 times. Individual bears were captured 1-9 times with a mean of 1.5 captures/bear. First-time captures, total captures, and capture success were similar between study areas (Table 4-1). History and circumstances of all bears handled are described in Appendix A.

Table 4-1. Black bear trapping success on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1992-2000.

		No.	No. Captures		Capture Success (trap-nights/bear)	
Area	Category	Trap-nights	First-time	Total	First-time	Total
NSA	Snare	1338	64	116	20.9	11.5
	Culvert	1564	76	162	21.7	9.7
	Total	2902	140	278	20.7	10.4
	Females		49	73	59.2	31.9
	Males		91	204	39.8	14.2
SSA	Snare	1552	79	116	19.6	13.4
	Culvert	2230	81	123	27.5	18.1
	Total	3782	160	239	23.6	15.8
	Females		54	73	70.0	51.8
	Males		104	164	36.4	23.1

Between January 1993 and April 2000, we handled or observed 339 bears (178 females, 137 males, 24 unknown sex) in dens 680 times. Individual bears were handled or observed 1-8 times with a mean of 2.0 observations/bear. Successful den investigations included 282 individual adults (233 females, 49 males), 99 subadults (65 females, 34 males), 95 yearlings (45 females, 44 males, 6 unknown sex) and 204 cubs (94 females, 91 males, 19 unknown sex). In addition to these successful den investigations, we attempted to visit the dens of 24 other bears, but were unsuccessful because of inaccessibility of dens (*n* = 14), and prior emergence from the den (*n* = 10).

During 1992-1999, we placed 409 radio-transmitters on 316 bears (181 females, 135 males). Transmitters included 287 adult-sized collars, 27 subadultsized collars, 55 expandable subadult collars, and 40 ear-tag transmitters. We obtained 5,723 radio-telemetry locations.

Telemetry error was estimated from 105 locations verified with ground investigation. On the NSA, error ranged from 50-1,100 m with a median of 200 m, and a mean of 285 m (*n* = 23). On the SSA, error ranged from 50-3,780 m, with a median of 505 m and a mean of 784 m (*n* = 82).

Physical Characteristics

Color phase was recorded for 471 bears on 918 occasions. Most bears (75%) were brown-phase. Confidently assigning a bear to a color phase was sometimes difficult, due to color differences in underfur, especially when coats were shedding. Black-phase bears were identified by their black guard hairs, but often had gray to brown underfur. Within the brown-phase, we observed hues ranging from blonde to cinnamon to dark chocolate or liver color. Due to bleaching and shedding, the hue of brown-phase individuals was observed to vary, depending on season. Many bears with light-colored coats during spring and summer were observed with dark brown coats in the fall or winter. Color phase has been described as changing for an individual (Beck 1991), but we found no definitive evidence of such change. We believe any recorded changes in color phase were due to seasonal changes in hair condition (shedding, bleaching), different conditions during observation (time of day, lighting), and differences in observers.

Percent color phase did not differ by sex ($X^2 = 0.03$, df = 1, $P = 0.85$, $n = 471$), but differed by study area ($X^2 = 35.5$, df = 1, $P < 0.001$, $n = 471$). On the NSA, 83% of females and 84% of males were brown phase. On the SSA, 58% of females and 64% of males were brown phase.

Coat condition varied throughout the year. Almost all bears (98%) had good coat condition during fall months (September-October, *n* = 132) and during the denning period (January-early April, *n* = 326). During May-August, we observed shedding or poor coat condition on 18-40% of bears (*n* = 267), with the highest proportion in July.

We obtained active-season weights or measurements for 280 individuals on 333 occasions. Weights and measurements differed among sex and age categories (Table 4-2). Mean weight of males increased significantly between cub age and 6-7 years, when mean weight appeared to level off (Figure 4-1). Mean weight of females increased between cub age and 2-3 years, when a gradual increase in weight was observed by age. A significant difference in male and female weights was observed by the ages of 2-3 and this deviation increased with age. Means for all other measurements showed similar trends (Figure 4-2).

Table 4-2. Mean and range for weights and measurements, by age category, of black bears recorded during the trapping season (May-October) on the Northern and Southern Study Areas, New Mexico, 1992-1999.

Measurement	Sex	Age	*n*	Mean	Range
Weight (kg)	Female	Cub	3	20.9	17 - 25
		Yearling	13	23.0	11 - 36
		2-3 years	33	46.2	21 - 71
		4-5 years	17	52.9	36 - 84
		6-7 years	10	64.1	52 - 82
		8-10 years	14	68.9	50 - 114
		>10 years	11	73.1	53 - 107
	Male	Cub	2	20.0	18 - 22
		Yearling	19	29.3	14 - 48
		2-3 years	71	62.8	27 - 105
		4-5 years	33	84.9	50 -130
		6-7 years	16	117.1	75 -178
		8-10 years	20	117.3	77 -159
		>10 years	23	110.2	70 -146
Chest girth (cm)	Female	Cub	3	51	48 - 53
		Yearling	14	52	45 - 63
		2-3 years	36	70	52 - 86
		4-5 years	21	75	62 - 97
		6-7 years	12	77	69 - 93
		8-10 years	16	83	75 - 103
		>10 years	14	84	69 - 98
	Male	Cub	2	54	47 - 61
		Yearling	19	60	45 - 83
		2-3 years	83	79	45 - 108
		4-5 years	38	92	70 - 120
		6-7 years	25	102	84 - 127
		8-10 years	25	104	86 - 124
		>10 years	27	105	88 - 124
Length (cm)	Female	Cub	3	105	100 - 108
		Yearling	14	117	96 - 142
		2-3 years	35	137	107 - 160
		4-5 years	21	148	110 - 162
		6-7 years	11	152	140 - 162
		8-10 years	16	154	139 - 175
		>10 years	13	159	146 - 170
	Male	Cub	1	104	
		Yearling	19	119	103 - 142
		2-3 years	82	153	115 - 184
		4-5 years	35	171	146 - 193
		6-7 years	22	177	161 - 205
		8-10 years	24	177	125 - 194
		>10 years	27	178	164 - 193

Measurement	Sex	Age	*n*	Mean	Range
Neck circumference (cm)	Female	Cub	3	32	29 - 34
		Yearling	14	32	27 - 38
		2-3 years	34	42	27 - 55
		4-5 years	21	46	40 - 54
		6-7 years	12	47	42 - 51
		8-10 years	16	50	44 - 58
		>10 years	13	50	42 - 59
	Male	Cub	1	31	
		Yearling	19	36	28 - 49
		2-3 years	81	48	36 - 69
		4-5 years	36	57	35 - 73
		6-7 years	24	64	22 - 78
		8-10 years	25	66	50 - 76
		>10 years	27	65	49 - 79
Front pad width (mm)	Female	Cub	3	76	73 - 79
		Yearling	14	81	73 - 85
		2-3 years	33	94	80 - 115
		4-5 years	21	99	93 - 108
		6-7 years	12	101	90 - 110
		8-10 years	16	104	90 - 120
		>10 years	14	106	95 - 116
	Male	Cub	1	82	
		Yearling	18	89	70 - 110
		2-3 years	78	108	75 - 135
		4-5 years	36	120	100 - 139
		6-7 years	24	125	110 - 149
		8-10 years	21	125	96 - 140
		>10 years	24	126	102 - 153
Rear pad length (mm)	Female	Cub	3	96	90 - 100
		Yearling	14	108	89 - 122
		2-3 years	34	123	103 - 143
		4-5 years	21	129	102 - 147
		6-7 years	12	135	120 -150
		8-10 years	16	138	124 - 153
		>10 years	14	135	122 - 150
	Male	Cub	3	112	108 - 117
		Yearling	18	119	103 - 140
		2-3 years	77	142	103 - 172
		4-5 years	37	156	140 - 187
		6-7 years	24	157	106 - 184
		8-10 years	20	161	140 - 190
		> 10 years	25	163	146 - 185

We obtained den-season weights or measurements for 183 cubs or yearlings on 238 occasions (Table 4-3). At approximately 4-8 weeks of age, mean weight of cubs was 2.0 kg, and mean weight did not differ by sex (t = -0.5, df = 165, P = 0.64, n = 167). At approximately 12-14 months, mean weight of yearlings was 20.8kg, and it did not differ by sex either (t = -0.5, df = 36, P = 0.63, n =38).

Table 4-3. Mean and range for weights and measurements of cub (<1 year) and yearling (1 year old) black bears, recorded during the den season (January-April) on the Northern and Southern Study Areas, New Mexico, 1992-1999.

Measurement	Age	*n*	Mean	Range
Weight (kg)	Cub	167	2.0	1.0 - 3.8
	Yearling	38	20.8	9.1 - 38.6
Chest girth (cm)	Cub	87	27	19 - 36
	Yearling	65	54	34 - 74
Length (cm)	Cub	44	46	36 - 60
	Yearling	49	105	82 - 134
Neck circumference (cm)	Cub	49	18	12 - 23
	Yearling	51	33	22 - 40
Front pad width (mm)	Cub	7	36	31 - 43
	Yearling	18	75	50 - 91
Rear pad length (mm)	Cub	7	43	38 - 47
	Yearling	18	101	80 - 140

We observed 1 unusual bear on the NSA, first captured as a 3-year-old and monitored for 3 years. This bear exhibited male and a female external genitalia. It was not clear whether this hermaphrodite was reproductively functional as either sex. The bear was not observed to produce cubs, but it was once observed in the company of a marked female bear during the mating season. Its size was also more closely aligned with that of males. Because of the lack of offspring and its large size, we treated this individual as a male for most analyses, such as survival and home range.

Research-related Injury, Mortality, and Den Disturbance

During 517 captures, bears sustained 1 mortality (0.2%) and 10 injuries (1.9%). The mortality was sustained by a snared subadult female killed by another bear, and 1 injury (severed toe and claw) was sustained by a snared adult male as he defended himself from another bear. The other 9 injuries were the result of bears chewing their snared foot and severing toes and/or part of the main pad. Two incidents occurred during 1992 on the NSA, and 7 occurred during 1993 or 1995 on the SSA. During 1993 on the SSA, trapping teams sometimes separated to examine snares and, after meeting up, returned to sites where bears were captured. We suspect this action may have contributed to some of the first incidents of foot chewing on the SSA, and this practice was immediately discontinued when snares were used. It appeared most other incidents occurred when function of the swivel mechanism was inhibited, however cause could not be identified in all cases. Factors contributing to loss of swivel action included: use of stacked log cubbies; use of small, but live plant materials as part of the cubby; and failure to remove small shrubs from the area reachable by the snared bear. We discontinued use of stacked-log cubbies and only used dry, brittle material in cubby construction. Complete elimination of these factors after 1995 resulted in no further incidents of foot chewing. The addition of bungee cords and hood springs to snares during 1995-1997 also may have reduced injuries.

In traps and dens, we immobilized 762 bears and experienced 3 handling mortalities (0.4%). We believe an adult male died from reaction to the immobilizing drugs because a necropsy revealed the bear had sustained internal injuries prior to capture and it also had a congenital heart defect. An adult female with a debilitating case of sarcoptic mange died during den handling. Probably as a result of the infection and blindness, she was very emaciated and weak. The dose of immobilizing drug was appropriate for a healthy bear, however it may have been too much for a bear in her poor condition. Another adult female died when her radio-collar blocked her airway when she became immobile in the den. The problem was not observed quickly enough, and her breathing and heartbeat stopped. Cardio-pulmonary resuscitation was attempted for 35 minutes, however she was not revived.

In 369 uses of radio-collars, 8 uses (2.2%) resulted in severe subdermal injury when bears outgrew the collar. One injury involved an adult male wearing an adult-sized collar. Another injury involved a maturing female wearing an adult -sized collar. The 6 other injuries occurred when juvenile bears were fitted with expandable collars. Injuries occurred both when collars expanded as designed (*n* = 3) and when collars failed to expand (*n* = 2). Four of 6 injuries resulted from collars worn >2 years because we were prevented from removing them by inaccessible dens, unsuccessful trapping, and loss of signal.

During 414 den visits, there were 33 instances when bears fled dens upon our approach. Nine of these instances (27%) involved adult females with offspring (5 with cubs, 4 with yearlings). Following our disturbance, 4 of 5 females with cubs were believed to have returned to their dens. One female abandoned a single cub, which was removed from the den and cross-fostered with another adult female with cubs. When disturbed, 3 of 4 females with yearlings fled without their offspring, while 1 of 4 fled along with her single yearling. One of the 3 females that fled without their yearlings returned to the den, while 2 did not return. It was unknown if 1 of these females reunited with her offspring, but the other was handled in a second den and her yearlings were not with her. One female on the NSA fled her den each time we visited it, including 4 times when we immobilized her as she fled the den. This bear accounted for 4 of the 9 incidents described above (3 with cubs, 1 with yearlings).

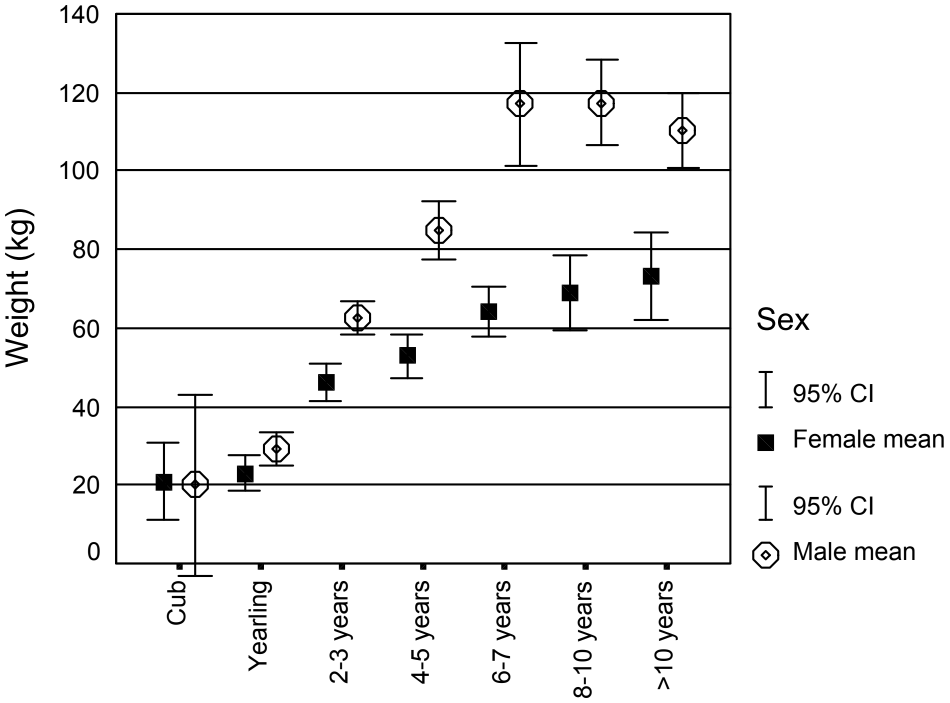


Figure 4-1. Mean and 95% confidence interval for weight (kg), by age category, of female and male black bears, recorded during the trapping season (May-October) on the Northern and Southern Study Areas, New Mexico, 1992-1999.

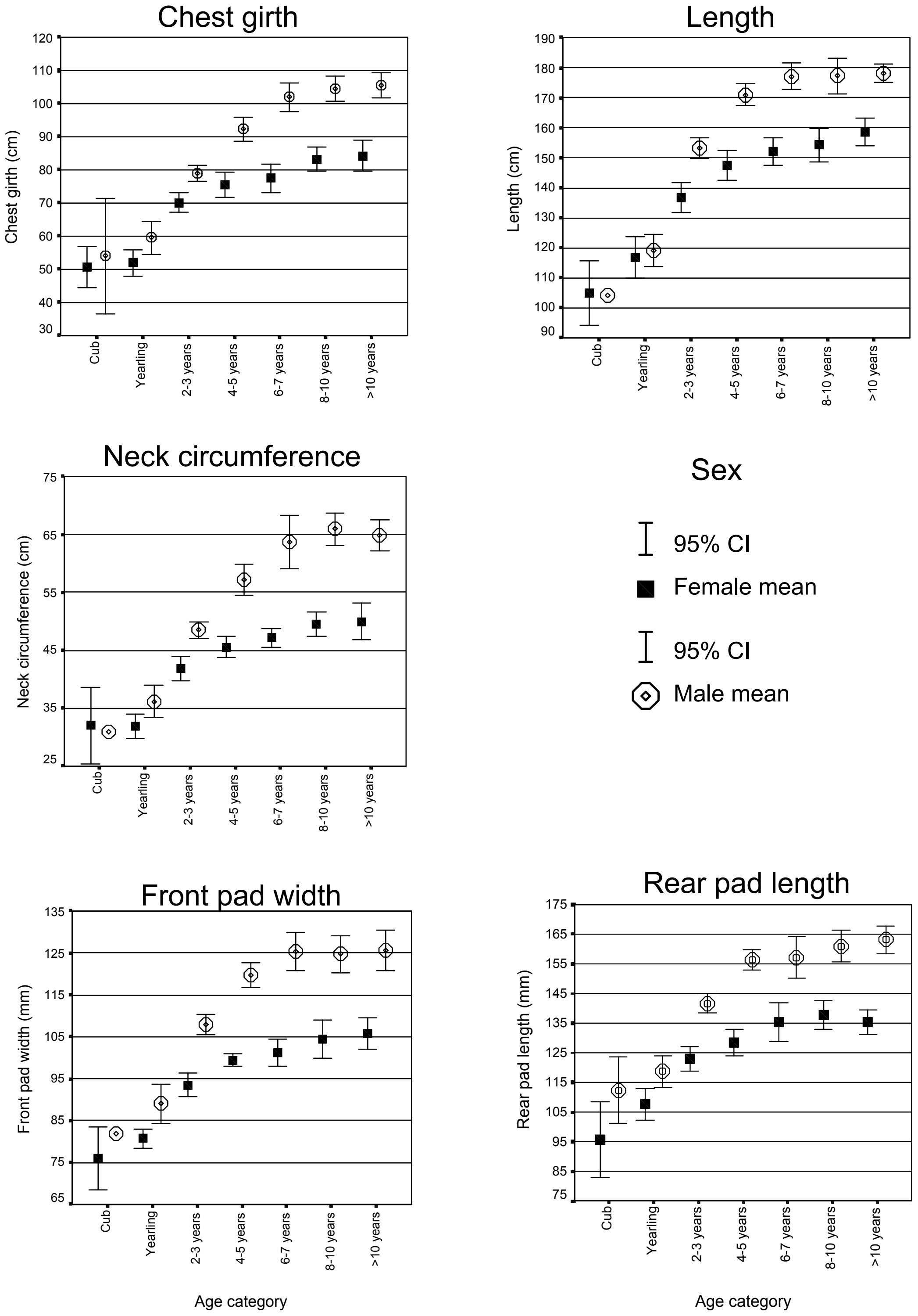


Figure 4-2. Mean and 95% confidence interval for measurements, by age category, of female and male black bears, recorded during the trapping season (May-October) on the Northern and Southern Study Areas, New Mexico, 1992-1999.

CHAPTER 5

VARIATION IN MAST PRODUCTION

A positive correlation between food abundance and black bear reproductive success has been widely reported, based on annual variability in foods (Jonkel and Cowan 1971, Rogers 1976, Eiler et al. 1989, Elowe and Dodge 1989, McLaughlin et al. 1994, Miller 1994), geographic variability in foods (Schwartz and Franzmann 1991, McLaughlin et al. 1994, Miller 1994) and differential feeding behaviors among bears (Rogers 1976, Elowe and Dodge 1989). In most studies, availability of hard mast (e.g., acorns and beechnuts) and soft mast (e.g., huckleberries and blueberries) appeared to have the greatest influence on reproduction. Reproductive success also has been linked to female nutritional condition (Kolenosky 1990, Noyce and Garshelis 1994, Samson and Huot 1995).

A first step in understanding New Mexico black bear ecology and population dynamics was to verify use and availability of mast species. We investigated bear foraging habits and variation in mast production on the 2 study areas during 1993-2000. Our objectives were to: (1) identify important mast species consumed by New Mexico black bears; (2) document annual variation in mast production of these species; (3) determine relationships between weather parameters and mast production; and (4) evaluate the feasibility of implementing statewide mast production surveys.

METHODS

Foraging Habits

We quantified bear foraging habits from scat analysis and observation. During 1992-1995, we collected scats incidental to field work. In addition, we visited selected ground locations identified from aerial telemetry to collect scats and observe bear sign. We recorded approximate date of deposition, location, and habitat descriptions for each scat. Data on other bear sign and activity also were noted. We analyzed scats using methods described by Hatler (1972) and visually estimated percent volume of each food item. We summarized scat contents during 3 seasons: premast (den emergence-20 July), early mast (21 July-15 September), and late mast (16 September-den entrance). During 1995-1996, we documented general trends in foraging habits by recording observations of bear sign and identifying primary contents of scats in the field.

Study Area Mast Surveys

We conducted mast production surveys to quantify annual variation in food abundance on the 2 study areas. Surveys were limited to species contributing most to bear diets, based on scat analysis, field observations, and previous studies in the Western U.S. On the NSA, surveyed species included Gambel oak (*Quercus gambelii*), wavyleaf oak (*Q. undulata*), pinyon (*Pinus edulis*), Rocky Mountain juniper (*Juniperus scopulorum*), one-seed juniper (*J. monosperma*), and chokecherry (*Prunus virginiana*). On the SSA, surveyed species included Gambel oak, gray oak (*Q. grisea*), pinyon, alligator juniper (*J. deppeana*), Utah juniper (*J. osteosperma*), and orange gooseberry (*Ribes pinetorum*). Timing of surveys coincided with the period just prior to peak ripening (mid August to mid September), to ensure most fruit were fully formed, but losses to wildlife were minimal.

We established mast survey routes across study areas designed to encompass variation in elevation and aspect. Survey routes followed roads, jeep trails, or foot trails, and ranged from approximately 0.8-8.0 km (0.5-5.0 mi), depending on the extent of appropriate habitat. On each transect, we designated 2-10 survey sites at predetermined intervals of 0.2-1.6 km (0.1-1.0 mi). At each site, we walked 10 paces away from the road and classified production for the closest 1-10 (usually 5) plants of each species. The same survey routes and sites were revisited each year, with the same number of plants classified at each site. One hundred individual plants were classified for oaks, junipers, pinyon, and gooseberry. Forty individual plants were classified for chokecherry. All species, except for chokecherry, were surveyed on 2-5 separate survey routes.

Ratings were assigned as described by Graves (1980): no visible fruit = 0; fruit visible after very close inspection = 2; fruit readily visible, but not covering entire plant = 4; or fruit readily visible and covering entire plant = 8. This sequence of numbers was chosen because it roughly represented a minimum ratio of fruit/plant among the 4 classifications.

Analyses were performed using SPSS statistical software (SPSS, Chicago, Illinois). Mean ratings were calculated for each species by year. Because the rating data were ordinal, the Kruskal-Wallis (KW) rank procedure was used to test for annual differences, by species and genera. The Student-Newman-Keuls (SNK) test was then used to detect differences among mean ranks and identify homogenous subsets (pool years). We used mean ratings of homogenous subsets to characterize mast production by species or genera, with the following ranges of values as guidelines: 0.0 - 1.4 = failure; 1.5 - 2.4 = poor; 2.5 – 3.9 = moderate; 4.0 – 4.9 = good; 5.0 – 6.0 = excellent. These ranges of values were flexible under certain circumstances. For example, if the mean rating of subset A was 1.6 and the mean rating of subset B was 2.4, subset B might be designated as “moderate” to differentiate it from subset A.

Relationship with Weather Variables

Forward and backward stepwise linear regressions, using S-PLUS 2000 statistical software (Insightful Corporation, Seattle, Washington), were performed using average oak mast index as the response variable. Explanatory environmental variables considered included temperature, last frost date, seasonal rainfall, and seasonal Palmer Drought Stress Index, all varying both between study areas and from year to year on each study area. Additional statewide variables, which differed from year to year but were the same for both study areas each year, were annual total wildland fire acres, winter El Nino state estimated by NOAA (coded as +1 for warm El Nino conditions, -1 for cold or La Nina conditions, and 0 for neutral). One-year time lags were considered. Analyses were run using 1993-1999 mast observations, to be tested with 2000 observations, and also with 1993-2000 mast observations.

District Mast Surveys

During 1999-2000, we distributed simplified mast survey forms to New Mexico Department of Game and Fish officers whose districts included bear habitat. For these surveys, mast production was assessed at the genera level for oaks, junipers, and pinyon. Officers were asked to observe mast production any time during September, coincident with other field activities, and answer the following questions for each genera (no specific training given to officers):

(a) What percentage of plants had fruit? (circle one)
< 25% = 1; 25-50% = 2; 51-75% = 3; > 75% = 4

(b) In general, of plants bearing fruit, how would you characterize the number of fruit per plant? (circle one or two)
scarce = 2; moderate = 3; abundant = 4; super abundant = 5

(c) How would you characterize overall fruit production? (circle one)
mast failure = 1; poor = 2; moderate = 3; good = 4; bumper crop = 5

For summarizing data, the subjective criteria were substituted with numerical variables, as shown above. Numerical values to questions (a) and (b) were multiplied to produce a mast production “score”. Numerical answers to question (c) were used as mast production "assessment". Officer surveys were summarized on a regional basis. Mean scores and assessments were calculated for each of the following mountain regions (see Chapter 11):

San Juan complex (San Juan and Jemez Ranges, Navajo Dam area)
Sangre de Cristo complex
Central (Sandia, Manzano, Zuni, and San Mateo ranges)
Gila complex (Mogollon, Tularosa, Mimbres, Gallinas, and Animas ranges)
Southeast (Sacramento, Capitan, and Guadalupe ranges)

We used Spearman’s rank correlation procedure to compare our mast survey results to scores and assessments provided by officers from the 2 Districts encompassing the study areas.

Follow-up Telephone Survey

We conducted a follow-up telephone survey during October-December 1999. Personnel from NMDGF were asked several questions regarding the ease of the survey, the time spent on the survey, and their willingness to participate in the survey on an annual basis.

RESULTS

Foraging Habits

Analysis of scats collected during 1993-1995, indicated most of the annual diet was plant matter on both study areas (Table 5-1). Diets during the pre-mast season (den emergence – 20 July) were dominated by grasses and forbs. On the NSA, most of diet was grasses, including *Poa*, *Festuca*, and *Muhlenbergia*. On the SSA, grasses and sedges were most dominant, including *Poa*, *Festuca*, *Muhlenbergia, Piptochaetium* and *Carex.*, Forbs appeared to be more important on the SSA, and included vetch (*Vicia* spp.), peavine (*Lathyrus* spp.), and golden pea (*Thermopsis rhombifolia*). Blossoms of New Mexico locust (*Robinia neomexicana*) also were consumed. On both study areas, ants (Formicidae) constituted a significant portion of the pre-mast season diet. Unlike the NSA, soft mast was a significant portion of the pre-mast diet for bears on the SSA. Mast species consumed included alligator juniper, Utah juniper, squawroot (*Conopholis alpina*), gooseberry (*Ribes* spp.), and hawthorn (*Crataegus* sp.).

Mast species became more dominant in the diets of bears on both study areas during the early mast season (21July – 15 September), and consumption of vegetation and ants was reduced. On the NSA, acorns of Gambel oak and wavyleaf oak were most common, comprising 56% of the scat volume. Other mast species consumed included chokecherry, squawroot, and gooseberry. On the SSA, important species consumed included juniper berries, acorns, pinyon nuts, gooseberries, prickly pear fruit (*Opuntia* spp.), and squawroot.

During the late mast season (16 September – den entrance), mast was the dominant food on both study areas. On the NSA, 88% of the scat volume was mast, with acorns comprising 87%. On the SSA, 82% of the diet was mast, with acorns accounting for 36%. Other species included juniper and prickly pear.

Observations and field examination of scats during 1995-2000 concurred with scat analysis findings reported above. On the NSA, grasses and insects were the most commonly observed pre-mast foods. During the early and late mast seasons, observations indicated acorns were the primary food sought by bears. However, consumption of 5 other soft mast species, not found during 1992-1995, were recorded. During the early mast season bears were observed to forage on squawbush (*Rhus trilobata*), wild plum (*Prunus americana*), and kinnikinnick (*Arctostaphylos uva-ursi*), and during the late mast season bears were observed to forage on Rocky Mountain juniper and one-seed juniper. Most juniper scats were encountered at den sites, indicating this food was primarily consumed during the late fall, just prior to den entry.

Table 5-1. Percent volume and percent frequency (in parentheses) of food items identified from black bear scats collected on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1993-1995.

	NSA			SSA		
Item	Pre-Mast Season[a] (*n* = 44)	Early Mast Season[b] (*n* = 20)	Late Mast Season[c] (*n* = 50)	Pre-Mast Season (*n* = 53)	Early Mast Season (*n* = 145)	Late Mast Season (*n* = 56)
Vegetation						
Poaceae / Cyperaceae	78 (89)	11 (30)	2 (10)	33 (60)	17 (34)	4 (16)
Forbs	2 (5)			9 (19)	3 (9)	5 (7)
Conopholis spp.		5 (5)		6 (6)	4 (6)	Tr [d](4)
Robinia neomexicana				5 (6)		
Prosopis glandulosa					3 (5)	
Hard and Soft Mast						
Quercus spp.		56 (60)	87 (98)	1 (6)	7 (10)	36 (43)
Juniperus spp.				2 (6)	32 (46)	36 (52)
Pinus edulis					11 (17)	2 (4)
Opuntia spp.					4 (10)	6 (11)
Ribes spp.		5 (5)		1 (4)	10 (21)	
Prunus virginiana		5 (5)	1 (2)			
Crataegus sp.				3 (4)		
Actea arguta	1 (2)					
Rhamnus sp.					Tr (1)	
Juglans sp.						Tr (2)
Sambucus sp.					Tr (1)	
Unidentified		3 (5)				2 (4)
Insect						
Formicidae	15 (48)	9 (15)	5 (6)	23 (66)	3 (13)	Tr (11)
Vespidae				Tr (4)	1 (4)	
Coleoptera	Tr (2)			1 (8)	Tr (3)	
Orthoptera			2 (2)			
Unidentified larvae	Tr (2)	3 (10)			Tr (1)	Tr (2)
Fungi	0	0	0	0	Tr (3)	2 (4)
Mammal						
Ursus americanus		Tr (5)	Tr (32)		Tr (6)	Tr (14)
Urocyon cinereoargenteus	1 (2)					
Cervidae			2 (8)			
Sciuridae	1 (2)					
Unidentified	Tr (7)			2 (2)	2 (6)	

[a] Den emergence-20 July
[b] 21 July-15 September
[c] 16 September-den entrance
[d] Trace amounts

On the SSA, observations during 1996-2000 also concurred with findings from scat analysis, with 1 possible exception. During 1997 and 1999, we observed bears feeding on juniper berries throughout the active season, beginning as early as April. These observations indicated juniper berries constituted more than 10% of the spring and summer diet as observed from scat analysis. Consumption of 2 other soft mast species, Wright silktassel (*Garrya wrightii*) and squawbush), was noted during 1996-2000.

Study Area Mast Surveys

Mast production varied annually for all species on both study areas ($P < 0.001$). Production of Utah juniper was most variable of the species surveyed, with crops ranging from failure to excellent (Table 5-2). Production of Gambel oak, gray oak, alligator juniper, and orange gooseberry also was variable, with crops ranging from poor to excellent or failure to good. Production of wavyleaf oak, Rocky Mountain juniper, and pinyon was generally low, with only 1 of 8 years exceeding a poor rating on either study area. Although production of one-seed juniper varied among years, all production was rated as failure.

Within most years on each study area, mast production varied by species or genera. With the exceptions of 1997 (NSA) and 2000 (SSA), at least 1 species produced mast in excess of poor each year. We observed only 1 year of outstanding mast production, when production of all species was at least moderate. This occurred on the SSA in 1998. Production of combined oak varied annually on both study areas. Combined juniper production varied greatly on the SSA, but juniper failure occurred every year on the NSA.

Relationship with Weather Parameters

Mast patterns differed between the study areas. The SSA had a higher correlation among species, but more variability within species over time. Analysis focused on environmental associations with oak mast, because oak had a consistent relationship to parturition (see Chapter 6).

For the NSA for 1993-1999, the best regressions with average oak mast used last frost date and El Nino state. Both a regression with frost date alone and a regression with both variables predicted good mast for 2000, as observed, but the regressions were not usable. The single variable model was not significant ($P = 0.185$) and the independent variables were negatively correlated (-0.60) in the model with both variables. For the NSA for 1993-2000, reasonable models were found with a single variable (last frost date) and 2 variables (last frost date and winter El Nino: Table 5-3). With the addition of the year 2000 data points, the correlation between frost date and El Nino (0.07) was eliminated. Both models leave much of the variation in oak mast unexplained, and neither correctly predicts the single NSA mast failure in 1993.

Table 5-2. Mast production survey results for 10 woody plant species examined on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1993-2000.

			Mast Production Rating by Year							
Area	Species	N	1993	1994	1995	1996	1997	1998	1999	2000
NSA	Gambel Oak	100	1.2[a] P[b]	3.4 M	1.6 P	3.3 M	2.3 P	3.5 M	1.5 P	5.9 E
	Wavyleaf Oak	100	0.6 F	3.3 M	2.4 P	1.9 P	2.3 P	2.8 P	2.4 P	2.0 P
	Combined Oaks	200	0.9 F	3.4 M	2.0 P	2.6 P	2.3 P	3.2 M	1.9 P	4.0 M
	Rocky Mtn. Juniper	100	2.6 M	0.3 F	0.1 F	0.6 F	1.6 P	1.7 P	0.8 F	1.0 F
	One-seed Juniper	100	0.1 F	0.8 F	0.2 F	0.02 F	0.8 F	0.3 F	0.9 F	0.04 F
	Combined Junipers	200	1.4 F	0.5 F	0.1 F	0.3 F	1.2 F	1.1 F	0.9 F	0.5 F
	Pinyon	100	2.4 M	0.5 F	1.2 P	2.2 P	0.3 F	1.4 P	1.8 P	0.4 F
	Chokecherry	40	---	2.9 M	2.4 M	1.6 P	0.6 F	3.9 M	3.1 M	---
SSA	Gambel Oak	100	1.6 F	1.3 F	2.1 P	1.1 F	3.5 M	4.6 G	0.7 F	1.5 F
	Gray Oak	100	2.5 M	1.1 F	4.1 G	0.6 F	1.6 P	4.4 G	0.1 F	0.0 F
	Combined Oaks	200	2.1 P	1.2 F	3.1 M	0.9 F	2.5 P	4.5 G	0.4 F	0.7 F
	Alligator Juniper	100	---	0.5 F	0.5 F	0.5 F	1.8 P	4.6 G	0.5 F	0.4 F
	Utah Juniper	100	---	4.4 G	4.9 G	2.2 P	4.6 G	5.9 E	1.8 P	0.8 F
	Combined Junipers	200	---	2.5 M	2.7 M	1.3 F	3.2 M	5.2 E	1.1 F	0.6 F
	Pinyon	100	1.3 F	0.2 F	1.1 F	0.8 F	0.4 F	3.6 M	0.1 F	0.1 F
	Orange Gooseberry	100	4.4 G	1.7 P	0.2 F	3.3 M	2.2 P	3.6 M	3.4 M	---

[a] Individual plants were visually rated using the following criteria and mean ratings are shown: no visible fruit = 0; fruit visible after very close inspection = 2; fruit readily visible, but not covering entire plant = 4; or fruit readily visible and covering entire plant = 8.

[b] Letters refer to the following relative scale for mast production: F = Failure, P = Poor, M = Moderate, G = Good, or E = Excellent. For each species, annual estimates designated with distinct letters were different based on the Kruskal-Wallis rank sum and Student-Newman-Keuls tests ($P \leq 0.10$).

For the SSA, good regressions with average oak mast were found with either winter El Nino state or average April temperature for 1993-2000 (Table 5-3). Models for 1993-1999 were nearly identical. El Nino and April temperature are strongly negatively correlated (-0.76 for 1993-1999 and –0.80 for 1993-2000), so the 2 models are related. The El Nino model correctly predicts the mast failures in 1996, 1999, and 2000, but not in 1994. The April temperature model correctly predicts the mast failures in 1996 and 2000, but not in 1994 or 1999.

Table 5-3. Regressions predicting average oak mast production from weather parameters for the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1993-2000.

Area	Model	Variable	Coefficient	*t*-value	*Model* R^2	Model *P*
NSA	1-variable	Intercept	12.4215	3.5	0.56	0.03
		Date of last 28°F frost	-0.0844	-2.8		
	2-variable	Intercept	12.1190	3.6	0.67	0.07
		Date of last 28°F frost	-0.0818	-2.8		
		Winter El Nino state	-0.3455	-1.3		
SSA	1-variable	Intercept	1.9250	6.8	0.72	<0.008
		Winter El Nino state	1.2833	3.9		
	1-variable	Intercept	18.3257	3.2	0.58	0.03
		Average April temperature	-0.3325	-2.9		

District Mast Surveys

Combining all genera, mast scores and evaluations were highly correlated (Spearman's *r* = 0.82, *P* < 0.001, *n* = 58), indicating both criteria (Question a*b vs. Question c) produced similar relationships. On the 2 study areas, scores were highly correlated with survey results (Spearman's *r* = 0.0.72, *P* = 0.008, *n* = 12), as were assessments (Spearman's *r* = 0.76, *P* = 0.004, *n* = 12), but scores displayed less variation at the lower levels.

Summarizing data for the 5 mountain regions, mast production was either failure or poor for all genera (Table 5-4). However, a few districts reported moderate and good production of oak and juniper. Some districts also reported moderate pinyon production, but none reported good production.

Phone Survey

Twenty-two NMDGF officers were interviewed in the follow-up phone surveys, but 3 (14%) did not complete mast surveys in their districts. One respondent thought the survey pertained only to an adjacent district; 1

respondent felt there was only marginal bear habitat in his district, therefore a survey was not necessary; and 1 respondent said he did not have time to participate.

Nineteen (86%) of the 21 NMDGF officers interviewed completed mast surveys in their districts. Summary of responses to 6 questions indicated that most respondents (94%) said it was easy to evaluate mast production using the criteria provided, while 1 respondent (5%) said it was moderately difficult. More than half of respondents (67%) said it was easy to evaluate their entire district, while several respondents (28%) said it was moderately difficult, and 1 respondent (6%) said it was difficult.

Similarly, more than half of respondents (64%) did not believe their districts needed to be subdivided for this survey, while several respondents (36%) believed districts should be subdivided. Two NMDGF personnel subdivided their districts by Game Management Unit (GMU) for the mast survey, and several respondents also suggested this option during the phone surveys. One respondent identified 4 separate sections of bear habitat within a district, but said these areas did not correspond with GMU boundaries. One other respondent suggested adding a section on the form for a description of the areas surveyed.

Almost all respondents (95%) said they were able to complete the surveys in the course of their usual duties; only 1 respondent (5%) said he had to devote specific time to the survey, but he added that it was not a large time commitment. All respondents agreed mast survey information is important for bear management, but several respondents voiced concern over how data would be used, or whether the surveys were detailed enough to be useful. All respondents (100%, n = 20) said they would be willing and able to participate in the survey on an annual basis. One respondent suggested the survey period be extended into October, since mast is still available, and officers spend many hours patrolling during that month.

DISCUSSION

Oak production was highly variable on both study areas, especially that of Gambel oak and gray oak. On the NSA, only 1 oak failure was recorded in 8 years of study, however 4 oak failures were recorded on the SSA in the same period. Continuation of mast surveys may allow us to determine if these observed frequencies of oak failure are consistent within the 2 regions of the state. Production was highly variable for Utah and alligator juniper, but was consistently low for Rocky Mountain and one-seed-juniper. If further surveys indicate a consistent trend, the lack of abundant juniper berries throughout northern New Mexico, where Utah and alligator juniper are largely absent, may have important implications for bear population dynamics. According to popular thought, abundant pinyon production occurs only once every 7 years. Results of our surveys concur with that belief, in that there was only 1 year of moderate production on each study area in 8 years. Results of statewide mast surveys showed, in most areas, mast production was relatively low in both 1999 and 2000.

The variables correlated with oak production were temperature and El Nino winter state, suggesting that a combination of moisture and temperature conditions for the winter and spring influence mast conditions in the following fall. Each of the oaks surveyed were species that flower and fruit within the same year, and we observed oak flowering from mid May-early June. Models for the NSA and SSA used different variables, and no useful relationship was found that applied to both areas. All of the models failed to predict at least 1 mast failure year; none predicted mast failure when no failure was observed.

MANAGEMENT IMPLICATIONS

Environmental cues did not provide a prediction of mast conditions adequate for bear management needs. Results of simplified surveys conducted by NMDGF officers were highly correlated with our more intensive survey results, indicating subjective criteria were adequate to distinguish variation in mast production. Results were most consistent with a score of relative numbers of fruit/plant and relative numbers of plants bearing fruit. Most officers indicated the criteria were reasonably easy to use and said they were able to complete the surveys in the course of their usual duties. Although most NMDGF officers were comfortable making assessments for their entire districts, others felt subdivision of their district into sections or Game Management Units made the assessments more realistic. Quality assessments of regional mast production will always be improved with higher sample sizes, therefore subdivision of districts may be preferable to district-wide surveys.

Table 5-4. Results of mast production surveys conducted by New Mexico Department of Game and Fish District Officers, New Mexico, 1999-2000[a].

		1999			2000		
Genera	Region / District	a*b	c	Rating	a*b	c	Ratings
Oak	San Juan complex						
	Aztec				4	3	P
	Chama				8	4	M
	Jemez Springs	2	1	F			
	Navajo Dam	1	1	F			
	Tres Piedras (GMU 51)	4	3	P			
	Tres Piedras (GMU 52)	12	4	G			
		4.8	**2.4**	**P**	**6.0**	**3.5**	**P**
	Sangre de Cristo						
	Cimarron	4	3	P	12	4	G
	Mora	4	3	P	4	3	P
	Pecos				1	2	F
	Penasco	1	2	F	1	2	F
	Raton	1	2	F	9	4	M
	Santa Fe	2	2	F			
		2.4	**2.4**	**F**	**5.4**	**3.0**	**P**
	Central						
	Belen	1	1	F	1	2	F
	Gallup	3	2	F	3	2	F
	Grants				1	2	F
	Grants (GMU 9)	9	4	M			
	Grants (GMU 10)	2	2	F			
	Grants (GMU 13)	3	3	F			
	Moriarty	1	2	F			
		2.8	**2.1**	**F**	**1.7**	**2**	**F**
	Gila complex						
	Quemado	1	2	F			
	Reserve	1	2	F	1.5	2	F
	Silver City	1	2	F	1	2	F
	Socorro				6	2	P
	T or C	1	2	F	4	3	P
		1.0	**2.0**	**F**	**3.1**	**2.3**	**F**
	Southeast						
	Alamagordo	3	2	F	1	2	F
	Carlsbad	1	1	F			
	Mayhill				9	4	M
	Mountainaire				2	2	F
	Ruidoso	4	3	P			
		2.7	**2.0**	**F**	**4.0**	**2.7**	**P**
Juniper	San Juan complex						
	Aztec				9	4	M
	Chama				4	3	P
	Jemez Springs	2.5	1	F			
	Navajo Dam	1	2	F			
	Tres Piedras (GMU 51)	4	3	P			
	Tres Piedras (GMU 52)	9	4	M			
		4.1	**2.5**	**P**	**6.5**	**3.5**	**P**
	Sangre de Cristo						
	Cimarron	4	3	P	2	2	F
	Mora	4	3	P	6	3	P
	Pecos				1	2	F

		1999			2000		
Genera	Region / District	a*b	c	Rating	a*b	c	Ratings
	Penasco	12	4	G	4	2	P
	Raton	1	2	F	6	3	P
	Santa Fe	12	4	G			
		6.6	**3.2**	**P**	**3.8**	**2.4**	**P**
	Central						
	Belen	1	2	F	1	2	F
	Gallup	4	2	P	10	4	M
	Grants				4	3	P
	Grants (GMU 9)	4	3	P			
	Grants (GMU 10)	3	2	F			
	Grants (GMU 13)	3	2	F			
	Moriarty	2	3	F			
		2.8	**2.5**	**F**	**5.0**	**3.0**	**P**
	Gila complex						
	Quemado	1	2	F			
	Reserve	4	2	P	1.5	1	F
	Silver City	4	3	P	9	4	M
	Socorro				1	1	F
	T or C	4	3	P	2	2	F
		3.2	**2.5**	**F**	**3.4**	**2.0**	**F**
	Southeast						
	Alamagordo	1	1	F	1	1	F
	Carlsbad	3	3	F			
	Mayhill				9	4	M
	Mountainaire				6	3	P
	Ruidoso	6	3	P			
		3.3	**2.3**	**F**	**5.3**	**2.7**	**P**
Pinyon	San Juan complex						
	Aztec				4	3	P
	Chama				4	3	P
	Jemez Springs	2	1	F			
	Navajo Dam	6	3	P			
	Tres Piedras (GMU 51)	4	3	P			
	Tres Piedras (GMU 52)	9	4	M			
		5.3	**2.8**	**P**	**4.0**	**3.0**	**P**
	Sangre de Cristo						
	Cimarron	6	3	P	1	2	F
	Mora	3	3	F	2	2	F
	Pecos				1	1	F
	Penasco	1	2	F	1	2	F
	Raton	1	2	F	2	2	F
	Santa Fe	4.5	3	P			
		3.1	**2.6**	**F**	**1.4**	**1.8**	**F**
	Central						
	Belen	4	3	P	1	1	F
	Gallup	6	4	P	6	3	P
	Grants				1	1	F
	Grants (GMU 9)	9	4	M			
	Grants (GMU 10)	6	3	P			
	Grants (GMU 13)	9	4	M			
	Moriarty	4	3	P			
		6.3	**3.5**	**P**	**2.7**	**1.6**	**F**
	Gila complex						

		1999			2000		
Genera	Region / District	a*b	c	Rating	a*b	c	Ratings
	Quemado	1	2	F			
	Reserve	1	2	F	1	1	F
	Silver City	1	2	F	9	4	M
	Socorro				1	1	F
	T or C	1	2	F	1	2	F
		1.0	**2.0**	**F**	**3.0**	**2.0**	**F**
	Southeast						
	Alamagordo	1	1	F	1	1	F
	Carlsbad	1	1	F			
	Mayhill				9	4	M
	Mountainaire				4	3	P
	Ruidoso	6	3	P			
		2.7	**1.7**	**F**	**4.7**	**2.7**	**P**

[a] Officers assessed production of oak, juniper, and pinyon production using the following subjective criteria: mean number of fruit/plant on a scale of 1-4 (a), percent of plants bearing fruit on a scale of 1-4 (b), and overall production on a scale of 1-5 (c). Scores (a*b) were highly correlated with more intensive surveys conducted concurrently (Spearman's *r* = 0.0.72, *P* = 0.008, *n* = 12), and ratings were calculated using the equation of the line. Letters refer to the following relative scale for mast production: F = Failure, P = Poor, M = Moderate, G = Good, or E = Excellent.

CHAPTER 6

REPRODUCTION AND CUB SURVIVAL

Maintenance and growth of wildlife populations are closely tied to reproductive output. Collectively, bear species exhibit some of the lowest reproductive rates among terrestrial mammals (Bunnell and Tait 1981). In many previous bear studies, a positive correlation between food abundance and black bear reproduction has been reported, based on annual variability in foods (Jonkel and Cowan 1971, Rogers 1976, Eiler et al. 1989, Elowe and Dodge 1989, McLaughlin et al. 1994, Miller 1994), geographic variability in foods (Schwartz and Franzmann 1991, McLaughlin et al. 1994, Miller 1994), and differential feeding behaviors among bears (Rogers 1976, Elowe and Dodge 1989). Reproductive success also has been linked to female nutritional condition (Kolenosky 1990, Noyce and Garshelis 1994, Samson and Huot 1995). Understanding the reproductive rates of black bears in New Mexico, as well as the factors that influence success, is important for monitoring population trend. On an annual basis, collection of actual data on bear reproduction would probably be labor-intensive and cost-prohibitive. However, documentation of annual variation in food abundance may serve as an index to bear reproductive success.

We investigated black bear reproductive success on the 2 New Mexico study areas during 1993-2000. Our objectives were to (1) document black bear reproductive parameters, including age of primiparity, natality, cub survival, recruitment, and litter interval; and (2) investigate relationships between mast production and reproductive parameters.

METHODS

Data on natality, litter size, and recruitment were collected during annual den investigations of radio-collared bears. We visited dens of adult females each year to ascertain their reproductive status. Dens of 2- or 3-year-old bears were visited annually or biannually to change or refit collars as necessary. We obtained cub survival data by revisiting dens of females whose cubs were handled or observed the previous year. Cubs were assumed to have died if they were absent from the den as yearlings, or if their mother died prior to 1 July in their birth year. Cubs whose mother died after 1 July and cubs whose fate was unknown (due to mother shedding collars, lost signals, inaccessible dens, etc.) were excluded from analyses.

We estimated mean age when the first litter is produced (age of primiparity) by constructing a cumulative table of ages for bears that had never give birth versus ages of bears when they first produced cubs.(Garshelis et al. 1998). The minimum age of primiparity was judged to be 4 years old, because no 1-, 2-, or 3-year-old bear was observed with cubs in the den (*n* = 76), and no

1- or 2-year-old bear was observed in estrus when captured between May and September (*n* = 21). We constructed the cumulative table by first including all bears whose reproductive status was verified during annual den investigations beginning at age 4 (*n* = 36). We also included females captured at age 4, whose reproductive status was judged from teat measurements, weight, lactation, or observation of cubs (*n* = 11). Among females captured at age 5, we included bears judged to never have given birth from teat measurements and weight, but entered them into the table only for later den investigations (*n* = 2). To backdate them to age 4 or include them for the year of capture would bias the sample against bears captured with their first cubs, because we could not distinguish first litters from subsequent litters for bears captured at ages >4 years. We used the same procedure to estimate mean age of primiparity relative to mast production during the previous fall (year-1).

We tested for variation in reproductive success relative to mast production using Mann-Whitney (MW), Kruskal-Wallis (KW), Chi-square, and Student-Newman-Keuls (SNK) tests. We report specific p-values associated with any differences declared. Annual reproductive events for the same female were treated as independent observations, as were offspring from the same female. When possible, we separated females into distinct subsets to lessen effects of any potential lack of independence. Variation in reproductive parameters was investigated relative to mast production during the previous fall (year-1) and relative to fall mast production 2 years previous (year-2). Mast production categories included combined oaks, combined junipers, pinyon, and softmast (chokecherry or gooseberry).

To construct a sample for estimating mean litter interval, we first included all bears whose interval was verified during annual den investigations (*n* = 63). We also included females whose interval was known from observation of offspring at capture (*n* = 2), and bears whose incomplete interval was known to be at least 3 years (*n* = 7). We included these latter bears in the analyses because long intervals were more difficult to document than short intervals. Reproductive status must be documented for at least 3 consecutive years to document a successful 3-year interval and at least 4 years for an unsuccessful 3-year interval. During this study, reproductive status was documented <3 times for 38% of individual bears (*n* = 64), reducing the likelihood of documenting longer intervals.

RESULTS

Age of First Birth

Age at birth of first litter was documented for 31 bears between 1992 and 2000, and mean age from this sample was 5.5 years. However, age(s) prior to primiparity were documented for another 18 bears aged 4-6. Ultimate age of primiparity was not documented among this sample because of collar removals at the end of the study (n = 6), collar removal due to a wound (n = 1), mortalities (n = 4), shed transmitters (n = 4), and lost signals (n = 3).

Among bears observed at each age that had not produced litters previously, only 9% of 4-year-old bears produced their first litters, while 40% of 5-year-olds, 67% of 6-year-olds, 75% of 7-year-olds, and 100% of 9-year-olds produced their first litters (Table 6-1). Proportions differed among ages (X^2 = 27.1, df = 5, P < 0.001, n = 97), with 4-year-old females having the most significant residual. When this age was excluded, proportions did not differ among other ages (X^2 P= 0.21, n = 51). Proportions did not differ between study areas within any age (X $P \geq$ 0.47). Accounting for the proportion of previously non-reproductive bears in the population at each age, analysis indicated 9% of bears produced their first litter at age 4, 37% at age 5, 36% at age 6, 14% at age 7, and 5% at age 9. The mean age of primiparity calculated from these percentages was 5.7 years. Mean age of primiparity was 5.8 years on the NSA and 5.7 years on the SSA. Although age of primiparity varied by 5 years among the entire sample, analyses indicated most bears (73%) produced their first litter either at age 5 or 6.

Table 6-1. Observed percent of previously non-reproductive female black bears (by age) that produced first litters, on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1992-2000.

	Age (years)[a]						Mean
Area	4	5	6	7	8	9	age
NSA							
n	28	19	8	3	1	1	
% of *n* with first litters	11	37	63	67	0	100	
Cumulative % with first litter	11	44	79	93	93	100	
Incremental % with first litter	11	33	35	14	0	7	5.8
SSA							
n	19	11	6	1			
Percent of *n* with first litters	5	46	67	100			
Cumulative % with first litter	5	48	83	100			
Incremental % with first litter	5	43	40	17			5.6
Combined							
n	47	30	14	4	1	1	
Percent of *n* with first litters	9	40	64	75	0	100	
Cumulative % with first litter	9	45	80	95	95	100	
Incremental % with first litter	9	36	35	15	0	5	5.8

[a] Proportions of previously non-reproductive bears that produced first litters were different among ages (P < 0.001), but were not different within ages between study areas (P > 0.45). Mean age at birth of first litter was calculated using incremental percentages.

Mean age of primiparity appeared to differ by oak production during the previous fall, however mean testing was not possible using this method. Mean age of primiparity following oak failure was 6.3 years. Mean age of primiparity following poor, moderate, and good oak production was 5.7 years, 5.7 years, and 5.8 years, respectively.

Natality

Between 1993 and 2000, reproductive data were obtained during 268 den investigations of 80 female bears aged 4-27 years. We estimated natality (cub production) using observations from all females. In addition, we separated the sample into 2 categories: non-reproductive females (those never having produced cubs prior to the current observation) and eligible reproductive females (those having produced cubs prior to the current observation). We considered all bears unaccompanied by yearlings "eligible" for cub production.

Overall natality of female bears ≥4 years old was 0.77 cubs/female/year and parturition rate (percent of females with cubs) was 43% ($n = 268$). Overall there was no difference (0.85 vs. 0.67, MW, $Z = -1.4$, $P = 0.15$) in natality on the NSA versus the SSA (Table 6-2). Parturition rate also did not differ by study area (X^2 $P = 0.32$). Among previously non-reproductive females, natality was 0.53 cubs/female/year and parturition rate was 33% ($n = 87$). Neither rate differed by study area (MW $P = 1.0$, X^2 $P = 0.81$). Among previously reproductive females, natality was 1.4 cubs/female/year and parturition rate was 77% ($n = 112$). Natality among these female bears was higher on the NSA (1.6 vs. 1.2, MW, $Z = -2.3$, $P = 0.02$), as was parturition rate (62% vs. 37%, $X^2 = 4.8$, df = 1, $P = 0.04$).

Table 6-2. Natality and recruitment of female black bears determined from den investigations on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1993-2000. Females were considered eligible for cub production if unaccompanied by yearlings in the den. Rates denoted by asterisks differed from others by reproductive history or study area ($P \leq 0.15$).

Area/	Natality (all females)			Natality (eligible females)			Recruitment (all females)		
Category of female	*n*	Rate[a]	%[b]	*n*	Rate[a]	%[b]	*n*	Rate[c]	%[d]
NSA	155	0.9	46	118	1.1*	60	133	0.4	27
SSA	112	0.7	39	85	0.9	52	98	0.4	27
Combined	267	0.8	43	203	1.0	57	231	0.4	27
Previously non-reproductive	45	1.0	64	35	1.3*	83	42	0.3	21
Previously reproductive	153	1.0	56	101	1.6	85	152	0.5	34

[a] No. cubs/female/year
[b] Percent of females with cubs
[c] No. yearlings/female/year
[d] Percent of females with yearlings

Within all categories of females, natality and parturition rate were positively associated with oak production during the previous year (Table 6-3). For all females and for reproductive females, natality was lower in years following acorn failures than all other years (KW $P < 0.001$, SNK $P = 0.05$), as was parturition rate (X^2 $P < 0.001$). Neither natality nor parturition rate differed relative to poor, moderate, or good oak production during the previous fall (KW $P \geq 0.37$, X^2 $P \geq 0.23$). Among previously non-reproductive females, natality varied by oak production (KW $P = 0.08$), however no distinct subsets were identified (SNK $P > 0.15$). Parturition rate was positively associated with oak production (X^2 $P = 0.10$), with the lowest rate associated with oak failure. However, among the previously non-reproductive females, strength of the test was limited by an age bias in the sample. Of the 18 previously non-reproductive females observed following oak failure, 13 (72%) were 4-year-olds, and 5 (28%) were aged 5 or 6. Following poor, moderate, and good oak production, 4-year-old females comprised 29% ($n = 45$), 40% ($n = 15$), and 0% ($n = 7$) of the sample, respectively. When 4-year-old bears were analyzed alone, natality was positively but weakly associated with oak production. Natality was 0.2 cubs/female/year following moderate oak production, but 0.0 following oak failure and poor production (KW, $X^2 = 4.3$, $P = 0.12$, $n = 32$, SNK $P = 0.15$). Parturition rate was higher following moderate oak production (0% vs. 17%, $X^2 = 4.4$, $P = 0.11$, $n = 32$). When non-reproductive bears >4 years old were examined, neither natality nor parturition rate varied significantly by oak production during the previous fall (KW $P \geq 0.77$, X^2 $P = 0.91$). Within all categories of females, neither natality nor parturition rate was positively associated with juniper, pinyon, or softmast production during the previous year.

In years following oak failures, natality was lowest when the failure was preceded by poor oak production, among all females and among eligible reproductive females (KW $P \leq 0.09$, SNK $P = 0.05$). When the failure was preceded by moderate or good oak production, 73% of eligible reproductive females produced cubs. However, none produced cubs when the failure was preceded by a poor oak crop ($X^2 = 10.0$, df = 2, $P = 0.007$, $n = 19$). This association was possibly observed for juniper production. During 1993, no juniper survey was completed on the SSA. However, scat analysis and bear weight data indicated juniper production was relatively low. If we assume a juniper failure, or even a poor juniper crop occurred in that year, then natality was positively associated with juniper production during the fall 2 years previous. However, the low oak and juniper production, prior to oak failure, occurred simultaneously, therefore it was not possible to ascertain which genera exerted more of an influence on natality.

Litter Size

A total of 115 litters were handled or observed in dens during 1993 - 2000. Litter size ranged from 1-3 cubs and mean litter size was 1.8 cubs (Table 6-4). Two-cub litters were most common (71%), followed by 1-cub litters (24%).

Three-cub litters were rare, accounting for only 5% of observations. Mean litter size on the NSA (1.9) did not differ ($Z = -1.6$, $P = 0.11$) from that on the SSA (1.7). Observed frequencies of 1-, 2-, and 3-cub litters did not differ by study area ($X^2 = 2.6$, df = 2, $P = 0.27$).

Table 6-3. Black bear reproductive parameters associated with variable oak production on 2 New Mexico study areas, 1993-2000. Natality (cubs/female/year) and parturition rates (percent of females with cubs) were analyzed relative to oak production during the previous fall (year-1). Following oak failure, rates were also analyzed relative to fall oak production 2 years previous (year-2). Recruitment rate (yearlings/female/year) and percent of females with yearlings were analyzed relative to fall oak production 2 years previous (year-2). Asterisks indicate distinct subsets differing from other observations within the category, with corresponding *P*-values provided.

Parameter /	Observations	Mast		Oak production rating[a]				KW[b]	SNK[c]	X^2
Category of females	included	year	*n*	F	P	M	G	*P*	*P*	*P*
Natality										
All (age $\geq$ 4)	All	Year – 1	262	0.3 *	0.9	1.0	0.7	<0.001	0.05	
	Year-1 = F	Year – 2	52		0 *	0.4	0.5	0.09	0.15	
Previously non-reproductive	All	Year – 1	85	0.1	0.6	0.5	0.9	0.08		
Eligible[d] reproductive	All	Year – 1	108	0.7 *	1.6	1.6	2.0	<0.001	0.05	
	Year-1 = F	Year – 2	19		0 *	1.5	1.3	0.01	0.05	
Percent with Cubs										
All (age $\geq$ 4)	All	Year – 1	262	16 *	47	59	40			<0.001
	Year-1 = F	Year – 2	52		0 *	20	32			0.08
Previously non-reproductive	All	Year – 1	85	11	38	33	57			0.10
Eligible reproductive	All	Year – 1	108	35 *	84	90	100			<0.001
	Year-1 = F	Year – 2	19		0 *	75	72			0.007
Recruitment										
All (age $\geq$ 5)	All	Year – 2	214	0.1 *	0.4	0.6	0.6	0.003	0.10	
Reproductive	All	Year – 2	157	0.2 *	0.6	0.7	0.7	0.009	0.05	
Percent with Yearlings										
All (age $\geq$ 5)	All	Year – 2	214	7 *	28	42	38			0.001
Reproductive	All	Year – 2	157	10 *	40	51	46			0.003

[a] F = Failure, P = Poor, M = Moderate, G = Good

[b] Kruskal-Wallis test

[c] Student-Newman-Keuls test

[d] Females were considered eligible for cub production if unaccompanied by yearlings in the den.

First litters were smaller than subsequent litters (1.6 vs. 1.9, $Z = -2.7$, $P = 0.008$, $n = 115$) and frequencies of 1-, 2-, and 3-cub litters also varied ($X^2 = 7.18$, df = 2, $P = 0.03$). Specifically, frequency of 1-cub litters was higher among first litters than among subsequent litters. Litter size did not vary by mast production of any species among all litters, first litters, or subsequent litters (KW $P \geq 0.24$).

Table 6-4. Size (range, mean, and relative frequency) of black bear litters observed on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1992-2001.

		Range	Mean[a]	Relative frequency[a]		
Area/Litter order	n	(cubs/litter)	(cubs/litter)	1-cub	2-cub	3-cub
NSA	71	1 – 3	1.9	20%	75%	5%
SSA	44	1 – 3	1.7	32%	66%	2%
Combined	115	1 – 3	1.8	25%	71%	4%
First litters	29	1 – 2	1.6**	41%**	59%	
Subsequent litters	86	1 – 3	1.9**	19%**	76%	6%

[a] Means and frequencies denoted by asterisks were different by litter order ($P < 0.10$).

Cub Survival

Cub survival was documented for 148 individual cubs from 82 litters handled or observed in dens between 1993 and 2000. Overall cub survival rate was 0.55, and observed rates did not differ by study area (X^2 $P = 0.22$) or sex (X^2 $P = 0.30$). Among litters observed, 45% experienced no mortality, 20% experienced partial mortality, and 35% were completely lost. Observed frequencies of litter fate did not differ by study area (X^2 $P = 0.53$).

Cub survival was lower among first litters than subsequent litters (38% vs. 60%, $X^2 = 4.9$, df = 1, $P = 0.03$, $n = 148$). Similarly, frequency of whole litter loss was higher among first litters than subsequent litters (57% vs. 30%, $X^2 = 5.7$, df = 2, $P = 0.06$, $n = 84$). Based on these findings, cubs were separated into these 2 categories for further analyses.

Among all litters and first litters, cub survival varied positively with juniper and pinyon production during the previous fall (X^2 $P \geq 0.10$), but no differences were found among subsequent litters (X^2 $P \geq 0.34$). The most significant residual corresponded to 100% cub survival ($n = 5$) observed in 1999, following the single most outstanding year of juniper, pinyon, and oak production on the SSA. Cub survival within the cohort born following 1998 was higher than within the combined cohorts born following years of lower production (100% vs. 56%, $X^2 = 3.9$, df = 1, $P = 0.07$, $n = 133$). When this cohort was excluded from analyses, cub survival no longer differed by juniper or pinyon production during the previous fall (X^2 $P \geq 0.55$). Instead, cub survival appeared to be weakly associated with oak production during the birth year (X^2 $P \geq 0.14$). The most significant residual was associated with cohorts born during years of oak failure. Their survival rate was lower than the rate observed for cohorts born during years of poor to good oak production (33% vs. 57%, $X^2 = 3.1$, df = 1, $P = 0.08$, $n = 136$). The association of low cub survival and oak failure during the birth year was masked when the 1999 cohort was included in analyses. Although this cohort was born during a year of oak failure, it experienced 100% survival, possibly owing to the super abundance of food produced in 1998. Field observations indicated mast of oak, pinyon, and especially juniper remained available long into the spring and summer of 1999, perhaps compensating for the lack of new production.

To account for the interacting effects of mast production during the previous fall and mast production during the birth year, we produced mast indices combining genera over the 2 periods. Cub survival was most significantly associated with an index of juniper production (during the previous fall) and oak production (during the birth year). For these analyses, we presumed juniper failure on the SSA during 1993 (as described above). Low cub survival was associated with mast failure by oak and juniper; intermediate cub survival was associated with poor to moderate production by oak and/or juniper; and high cub survival was associated with good to excellent production by oak and/or juniper. These patterns in survival were observed among all litters (13% vs. 54% vs. 76%, $X^2 = 9.7$, df = 2, $P = 0.008$, $n = 138$) and among subsequent litters (13% vs. 60% vs. 83%, $X^2 = 10.1$, df = 2, $P = 0.006$, $n = 108$). Among first litters, no cubs were born in years when both genera failed, however, higher cub survival was associated with good to excellent production (29% vs. 67%, $X^2 = 3.8$, df = 2, $P = 0.10$, $n = 30$).

Cub survival varied annually on the SSA within all categories (X^2 $P \leq 0.08$). On the NSA, cub survival did not vary annually within any category (X^2 $P \geq 0.13$). The uniform cub survival observed on the NSA was associated with consistent poor to moderate combined mast production. The variable cub survival on the SSA (13% vs. 63% vs. 76%, $X^2 = 9.9$, df = 2, $P = 0.007$, $n = 48$) was positively associated with all 3 levels of mast production. When all observations from the NSA were compared to the SSA observations associated with poor to moderate mast production, no difference was found in the cub survival rate ($P = 0.45$).

Cause of death was rarely documented among cubs, because they were not fitted with radio-transmitters. However, cause of death was documented for 8 cubs, all on the NSA. Two sibling female cubs were killed in August 1993 by an automobile when they attempted to cross a 2-lane highway in Ute Park, adjacent to a campground. These cubs, as well as their mother, frequently obtained food from visitors to the campground and from unsecured garbage containers. In February 1997, a dead female cub was found at the entrance of her den. Her mother and female sibling were hibernating within the den. The position and condition of the carcass indicated she had died at least 6 weeks prior to our discovery and that she had been dragged from the den chamber (probably by her mother). Examination of the carcass indicated a broken pelvis, suggesting she may have died from internal injuries, but cause of the injuries was unknown. This family resided in a part of the study area characterized by very steep slopes adjacent to a 2-lane highway, therefore the injuries may have been sustained in a fall or an automobile collision. Five cubs in 2 litters presumably died from predation, along with their mothers. Although no cub remains were found, evidence indicated their mothers had been killed by predators, possibly bears. The first incident occurred in May 1995 and the second incident occurred in April 1999.

Recruitment

We estimated recruitment using observations from all females ≥5 years old and observations of reproductive females only. Overall recruitment of females ≥5 years old was 0.40 yearlings/female/year and 27% of 232 females were accompanied by yearlings in the den. Rates did not differ by study area (MW $P \geq 0.78$, Table 6-2). Recruitment of previously reproductive females was 0.53 yearlings/female/year and percent of females with yearlings was 35% (n = 175). These rates did not differ by study area either (MW $P \geq 0.79$).

Within both categories, recruitment was positively associated with fall oak production 2 years previous (KW $P \leq 0.09$, SNK $P \leq 0.10$). Specifically, recruitment was lower 2 years after oak failures than all other years (Table 6-3). Percent of females with yearling also was lower 2 years after oak failures than all other years ($P \leq 0.003$). Neither rate differed relative to poor, moderate, or good oak production 2 years previous ($P \geq 0.43$), nor did they differ by production of juniper, pinyon, or softmast production 2 years prior ($P \geq 0.49$).

Litter Interval

We documented 65 complete litter intervals and 7 incomplete intervals known to be at least 3 years, occurring between 1992 and 2001 (Table 6-5). Incomplete intervals ranged from 3-5 years. However 3 of the 7 incomplete intervals (two 3-year intervals and one 5-year interval) were documented for bears believed to have reached reproductive senescence at 16, 24, and 25 years of age, respectively. Because it was likely these bears would not complete the intervals, these 3 observations were excluded from analyses. In fact, the diseased 16-year-old female did not survive to complete her interval.

Observed litter interval ranged from 1-3 years. One-year intervals occurred when entire litters were lost and bears bred again. Two- and 3-year intervals occurred both when litters were lost and cubs survived, but 3-year intervals included an additional year when the bear failed to produce a litter. Mean litter interval was 1.8 years and it was slightly lower on the NSA than the SSA (1.7 vs. 1.9, $Z = -1.7$, P = 0.09, n = 69). However, relative frequencies of 1-, 2-, and 3-year intervals were not different between study areas (X^2 $P = 0.15$). Unsuccessful intervals (when entire litters were lost) ranged from 1-3 years with a mean of 1.3 years (n = 27). For unsuccessful intervals, neither mean interval nor frequencies of 1-, 2-, and 3-year intervals differed by study area (X^2 $P >$ 0.44). Successful intervals (when some or all cubs survived) ranged from 2-3 years with a mean of 2.1 years (n = 42). Among successful intervals, frequency of 3-year intervals was lower on the NSA (X^2 $P = 0.07$), resulting in a lower mean successful interval (2.0 vs. 2.2, $Z = -1.9$, $P = 0.05$).

Table 6-5. Ranges, means, and relative frequencies of black bear litter intervals observed on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1992-2001.

		Range	Mean[a]	Relative frequency[a]		
Interval type/Area	*n*	(years)	(years)	1-year	2-year	3-year
All intervals						
NSA	44	1 - 3	1.7*	34%	61%	5%
SSA	25	1 - 3	2.0*	20%	64%	16%
Combined	69	1 - 3	1.8	29%	62%	9%
Successful intervals						
NSA	25	2 - 3	2.0*		96%*	4%*
SSA	17	2 - 2	2.2*		77%*	23%*
Combined	42	2 - 3	2.1		88%	12%
Unsuccessful intervals						
NSA	19	1 - 3	1.3	79%	16%	5%
SSA	8	1 - 2	1.4	63%	37%	
Combined	27	1 - 3	1.3	74%	22%	4%

[a] Means and frequencies denoted by asterisks were different by study area (X^2 $P < 0.10$).

Within unsuccessful 2- and 3-year intervals, and within successful 3-year intervals, bears failed to produce cubs at 1 or 2 reproductive opportunities. We observed 14 failed reproductive opportunities, and 71% coincided with oak failures during the previous fall, while 29% coincided with poor to good oak production. Conversely, within 1-year intervals and successful 2-year intervals, bears reproduced at the first reproductive opportunity. We observed 52 successful reproductive opportunities, and only 14% coincided with oak failures, while 84% coincided with poor to good oak production. These observed ratios of failed to successful opportunities varied by oak production ($X^2 = 19.8$, df = 3, $P < 0.001$, $n = 66$).

DISCUSSION

The influence of mast production on age of first production of cubs was not entirely clear. Mean age of first litter appeared to increase in years following oak failure. However, production of first litters did not appear to decline, except among 4-year-old bears. This result was possibly due to the small sample size of previously non-reproductive bears aged >4 years observed during years following oak failure. Among females that had produced multiple litters, a higher frequency of skipped reproductive opportunities occurred following oak failure. Therefore, it would be expected that reproduction of potential first litters would also decline. However, production of first litters may not be determined solely by mast production during the previous year. Instead, a bear's ability to produce her first litter may be influenced by mast production throughout her developing years. Noyce and Garshelis (1994) postulated age at birth of first litter may be more closely tied to cub growth rates and hence the condition of the mother. The more important influence of mast production may be the onset of first estrus. Of 3-year-old females handled between May and September (*n* = 18), only 11% showed signs of estrus, indicating most 4-year-old bears would not reproduce regardless of mast abundance. Even among non-reproductive bears aged 4-6 (*n* = 14), only 43% handled during the mating season appeared to be in estrus.

The influence of oak production, especially acorn failures, on bear reproductive success appeared to be strong. Natality, and subsequently recruitment, was reduced by more than 50% following years of oak failure. Rates were reduced to zero when oak failure was preceded by poor oak production. Availability of hard mast has been tied to reproductive success in several regions (Eiler et al. 1989, Elowe and Dodge 1989, McLaughlin et al. 1994). Neither natality nor recruitment varied following poor, moderate, or even good oak production. Following poor to good production, 94% of eligible reproductively experienced females produced cubs, and no increase in litter size was observed when oak production was high. This suggests only a minimum threshold of high quality food is needed for successful reproduction.

Juniper production possibly had a secondary effect on natality, when oak production failed. Natality rates were zero when oak failure was preceded by poor juniper production. However this poor juniper production coincided with poor oak production, making it impossible to ascertain which genera may have exerted the greater influence on natality. Given the primary effect oak had on reproductive success, it is probable that oak also exerted the greater secondary effect.

Juniper production probably had more of an impact on cub survival than natality. From our observations, juniper berries began to ripen from September to October and remained on the tree through late fall. Berries began to drop during winter and early spring. We observed consumption of significant quantities of juniper berries by bears during fall, spring, and summer (unpublished data). Therefore, more than any other mast genera, juniper could continue to affect the nutritional condition of bears and their cubs long after emergence from the den. Comparing study areas, consumption of juniper berries appeared to be related to production. Juniper production failed each year on the NSA, and only limited consumption of juniper berries was observed, primarily during late fall. The lack of this important spring food, combined with no occurrence of good or excellent fall oak production, resulted in consistent, but low cub survival on the NSA. On the contrary, juniper production varied greatly on the SSA, with crops ranging from failure to excellent. Juniper berries were a significant food item in the spring and summer diets of bears on this area (see Chapter 5). The variable cub survival observed on the SSA was associated with varied levels of juniper and oak production.

No positive association was found between pinyon production and reproductive success. On each study area, pinyon production was better than poor during only 1 year. Unfortunately, on the SSA, the moderate pinyon crop coincided with a good oak crop and an excellent juniper crop in 1998. These simultaneous events did not allow us to assess the effect of pinyon alone on reproductive success. On the NSA, moderate pinyon production occurred in 1993, when both oak and juniper production failed. Nonetheless, natality and recruitment was zero following this production, indicating a moderate supply of pinyon nuts did not compensate for the lack of acorn production. This result may be due to the timing of availability. Pinyon cones mature and open approximately 6 to 8 weeks after the ripening of acorns, possibly limiting the foraging opportunities of bears readying for hibernation. More study is needed to determine the influence of pinyon production on bear reproduction, especially in the absence of other foods.

Production of chokecherries and gooseberries did not appear to influence reproductive success. Compared to the other species surveyed, these soft mast species were more limited in distribution, and were probably available to only a fraction of the bear population. Analyses of foraging habits indicated these species also accounted for <10% of scat volume during the fall (see Chapter 5).

In their study comparing body condition to reproductive success, Noyce and Garshelis (1994) concluded black bears respond to declining nutrition by modifying reproductive performance in the following sequence: (1) litter size, (2) age of primiparity, (3) cub survival, and (4) litter frequency. Our analyses indicated the sequence may be exactly opposite in New Mexico. The greatest influence of mast failure on bears in New Mexico appeared to be a reduction in the number of females producing litters, hence an increase in litter interval. Second, cub survival appeared to decline associated with mast availability. Third, mast failure was associated with a decrease in the percent of bears producing first litters and a resulting increase in the age of primiparity. Litter size did not appear to be associated with availability of mast, among first litters or subsequent litters.

MANAGEMENT IMPLICATIONS

Documenting annual mast production, particularly occurrence and frequency of mast failures, may be an effective tool for monitoring black bear reproductive success in New Mexico. Continuation of the statewide mast surveys, as conducted by NMDGF officers during 1999-2000 (see Chapter 5), will provide valuable data for all regions of bear habitat. These data will be useful for analyzing population trend and interpreting harvest data with the bear population model.

Chapter 7

SURVIVAL RATES AND CAUSES OF MORTALITY

As in many states, the primary foundation for black bear management in New Mexico is information obtained from hunter-killed bears. Fluctuations in the sex and age composition of kills are seen as signals of changing population trends. However, trends in kill data can sometimes be misleading (Garshelis 1991). Therefore, interpretation of kill data is often aided by supporting information about bear population characteristics, especially survival rates, and associated cause-specific mortality rates.

We investigated black bear survival on 2 New Mexico study areas. To better understand the effects of hunting on black bears, a hunting closure was instituted on 1 study area that remained in effect from 1992-1997. Our objective was to document survival and cause-specific mortality rates by sex and age category.

METHODS

We estimated adult (≥5 years old), subadult (2-4 years old), and yearling (1 year old) survival rates using data from bears equipped with radio-transmitters. We monitored radio-collared bears from fixed-wing aircraft on a 14-day schedule during the active season (weather permitting). Radio-collars were constructed to emit a "mortality" signal when they remained stationary for more than 2 hours. We ground-tracked all collars emitting a mortality signal to determine whether the signal was a mortality or a dropped collar. We determined approximate date and cause of mortality (when possible).

Hunting mortalities of marked bears were recorded through the New Mexico Department of Game and Fish (NMDGF) mandatory pelt tag program. Personnel of the Colorado Division of Wildlife (CDOW) and the Arizona Department of Game and Fish (ADGF) also reported hunting mortalities. Depredation mortalities and relocations of marked bears were reported by the NMDGF and the CDOW.

Survival rates were calculated using the staggered entry method (Pollock et al. 1989). Rates were estimated separately for each study area by year, within 26 quarter-monthly intervals from May 1 – November 15. Mortality rates for specific causes of death were calculated as 1– survival rate estimated with deaths from other causes treated as censors. Annual rates over 1993-1999 were averaged with years weighted equally; annual confidence intervals were pooled (N.S. Urquhart, personal communication.)

We used data from all bears with working transmitters monitored for ≥1 day during the active season. Bears whose signals were not heard for periods exceeding 45 days were censored from analyses beginning on the last day of contact. If contact was re-established, bears re-entered the analyses on the day the first signal was heard. If contact was not re-established, bears did not re-enter the analysis.

Radio-telemetry contact was permanently lost for numerous bears during the study period. Some signal loss was probably attributable to premature transmitter failure, transmitter battery expiration, or long-range movements made by bears. However, we suspect other signal loss was due to deliberate destruction of transmitters following human-caused mortality. Signal loss also may have been due to transmitter damage caused by predation. To account for these possibilities in our survival estimates, we identified a portion of the missing bears as possible mortalities.

Assignment of potential mortality for each bear was based on transmitter type, expected battery life left on its transmitter, known failure rate for that transmitter type, and information on subsequent recapture, observation, or mortality. Signal loss was attributed to battery expiration if it occurred at ≥70% of battery life. Signal loss was attributed to known failure if transmitters were recovered or observed not functioning or not functioning properly (timer failure of eartag transmitters). Signal loss was attributed to possible signal failure when bears were later captured or killed by hunters not wearing transmitters. Signal loss was attributed to possible damage or weak signal if temporary signal loss occurred ≥3 times or if signal loss occurred during the time the bear was denned. Signal loss not attributed to any of these causes was considered possible mortalities. We also reclassified 1 handling mortality as a possible natural mortality due to the poor condition of the bear. Possible survival rates were then calculated including known and suspected mortalities.

RESULTS

Possible Mortalities from Signal Loss

Known and possible failure rates were only 1% and 2% for Telonics and Ursus Technologies (UT) radio-collars, respectively (Table 7-1). However, known failure rate for the Advanced Telemetry Systems (ATS) eartag transmitters was 13%. Due to this high rate of known failure among ATS transmitters, and an even higher number of unexplained signal losses (32%), no missing bears wearing ATS eartags were considered possible mortalities. Eight missing bears wearing Telonics or UT radio-collars were considered possible mortalities due to unexplained signal loss.

Known and Possible Survival Rates

Observed adult female survival rates were very similar for the 2 study areas and were above 90% (Table 7-2). Most mortality of adult females was human-caused, including hunter kills, depredation kills, and illegal kills (Table 7-3). Surprisingly, female hunting mortality rates were fairly similar for the 2 study areas, despite the hunting closure from 1992-1997 on the NSA. Of 4 adult female bears killed by hunters on the NSA, 1 (25%) was taken after the closure was lifted, 2 (50%) were known to be taken outside of the closure area, and 1 (25%) was reported as taken outside of the hunting closure area, however examination of her movements suggest this may not have been true. Depredation mortalities (*n* = 2) were observed only on the NSA, while illegal kills (*n* = 2) were observed only on the SSA. The 2 illegal kills occurred during the hunting season but no carcasses were found (only cut collars), therefore they may have been unreported legal kills. Of 4 mortalities of unknown cause, 3 (75%) occurred during the hunting season and may have been associated with hunting. However, we found no evidence confirming this due to the condition of the carcasses. The other mortality of unknown cause occurred during August. Despite finding an almost intact carcass, we could not identify the cause of death, but it did not appear to be human-caused.

Table 7-1 . Signal loss from radio-telemetry transmitters fitted on black bears on the Northern Study Area and Southern Study Area, New Mexico, 1992-1999.

	Telonics Radio-Collars	UT Radio-Collars	ATS Eartag Transmitters
Transmitters Used	287	55	38
Total Signal Loss	**20 (7%)**	**9 (16%)**	**24 (63%)**
Known or Probable Battery Expiration	9 (3%)	4 (7%)	7 (18%)
Known Failures	1 (0.3%)	1 (2%)	5 (13%)
Possible Failures with Known Fate	4 (1%)	0	0
Possible Damage or Weak Signal	0	2 (4%)	0
Unexplained Losses	6 (2%)	2 (4%)	12 (32%)

Two known natural mortalities occurred on the NSA and both appeared to be predation. Both females killed had new cubs and the predation occurred during spring. Evidence for the first mortality indicated the bear was killed in a struggle with another bear. Evidence for the second mortality was not conclusive, but bear sign in the area suggested the predator may have been a bear. A possible mortality was observed on the NSA and involved an adult female with a severe case of sarcoptic mange. Her mortality was actually a result of our handling in the den. However she was extremely emaciated and essentially blind (from callousing over her eyes), and we suspect she would not have survived through spring.

Known and possible survival rates of subadult females also were similar between study areas. Known survival rates were very similar to adult females; however possible rates appeared to be somewhat lower. Most mortality of subadult females also was human-caused. Again, hunting mortality rates were fairly similar for the 2 study areas, despite the hunting closure. The single subadult female killed by a hunter on the NSA was reported as taken outside of the hunting closure area, however examination of her movements suggest this may not have been true. Again, depredation mortality (*n* = 1) was observed only on the NSA. The 2 mortalities of unknown cause were observed on the SSA. Although no cause of death could be identified, timing and locations of these mortalities did not suggest they were human-caused.

Table 7-2. Observed survival rates and 95% confidence intervals (in parenthesis) of adult (≥ 5 years old), subadult (2-4 years old), and yearling (1 year old) black bears monitored on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1993-1999. Rates were obtained using the staggered entry method. Known rates included documented mortalities, while possible rates included known and suspected mortalities. Sample size is reported in bear-years.

	NSA			SSA			Combined	
	n	Known	Possible	*n*	Known	Possible	Known	Possible
Female								
Adult	131	0.93 (0.81-1.0)	0.92 (0.79-1.0)	119	0.90 (0.73-1.0)	0.90 (0.73-1.0)	0.92 (0.81-1.0)	0.91 (0.80-1.0)
Subadult	67	0.94 (0.72-1.0)	0.86 (0.58-1.0)	54	0.91 (0.71-1.0)	0.89 (0.68-1.0)	0.93 (0.78-1.0)	0.88 (0.70-1.0)
Yearling	19	0.75 (0.56-0.86)	0.75 (0.56-0.86)	19	0.97 (0.84-1.0)	0.97 (0.84-1.0)	0.85 (0.63-1.0)	0.85 (0.63-1.0)
Male								
Adult	77	0.89 (0.69-1.0)	0.89 (0.69-1.0)	80	0.91 (0.68-1.0)	0.82 (0.53-1.0)	0.91 (0.75-1.0)	0.87 (0.71-1.0)
Subadult	27	0.94 (0.73-1.0)	0.94 (0.73-1.0)	36	1.0 (1.0-1.0)	0.97 (0.83-1.0)	0.95 (0.73-1.0)	0.92 (0.67-1.0)
Yearling	21	0.90 (0.68-1.0)	0.87 (0.59-1.0)	13	0.82 (0.30-1.0)	0.76 (0.24-1.0)	0.86 (0.55-1.0)	0.83 (0.47-1.0)

Unexplained signal loss occurred for 3 subadult females, 2 on the NSA and 1 on the SSA, and these losses were identified as possible illegal kills. Two (67%) signals were last heard just before the start of hunting seasons, suggesting bears may have been unreported legal kills.

Observed yearling female survival was lower on the NSA than the SSA, but sample sizes were relatively small. On the NSA, all mortalities (*n* = 3) were of natural causes. One bear appeared to have died of starvation after emerging from the den with low weight. One bear appeared to have been preyed on by a mountain lion. One bear may have been preyed on by a bear. However, no clear evidence of predation was found, other than the fact the carcass was fed on by a bear. It should be noted the 2 mortalities attributed to predation might have been affected by our research activities. During 1994, larger collars were put on young bears and the burden of these large collars may have affected their survival. Since that time, we have used smaller, expandable collars on yearling and subadult bears in an effort to reduce our influence on survival. On the SSA, one mortality of a subadult female was attributed to illegal kill. This mortality occurred during the hunting season but no carcass was found (only a cut collar); therefore it may have been an unreported legal kill.

Table 7-3. Cause-specific mortality rates of adult (≥ 5 years old), subadult (2-4 years old), and yearling (1 year old) black bears monitored on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1993-1999. Rates were obtained using the staggered entry method. Known rates included documented mortalities, while possible rates included known and suspected mortalities.

			NSA		SSA		Combined	
Sex	Age class	Cause	Known	Possible	Known	Possible	Known	Possible
Female	Adult	Hunt	0.04	0.04	0.07	0.07	0.05	0.05
		Depredation	0.01	0.01	-	-	<0.01	<0.01
		Illegal kill	-	-	0.01	0.01	<0.01	<0.01
		Natural	0.01	0.02	-	-	0.01	0.03
		Unknown	0.01	0.01	0.02	0.02	0.02	0.02
		Total	**0.07**	**0.08**	**0.10**	**0.10**	**0.08**	**0.09**
	Subadult	Hunt	0.05	0.05	0.04	0.04	0.04	0.04
		Depredation	0.02	0.02	-	-	0.01	0.01
		Illegal kill	-	0.08	-	0.02	-	0.05
		Unknown	-	-	0.05	0.05	0.02	0.02
		Total	**0.06**	**0.14**	**0.09**	**0.11**	**0.07**	**0.12**
	Yearling	Natural	0.25	0.25	-	-	0.13	0.13
		Illegal kill	-	-	0.03	0.03	0.02	0.02
		Total	**0.25**	**0.25**	**0.03**	**0.03**	**0.15**	**0.15**
Male	Adult	Hunt	0.02	0.02	0.07	0.07	0.05	0.05
		Depredation	0.03	0.03	-	-	0.01	0.01
		Illegal kill	0.03	0.03	-	0.10	0.02	0.05
		Automobile	0.03	0.03	-	-	0.02	0.02
		Hunt (Arizona)	-	-	0.02	0.02	0.01	0.01
		Total	**0.08**	**0.08**	**0.09**	**0.18**	**0.09**	**0.13**
	Subadult	Depredation	0.06	0.06	-	-	0.06	0.06
		Illegal kill	-	-	-	0.03	-	0.02
		Total	**0.06**	**0.06**	**-**	**0.03**	**0.05**	**0.08**
	Yearling	Illegal kill	0.10	0.10	-	-	0.07	0.07
		Natural	-	-	0.08	0.14	0.02	0.02
		Unknown	-	0.03	0.10	0.10	0.05	0.09
		Total	**0.10**	**0.13**	**0.18**	**0.24**	**0.14**	**0.17**

Known adult male survival rates were very similar for the 2 study areas and were above 90%. However, including possible mortalities, the possible survival rate dropped to 82% on the SSA. Specific causes of death were different between study areas, however all were human-caused. Mortality sources for adult males included hunting, illegal kill, depredation kill, and automobile collision. As expected, male hunting mortality was lower on the NSA than on the SSA, and the single adult male killed by hunters on the NSA was taken after the hunting closure was lifted. One adult male captured on the SSA was killed in Arizona during their hunting season. On the NSA, 2 adult males were illegally killed outside of the hunting season. Radio-collars of these males were disposed of in Eagle Nest Lake and in the Cimarron River. On the NSA, 2 adult males appeared to have died from collisions with automobiles on U. S. Highway 64 in Cimarron Canyon.

Unexplained signal loss occurred for 3 adult males on the SSA, and these losses were identified as possible illegal kills. None of these possible mortalities occurred during the hunting season, suggesting they were not unreported legal kills. Although these mortalities cannot be verified, the documented occurrence of illegal kills of adult males on the NSA, coupled with documented occurrence of illegal kills of other bears on the SSA, indicate a high probability for illegal kill of adult males on the SSA. Inclusion of these possible mortalities doubled the mortality rate of males on the SSA.

Observed survival rates of subadult males were high on both study areas, and no hunting mortality was documented. The single documented mortality was a depredation kill following an incident on Philmont Scout Ranch when the bear entered a camp and scratched a scout inside a tent.

Unexplained signal loss occurred for 1 subadult male on the SSA, and this loss was also identified as a possible illegal kill. This possible mortality occurred during the bear hunting season, suggesting it may also have been an unreported legal kill.

Observed male yearling survival appeared lower on the SSA than the NSA. The single mortality documented on the NSA was an illegal kill during the bear season (the carcass was found). On the SSA, 1 yearling male mortality was due to predation by another bear. Cause of death was not known for the other 2 mortalities, but locations and dates did not suggest they were human-caused.

One SSA yearling bear never left the den following our den investigation. We suspect he may have died as a result of our handling, therefore this bear was censored in analysis of the known survival rates. However, the bear may have also died from natural causes, therefore it was included in analysis of possible mortality. Inclusion of this mortality increased the observed total mortality rate on the SSA from 18% to 24%. Unexplained signal loss occurred for 1 yearling male on the NSA, and this loss was attributed to an unknown cause. The signal was lost from this bear only weeks out of the den, and it was unlikely the possible death was human-caused.

DISCUSSION

Although not statistically distinct, survival rates appeared to differ among sex-age categories during this study. Among adult and subadult bears of both sexes, human-caused mortality was most common. Among yearling bears, most mortality was from natural causes, but human-caused mortality was also observed. Mortality from hunting was lower on the NSA and this difference was probably attributable to the hunting closure in effect from 1992-1997. However, even during the years of closure, hunting mortality was observed on the NSA. Most mortalities occurred outside of the closed area, indicating it was not large enough to allow complete protection for resident bears. However, we suspect 2 of the hunt mortalities occurred within the area of the hunt closure, indicating a possible source of illegal activity. Other sources of human-caused mortality included illegal kill, depredation kill, and automobile collisions. These sources of mortality were substantial, especially on the NSA, where they accounted for as much as 10% mortality.

Within the Southwest, observed adult female survival rates from this study were similar to those reported in Colorado (0.96: Beck 1991) and Mexico (0.94, Doan-Crider and Hellgren 1996), but higher than those reported in Arizona (0.85: LeCount 1990). Observed adult male survival rates were slightly higher than those reported in Arizona (0.85: LeCount 1990) and substantially higher than those reported in Colorado (0.70: Beck 1991).

The lack of documented hunting mortality among subadult males was surprising, given the substantial proportion of subadult males observed in hunter harvests. Relative to adults, and even subadult females, sample sizes were low for subadult males; therefore these results should be interpreted with caution. Our observed subadult male survival was higher than that observed in Colorado (0.76: Beck 1991), but our observed subadult female survival was similar to Colorado (0.94: Beck 1991).

Yearling survival rates appeared lower than those of adults and subadults, however much of the documented mortality was due to natural causes. Due to the small sample sizes associated with this ageclass, these results should also be interpreted with caution. Yearling survival rate was lower than the rate reported for Colorado (0.94: Beck 1991).

MANAGEMENT IMPLICATIONS

Among adult and subadult bears, most mortality was human-caused. In addition to hunting, illegal kills and depredation kills were significant sources of mortality for these bears. Illegal kills were documented on both study areas, and many of the unexplained losses were probably due to illegal kills followed by destruction of the transmitters. We were unable to verify any of these possible mortalities, therefore these possible rates should be viewed as maximum rates. Depredation mortality was only documented on the NSA. The proximity of the NSA to several towns, as well as the inclusion of Philmont Scout Ranch within its boundaries, increased the likelihood of bear-human interactions.

It is important to recognize that there was no legal hunting on the NSA during 1992 through 1997. Therefore the hunting mortality rates observed may not reflect actual mortality of bears from hunting in northern New Mexico. The possibility of total mortality exceeding the rates we observed must be considered when interpreting harvest data and output from the population model.

CHAPTER 8

DENNING CHRONOLOGY AND DEN SITE SELECTION

As omnivores, New Mexico black bears are faced with reduced foraging opportunities during winter, primarily due to a lack of new plant growth, desiccation of existing plant matter, and accumulation of snow. Like bears throughout most of their range, New Mexico bears respond to this limited food supply by hibernating. Use of dens or shelters during this extended period of immobility provides both security from predators and protection from extreme weather (Nelson and Beck 1984, Beck 1991).

Timing of den entry and emergence is widely variable among populations and between individuals within a population. Typically, female bears enter dens earlier and emerge from dens later than male bears across North America (Tietje and Ruff 1980, Beecham et al. 1983, LeCount 1983, O'Pezio et al. 1983, Beck 1991, Schooley et al. 1994, Weaver and Pelton 1994, Oli et al. 1997). The prolonged denning period of females is usually most pronounced for adults giving birth during that period. Knowledge of the denning chronology of New Mexico black bears may facilitate more effective management of hunting. In many states and provinces, patterns of differential denning chronology afford wildlife managers an opportunity to regulate the demographic composition of bear harvests (Troyer 1961, Lindzey 1981). In addition, interpretation of hunter-kill data also is enhanced with an understanding of the denning behavior of populations (Alt 1977, O'Pezio et al. 1983).

Knowledge of den site characteristics is also valuable. Energetic properties and level of security of the physical site of hibernation may play a role in the success of bear populations. Where quality den sites are limited, forest management practices can be adjusted to increase their availability (Weaver and Pelton 1994, Oli et al. 1997).

Our objectives were to (1) document den entrance and emergence dates by sex-age category and study area, and (2) document den site characteristics by sex and study area.

METHODS

Denning Chronology

We estimated dates of den entrance and den emergence using aerial telemetry data. During appropriate months (1 October–15 December and 15 March–30 May), we intensified our flight schedule in an effort to locate each radio-collared bear once per 7-10 days (weather permitting). We did not attempt to determine exact dates of den entry or emergence by observation because of the possibility of disturbance.

Studies have shown bears often concentrate their movements around den sites days or weeks before den entry, and bears often remain in the den vicinity after emergence in the spring (Lindzey and Meslow 1976, LeCount 1980, Tietje and Ruff 1980, Beecham et al. 1983, Kolenosky and Strathearn 1987). Our observed telemetry error prevented us from distinguishing very small movements associated with a specific den location. Therefore, we defined denning dates as those when bears were in the den vicinity, not dates of actual movement into or out of the den cavity.

For each consecutive location, we assigned active or denned status based on its proximity to the previous location or its proximity to the actual den site (documented during a den visit). Other relevant information, particularly observer notes and "mortality" signal status, also were considered. Denning occurred when a bear was found in the "same" location during 2 or more consecutive flights, or when a bear was located at its documented den site. Locations were considered the same if they were within the median aerial telemetry error radius of 505 m. Bears were considered active the first time they were located more than 505 m from the den site in the spring.

We defined the fall den entry date as the midpoint between the last active location and the first denned location. Similarly, we defined the spring den emergence date as the midpoint between the last denned location and the first active location (O'Pezio et al 1983). For den entry, we limited our analyses to those observations when the period between relevant locations was $\leq$15 days; and for den emergence, we limited the period to $\leq$20 days. These criteria allowed us to use approximately 50% of our data. To eliminate the potential bias of our research activities, we excluded den emergence observations when the first active location occurred following our den visit.

We used analysis of variance (ANOVA) to determine differences in den chronology among the following sex-age categories: pregnant females (with cubs at den emergence), females with yearlings, other females, adult males, and subadult males. We used t-tests to determine differences within distinct categories between study areas.

We determined total denning period for bears with entrance and emergence dates as defined above. Differences in denning period was tested among sex-age categories using ANOVA and tested between study areas using *t*-tests. All analyses were performed using SPSS software (Chicago, Illinois); where appropriate because of variance differences, degrees of freedom are expressed as decimals.

Den Characteristics

We documented den characteristics, site features, and habitat variables during all visits to winter dens. Den type, number of entrances, types of bedding material, and prior use were recorded. Prior use was known when previous visits to the same den were made. Prior use was judged probable based on characteristics such as vegetation growth on the dirt berm of an excavated den, soil compaction of the berm, and old claw marks on hollow trees. We recorded elevation, topographic position, slope, and aspect of each den site. Habitat type was assigned following Brown (1982). We estimated canopy cover above 0.9 m (3 ft), and ground cover at 0-0.3 m (0-1 ft) and 0.3-0.9 m (1-3 ft) in the following categories: 1-5%, 6-25%, 26-50%, 51-75%, 76-100%. For analysis of aspect at the den site, aspect was classified into 9 categories: N, NE, E, SE, S, SW, W, NW, and flat (no aspect).

RESULTS

Denning Chronology

Among all bears on both study areas, observed den entrance dates ranged from 25 September-7 February (*n* = 179). Range of den entrance dates differed among sex-age categories and between study areas (Table 8-1). Among males, the first observed den entrance date was 18 October, while the latest was 29 December. Among females, the first observed den entrance date was 25 September, while the latest was 7 February. Among both sexes, the majority of bears entered dens between mid October and mid November (Figure 8-1).

Table 8.1. Ranges and means of black bear den entrance dates, by sex-age category, observed on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1992–1999.

Area	Sex-age Category	*n*	Earliest	Latest	Mean
NSA	Pregnant females	33	25 September	21 November	26 October
	Females with yearlings	18	12 October	8 December	3 November
	Other females	27	7 October	28 November	2 November
	Adult males	27	18 October	21 November	3 November
	Subadult males	13	19 October	24 November	2 November
SSA	Pregnant females	10	29 October	15 November	11 November
	Females with yearlings	7	3 November	27 January	28 November
	Other females	31	20 October	7 February	8 November
	Adult males	8	29 October	29 December	18 November
	Subadult males	5	2 November	10 December	11 November

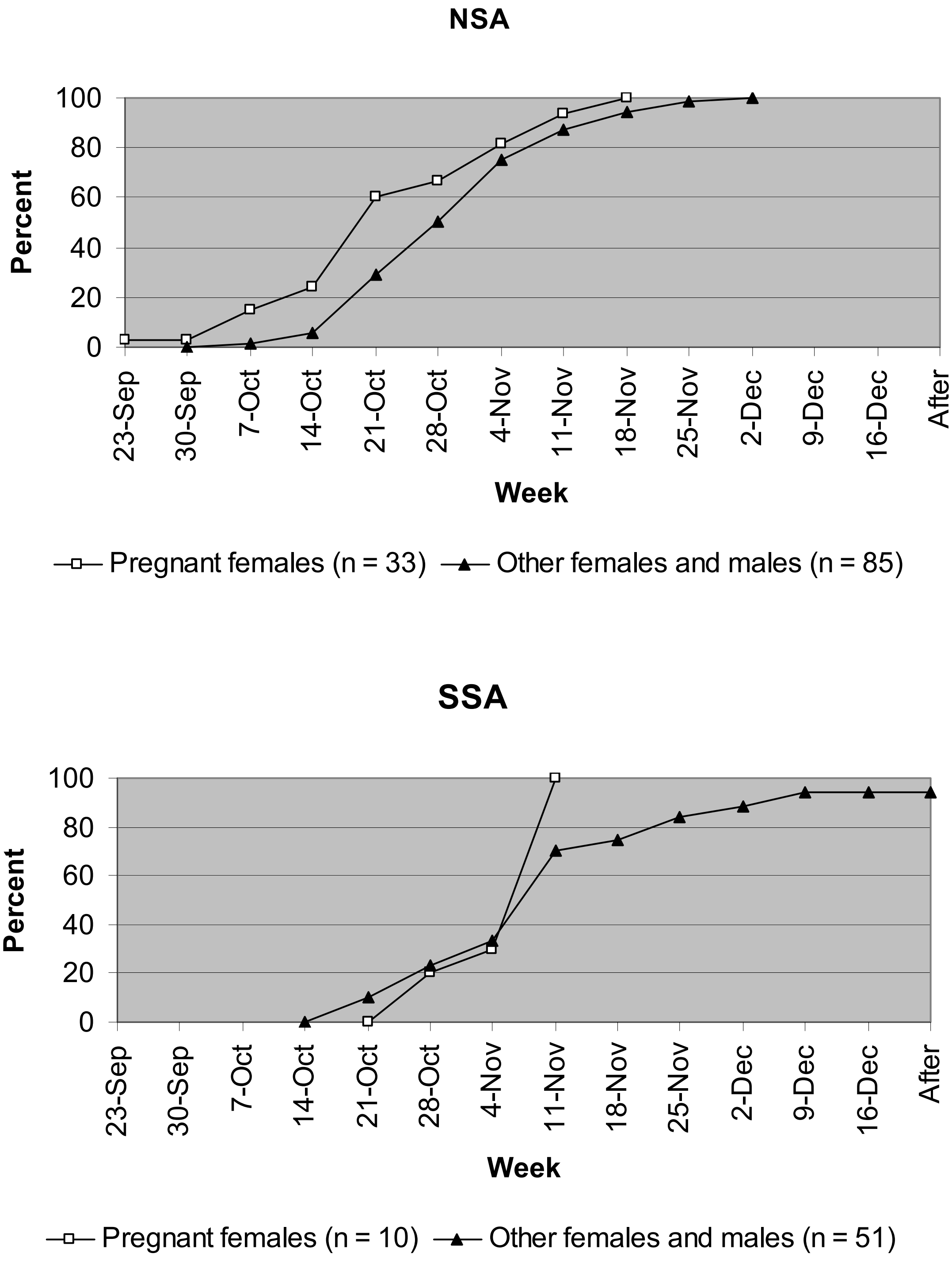


Figure 8-1. Cumulative percent of black bears that entered dens, by week, on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1992-1999.

Mean den entrance date differed among the 5 sex-age categories (F = 2.5; df = 4,174; *P* = 0.05), but subsets were not distinct. When observations were divided into 3 categories (pregnant females; females with yearlings; other females and males), 2 distinct subsets were identified (SNK, *P* = 0.05). Mean entrance date of pregnant females was 29 October, while that of all other bears was 6 November. Comparison of 95% confidence intervals indicated pregnant females entered dens approximately 1-15 days earlier than all other bears.

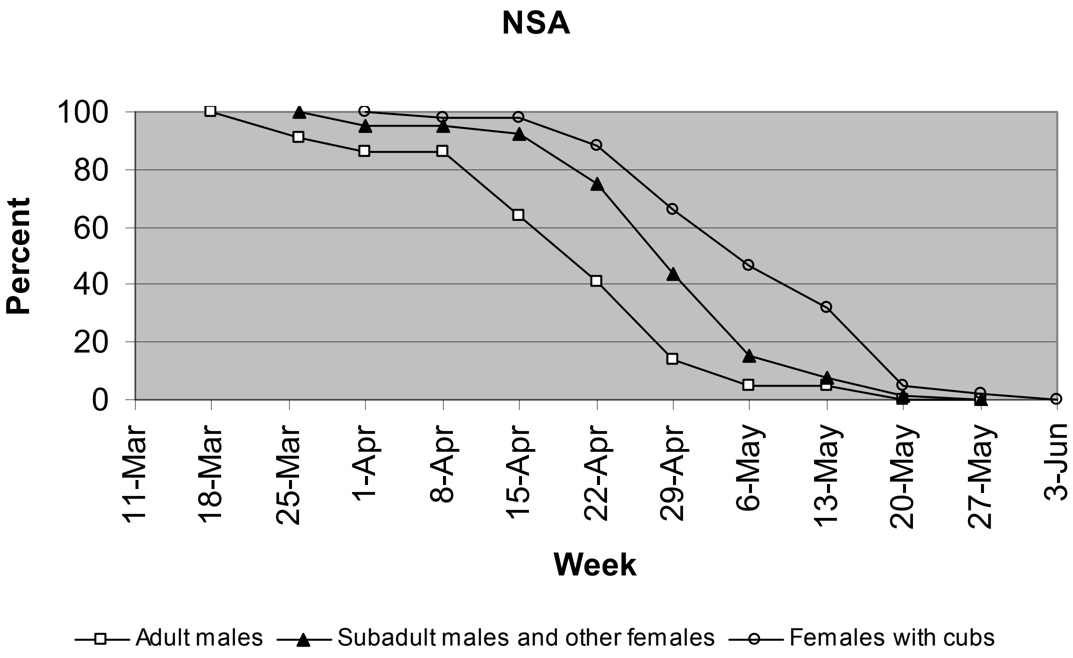
Within both groups, mean den entrance date also differed between study areas. Pregnant females entered dens approximately 4-25 days earlier on the NSA (26 October vs. 10 November, *t* = -4.3, df = 27.9, *P* < 0.001). Other bears entered dens about 2-19 days earlier on the NSA (3 November vs. 13 November, *t* = -3.0, df = 68.3, *P* = 0.003).

On the SSA, mean den entry date differed by oak production for the group of other females and subadult males (F = 3.4, df = 2,40, *P* = 0.04, *n* = 42) and for pregnant females (*t* = -4.1, df = 2.0, *P* = 0.05, *n* = 9). Other females and subadult males entered dens later during the years of good oak production than all other years (30 November vs. 8 November, SNK *P* = 0.05). Pregnant females entered dens later during years of good oak production than during years of poor production (15 November vs. 31 October). Mean den entry date did not differ significantly by oak production on the NSA.

Among all bears on both study areas, observed den emergence dates ranged from 21 March-5 June (*n* = 177). Range of emergence dates was similar for males and females (Table 8-2). Among males, the earliest observed date was 21 March, while the latest was 20 May. Among females, the first observed den emergence date also was 21 March, while the latest was 5 June. Among both sexes, the majority of bears emerged from dens during April (Figure 8-2).

Table 8.2. Ranges and means of black bear den emergence dates, by sex-age category, observed on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1993–1999.

Area	Sex-age Category	*n*	Earliest	Latest	Mean
NSA	Females with cubs	40	9 April	5 Jun	10 May
	Females with yearlings	19	13 April	19 May	4 May
	Other females	31	1 April	23 May	1 May
	Adult males	20	21 March	20 May	21 April
	Subadult males	7	29 March	20 May	30 April
SSA	Females with cubs	10	28 March	29 April	24 April
	Females with yearlings	3	21 March	6 May	15 April
	Other females	28	21 March	31 May	21 April
	Adult males	12	23 March	6 May	14 April
	Subadult males	7	6 April	6 May	24 April



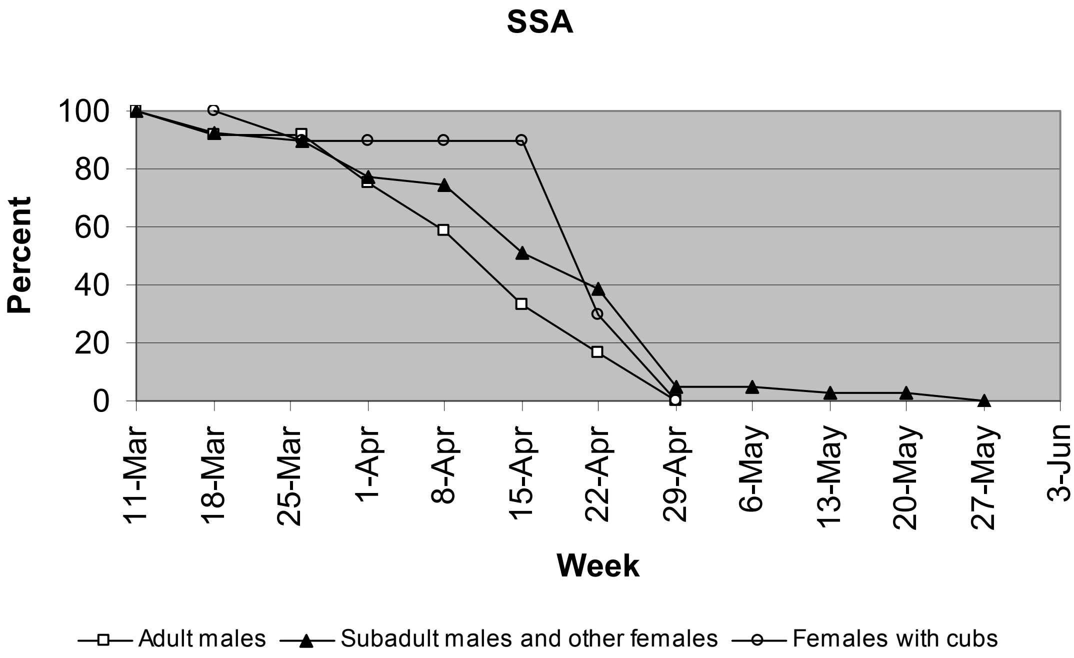


Figure 8-2. Decreasing percent of black bears remaining in dens, by week, on the Northern Study Area (NSA) and southern Study Area (SSA), New Mexico, 1993-1999.

Mean den emergence date differed among the 5 sex-age categories (F = 9.8; df = 4, 172; *P* < 0.001). Using a SNK test, females with yearlings, other females, and subadult males constituted a homogenous subset. When this combined group was compared to females with cubs and adult males, all 3 categories were different (SNK, *P* = 0.05). Adult males emerged earliest with a mean date of 18 April. The mean date for combined group was 28 April. Females with cubs emerged the latest, with a mean date of 7 May.

Comparing these groups between study areas, we observed some differences in mean date. Among the combined group of other females and subadult males, bears emerged about 2-19 days earlier on the SSA (21 April vs. 2 May, *t* = 3.8, df = 93, *P* < 0.001). Females with cubs emerged from dens about 6-27 days earlier on the SSA (24 April vs. 10 May, *t* = 4.4, df = 48, *P* < 0.001). Mean date did not differ between areas for adult males (19 April, *t* = 1.6, df = 32, *P* = 0.12).

Total denning period for 83 individuals varied significantly among the 5 sex-age categories (F = 2.6; df = 4, 78; *P* = 0.04), however homogenous subsets overlapped (Table 8-3). Denning period of adult males was different from all other bears combined. Denning period of adult females with cubs also differed from all other bears combined. Combining all sex-age categories, mean denning period was shorter on the SSA than the NSA (165.6 vs. 178.0 days, *t* = 2.4, df = 81, *P* = 0.02).

Table 8.3. Ranges and means of black bear total denning period (days), by sex-age category, observed on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1993–1999.

Area	Sex-age Category	*n*	Minimum	Maximum	Mean
NSA	Females with cubs	16	165	229	187.1
	Females with yearlings	10	145	201	172.4
	Other females	13	145	216	173.8
	Adult males	8	155	203	173.8
	Subadult males	3	162	197	178.0
SSA	Females with cubs	3	171	181	174.3
	Females with yearlings	2	151	163	157.0
	Other females	19	42	198	170.6
	Adult males	6	98	170	142.7
	Subadult males	3	171	185	180.3

Den Characteristics

Over 64% of 390 dens visited during 1993-2000 were associated with rock structure, including excavations under rock (35%) and natural rock cavities (30%). Den types associated with tree structure were used to a lesser degree (a total of 31%), with 20% of dens excavated under trees and 11% in natural tree cavities.

Use of den types differed by sex and study area (X^2 = 96.1, df = 18, *P* < 0.001, *n* = 387). Females and males on the NSA used dens excavated under rocks more than bears on the SSA (Table 8-4). Females on the SSA used tree cavity dens and dens excavated under trees more than any other group. Males on the SSA used rock cavity dens more than any other group.

Table 8-4. Relative use of den types by female and male bears on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1993-2000.

	NSA		SSA	
Den type	Females (*n* = 173)	Males (*n* = 53)	Females (*n* = 132)	Males (*n* = 29)
Rock cavity	0.25	0.32	0.24	0.69
Tree cavity	0.06	0	0.24	0
Excavated under rock	0.43	0.60	0.17	0.24
Excavated under tree	0.21	0.08	0.27	0.03
Excavated into ground	0.03	0	0.06	0.03
Ground nest	0.01	0	0.01	0
Other	0.01	0	0	0

Bears denned in a variety of habitats (Table 8-5). The most commonly used habitats were mixed conifer forests (45%), pinyon-juniper woodlands (21%), spruce-fir forests (13%), ponderosa pine forests (9%), and oak shrublands (8%). Other den-site habitats included aspen forests (3%), bristlecone and limber pine forests (2%), desert shrubland (<1%), and subalpine-plains grassland (<1%). On each study area, bears denned most frequently in mixed conifer habitat. Bears of the NSA used pinyon-juniper habitat secondarily, while SSA bears used pinyon-juniper and oak habitats secondarily.

Denning habitat differed by sex and study area (X^2 = 63.5, df = 24, *P* < 0.001, *n* = 380). Males denned in scrub oak habitat more frequently than females on both study areas (Table 8-5). Females on the NSA denned in spruce-fir habitat more frequently than other groups and SSA females denned in mixed conifer habitat more frequently than other groups. Use of pinyon-juniper and ponderosa habitats did not differ between sexes on either study area.

Certain den types were more closely associated with specific habitats. Over 95% of tree cavity dens were located in mixed conifer or spruce-fir habitat (*n* = 42), with the vast majority (83.3%) located in mixed conifer habitat. Over 82% of dens associated with tree structure were located in mixed conifer or spruce-fir habitats (*n* = 120). All dens located in scrub oak habitat (*n* = 28) and

88% of dens located in pinyon-juniper habitat (*n* = 69) were rock cavity dens or dens excavated under rocks.

Table 8-5. Relative use of habitat types for denning by female and male bears on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1993-2000.

	NSA		SSA	
Habitat type	Females (*n* = 174)	Males (*n* = 50)	Females (*n* = 126)	Males (*n* = 27)
Grassland	0.01	0	0	0
Oak shrubland	0.01	0.20	0.08	0.26
Pinyon -juniper woodland	0.22	0.24	0.13	0.22
Ponderosa pine forest	0.10	0.06	0.10	0.07
Aspen forest	0.02	0.02	0.02	0.07
Mixed conifer forest	0.41	0.36	0.57	0.33
Spruce-fir forest	0.20	0.10	0.09	0.04
Bristlecone-limber pine forest	0.03	0.02	0	0

Elevation at den sites ranged from 1,636 - 3,576 m (5,400 - 11,800 ft). Elevation differed by study area (t = 7.5, df = 385, $P < 0.001$, n = 385); elevation at NSA den sites averaged 2,657 meters (8,768 feet) whereas SSA den sites averaged 2,427 meters (8,010 feet). Elevation differed by sex on each study area. Males on the NSA denned at lower elevations than females (2,485 vs. 2,706 m, t = 4.0, df = 222, $P < 0.001$, n = 224), as did males on the SSA (2,332 vs. 2,448 m, t = 2.4, df = 159, P = 0.02, n = 161).

Aspect at den site differed by sex and study area (X^2 = 51.1, df = 24, P = 0.001, n = 390) and the significant differences were primarily among females. Female bears on the NSA selected dens with SW aspects more frequently and dens with NW aspects less frequently than other bears. Female bears on the SSA selected dens with NW aspects more frequently and dens with S or SE aspects less frequently than other bears. There was no difference between study areas in use of aspect by male bears (X^2 = 4.7, df = 7, P = 0.70, n = 82).

Slope at den sites ranged from 0^o – 90^o and the mean was 28^o (n = 386. Only 1 den site had a slope of 90^o. It was a natural rock cavity den used by a subadult male on the SSA, situated on a sheer cliff face with a narrow path to the entrance. There was no difference in slope at the den site between study areas (P = 0.173). However, there was a difference between the sexes, with males using steeper slopes than females (31^o vs. 27^o, P = 0.006).

Bears denned at all categories of topographic position, however few den sites were located on ridge-tops (5%) or bottoms (3%). Most den sites were located at the upper portion of slopes (42%), the mid portion of slopes (37%), or the lower portion of slopes (13%). Bears on the NSA denned most frequently at mid-slope (43%), while SSA bears denned most frequently on the upper slope (48%).

The number of useable entrances into a den ranged from 1 to 4, but most dens had only 1 entrance (94%, $n = 390$). Twenty-one dens had 2 entrances (5%), 2 dens had 3 entrances (1%), and 1 den had 4 entrances (<1%). Eighteen of 24 (75%) dens with more than 1 entrance were natural rock cavity dens. Only 7% of den entrances were blocked with bedding material ($n = 381$), and this frequency did not differ by study area or sex ($P \leq 0.11$). Snow covered 22% of den entrances ($n = 377$); this frequency did not differ by study area or sex ($P = 0.67$). Snow cover ranged from approximately 15cm to 1.2m. Typically, there was a small hole in the snow (5-15cm diameter) that was kept open by heat generated from within the den.

Bedding material was found in 93% of all bear dens ($n = 360$) and was common to all sex and age categories. Percent of dens with beds was high on both study areas, however SSA females used beds most frequently and NSA females used beds least frequently (98% vs. 89%, $X^2 = 7.5$, df = 3, $P = 0.06$, $n = 357$). Common bedding materials found in 351 dens were pine needles (48%), twigs (42%), leaves (39%), and grass (37%). Other materials included conifer boughs, duff , bark, bracken fern (*Pteridium* spp.), yucca (*Yucca* spp.), beargrass (*Nolina microcarpa*), conifer cones, lichen, moss, agave (*Agave* spp.), silktassel (*Garrya* spp.), and remains of rodent midden. An earthen floor, sometimes strewn with stones, characterized dens lacking a bed.

Of 390 dens visited on both study areas, 10% were definitely used in years prior to the visit, and an additional 26% likely were used in years prior to the visit. There was a difference in the frequency of den re-use by study area ($X^2 = 14.8$, df = 1, $P < 0.001$, $n = 387$). Definite or probable re-use occurred at 43% of the NSA den sites, but only 24% of the SSA den sites. On the SSA, males denned in sites believed to have been previously used more often than females (38% vs. 21%, $X^2 = 4.0$, df = 1, $P = 0.06$, $n = 161$). Rates of probable re-use did not differ by sex on the NSA ($P = 0.27$). Several bears on the NSA were observed to use the same den 2-5 times during the study period. Use of the same den by different individuals also was observed.

DISCUSSION

Johnson and Pelton (1980b) proposed that 2 factors interact to ensure optimal timing of hibernation and denning of black bears. The primary factor is a genetically controlled hormonal response to photoperiod, or day length. This factor is modified by annually variable elements such as weather and food supply. These factors interact to provide the final stimulus to den.

Erickson and Youatt (1961) reported that prolonged feeding delayed denning of captive bears, but when feeding was terminated, denning occurred promptly. Delayed den entrance by wild black bears has been documented during years of greater fall food availability in Maine (Hugie 1982, Schooley et al. 1994), Alberta (Tietje and Ruff 1980), Tennessee (Johnson and Pelton 1980b), and Idaho (Beecham et al. 1983). In Ontario, bears that fed on acorns, a food with high fat and carbohydrate content (Eagle and Pelton, 1983), denned significantly later than bears not feeding on acorns (Kolenosky and Strathearn 1987). Shorter denning periods observed in mild climates has led to the theory that bears forage until they encounter a decreasing or negative energy return per unit of search effort (Lindsey and Meslow 1976, Johnson and Pelton 1980b).

Timing of den entrance also has been reported to be influenced by various weather factors including snowfall (Jonkel and Cowan 1971), temperature (Johnson and Pelton1980b, Rogers 1987), and precipitation (Lindzey and Meslow 1976, Johnson and Pelton 1980b). However, Schwartz et al. (1987) and Schooley et al. (1994) reported that variation in den entry was not strongly associated with weather patterns during autumn. Bears have the physical capability to survive brief periods of hostile weather, and onset of hibernation is probably not controlled by changes in weather. Rather, inclement weather typically coincides with decreased food availability, and tends to compound the negative energy return of a dwindling food supply by increasing the foraging effort required to obtain food. In the case of snow cover, food is exponentially more difficult to find and retrieve per unit effort of search.

On average, we observed bears entering dens 1-2 weeks later than usual during a single year of outstanding food production on the SSA. Two females without offspring were observed to delay den entrance until January and February. That year of outstanding mast production also was characterized by mild weather and little snowfall, allowing for increased foraging opportunities. Dates of den entrance were not different among years of oak production ranging from failure to moderate. Overall, our results lend support to the theory of negative energy return and that food availability is the primary proximate cause of black bear den entry. We hypothesize that years of mast failure do not result in earlier den entrance because the endogenous rhythm has not yet prepared bears to den. Weather factors are likely a secondary proximate cause of den entrance.

Smith et al. (1994) summarized denning chronology results of 25 black bear research projects and concluded that populations of more northern latitudes and higher elevations tend to enter dens earlier, remain denned longer, and emerge later. Our data suggest this pattern may exist within New Mexico. Mean entrance dates of the SSA population were very similar to those of central Arizona (LeCount 1983), and were approximately 2 weeks later than those observed on the NSA. Entrance dates of NSA bears were more similar to those of Colorado (Beck 1991) and Idaho (Beecham et al. 1983). Bears inhabiting mountain ranges in New Mexico of lower elevations than our study areas may display this trend to a greater degree. With uniform hunting seasons for black bears throughout New Mexico, regional differences in denning chronology will likely affect the demographic composition of the harvest and interpretation of population sex and age structure from harvest data.

Differential denning dates among demographic segments of black bear populations has been widely reported in such regions as the Southwest (LeCount 1983, Beck 1991), the Pacific Northwest (Lindzey and Meslow 1976, Schwartz et al.1987, Smith et al. 1994), the intermountain west (Tietje and Ruff 1980, Beecham et al. 1983), the Northeast (O'Pezio et al. 1983, Schooley et al. 1994), and the Southeast (Johnson and Pelton 1980b, Weaver and Pelton 1994, Oli et al. 1997). Typically, females enter dens earlier than males. Pregnant females enter dens earlier than any other group, and adult males enter dens latest. The reverse sequence is commonly observed at den emergence. Subadult entrance and emergence appears to be more random and has not exhibited the definitive patterns apparent between sex and reproductive groups. Bears of New Mexico exhibited these same demographic variations and fit the overall pattern documented with other research projects. Mean den entrance date for pregnant females was earlier than all other bears on both study areas. The weekly cumulative percentage of pregnant females having entered dens was 5-30% greater than for all other bears on the NSA during peak entrance in October; den entry by pregnant females on the SSA probably was similar but sample size was too small to document this pattern. Den emergence patterns in New Mexico also fit the general pattern of other research findings. Adult male bears on both study areas emerged earliest and females with cubs emerged latest. Mean emergence dates differed by 10-20 days between these groups. The weekly cumulative percentage of adult males that had departed the den vicinity was 20-50% greater than for females with cubs during peak emergence in April and May.

Bears of New Mexico exhibited these same demographic variations and fit the overall pattern documented with other research projects. Mean den entrance date for pregnant females was earlier than all other bears on the NSA and the SSA. Also, the weekly cumulative percentage of pregnant females that had entered the den was 5-30% greater than for all other bears on the NSA during October; den entry by pregnant females on the SSA probably was similar but sample size was too small to assess this pattern . These differences generally agree with other documented populations.

Emergence from dens in New Mexico also fit the general pattern of other research findings. Adult male bears on both study emerged earliest, females with cubs emerged latest; average emergence dates differ by 10 to 20 days between those groups. Also, the weekly cumulative percentage of adult males that had departed the den vicinity was 20-50% greater than for females with cubs during peak emergence in April and May. However this emergence schedule was about 20 days later on the NSA than the SSA. These differences generally agree with other documented populations.

We found that male and female black bears selected different types of den sites and den structure, and that trends were similar between regions in New Mexico. In general, males denned at lower elevations, on steeper slopes, in oak habitats, and in rock dens. Females used dens associated with trees with greater frequency than males and denned at higher elevations, on more moderate slopes, and in spruce-fir and mixed conifer habitats. While some of the variation in the aforementioned den characteristics may be inter-related (primarily site-characteristics), much of the differences that we observed in New Mexico can, in large part, be explained by differing needs of the sexes and the adaptive significance they afford each sex.

Black bears den for periods up to 6 months long and can lose 14-34% of their body weight during the denning period (Hock 1960, Erickson and Youatt 1961, Tietje and Ruff 1980). Females nursing cubs may lose an additional 9% above the 25% that other females lose during denning (Tietje and Ruff 1980). In addition, factors other than metabolic expenditure also influence energy conservation during the denning period. Bears have been documented changing dens within a winter apparently by natural causes (LeCount 1980, Weaver and Pelton 1994). Abandonment of a den site was estimated to cause a doubling of over-winter weight loss (Tietje and Ruff 1980). Considering the intense physiological demands of denning, lactation, and the generally poor forage conditions available to bears upon emergence, the need for den types that favor energy conservation during this period is obvious.

The insulating capacity of snow is well known and of great significance to bears of more northern regions where accumulations are deep enough to cover dens and mid-winter thawing is not frequent (Tietje and Ruff 1980). We found that 22% of dens in New Mexico were covered with snow at our visit date. We did not detect any difference in the frequency with which male and female dens were covered with snow. Interestingly, there also was no difference in frequency of snow-covered dens between study areas even though the NSA was farther north and included areas of higher elevation. Bears on the SSA, particularly females, used NE slopes more frequently which may account for this lack of difference. Female use of higher elevations on both study areas may represent an inclination to use more insulated dens.

Use of tree cavity dens by black bears may result in energetic conservation in regions where snow accumulations are not significant, mid-winter rains occur, or intermittent flooding occurs (Johnson and Pelton 1980b, Weaver and Pelton 1994, Oli et al. 1997). Johnson et al. (1978) simulated winter heat loss of denned black bears and concluded that enclosed tree cavity dens accounted for a 15% energy savings compared to open ground dens. However, Thorkleson and Maxwell (1974) suggested while dens afford protection from conductive, convective, and radiant heat loss, the increased air circulation can greatly reduce their thermal efficiency. Because of its latitudinal position and range of elevations, New Mexico falls somewhere between the typical northern bear habitats and those with less severe winters. The fact that only 22% of dens were covered with an insulating blanket of snow indicates that thermally insulated dens may have great importance for bears in New Mexico. The need for more thermally efficient dens may be greater for females and younger bears due to their higher surface area to volume ratio. Observed use of tree dens was higher on the SSA, where snow accumulation was more limited. Although male bears have been observed to use hollow trees for denning in other regions (C. Godfrey, pers. commun., 1998), no use of tree cavity dens by males was observed during this study. It is possible that availability of large cavities suitable for adult males is limited in New Mexico.

In addition to energetic conservation, security is another factor of importance related to den type. Predation of denned black bears by wolves (Rogers and Mech 1981), man (Erickson 1964), and other bears (Rogers 1977, Tietje and Ruff 1980, Alt 1984) has been reported. Security of the den site is affected by inaccessibility, defensibility, and cover. Females may seek tree den types because of a greater need for security, due to their smaller size and the vulnerability of cubs. Bears that den in hollow tree cavities above the ground are less accessible to potential predators than those in other den types. During this study, no elevated tree cavity dens were abandoned at our approach, supporting previous contentions that bears denned in trees were less vulnerable to human disturbance than those using ground (Johnson and Pelton 1981, Weaver and Pelton 1994). Den types other than elevated tree cavities appear to be less secure, but similarly inaccessible and defensible to each other. Ninety-four percent of the dens we examined had only 1 entrance. Although lethargic and approachable while denned, bears remain capable of defending themselves. Cover would appear to function for security purposes by reducing the odds that a den could be located, and, as we often found during the research effort, by functioning as an auditory alarm system. Undetected approaches to dens were difficult to achieve in thick scrub oak and mountain mahogany vegetation and/or steep terrain covered with loose rocks.

Craighead and Craighead (1972) suggested grizzly bear use of northern aspects for den sites reduced the likelihood of a flooded den as the result of a mid-winter thaw. Cub mortality from hypothermia and drowning, associated with flooding of dens, has been observed (Alt 1984, Hayes and Pelton 1994, Weaver and Pelton 1994). Although SSA females appeared to favor dens with NW aspects, NSA females tended to avoid this aspect, selecting sites with SW aspects instead. Snowmelt on south-facing slopes was relatively common on both study areas. We observed flooding of a maternal den on the NSA during a den visit in late March. The den was beneath a rock ledge where snow was melting through the roof of the den. The female, her 2 cubs, and all of the bedding material were extremely wet, however the female remained lethargic. Fearing for the survival of the cubs, we dried them, put fresh bedding under them, and attempted to redirect the snowmelt. Fortunately, the bears moved from the den within 2 days after the den visit. It is unknown if the bears would have moved without our disturbance. On the SSA, females may have selected north-facing slopes to avoid frequent snowmelts that may reduce cub survival; however other factors, such as availability of large tree dens, may have caused them to select these sites.

Relatively high levels of den reuse have been documented in other regions, particularly in western states, such as Colorado (Beck 1991), Idaho (Beecham et al. 1983), and Alaska (Smith et al. 1994). Methodologies used to determine rates of den reuse differed widely among studies, making comparison difficult. Lindzey and Meslow (1976) documented a high degree of den reuse (90% of all bears reused dens) and attributed it to reduced den site availability following logging. Schwartz et al. (1987) documented competition among bears for den sites. The wide variety of den types observed during this study suggested availability of dens was not limiting.

MANAGEMENT IMPLICATIONS

The verified differential in den entry and emergence dates among sex and age groups has application to setting bear hunting seasons to accomplish various objectives. However, den entry and emergence dates are highly variable and generally span a period exceeding 2 months. We observed variation relative to mast production; other factors undoubtedly play a role influencing the timing from year to year. No single timing scenario is appropriate for every use. This information also is valuable for interpreting past and future harvest composition relative to season timing and region. These interpretations are especially important for selecting information to be used in the Population Model as a management tool.

Dens that facilitate security and energy conservation during hibernation period are of significant value to black bears, and female bears exhibit a tendency to select tree cavity dens when available. Retention of large diameter live trees, large snags, and large fallen logs may be a valuable goal to benefit black bears in all forest management plans and programs.

CHAPTER 9

HOME RANGE, MOVEMENTS, AND HABITAT USE

Relative to most North American game species, black bears exhibit very large home ranges, and are known to travel great distances to reach abundant food sources (Amstrup and Beecham 1976, Lindzey an Meslow 1977, Garshelis and Pelton 1981, Warburton and Powell 1985, Smith and Pelton 1990, Wooding and Hardisky 1994). A thorough understanding of the movement patterns of bears may help agencies identify and manage distinct subpopulations within a state, and work with neighboring states to manage inter-state populations. Information about dispersal rates may aid in interpreting hunter-kill data, as it relates to emigration and immigration. Knowledge of the sources of bear-human conflict and effectiveness of translocation may aid in management of nuisance and depredation complaints.

We investigated black bear home range and movements on 2 New Mexico study areas during 1992-2000. Our objectives were to (1) document black bear home range size by sex and study area; (2) investigate seasonal movement patterns by sex and age category; (3) investigate general habitat use patterns on each study area; (4) examine dispersal of subadult males and females; (5) examine patterns of nuisance and depredation activities by sex and study area; and (6) compare movements of translocated bears by sex and age category.

METHODS

For analysis of home range and movements, we used aerial telemetry locations, capture and recapture locations, den locations, and locations of mortalities (including hunter kill or depredation kill locations). Locations were classified by season: den, premast (den emergence to 20 July), and mast (21 July to den entry). To eliminate autocorrelation of locations, we excluded recapture locations if the bear was captured more than once at the same trapsite during the same trap period. When the interval between 2 locations was <5 days, we excluded the second location if the distance between the 2 locations was <1000 m for females or <1500 m for males.

Numerous studies of black bears have documented extensive movements to abundant food sources, especially during the fall foraging period. Although these distant locations are a significant part of a bear's lifetime home range, we wished to discriminate them from the locations representing areas of concentrated, multi-annual use. For each bear, we selected den locations and locations from the premast season. For each location, we determined the distance to its nearest neighbor. For each bear, we multiplied the maximum distance by 1.5, and this became our critical value. Any mast season location exceeding this critical distance from any den or premast location was considered a long-range movement. If the maximum distance was ascribed to an outlier among the den and premast locations and the maximum distance was more than 2 times the second longest distance, we usually reclassified the outlier as a long-range movement, and reanalyzed based on the second longest nearest neighbor distance. In most of these circumstances, the outliers appeared to be associated with movements to summer foods (mostly during July) or return movements from distant den locations (mostly during February to April). For the few subadult bears determined to be dispersing as described below, we used the above criteria only for locations when the bears were resident in their natal range. During years of active dispersal, we did not classify any locations as long-range movements.

Home Range

Multi-annual total home ranges were estimated using all locations, while multi-annual primary home ranges were estimated excluding long-range movements. Home range was estimated using the 100% minimum convex polygon (MCP) method (Mohr 1947) and the 95% fixed kernel (FK) method with the least squares cross validation procedure as the smoothing parameter (Silverman 1986). Estimates were calculated using the Animal Movements extension (P. Hooge, USGS-BRD, Alaska Biological Science Center) developed for use with ArcView software (Environmental Systems Research Institute, Redlands, California). A minimum sample size of 30 locations was required for bears to be included in home range analyses. Mean home range size was compared by sex and study area using *t*-tests.

Movements

We estimated the center of each primary home range using the arithmetic mean. We then calculated an “activity radii” for each bear location as the distance between the location and the home range center (Dice and Clark 1953). To determine the effect of sample size on our ability to estimate the home range center, and thus activity radii, we calculated incremental mean activity radii for each bear by sample size, starting with the first 3 premast locations. We then calculated the percent change in the mean activity radius as sample size increased. Minimum sample size was achieved when the mean percent change fell below 5%. Bears with sample sizes below this number were excluded from analyses using activity radii. Differences in mean activity radius by sex, ageclass, season, and study area were tested using *t*-tests and analysis of variance (ANOVA), with individual bears as a random factor.

Habitat Use

We defined habitats using land cover data obtained from the New Mexico Gap Analysis Project (NMGAP, Thompson et al. 1996). These data included 42 land cover types, primarily based on dominant vegetation and canopy cover. For analysis of general use, we reclassified these land cover types into 6 broad categories: closed forest/closed woodland, open forest, open woodland, open shrubland, open grassland/tundra, and other land cover.

We used bear location data compiled for home range analyses to document use of these habitat types by the bear populations on each study area. For these analyses, locations outside of New Mexico were excluded. For each bear location, a scan area was created with a radius corresponding to the median telemetry error for each study area (NSA = 200 m, SSA = 505 m). Scan areas were overlaid onto the NMGAP map and habitats found within the buffer area were determined. When more than 1 habitat type was found within a scan area, use was weighted by the inverse of the number of types within the scan area (ranging from 1-3). Percent use was defined by percent of locations within each habitat type by season.

We determined availability of habitat types using composite home range data. We created composites of the 100% MCP and the 95% FK total home ranges for all radio-transmittered bears, excluding the locations outside of New Mexico as described above. We also excluded the single long-range movement to Elephant Butte Lake (observed for a male on the SSA), because this single location would have greatly inflated the available habitat area. Relative distribution of habitat types within the composite home ranges was determined by assigning habitat type to random points generated at approximately 1 point/km^2. Patterns of selection versus avoidance of habitat types were estimated using use versus availability analyses (Neu et al. 1974).

Dispersal

We estimated dispersal rates using 2 samples of radio-transmittered juvenile bears. The first sample consisted of bears whose natal range was known (those handled as cubs or yearlings in the den). The second sample consisted of bears whose natal range was not verified (those captured as yearlings or subadults). Dispersal was determined by examining annual changes in premast movements. We considered a bear dispersed when it moved from 1 premast range to a second premast range (with no overlap).

Nuisance or Depredation Activity and Post-translocation Movements

We identified areas of potential human conflict for bears on each study area. We restricted analyses to areas of predictable potential food sources, including towns, public campgrounds, and other known sources of garbage or food. Areas of unpredictable potential food sources, such as backcountry campsites, were not assessed. We determined percent of all MCP home ranges of bears >1 year old that overlapped these areas of potential human conflict. In addition, nuisance and depredation complaints reported to NMDGF were recorded for marked study bears. Percent of each study population involved in these complaints was determined by sex.

During the study period, several radio-collared study bears were translocated by NMDGF personnel due to nuisance or depredation activities. We documented post-translocation movements of radio-collared bears to determine rate of return.

RESULTS

Home Range

Mean total and primary home range size was larger for males than females (*P* < 0.001) on both study areas (Table 9-1). Total home range size varied greatly by individual, especially using the MCP method. Total MCP home range size ranged from 104.8 km^2 to 3,343.8 km^2 for males. Variation in FK home range size was not as great, but still notable. The largest home range size was that of a SSA adult male (M380) that made a single long-range movement to the vicinity of Elephant Butte Lake. Although this home range size greatly exceeded those of other males, it may actually reflect the potential areas used by SSA bears. Of 8 SSA males with estimated home ranges, 7 (88%) were not found for 1-4 periods exceeding 45 days, indicating many long-range movements were not documented. The single SSA male bear that was consistently located (M326) had a total MCP home range size of 847.1 km^2 and a FK home range size of 213.4 km^2. On the NSA, only 3 of 10 (30%) bears were missing for 1-3 periods exceeding 45 days. Therefore, home ranges were probably more accurately documented for NSA males than SSA males. No significant differences were found between NSA and SSA male total home ranges (*P* ≥ 0.39), however the higher frequency of missing bears on the SSA may indicate total home ranges were larger.

Total MCP home range size ranged from 10.2 km^2 to 866.7 km^2 for females. Among females, the largest total home range size was that of a SSA adult female (F804) that appeared to have 2 distinct primary home ranges. One range was located within the study area, while the other was located within the Gila Wilderness. Most of the large sizes of other female total home ranges were attributable to isolated long-range movements. Mean total home range size was not significantly different by study area (*P* ≥ 0.25). On the SSA, 15 of 26 (58%) female bears were not found for 1-2 periods exceeding 45 days, but only 4 of 35 (11%) females were missing for a single period exceeding 45 days on the NSA. This may indicate total home ranges were larger on the SSA.

Mean primary home range size estimates were approximately 3-5 times larger for males than females (*P* ≤ 0.01) on both study areas (Table 9-1). Among males, ranges and means of primary home range size were very similar between study areas, and no differences were found (*P* ≥ 0.96). Mean primary home range size estimates of SSA females were nearly twice as large as estimates for NSA females. The difference was significant for the MCP estimates (*t* = -2.1, df

= 27.0, *P* = 0.05) and slightly significant for the FK estimates (*t* = -1.7, df = 24.6, *P* = 0.10).

Table 9-1. Size (km^2) of multi-annual minimum convex polygon and 95% fixed kernel home ranges for black bears monitored on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1992-2000. All estimates differed by sex within study areas ($P < 0.001$) and estimates of primary home range differed between areas for females ($P \leq 0.003$).

				Minimum Convex Polygon		Fixed Kernel	
			n[a]	Mean	Range	Mean	Range
Total[b]	NSA	Female	35	123.3	10.2 - 482.0	70.2	17.2 - 509.1
		Male	11	417.8	104.8 - 855.3	370.1	112.0 - 800.1
	SSA	Female	26	172.4	17.4 - 866.7	116.6	16.4 - 1001.7
		Male	8	769.8	180.6 - 3343.8	383.8	213.4 - 967.9
Primary[c]	NSA	Female	28	24.0	7.2 - 50.4	27.6	10.6 - 45.2
		Male	10	132.1	46.6 - 266.6	162.1	56.4 - 307.7
	SSA	Female	25	43.1	10.7 - 222.7	55.8	13.7 - 430.9
		Male	4	130.1	74.6 - 180.1	163.4	102.3 - 231.4

[a] Sample included individuals with ≥30 locations
[b] Total home ranges included all locations
[c] Primary home ranges excluded long-range movements

Movements

Mean activity radius around home range centers was smaller during the premast season than during the mast season for all sex-age categories, except yearling females and SSA male yearlings ($P \leq 0.05$, Table 9-2). On both study areas, mean activity radii were larger for adult and subadult males than all other sex-age categories during the premast season and during the mast season ($P < 0.001$).

Among adult and subadult males, mean activity radius did not differ between study areas during either season ($P \geq 0.28$). Among all females and yearling males, mean activity radius was larger on the SSA than the NSA during the premast season (*t* = -5.1, df = 775.2, *P* < 0.001), but not during the mast season (*t* = -0.3, df = 1899.0, *P* = 0.79).

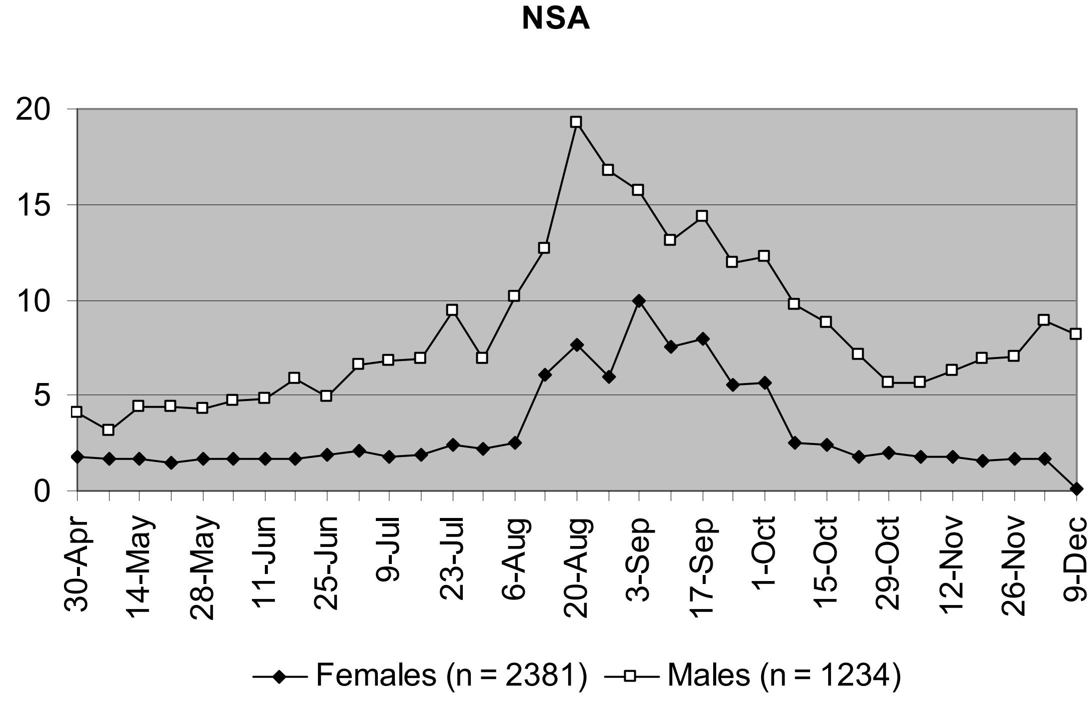
Mean activity radius was larger during years of oak failure than all other years for adult and subadult males on the NSA (16.2 vs. 9.1 km, *P* < 0.001) and the SSA (19.3 vs. 9.5 km, *P* < 0.001). The same was observed for all females and yearling males on the SSA (5.4 vs. 3.9 km, *P* = 0.001), however no difference was observed for that group on the NSA (*P* = 0.21).

On both study areas, mean activity radii of male bears displayed a gradual increase throughout the premast season, while mean activity radii of female bears remained relatively constant (Figure 9-1). On the NSA, both sexes appeared to increase movements during mid-August and continue to move until early October. On the SSA, both sexes increased movements during late August and continued to move widely through late October. Peaks of fall movements appeared to occur earlier for males on both study areas. Peaks also appeared to occur earlier on the NSA than the SSA.

Table 9-2. Activity radii (km) around home range centers for black bears monitored on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1992-2000. Mean activity radius differed by season and sex for all age classes, except yearling males (*P* = 0.05).

			Premast (den emergence - 20 July)			Mast (21 July - den entry)		
			n	Mean	Range	*n*	Mean	Range
NSA	Female	Adult	561	1.9	0.03 - 23.1	649	4.8	0.08 - 41.4
		Subadult	229	1.6	0.2 - 7.2	298	6.1	0.08 - 35.7
		Yearling	47	1.1	0.04 - 4.7	55	2.1	0.1 - 22.0
	Male	Adult	384	5.3	0.2 - 40.5	382	11.6	0.2 - 53.5
		Subadult	99	3.9	0.2 - 63.2	88	9.7	0.6 - 46.1
		Yearling	53	1.7	0.04 - 5.3	57	4.5	0.2 - 28.1
SSA	Female	Adult	400	2.6	0.09 - 57.1	561	4.5	0.1 - 55.4
		Subadult	137	2.2	0.03 - 10.8	205	4.2	0.04 - 27.5
		Yearling	25	2.2	0.03 - 6.3	50	5.2	0.6 - 17.2
	Male	Adult	174	7.6	0.2 - 59.1	180	14.5	0.3 - 134.9
		Subadult	74	6.1	0.4 - 28.6	82	14.1	0.2 - 75.8
		Yearling	21	4.6	0.8 - 24.9	28	3.1	0.5 - 6.5

Percent of all locations considered long movements (outside of primary home ranges) also increased during the fall mast season (Figure 9-2). On the NSA, from late August until early October, over 40% of male locations and over 30% of female locations were long-range movements. On the SSA, over 25% of female locations were long-range movements from late August to late October. For SSA males, sample sizes were smaller than other categories, therefore that group exhibited more variation, but in general more than 20% of male locations were long-range movements between mid August and late October.



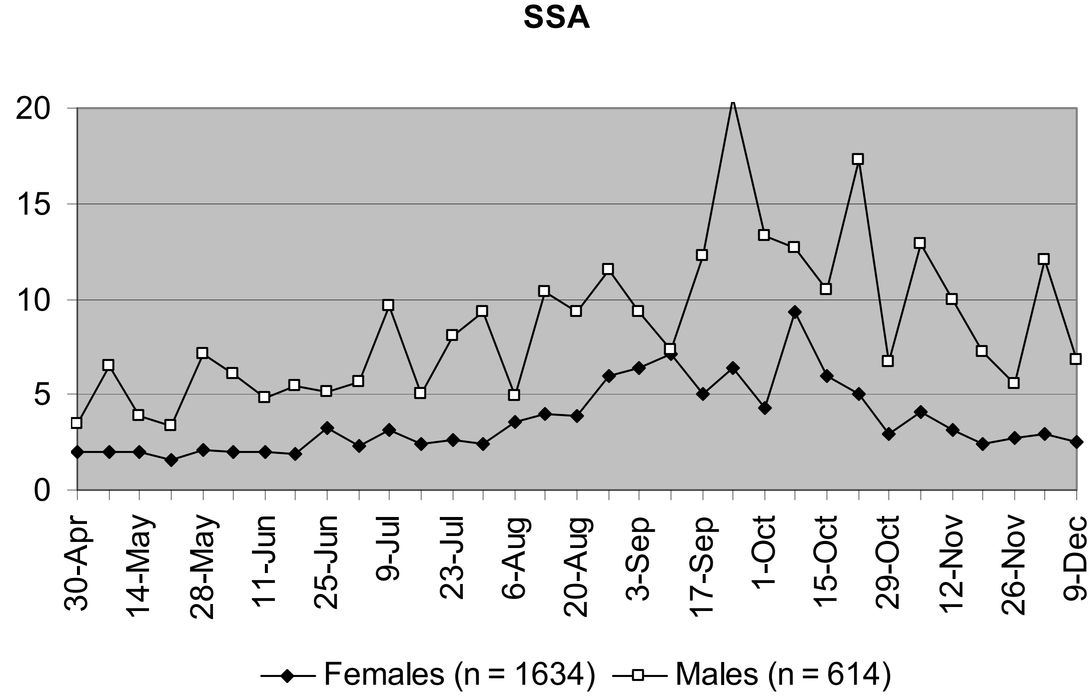


Figure 9-1. Mean activity radius (km) around home range centers, by week, for male and female black bears monitored on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1992-2000.

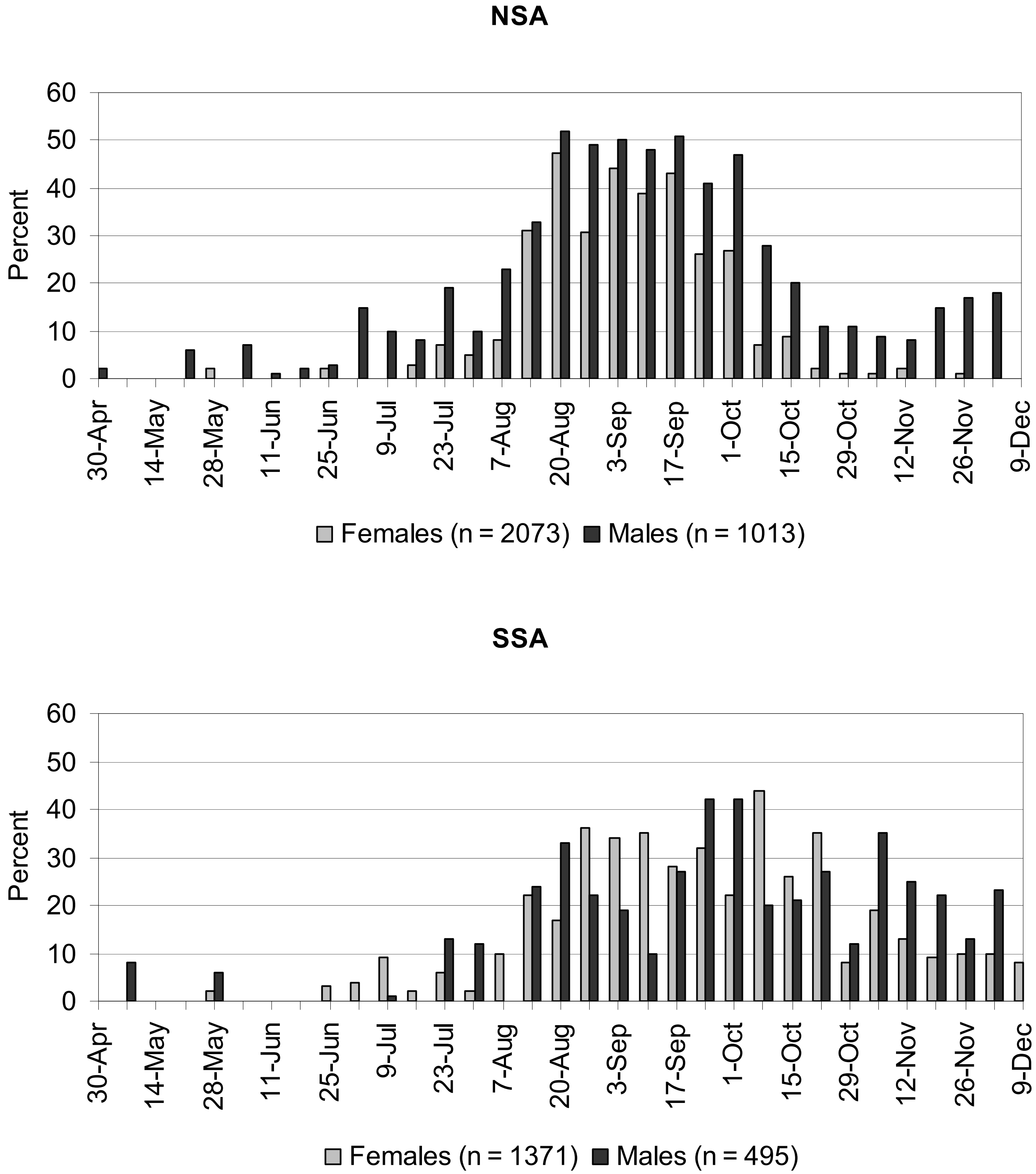


Figure 9-2. Percent of black bear locations considered long-range movements (outside of primary home ranges), by week, on the Northern Study Area (NSA) and the Southern Study Area (SSA), New Mexico, 1992-2000.

Habitat Use

Patterns of habitat use were very similar between the 2 study areas. On both study areas, analyses indicated bears were highly selective of the closed forest and woodland habitat types during all seasons, with >80% of locations occurring in these types (Table 9-3). Areas of open shrubland also were selected, but use and availability of this type was more limited. Areas of open woodland and open grassland were avoided, and most locations (96%, *n* = 460) within these habitats occurred within 500 m of the edge of closed-canopy habitats.

Table 9-3. Observed use versus availability of habitat types by black bears on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1992-2000.

		Observed percent use by season			Percent in composite home range		
Area	Habitat type	All year	Premast season	Mast season	MCP	95K	Result *P* < 0.001
NSA	Closed forest/ woodland	90	92	87	79	77	Selected
	Open woodland	4	3	4	4	5	Avoided[a]
	Open shrubland	3	2	3	2	1	Selected[b]
	Open grassland	3	3	4	16	16	Avoided
	Agricultural land	0	0	0	1	1	
	n	3085	1883	1203			
SSA	Closed forest/ woodland	85	86	84	76	71	Selected
	Open woodland	3	2	4	11	13	Avoided
	Open shrubland	6	7	6	1	2	Selected
	Open grassland	7	6	7	12	14	Avoided
	n	2444	1176	1015			

[a] Not significant relative to MCP composition

[b] Not selected during premast season

Habitat use patterns differed slightly by sex during the premast season on both study areas, but closed forest and woodland habitats still accounted for >85% of use for both sexes. On the NSA, more male locations were found in open grassland habitats (4% vs. 2%) and agricultural lands (1% vs. 0%) than females (X^2 = 13.1, df = 4, *P* = 0.01, *n* = 1883). On the SSA, more male locations were found in open woodland habitats (3% vs. 1%) and open shrubland habitats (6% vs. 3%) than females (X^2 = 24.0, df = 4, *P* < 0.001, *n* = 1170).

Dispersal

No dispersal was observed among female bears whose natal range was known, however dispersal was observed among male bears (Table 9-4). Radio-telemetry monitoring ended prior to dispersal for most males (76%), due to shed transmitters, collar removal, mortality, or lost contact. Of males monitored until age 4, 100% dispersed from their natal range. Five dispersal movements were documented. Two males (40%) dispersed during fall of their yearling year, 2 males (40%) dispersed during fall of their second year, and 1 male dispersed during the spring of his third year (20%). Dispersal distance ranged from approximately 25-60 km. Interestingly, 2 littermates dispersed at the same time to the same area and made similar movements to fall mast.

In addition to these known dispersal observations, we also documented the probable dispersal of a male bear captured as a subadult. This bear appeared to disperse during late summer of its third year, when it moved approximately 45 km from its previous range and established a new home range. This individual was known to maintain this home range until fall of his fifth year.

Table 9-4. Rate of dispersal, by age, for juvenile black bears monitored with radio telemetry on the Northern and Southern Study Areas, New Mexico, 1993-2000.

	Age	*n*	Percent Dispersed[a]	Details
Females	1	21	0	
	2	9	0	
	3	8	0	
	4	2	0	
	5	2	0	
Males	1	17	0	
	2	13	15	2 bears left natal range in fall of yearling year
	3	4	100	1 bear left natal range in fall of second year 1 bear left natal range in spring of third year

[a] By end of premast season (20 July)

Nuisance or Depredation Activity and Post-translocation Movements

On the NSA, radio-telemetry data was obtained for 52 females bears and 41 male bears >1 year old. Primary MCP home ranges of 81% of females and 90% of males overlapped areas of potential human conflict. The most common area of overlap was Philmont Scout Ranch, used by 65% of females and 90% of males. Public campgrounds were found within 10% of female and 34% of male home ranges. The towns of Eagle Nest, Ute Park, or Cimarron, or the Eagle Nest Reintegration Center were found within 15% of female and 39% of male home ranges.

On the SSA, radio-telemetry data were obtained for 41 females and 35 males >1 years old. Primary MCP home ranges of 3 (7%) females and 4 (11%) males overlapped areas of potential human conflict. Areas of overlap included 2 public campgrounds at Willow Creek and Snow Lake. None of the home ranges of SSA bears overlapped towns.

On the NSA, 14% of females and 20% of males >1 year old were known or suspected of potential nuisance or depredation activity (*n* = 158), but only 2% of females and 1% of males on the SSA were involved in these activities (*n* = 154, Table 9-5). Of 28 NSA bears involved in nuisance or depredation activities, half (50%) were attracted to towns with unsecured garbage or other available foods. Garbage was made available to bears most often by the use of open dumpsters lacking bear-resistant lids. Foods associated with homes included hummingbird feeders, pet foods, deer feed, and garbage. Nuisance activities of 7 bears (25%) were associated with Philmont camps and activities of 5 bears (18%) were associated with public campgrounds. Three depredation complaints (11%) arose from depredation of domestic pigs or apiaries.

Table 9-5. Percent of marked black bears >1 year old known or suspected of nuisance or depredation activities on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1992-1999.

			Percent suspected of nuisance	Percent causing nuisance or depredation complaints by management action			Total
Area	Sex	*n*	activity	Hazed	Translocated	Killed	percent
NSA	Females	57	7	2	4	2	14
	Males	101	4	3	8	5	20
SSA	Females	56	0	0	2[a]	0	2
	Males	98	1	0	0	0	1

[a] Both bears were translocated into the study area from outside its boundary

On the SSA, both female bears translocated because of nuisance activity were actually moved onto the study area from outside its boundary. One incident arose at a public campground and the other was associated with a backcountry camp. The single male bear suspected of depredation activity was found shot dead near a cattle carcass. It was unknown if the bear was responsible for the death of the cow.

Post-translocation movements were documented following 11 translocations of 8 bears (Table 9-6). Translocation distances ranged from 26-84 km and overall rate of return was 73%. Return movements took from approximately 1-328 days. Return rate of adult bears was 100%, and each individual appeared to begin return movements immediately following translocation. Return rate of subadult bears was 57%, and 3 of 4 bears that did not attempt return movements were males.

DISCUSSION

Evidence indicated bears on the SSA, in general, moved over larger areas than bears on the NSA. Mean premast activity radii and primary home range size was larger for females on the SSA. Although no differences in male home range size or activity radii were found between study areas, the higher frequency of missing bears on the SSA suggested they may have moved greater distances than documented. Many have postulated home range size is an indication of habitat quality. The premise is when food is abundant and evenly distributed animals do not need to search far for food. When food is scarce and distribution is patchy, animals need to move more widely in search of food. We do not have detailed information on the distribution of food plants on each study area, but examination of habitat data showed that availability of mast-producing habitats did not differ between study areas. However, relative consumption of premast foods did appear to differ between study areas (see Chapter 5). On the NSA, the premast diet was dominated by grasses. On the SSA, the premast diet was characterized by less consumption of grasses, and greater consumption of mast and woody plants. The more arid conditions of the SSA, coupled with livestock grazing, may limit the availability of grasses to bears, and compel individuals to search more widely for other foods, such as juniper berries.

Table 9-6. Rate of return, by sex-age category, for nuisance bears translocated into or away from the Northern and Southern Study Areas, New Mexico, 1993-2000.

Sex	Age class	*n*	Percent Returned	Distance Moved	Details
Female	Adult	2	100%	38-47 km	Both bears previously moved as subadults, both returned
	Subadult	4	75%	25-58 km	The bear that did not return moved to another human development
Male	Adult	2	100%	45 km	One individual moved twice
	Subadult	3	0%	65-85 km	All bears appeared to establish home ranges in new area, no further nuisance activity documented

The fall foraging period lasted for over 2 months. On the NSA, bears ranged widely beginning in early August and ending during early to mid October. On the SSA, fall movements were less well-defined, but ranged from mid August to late October. On both study areas, peaks of male movements appeared to occur earlier than those of females, and initiation of long-range movements was earlier for males on the NSA. Earlier initiation of fall movements to oak stands by male black bears also was observed in Great Smoky Mountain National Park (Garshelis and Pelton 1981).

Increased fall travel distances during years of food shortage have been reported in other bear studies (Garshelis and Pelton 1981, Beck 1991). Mast season activity radii of black bears in New Mexico were significantly larger during years of oak failure for most sex-age categories, indicating bears may have had to travel farther in search of food when oak production failed. The increased movements and unfamiliarity of distant areas may make bears more vulnerable to hunting. Higher bear harvest levels have been associated with shortages of natural foods in Massachusetts (McDonald et al. 1994) and Minnesota (Noyce and Garshelis 1997). This has important ramifications for interpreting and predicting fall harvest of bears.

Analyses of habitat use indicated bear movements were strongly associated with closed forest and closed woodland habitat types. Open habitats, including grasslands and open woodlands, appeared to be avoided, particularly by female bears. Use of the open shrubland habitat was relatively low, but was higher than expected given its low occurrence. Oak species are an important component of many montane shrubland communities in New Mexico, and general observations throughout the study period indicated bears sought these habitats during the fall foraging period. Based on ground knowledge of the study areas, we believe shrubland communities were under-represented in the NMGAP landcover map (Thompson et al. 1996) we used for habitat analysis (see Chapter 11). This probably limited our ability to assess actual use of shrubland habitat. Selection for closed canopy habitats, avoidance of open habitats, and use of edges by black bears have been reported in other black bear studies in the West (Lindzey and Meslow 1977, LeCount and Yarchin 1990).

Overlap of bear home ranges with areas of potential human conflict was very different between the 2 study areas. Most bears on the NSA had 1 or several sources of human-related food within their primary home ranges, but few bears on the SSA had access to predictable human-related foods. Given these circumstances, it is easy to explain the substantial depredation mortality observed on the NSA and the lack of such mortality on the SSA (see Chapter 7).

Despite the potential for conflict on the NSA, most bears did not engage in nuisance or depredation activities. At least 35 female study bears had home ranges partly or entirely within Philmont Scout Ranch, however only 3 of these bears created nuisance problems requiring management action. Likewise, at least 37 male study bears used areas of Philmont, but only 2 were involved in nuisance complaints. Throughout the study period, Philmont maintained strict guidelines for storing foods in established camps and on the trail. These precautions appeared to be effective at minimizing bear-human conflict.

Compared to bears using areas of Philmont, far fewer study bears (9 females and 17 males) had home ranges encompassing towns or campgrounds. However, the majority of documented conflict was associated with these areas. In each of the 3 towns close to the NSA and the Eagle Nest Reintegration Center, garbage disposal was achieved using non bear-resistant dumpsters, often distributed throughout residential areas. These dumpsters were probably the initial attractant drawing bears into human-populated areas. The reward of high-calorie food obtained from dumpsters was probably enough to overcome the natural wariness of bears to humans (Herrero 1989). Human habituation, or loss of innate fear of humans, has been directly associated with use of human-related foods by black and grizzly bears (Hastings et al. 1989, Herrero 1989). In human-populated areas of the NSA, the transition from wariness to human habituation probably fit the circumstances described by Herrero (1989), whereby over time, when use of human-related foods did not result in harm or harassment to the bear, habituation developed. Increased use of other human-related foods, such as hummingbird feeders or pet food, was a predictable outcome of this progression. In the end, bears and humans can be negatively impacted by these events. Mortality of male and female bears was observed on the NSA due to nuisance and depredation problems. In most cases, bears were destroyed because they were considered a threat to human safety. In addition, many incidents of human injury and fatality from black and grizzly bears have been attributed to human habituation (Herrero 1989).

Increases in black bear nuisance problems have been correlated with shortages in natural foods (Rogers 1976, Rogers 1987). The small number of depredation complaints recorded on an annual basis, and the occurrence of only 1 oak failure on the NSA prevented us from drawing any conclusions about the effect of natural food availability on bear problems in New Mexico. However, general observation in the region of the NSA hinted at an association of bear problems with spring and summer periods lacking rainfall. Analyses of bear complaints relative to fall mast production and spring to summer conditions is needed in New Mexico.

Use of translocation as a means of solving nuisance or depredation complaints had variable success. All translocated adult bears returned to their original home range within days or months of their translocation. However, in most cases the time elapsed before their return did allow for immediate resolution of the problem. Some translocations of subadult bears, especially males, were successful in that bears remained in the new area, and did not resume nuisance behavior. This was probably due to behavioral differences between sex-age categories. Subadult male bears may not have attempted return to their previous home range, because of the dispersing behavior characteristic of this age class. On the contrary, adult bears, and even subadult females displayed a high degree of home range fidelity during our study, indicating they would most like show homing behavior following translocation. Homing behavior of translocated bears has been widely reported and an inverse relationship between distance moved and probability of return was evident in all studies (Sauer et al. 1969, Beeman and Pelton 1976, McArthur 1981, Rogers 1986). In general, bears translocated more than 65 km from the capture site were less likely to exhibit homing behavior. Despite some success, translocation is not without cost to bears. Survival rates of translocated bears were found to be only 23% in Virginia and the primary cause of death was automobile collisions (Comly-Gericke and Vaughan 1997).

MANAGEMENT IMPLICATIONS

Analyses of bear movement data and distribution among habitat types on the 2 study areas illustrated the importance of distinguishing how male and female bears use the landscape differently. These analyses also indicate the importance of considering the season and condition of food supply when drawing conclusions about the presence of bears in specific locations.

Three of the largest tracts of bear habitat in New Mexico (the San Juan complex, the Sangre de Cristo complex, and the Gila complex) are contiguous with bear habitat in Colorado or Arizona (see Chapter 11). Two small tracts (the Bootheel region and the Guadalupe region) share habitat with Arizona or Texas. Evidence indicates bears commonly cross state boundaries during fall foraging and dispersal. Therefore, bear management in New Mexico is not independent of these other states. Some understanding of the population trend in these other states is vital for estimating the potential impact of immigration and emigration on New Mexico black bear populations.

Analysis indicated a small percentage of individuals within a bear population engage in nuisance and depredation activities. Most documented bear problems were associated with human-related foods, especially garbage. Efforts to reduce accessibility of human-related foods will be instrumental in reducing the likelihood of bear problems on an annual basis. More information is needed on the relationships of natural food availability and bear problems. Increase in nuisance problems have been associated with food shortage in other regions,. Therefore, during years of low natural food abundance, problems can be expected to increase above the average level in New Mexico.

There is an apparent differential between subadult and adult bears regarding homing after translocation. This difference suggests that choices about relocating nuisance or depredating bears need to consider age and sex of the animal in addition to other factors surrounding the complaint.

CHAPTER 10

POPULATION DENSITY AND SEX-AGE COMPOSITION

For wildlife managers, 2 of the most desirable facts about a wildlife population are a firm estimate of total number of individuals and a tally by sex and age category. Sound wildlife management can be, and most often is practiced in the absence of these data. Nonetheless, population data are invaluable for monitoring population trend, setting hunt regulations, and providing adequate suitable habitat. Estimates of density and sex-age composition are among the most difficult values to obtain for wild populations, and black bears present some special challenges. Their solitary nature, forest-dwelling habit, and low densities make them difficult to enumerate using survey methods common for other big game species. Most often mark-recapture methods have been used to estimate black bear density (LeCount 1982, Beecham 1983, Miller et al. 1987, Garshelis 1992, Clark and Smith 1994).

At the beginning of this study, reliable information on population size and structure was lacking in New Mexico. The NMDGF had a long-standing populations estimate of 3000 bears statewide; however the means by which this estimate was deduced were not available. Our objective was to determine density and sex-age composition of study populations annually and with all years combined. This information would be valuable in estimating statewide and regional population numbers and for comparison of the sex-age composition of the live population to that of hunter-killed bears.

METHODS

Although the number of captures and recaptures were numerous, our trapping effort was primarily designed to capture an increasing sample of unmarked adult females. For this reason, it did not lend itself to a traditional capture-recapture analysis. We used population reconstruction (Eberhardt and Knight 1996), or backdating, to estimate a minimum population size of bears on each study area. This technique simply counts each individual as part of a study population during years when it was known or presumed to be resident, based on knowledge of its age. To translate this count into a density estimate, the critical element becomes the size of the area occupied by the individuals.

We defined a multi-year "effective sampling area” based on distribution of trap sites (Caughley 1977, Clark and Smith 1994). For each sex, we applied a buffer around each trap site equal to the mean activity radius of adult bears. We used the mean activity radius for the time period before most bears began to make long-range movements to fall mast (1 May – 12 August, see Chapter 9). We also restricted trap sites to those trapped within this period. The buffer areas around each trap were merged into a composite, and this became our effective sampling area. On the NSA, sampling areas used were 297.1 km ^{2} for females and 545.4 km ^{2} for males. On the SSA, areas used were 538.6 km ^{2} for females and 969.2 km ^{2} for males. In essence, size of the area differed by sex, based on observed differences in movement patterns. Because males ranged over larger areas than females, we were able to sample a larger area for males than females using a single trap site.

We constructed a table of bears known alive during each year, by backdating from the last known observation of each study bear. Because no dispersal was observed among females (see Chapter 9), we counted bears as resident during all years if they were captured during the 1 May-12 August season. If they were captured during the mast season, they were counted only if they were known from radio-telemetry monitoring to reside within the effective sampling area. Female offspring of resident females were counted as residents. Due to observed dispersal patterns of males (see Chapter 9), we used different criteria. For males captured as adults, we could not assume they were born on the effective sampling area, therefore we counted them as resident only back to the age of 4 years. For males captured only as subadults and not monitored with radio-telemetry, we counted them as resident only during years when they were captured. For males captured as yearlings, we backdated until birth. Male offspring of resident females were counted as resident only as yearlings or until dispersal was observed through radio-telemetry monitoring.

We determined annual and mean population densities of bears $\geq$1 year old based on these counts. We did not assume we captured all resident bears within the sampling area; therefore these estimates were considered minimum. Because more female bears were monitored with radio-telemetry than male bears, more information on residency and survival was obtained for female bears. Therefore, although we used this method to estimate the sex-age composition of the populations, we recognized it could be biased toward females. Relative proportions of yearlings were also probably underestimated. Because capture probabilities appeared to be lower for this age class, and most bears were captured as adults, bears that did not survive their yearling year would not appear in our analyses.

RESULTS

Estimates of adult and subadult densities remained relatively constant from year to year, on both study areas (Table 10-1). Number of females, particularly adult females, varied little between years. Number of males generally decreased over the years of study; however this decrease may have been due to a reduction in trapping effort rather than an actual change in numbers. Densities of yearlings were more variable. Bear density appeared to be higher on the NSA than the SSA. Mean estimates of adult bears were 45% lower for females on the SSA and 29% lower for males.

Relative proportions of sex-age categories varied annually, with most of the changes observed in the yearling age class. Proportions of subadult males also varied, with peaks observed during 1993-95 on the NSA and 1994-95 on the SSA.

Table 10-1. Density (bears/100 km^2) of adult (≥5 years old), subadult (2-4 years old), and yearling (1 year old) black bears sampled on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1993-1999[a].

			Year							All
Area	Sex	Age class	1993	1994	1995	1996	1997	1998	1999	years
NSA	Female	Adult	4.7	5.0	5.0	5.4	6.7	7.7	7.4	6.0
		Subadult	3.4	4.0	4.7	3.7	3.4	2.7	2.4	3.5
		Yearling	2.0	1.7	0.7	2.0	0.7	2.4	1.7	1.6
		Total	**10.1**	**10.8**	**10.4**	**11.1**	**10.8**	**12.8**	**11.4**	**11.1**
	Male	Adult	3.3	3.1	3.3	3.9	3.3	2.6	2.2	3.1
		Subadult	2.9	4.6	2.8	1.1	1.3	1.5	0.9	2.1
		Yearling	0.4	0.4	0.0	1.1	0.7	0.9	1.3	0.7
		Total	6.6	8.1	6.1	6.1	5.3	5.0	4.4	5.9
	Grand Total		**16.7**	**18.8**	**16.5**	**17.2**	**16.1**	**17.7**	**15.8**	**17.0**
SSA	Female	Adult	2.6	2.8	2.8	3.5	3.2	3.9	4.1	3.3
		Subadult	2.0	2.2	3.2	2.2	1.9	1.1	1.1	2.0
		Yearling	0.4	1.9	0.6	0.2	1.1	0.7	1.1	0.8
		Total	**5.0**	**6.9**	**6.5**	**5.9**	**6.1**	**5.8**	**6.3**	**6.1**
	Male	Adult	2.7	2.6	2.4	3.1	2.0	2.0	0.7	2.2
		Subadult	0.3	1.7	1.9	0.7	0.4	0.4	0.4	0.8
		Yearling	0.1	0.3	0.0	0.0	0.9	0.4	0.7	0.4
		Total	**3.1**	**4.5**	**4.2**	**3.8**	**3.3**	**2.8**	**1.9**	**3.4**
	Grand Total		**8.1**	**11.4**	**10.7**	**9.8**	**9.4**	**8.5**	**8.2**	**9.4**

[a]Estimates were derived using population reconstruction within an effective sampling area based on distribution of traps.

Population sex-age composition was very similar for the 2 study areas (Table 10-2). Adult females constituted approximately 35% and adult males accounted for 18-23% of study populations. Relative proportions of yearlings varied annually.

DISCUSSION

Although this method had limitations, we believe the estimates derived were relatively accurate, particularly for adult and subadult bears. The raw numbers of individuals counted within the sampling areas were similar for the 2 study areas, as expected considering the nearly equal trapping success (see Chapter 4). The primary factors contributing to differences in density estimates were observed difference between study areas in activity radius and the differences between study areas in total area sampled. The smaller activity radii observed on the NSA, coupled with the more restricted study area boundary, resulted in smaller effective sampling areas, thus higher densities. The activity radius values used to generate the effective sampling error appeared to be fairly accurate, based on comparisons with the composite primary MCP home ranges (see Chapter 9) for the individuals counted as residents (Figures 10-1 and 10-2). For females, the composite home range areas were only 5-6% larger than the effective sampling area, and most individual home ranges were well within its boundary. For males, the composite home range area was 28-59% larger, but most individual home ranges were still contained within the sampling area. A high degree of home range overlap was observed between individuals, especially males. Therefore, the composite home range areas would likely contain more unsampled individuals, especially on the outer edges, well away from trap sites.

Table 10-2. Estimated proportions of adults (≥5 years old), subadults (2-4 years old), and yearlings (1 year old) within black bear populations sampled on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico, 1993-1999[a].

			Year							All
Area	Sex	Age class	1993	1994	1995	1996	1997	1998	1999	Years
NSA	Female	Adult	0.28	0.27	0.31	0.31	0.42	0.44	0.47	0.35
		Subadult	0.20	0.21	0.29	0.22	0.21	0.15	0.15	0.20
		Yearling	0.12	0.09	0.04	0.12	0.04	0.13	0.11	0.09
		Total	**0.60**	**0.57**	**0.63**	**0.65**	**0.67**	**0.72**	**0.72**	**0.65**
	Male	Adult	0.20	0.17	0.20	0.22	0.21	0.14	0.14	0.18
		Subadult	0.18	0.24	0.17	0.06	0.08	0.08	0.06	0.13
		Yearling	0.02	0.02	0.00	0.06	0.05	0.05	0.08	0.04
		Total	**0.40**	**0.43**	**0.37**	**0.35**	**0.33**	**0.28**	**0.28**	**0.35**
SSA	Female	Adult	0.32	0.24	0.26	0.36	0.33	0.46	0.50	0.35
		Subadult	0.25	0.20	0.29	0.23	0.20	0.13	0.14	0.21
		Yearling	0.05	0.16	0.05	0.02	0.12	0.09	0.14	0.09
		Total	**0.62**	**0.60**	**0.61**	**0.61**	**0.65**	**0.67**	**0.77**	**0.64**
	Male	Adult	0.33	0.23	0.22	0.32	0.21	0.23	0.09	0.23
		Subadult	0.04	0.14	0.17	0.07	0.04	0.05	0.05	0.09
		Yearling	0.01	0.03	0.00	0.00	0.10	0.05	0.09	0.04
		Total	**0.38**	**0.40**	**0.39**	**0.39**	**0.35**	**0.33**	**0.23**	**0.36**

[a] Estimates were derived using population reconstruction within an effective sampling area based on distribution of traps.

Although density estimates were quite different by study area, estimates of sex-age composition were remarkably similar. Given similar survival rates observed on the 2 study areas (see Chapter 7), our estimates of density and composition appear relatively accurate. However, densities observed on the NSA may have been higher than in similar habitat where hunting was not restricted. Our data are not sufficient to rigorously assess that question.

Figure 10-1. Size of the effective sampling area used for estimating black bear density, relative to primary minimum convex polygon home ranges of resident bears on the Northern Study Area, New Mexico, 1992-2000.

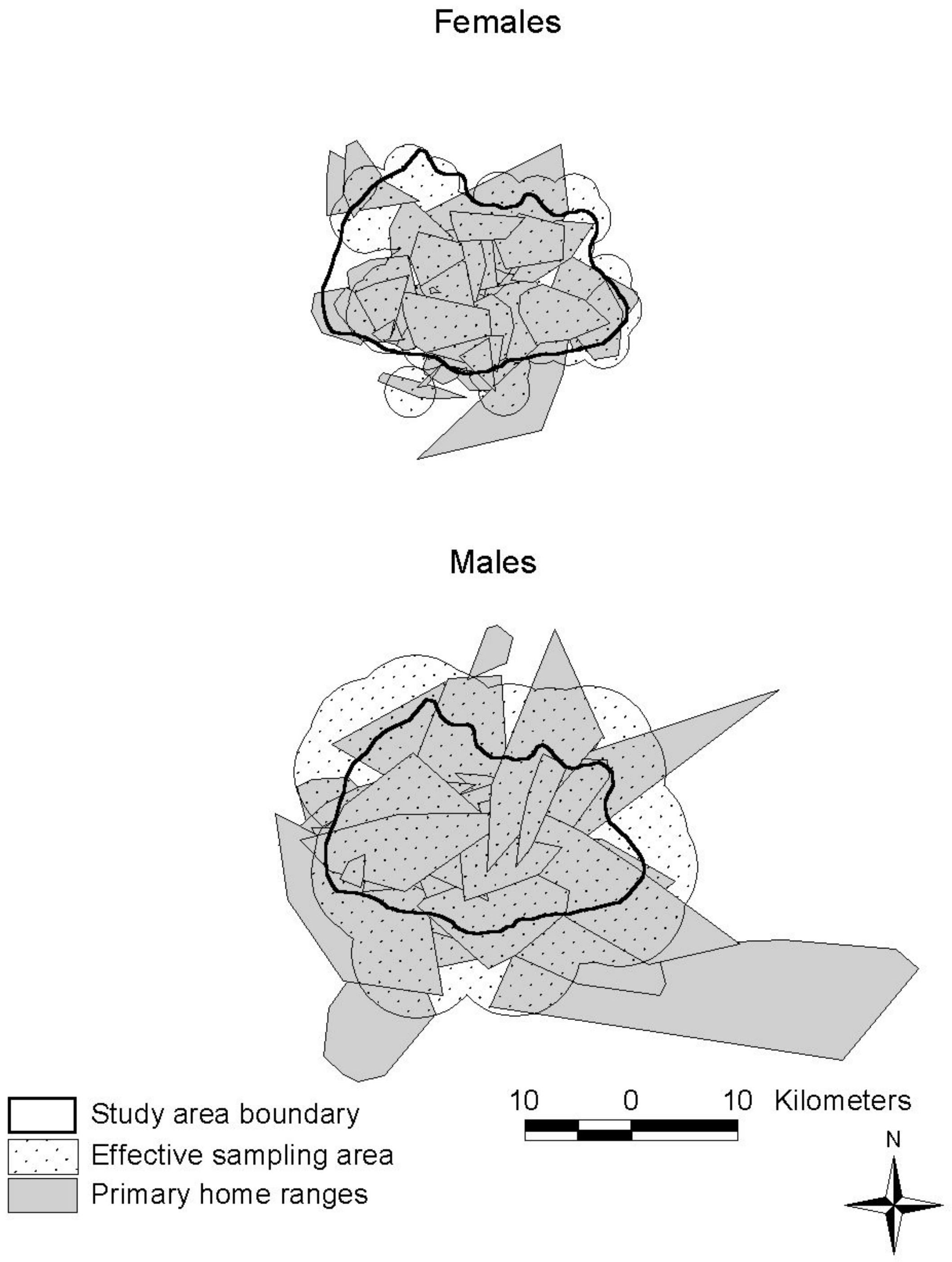


Figure 10-2. Size of the effective sampling area used for estimating black bear density, relative to primary minimum convex polygon home ranges of resident bears on the Southern Study Area, New Mexico, 1992-2000.

Densities and proportions of yearlings were quite variable among years. For each study area, the years of lowest yearling density (1995 on the NSA, 1996 on the SSA) corresponded to years following oak failure (see Chapter 6). On both study areas, the densities and proportions of yearlings were lower for males than for females. We suspect this was a product of the sampling and estimation method, and did not accurately reflect true values. In any given year, most yearlings counted within the sampling area were offspring of resident females, not trapped bears. Because the male sampling area was larger than the female's, there were likely unsampled females within it. Because we could not count their offspring, the resulting density estimates for male yearlings were lower than those of females. The density estimates for females in these age classes were probably more accurate.

Black bear density has been estimated in many regions of North America, primarily using mark-recapture or mark-resight methods. The variability of these estimates is tremendous, with densities as low as 1.8 bears/100 km ^{2} in the Snowy Mountains of southeast Wyoming (Grogan and Lindzey 1999) to 149 bears/km^2 on a coastal island in Washington (Lindzey and Meslow 1977). Within the Southwest, density estimates have ranged from 12-16 bears/100 km^2 in west-central Colorado (Beck 1991) to 71 bears/100 km^2 in north-central Arizona (LeCount 1987). Our density estimates appeared reasonable in the context of these other studies.

MANAGEMENT IMPLICATIONS

The density estimates obtained for the study areas can be used in conjunction with habitat data (see Chapter 11) to estimate statewide and regional population sizes. However, these estimates must be used with caution. Arguably, our study was conducted within some of the most productive bear habitat in New Mexico, particularly the NSA. Direct extrapolation of these density values to all areas of bear habitat would not be realistic.

The sex-age composition estimated for the study areas also can be compared to the structure of hunter kill data and simulated population structures generated using the bear population model (see Chapter 14). These analyses may aid in current and future interpretation of bear population trend, as reflected in the harvest data.

CHAPTER 11

A MODEL OF STATEWIDE HABITAT SUITABILITY AND POPULATION SIZE

Understanding the population status and trend of large carnivores, such as bears, over large landscapes is constrained by limited by availability of detailed empirical data and few approaches to analysis and display of spatial information (Merrill et al. 1999). Habitat analysis using GIS technologies has proven useful for management of wildlife in general (Scott et al. 1993, Horino and Miura 2000) and black bears in particular (Clark et al 1993, van Manen and Pelton 1997). These approaches can be useful to forecast future impacts of human population growth or habitat alteration. Van Manen et al. (1997) considered forecasting capabilities fundamental to the management process.

In this chapter, we describe the New Mexico landscape from the perspective of bear habitat suitability. Specifically, we make spatial predictions as to potential availability of mast species and the potential for human interaction. Our objectives were to: (1) predict suitable black bear habitat in New Mexico, (2) derive associated statewide and regional population estimates, and (3) analyze potential human influences on bear habitat. These objectives involved GIS analyses of bear habitat associations based on habitat use and movements observed on the 2 study areas. These associations were applied to a land cover map of New Mexico and other spatial criteria to depict predicted suitable bear habitat. Factors (roads, human population density, hunter kills) known to affect bear populations were overlaid with suitable habitat to develop spatially explicit perspectives on potential hunting mortality and bear-human conflict.

Information gathered from these exercises should help managers better understand the status of black bears across the state and serve as the basis for black bear management. The bear habitat model is a tool that identifies where bears have the potential to occur, the spatial boundaries of distinct populations, the degree of isolation between populations, and whether landscape characteristics differ among populations. These perspectives can aid in forecasting bear management needs and challenges.

METHODS

Habitat Model Development

A spatial model predicting the extent of suitable black bear habitat was developed using a rule-based system with GIS technologies, based on the New Mexico Gap Analysis (NMGAP) land cover map (Thompson et al. 1996) and biological information derived from field studies during 1992-2000. The habitat model was developed using ESRI Arc/View script language. The NMGAP land cover map includes 42 cover classes, described by dominant vegetation and canopy cover. Each of these cover classes was assigned to 1 of 4 categories of relative suitability for bears based on habitat use observed on the 2 study areas (see Chapter 9) and cover type descriptions. Suitability was rated as primary, secondary, edge use, and no use (Table 11-1). Cover classes rated as primary included all closed-canopy forest and woodland types, because more than 80% of bear locations were found within these types. Cover classes rated as secondary included shrubland types used more than expected, but accounting for <10% of total use. Cover classes rated as edge use included open woodland and grassland types used less than expected. Analyses indicated these types were used by bears, but usually in close proximity to more suitable habitats. Cover classes associated with humans, such as agriculture or urban, were rated as no use. Desert cover types also were classified as no use.

Each land cover class also was assigned to 1 of 3 categories of relative mast production potential, based on cover type descriptions (Thompson et al. 1996) and occurrence of oak, juniper, or pinyon species within cover classes. Categories were high, poor, and no mast production potential.

The habitat model first selected all land cover classes classified as primary. Secondary types were then selected only if they were adjacent to a primary type. Edge use types were then selected if they were adjacent to a primary type, and only that portion within a 500 m buffer from the primary type was included in predicted habitat.

When these areas were identified, we used GIS analyses in the model determine the area of each contiguous tract of suitable habitat (regardless of its habitat suitability score). Tracts >300 km^2 were selected as suitable habitat. This size represented the approximate area supporting 50 individual bears based on density data from the NSA (see Chapter 10), and we deemed this a "minimum sustainable population". Also, tracts >20 km^2 (large enough to support 1-2 bears based on home range data) were selected only if they were within 15 km of a habitat tract large enough for a minimum sustainable population.. All other tracts were considered too small or too isolated to be included in the final model.

The model was designed to allow users to vary the habitat scores for each land cover class, minimum tract size for a sustainable population, minimum tract size for a single individual, and maximum distance that an individual must be from viable population before it is considered too isolated from the population. Predictions of bear habitat reported here were based on values described above.

The model was designed to generate 2 maps of black bear habitat. The first was the detailed map described above. The second was a generalized distribution map that identified major regions of bear habitat. To develop this map, internal, unselected polygons were absorbed and the boundaries were simplified by expansion and shrinking of the boundary. This eliminated much of the reticulation and complexity of the polygon boundary. We found that doing this process twice resulted in a better generalization.

Table 11-1. Habitat suitability and mast potential assignments used in the statewide black bear habitat model for New Mexico; land cover classes are from Thompson et al. (1996).

NMGAP Code	Description	Suitability	Mast potential
1111	Rocky Mountain Alpine Graminoid Tundra	EdgeUse	None
1112	Rocky Mountain Alpine Forb Tundra	EdgeUse	None
2111	Subalpine Conifer Forest	Primary	None
2112	Subalpine Broadleaf Forest	Primary	None
2121	Rocky Mountain Upper Montane Conifer	Primary	Poor production
2122	Rocky Mountain Lower Montane Conifer	Primary	High production
2211	Madrean Lower Montane Conifer Forest	Secondary	High production
3111	Upper Montane Open Conifer Woodland	EdgeUse	None
3121	Rocky Mnt/Great Basin Closed Conifer	Primary	High production
3122	Rocky Mnt/Great Basin Open Conifer	EdgeUse	None
3211	Madrean Closed Conifer Woodland	Primary	High production
3222	Madrean Open Oak Woodland (Encinal)	Secondary	High production
4110	Rocky Mountain Montane Scrub & Interior	Secondary	High production
4111	Rocky Mountain Montane Deciduous Scrub	Secondary	High production
4121	Broadleaf Evergreen Interior Chaparral	Secondary	High production
4131	Plains-Mesa Broadleaf Sand-Scrub	None	High production
4211	Great Basin Microphyllous Desert Scrub	None	None
4212	Great Basin Broadleaf Deciduous Desert	None	None
4220	Chihuahuan Desert Scrub	None	None
4221	Chihuahuan Broadleaf Evergreen Desert	None	None
4222	Chihuahuan Broadleaf Deciduous Desert	None	None
5110	Rocky Mountain Subalpine and Montane	EdgeUse	None
5121	Short Grass Steppe	EdgeUse	None
5122	Mid-Grass Prairie	EdgeUse	None
5123	Tall Grass Prairie	None	None
5211	Great Basin Foothill-Piedmont Grassland	EdgeUse	None
5212	Great Basin Lowland/Swale Grassland	None	None
5220	Chihuahuan Desert Grassland	EdgeUse	None
5221	Chihuahuan Foothill-Piedmont Desert	EdgeUse	None
5222	Chihuahuan Lowland/Swale Desert	None	None
6110	Rocky Mountain Montane Forested/Shrub	Secondary	None
6120	Southwest & Plains Forested/Shrub Wetland	Secondary	None
6131	Arroyo Riparian Scrub	None	None
6210	Persistent Emergent Wetlands	Secondary	None
6211	Graminoid Wetlands	EdgeUse	None
9110	Dryland Agriculture	None	None
9120	Irrigated Agriculture	None	None
9210	Barren	None	None
9220	Mine/Quarries	None	None
9230	Rock Outcrop	None	None
9310	Urban	None	None
9320	Urban Vegetated	None	None
9410	Riverine/Lacustrine	None	None
9420	Basin/Playa	None	None

Estimates of statewide and regional black bear population size were derived by extrapolating mean density estimates from the 2 study areas (see Chapter 9) to areas of primary habitat. Density estimates from the NSA were used to estimate population size on the San Juan and Sangre de Cristo complexes. Density estimates from the SSA were used for all other regions.

GIS data and related metadata (Appendix B) and the habitat model (Appendix C) are included on a CD associated with this report. The habitat model is written in ESRI Arc/View script language and this package, with Spatial Analyst is needed for its use. The script language used for the New Mexico bear habitat model is contained in a file on the CDs associated with this report.

Hunter-Kill Locations

We used locations (UTM coordinates reported to the nearest 1000 m) recorded for hunter-killed bears obtained from the NMDGF harvest data (see Chapter 13) to compile a point file of bear kill locations. Accuracy of data was verified by comparing the recorded GMU with the recorded location, and obvious mistakes were corrected. Records for which the numeric portion of the GMU did not match with valid coordinates were discarded from analyses.

A total of 3,047 records of hunter-killed bears were available for the years 1990-1999, but 420 records (14%) were discarded due to a lack of UTM coordinates or UTM coordinates inconsistent with the GMU recorded. Examination of relative numbers of discarded records by year and GMU did not indicate any bias in the remaining sample of 2,627 records.

Human Interface

We created a coverage depicting total road length within the mean activity radius for female and male bears during the fall season (1 September-den entry, see Chapter 9). Mean activity radii were calculated for bears on both study areas, and a radius of 7.0 km was used for females and 12.0 km was used for males. A coverage depicting New Mexico roads was obtained from the U.S. Census Bureau (http://www.uscensus.gov). Road length was tabulated for each region. Analysis of total length of secondary roads within female (7 km) and male (12 km) fall activity radii was designed to estimate the potential length of road a bear might encounter during months of fall hunting. These data were derived by calculating the length of roads within 7-km or 12-km radii of points distributed at 1-km intervals across all of New Mexico.

A coverage of U.S. census blocks was used to evaluate distribution of bear habitat relative to human populations. Population blocks with human residential density >1 person/ha and >5 households were identified. Buffers created around these population centers represented areas within 5-20 20 km.

Conceptually, we viewed human activity relative to potential effect on the bear population. Bear hunters pose the greatest relative direct effect on a bear population, therefore we tried to obtain available information on distribution and magnitude of bear hunting activity statewide. Secondly, human activity on the landscape can cause significant indirect and direct influence on bear distribution and mortality (e.g., interaction with or avoidance of recreationists, bear mortality to depredation complaints or vehicle collision). In addition to bear mortality, interactions with humans can be highly visible events. We sought spatial data that would identify the degree of human use (not including recreationists) on the landscape. Recreationists were considered a separate group. Their interactions with bears are varied but generally present seasonal and dispersed effects. Residential and recreational uses were conceptually separated not only because of their effect on the bear population but to the social aspects of management. A nuisance bear is different to a resident versus a recreationist regarding the type of mitigation possible.

With this conceptual framework we searched for data to develop indices of human use of the landscape. We directed our search toward data that were statewide in scope. NMDGF harvest survey data were obtained, compiled, and linked to GMU coverages to depict relative hunter occurrence on the landscape. Similarly, angler survey data obtained from NMDGF were linked to a coverage of New Mexico fishing waters. We anticipated that these data will represent areas of possible hunter/angler-bear interaction. We also made attempted to obtain United States Forest Service (USFS) Lands spatial data as they contain a significant portion of bear habitat in New Mexico. We looked for spatially explicit measures of use and locations of facilities. We acquired recreation data from the USFS including limited recreation user days data and point locations of recreation facilities. In addition, we acquired recreation user days data from the New Mexico State Parks and the National Park Service.

RESULTS

Predicted Suitable Habitat

The habitat model prediction depicted prospective distribution of suitable black bear habitat (Figure 11-1) across approximately 58,939 km^2 (5.9 million hectares or 14.6 million acres). Simplification of the boundaries identified 10 distinct regions of predicted black bear habitat: 4 large regions including the San Juan complex, the Sangre de Cristo complex, the Gila complex, and the Sacramento region; 3 smaller, relatively isolated tracts including the Zuni region, Mt. Taylor region, and Sandia/Manzano region; and 3 small regions connected to larger range outside New Mexico, including the Chuska region, Bootheel region, and the Guadalupe region. The simplification process did not distinguish the San Juan complex and the Sangre de Cristo complex. We artificially separated these complexes, with the boundary defined as the Rio Grande. All applicable summaries reported here use this stratification of the state.

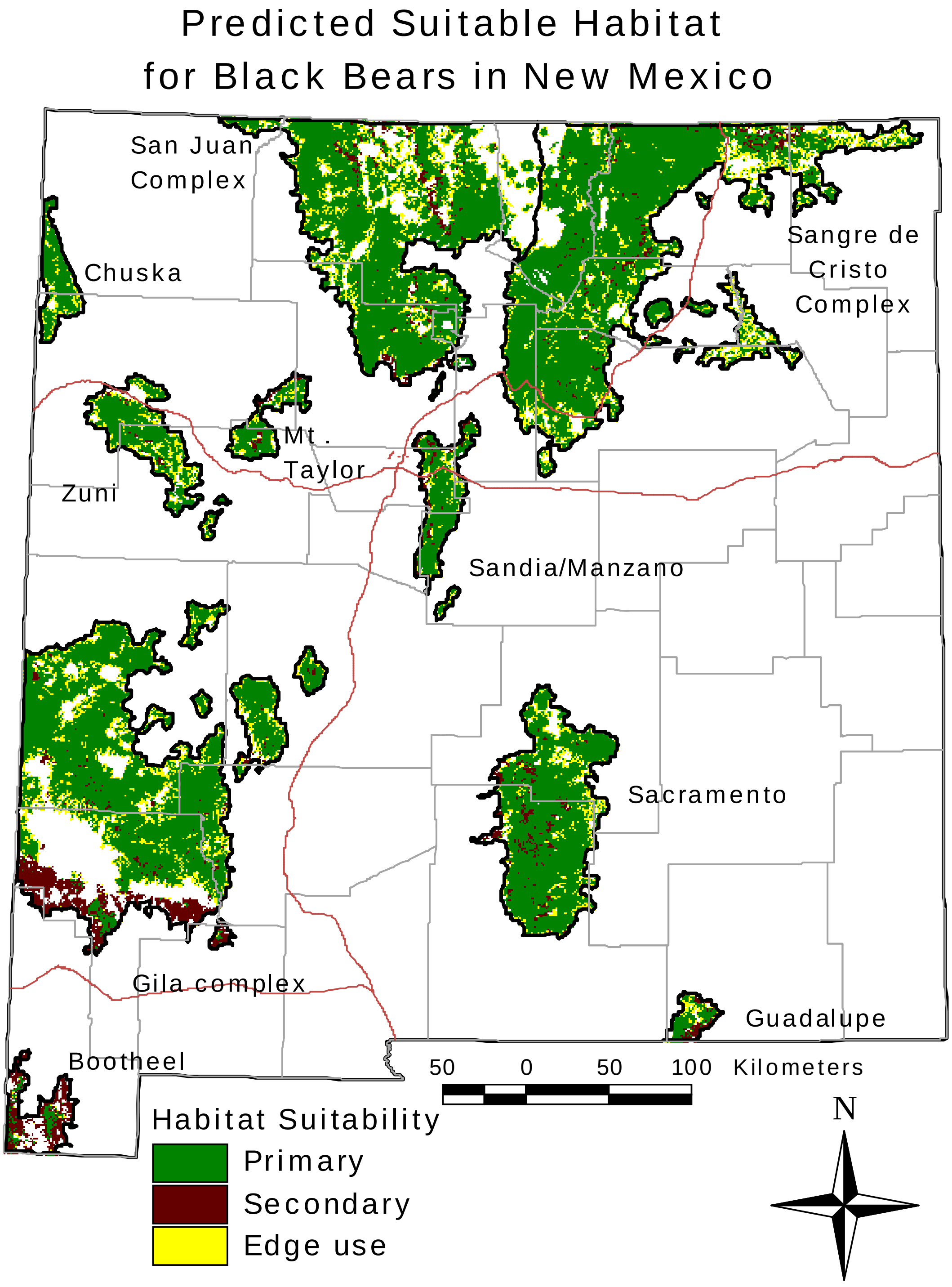


Figure 11-1. Map of predicted suitable habitat for black bear in New Mexico.

Of the 5.9 million ha of suitable habitat, 75% was comprised of primary cover types, 7% was comprised of secondary cover types, and 18% was comprised of edge use cover types (Table 11-2). Relative proportions of these types varied among regions. Most notably, the Bootheel region was comprised of relatively little primary habitat. Among the 4 large regions, the Gila complex had less primary habitat and more secondary habitat (Table 11-2).

Mast potential within suitable bear habitat showed some variability among regions (Figure 11-2). Areas of poor mast production potential were associated with higher elevations, especially in the San Juan complex, the Sangre de Cristo complex, the Gila complex, and the Sacramento region. When primary habitat was overlaid with mast production potential, only 280 km^2 was found to be >7.0 km from areas of high mast production potential. This distance corresponds to the observed mast season activity radius of female bears. That limited area with no mast production potential was located within the highest elevations of the Pecos Wilderness in the Sangre de Cristo complex.

Land ownership differed among the regions (Table 11-2). Nearly half of the predicted suitable bear habitat was managed by the USFS (Figure 11-3). Private landowners were the second most predominant stewards bear habitat, with about one third of all lands under private ownership. Tribal lands comprised about 10% of bear habitat, but it was concentrated in 3 regions. All of the Chuska range was situated within the Navajo Reservation, and large portions of the San Juan complex and the Sacramento region were found within the Jicarilla Apache and Mescalero Reservations, respectively. State lands and Bureau of Land Management properties constitute a relatively small portion of New Mexico bear habitat (Figure 11-3).

Human Interface

Locations of hunter-killed bears overlaid with the predicted habitat indicated strong corroboration of the habitat model predictions of habitat distribution (Figure 11-4). Significant tracts with no recorded bear kills were tribal lands and the Guadalupe and Bootheel regions. The Sandia range found within the north part of the Sandia/Manzano region also lacked records of bear kills. Overall, 95% (*n* = 2,488) of the bear kills occurred within the regional boundaries of predicted bear habitat. Of the 5% occurring outside boundaries, most were located north of the Gila complex. Bear kills are expected outside of predicted habitat because of occurrence of transient bears and slight errors in the predictive model.

Total road length within a female activity radius was highly variable statewide (Figure 11-5), but relatively uniform for a male activity radius (Figure 11-6). Approximately 40% of the bear habitat had >120 km of road within a female activity radius, while greater than 80% of the habitat had >120 km of road within a male activity radius.

Table 11-2. Summary of habitat model predictions and bear population estimates statewide and by region in New Mexico (see text and Figure 11-1 for description of regions).

	Statewide	Sangre de Cristo complex	San Juan complex	Gila complex	Sacramento region	Zuni region	Mt Taylor region	Sandia / Manzano region	Bootheel region	Chuska region	Guadalupe region
Predicted habitat (km^2)											
Total range	70,680	19,350	16,006	19,594	7,123	2,584	988	1,969	1,363	1139	564
Suitable habitat	58,939	16,960	12,495	15,472	6,642	2,242	887	1,788	895	1,060	499
Type of suitable habitat (%)											
Primary	75.10	79.74	77.70	71.25	80.21	68.86	64.85	72.66	21.29	75.79	53.31
Secondary	6.95	2.08	4.02	11.26	5.90	2.84	9.15	8.19	74.96		28.83
Edge use	17.96	18.18	18.28	17.49	13.89	28.29	26.00	19.15	3.75	24.21	17.86
Mast potential of suitable habitat (%)											
None	21.93	26.34	24.33	18.47	14.35	28.29	26.61	19.88	3.75	24.74	17.86
Poor	11.84	19.47	10.19	8.16	13.47	0.25	2.42	8.83		5.81	
High	66.23	54.19	65.48	73.37	72.19	71.46	70.97	71.29	96.25	69.45	82.14
Stewardship of suitable habitat (%)											
USFS[a]	49.89	27.32	49.19	82.86	45.05	50.72	50.60	40.77	23.22		58.49
Private	31.60	62.88	22.57	10.15	22.03	19.23	35.84	47.03	55.22		5.19
Tribal	10.61	2.14	20.30		27.01	15.97	1.57	7.35		100.00	
BLM[b]	3.79	1.98	5.38	4.22	2.67	4.14	11.79	0.86	15.25		9.12
State	3.18	5.55	1.04	2.75	2.93	1.55	0.20	3.89	6.31		3.58
NPS[c]	0.61	0.03	0.76	0.01		6.31					23.62
DOE[d]	0.15		0.72								
DOD[e]	0.12				0.31	2.09		0.10			
USFWS[f]	0.03	0.10									
BOR[g]	0.01	0.00	0.06								
Population estimate (bears ≥1 year old)											
Total bears	5947	2299	1651	1047	506	147	55	123	18	76	25

[a] U.S. Forest Service
[b] Bureau of Land Management
[c] National Park Service
[d] Department of Energy
[e] Department of Defense
[f] U. S. Fish and Wildlife Service
[g] Bureau of Reclamation

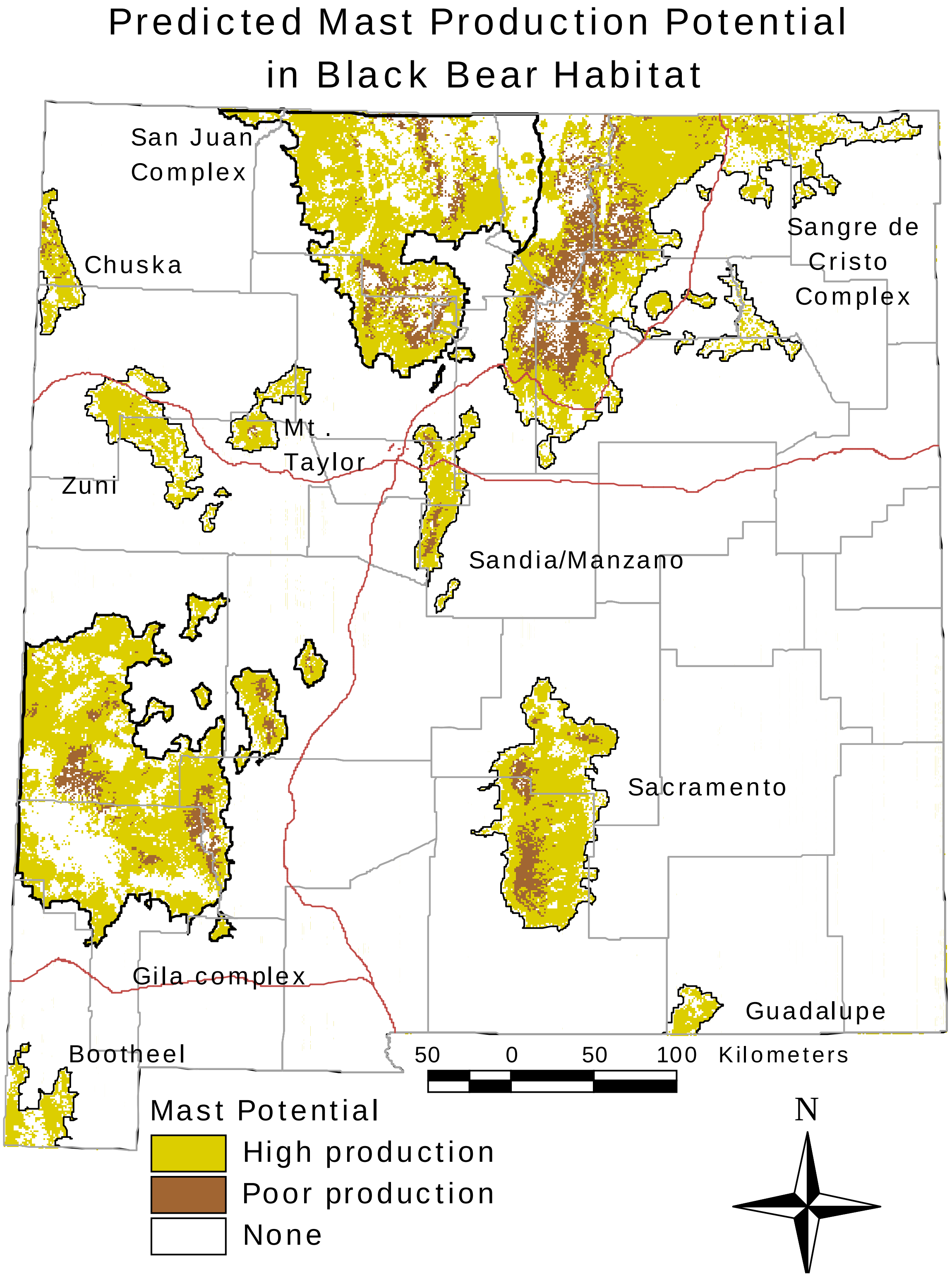


Figure 11-2. Distribution of mast production within predicted black bear suitable habitat.

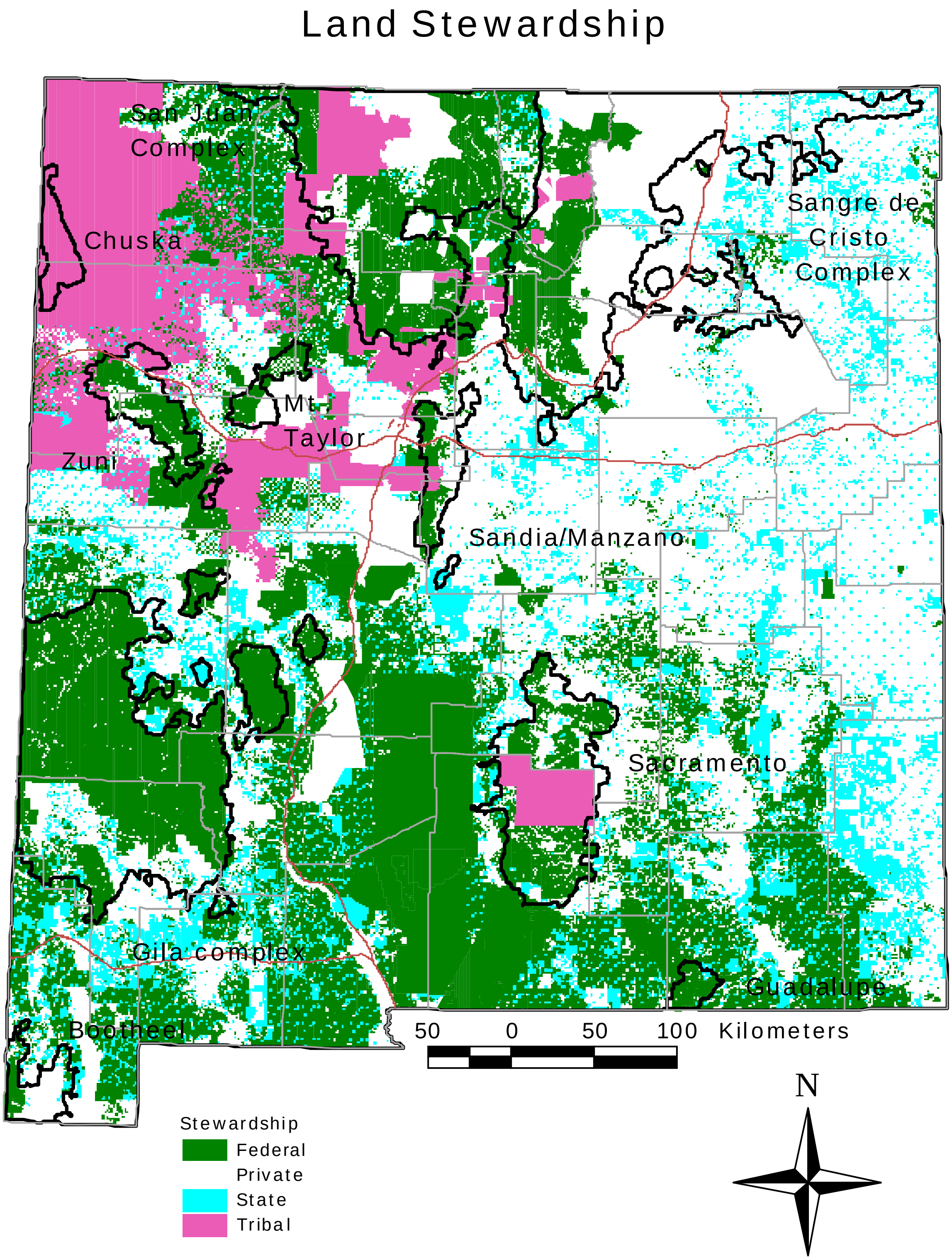


Figure 11-3. Federal, state, tribal, and private land stewardship (ownership) relative to predicted suitable black bear habitat in New Mexico.

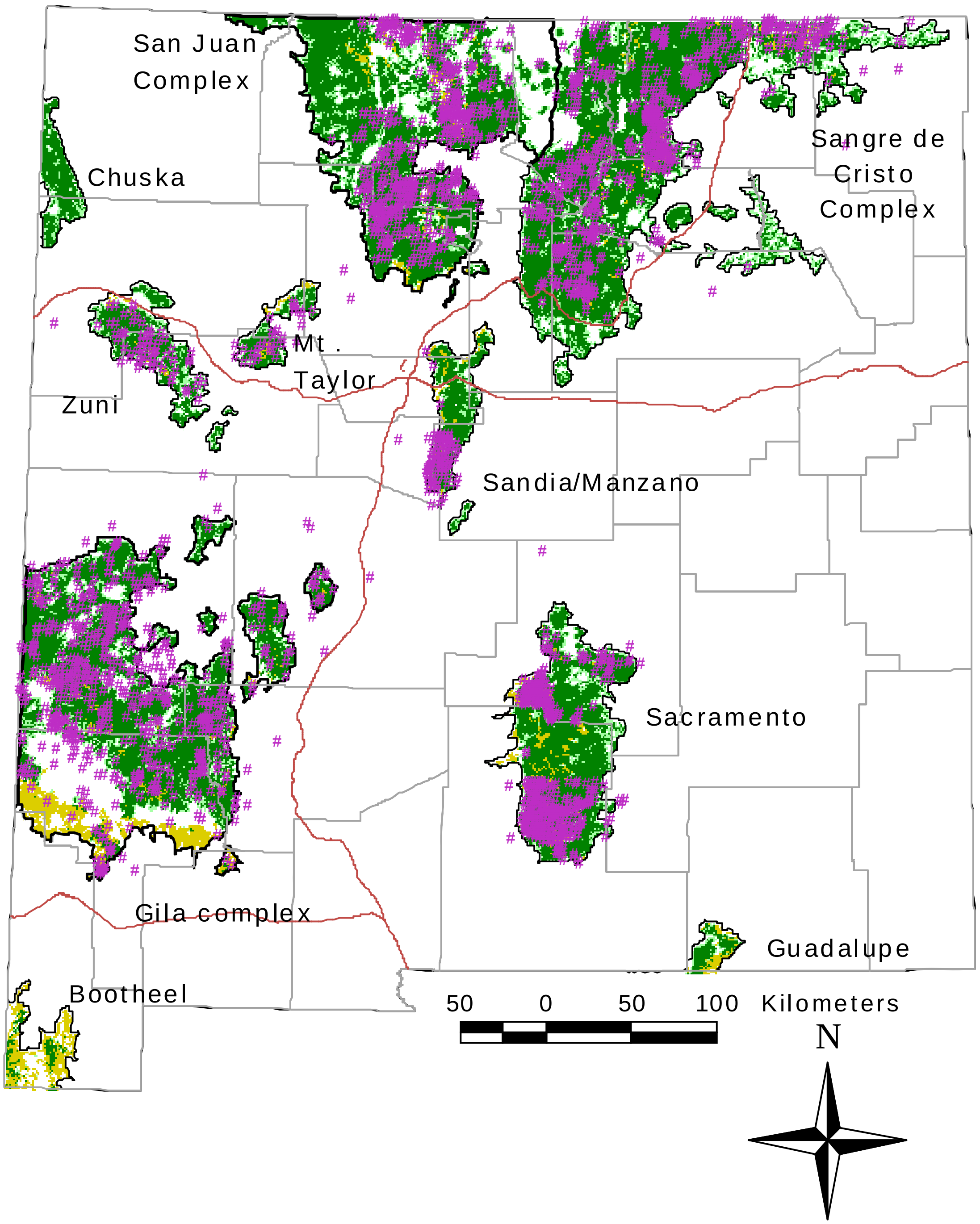

Location of Bear Kills by Hunters 1990-1999

Figure 11-4. Distribution of reported bear kills by hunters from 1990 to 1999.

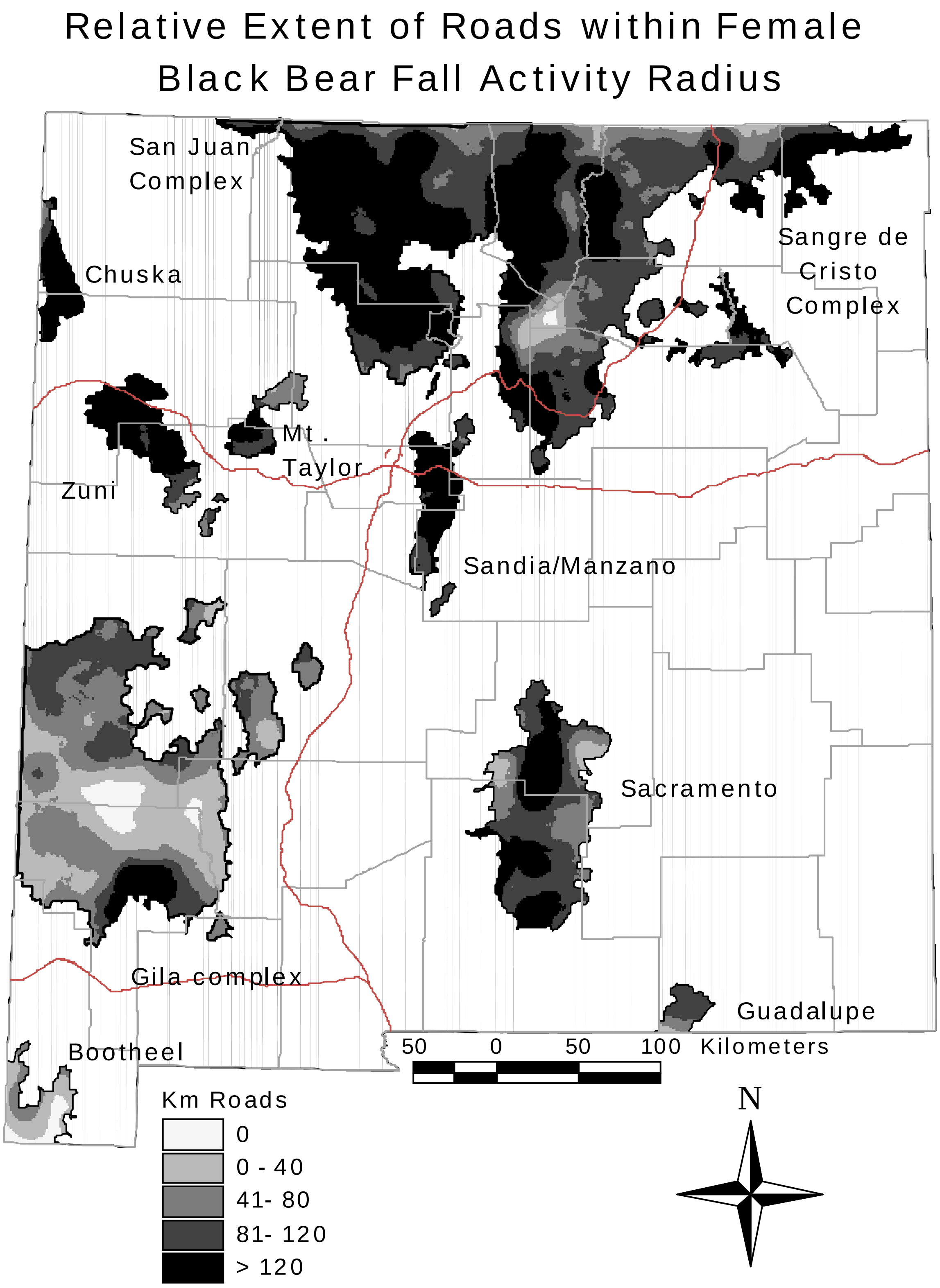


Figure 11-5. Extent of secondary roads within a female black bear fall activity radius (7 Km) in New Mexico.

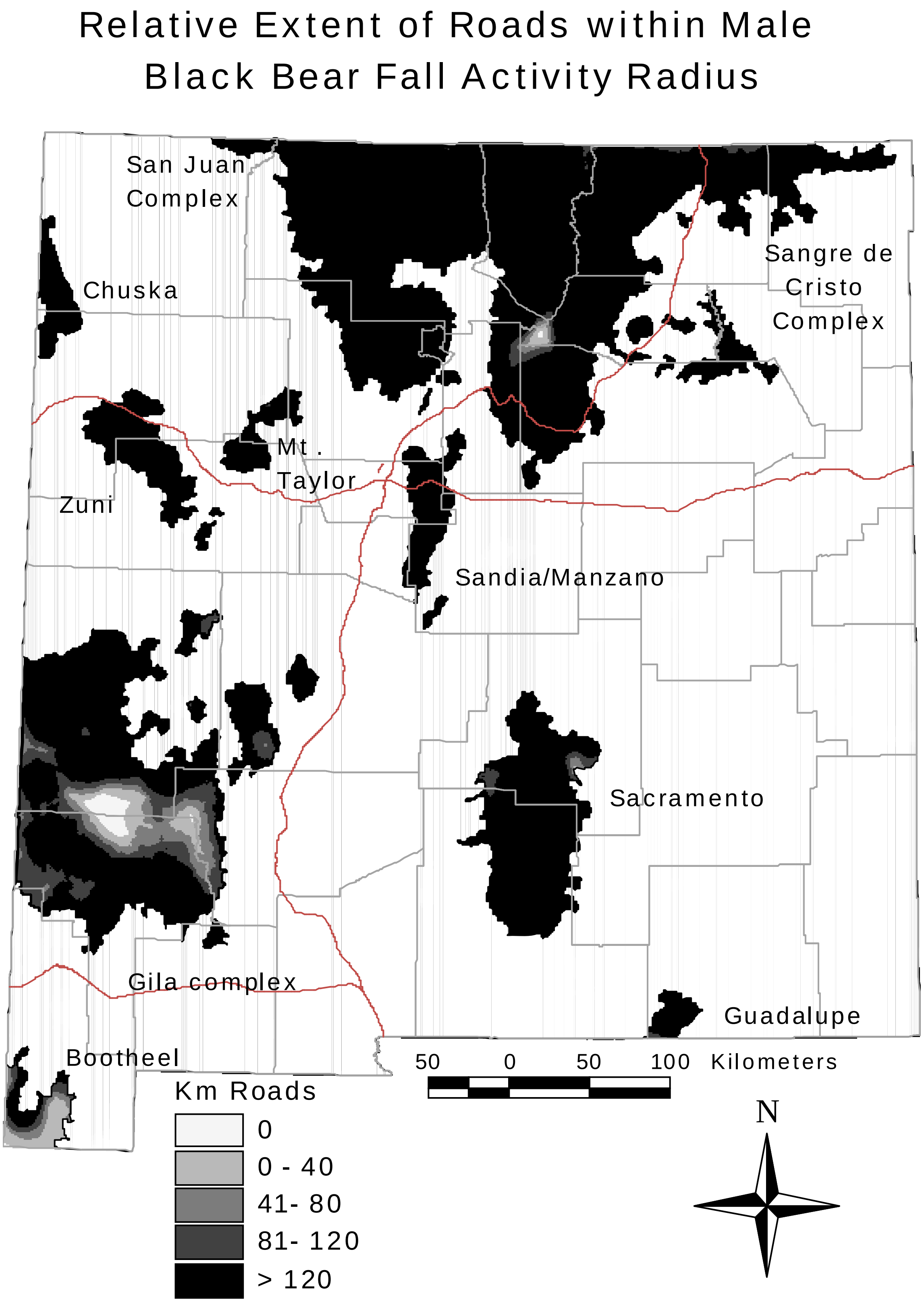


Figure 11-6. Extent of secondary roads within a male black bear fall activity radius (12 km) in New Mexico.

All predicted regions of bear habitat displayed areas that were in proximity to human populations (Figure 11-7). Statewide, 17% of bear habitat was within 5 km of human populated areas. Percent of bear habitat within proximity to human populations differed regionally, with the highest proportions observed in the Sandia/Manzano region, the Sacramento region, and the Sangre de Cristo complex (Table 11-3). Within the Guadalupe region and the Bootheel region, more than 60% of bear habitat was >20 km from human populated areas.

Table 11-3. Percent of predicted suitable black bear habitat within 0 to 20 km of human-populated areas (> 1 person/ha and > 5 households) in New Mexico, based on 2000 U.S. Census Bureau block data and sorted by area of bear habitat.

Region	Area (km^2)	< 5 km	< 10 km	< 15 km	< 20 km	>20 km
Sangre de Cristo	16,960	23.16%	48.77%	66.66%	80.15%	19.85%
Gila	15,472	6.49%	19.69%	36.47%	53.98%	46.02%
San Juan	12,495	14.96%	38.71%	60.96%	75.35%	24.65%
Sacramento	6,642	28.15%	57.50%	74.82%	87.77%	12.23%
Zuni	2,242	17.73%	45.29%	69.15%	86.19%	13.81%
Sandia/Manzano	1,788	50.76%	79.79%	95.63%	98.68%	1.32%
Chuska	1,060	10.30%	43.39%	79.03%	94.64%	5.36%
Bootheel	895	0.89%	4.89%	9.63%	14.18%	85.82%
Mt Taylor	887	1.47%	14.59%	38.16%	60.88%	39.12%
Guadalupe	499	0.10%	5.37%	17.27%	34.38%	65.62%

Predictions for proximity to secondary roads and proximity to human populations did not necessarily coincide. Some areas with relatively higher length of road within activity radii were situated in areas of low human populations, particularly private and USFS lands in the Gila complex and private and tribal lands in the San Juan complex.

Our compilation of various coverages and data sets regarding distribution of human recreation produced information of varied completeness, quality, and spatial resolution. We judged that these data in current form were insufficient to perform detailed analyses relative to distribution of bear habitat and population estimates. Nonetheless,. we anticipate that these data, if further compiled with specific objectives in mind, can be used to depict areas of possible human-bear interactions. Thus, we provide these data digitally (see Appendix C) for future users of this report and the associated modeling tools. Those data include consolidated NMDGF hunter and angler survey results for hunt year 1990-1991 through 1999-2000 (hunt year generally is April-March). We were unable to collect spatially explicit results for small game and birds (except turkey). The finest spatial resolution available for all hunts is the GMU. Because some data are missing, care must be taken not to make literal interpretations of absolute hunter days from these data. However, this data set can provide a fair indication of the spatial distribution of hunting activities in New Mexico with further editing.

Distance of Predicted Black Bear Habitat to Human-Populated Areas

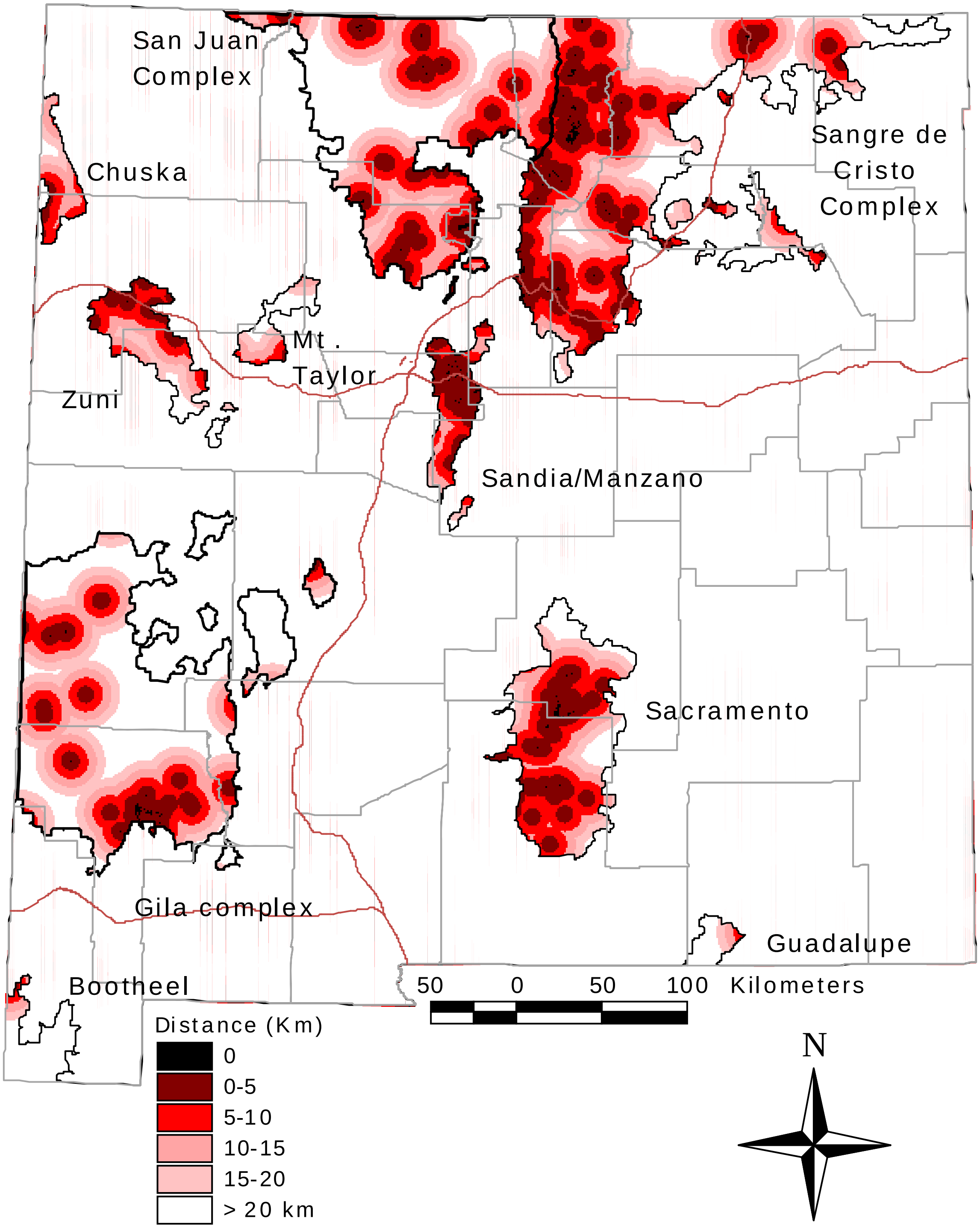


Figure 11-7. Distance of predicted black bear habitat to human-populated areas (>1 person per hectare and >5 households) in New Mexico.

Bear Population Estimate

Extrapolating observed density estimates (see Chapter 10) to areas of primary habitat yielded a statewide population estimate of 5,947 bears >1 year old, pertaining to the premast season (Table 11-2). Regional estimates ranged from 18 bears in the Bootheel region to 2,299 bears in the Sangre de Cristo complex. The small populations (<50 bears) estimated for the Bootheel and Guadalupe regions reflect areas of contiguous habitat with Arizona and Texas

DISCUSSION

In the NMGAP methodology (Thompson et al. 1996), prediction of suitable habitat for a species was based on the premise that a species distribution was all suitable land cover categories within that species general range. Other ancillary variables, such as elevation or soil classification also were included in the habitat modeling when those values were represented on spatially-registered maps. This methodology has proven useful for developing landscape and regional scale maps of species occurrence (Edwards et al. 1996). Another approach is to assign a numeric score to habitat rather than assignment to categories (Boyce and McDonald 1999, Kliskey et al. 1999). In constructing the statewide black bear habitat model for this study , we enriched the modeling process by classifying suitable habitat into multiple categories (e.g., primary, secondary , edge, and no use) rather than the Boolean response (suitable or not) used in NMGAP (Thompson et al. 1996). Our more enriched approach provided greater realism in identifying occupied habitat.

As with all modeling exercises, our habitat prediction results were a compromise between realism, practicality, and data limitations. The largest impediment to a “true” habitat map was the size and scale of this objective. Scaling is probably the most difficult aspect of landscape ecology and the subject of intense research. Large, mobile animals function at a relatively larger scale (Wiens, 1982). Scale is also not independent of spatial pattern (O’Neill et al. 1988). Changing of scale can greatly change perceived landscape patterns. When inappropriate scales are used, true biological relations can become masked or false patterns can emerge (Scott et al. 1996).

Our model was limited to data available as of summer 2001. To our knowledge, NMGAP is the only statewide coverage of land cover (42 themes at 2-100 ha resolution) that exists. There are other vegetation coverages that are more detailed in thematic and spatial resolution but they are not statewide in scope. For example, databases and digital vegetation coverages developed by the USDA Forest Service may provide more comprehensive information appropriate for analysis of black bear habitat quality. Although not statewide, these data would provide insight into a majority of the bear habitat in New Mexico. However, although the data are publicly accessible, at present they are not complied in a single archive to our knowledge.

Bear reproduction is inherently stochastic with its variability tied to mast crop variability, particularly oaks. Our ability to define this variability statewide was limited because there is no temporal variability in the land cover map. In addition, the land cover map does not differentiate on the basis of subdominant species in each land cover class. Most oak species in New Mexico exist as understory species in several different cover types, therefore the actual abundance of these species cannot be predicted using the current data. Although general predictions of mast potential were developed, more detailed data would be necessary to assess actual habitat productivity between regions.

We were purposely careful to identify suitable habitat and this map should be considered potential habitat rather than actual bear distribution on any given day or in a single year. It is very important to recognize that bears (e.g., transients) can occur in New Mexico outside of the predicted habitat areas. The key consideration is that we modeled conditions on the landscape that are considered to be reliably associated with routine occurrence of reproductively sustaining bear population.

As the human population increases, human-bear interactions have the potential for increase. This raises the value of human-bear interface data. These data serve as a tool to increase the ability of a game/land manager to predict areas of interactions between bears and humans. Spatial data provide a means to “visualize” these areas of interaction on the landscape.

The study area density estimates were derived in productive bear habitat that arguably represents some of the best habitat within their prospective regions. These values may not be applicable to areas of low quality habitat. However, some of this difference was accounted for in the habitat suitability analysis, where secondary habitat was identified. Because the population estimate was derived by extrapolating to primary habitat only, lower quality habitat did not unduly influence the population estimate.

MANAGEMENT IMPLICATIONS

The statewide estimate of 5,947 bears derived from habitat-density extrapolation is similar to the independent estimate derived from population modeling (see Chapter 14). That estimate of 5,200 bears was for the state, excluding the Zuni, Mt. Taylor, Sandia/Manzano, and Chuska regions. Both estimates are for the pre-mast season (May-early August) and excluded cubs of the year.

Statewide population estimates derived from this study refute previous estimates. Our estimates indicate a statewide population of approximately twice the long-standing estimate of 3,000 bears previously used by the NMDGF. However, these estimates do not suggest a doubling of the bear population in the past decade. Rather, these estimates are based on better information including demographics, density, and habitat extent.

Annual trends in black bear reproductive success were highly influenced by fall mast crops, especially the abundance of acorns. Within predicted bear habitat, mast producing land cover types were found within 7 km (female activity radius) of primary habitat throughout New Mexico except for about 300 km^2 in the Sangre de Cristo complex. This indicates that nearly all bears have access to habitat with potential for producing important mast producing species. However, the actual abundance of oak, juniper, and pinyon within different regions remains unknown. In the future, incorporation of more detailed data, especially on distribution of oak species, may provide valuable insight into the relative productivity of habitats throughout the regions of New Mexico.

Estimated statewide bear habitat encompasses approximately 14.6 million acres, of which 75% is primary habitat. Primary habitat represents about 13.5% of the state. Approximately 17% of bear habitat is situated within 5 km of human populations. These dimensions clearly illustrate the extent of bear exposure to human influences. More detailed analyses of the dataset provided can be used to target bear conflict and nuisance reduction efforts.

The modeling algorithm is intentionally constructed to alter the criteria so managers can examine different habitat assumptions and land management scenarios. Further, the modeling approach allows incorporation of future, improved spatial data sets (e.g., more resolved land cover) with minimal adaptation or cross-walking of habitat categorizations. Accordingly, it will be interesting and wise to perform sensitivity analyses of conclusions based on this coverage and future modifications.

CHAPTER 12

RELIABILITY OF HARVEST DATA

INTRODUCTION

In New Mexico, as in many states, interpretation of black bear population trend is based primarily on harvest data. Annual harvest data include the total number of hunter-killed bears and sex-age composition in the kill. Given the complexities associated with documenting population trend (Miller 1990, Garshelis 1991), determining the accuracy and consistency of current methods is important.

Age composition of NMDGF harvest data is determined using the cementum annuli aging technique on teeth collected from each bear. This method involves counting the layers of cementum deposited in teeth. Each year, 2 types of cementum are produced which are visible when stained. The first layer is a dark narrow band deposited during the winter months. The second layer appears broad and lightly-stained and is produced during the growth seasons of spring, summer, and fall (Harshyne et al. 1998). When a thin cross-sectional segment of the tooth is viewed, these layers can be counted as an estimate of the animal's age, similar to growth rings on a tree. This method was first developed using canine teeth collected from hunter-killed bears (Sauer et al. 1966, Stoneberg and Jonkel 1966). The technique was further refined by use of the small vestigial premolar tooth, which can be collected from live animals as well as hunter-killed bears (Willey 1974). Accuracy of the cementum annuli aging technique has been tested in only a few locations across North America (McLaughlin et al. 1990, Harshyne et al. 1998). Diet and variability in food supplies are known to affect deposition of cementum layers, therefore accuracy rates from other regions may have no bearing on New Mexico bears. Our objective was to determine the accuracy and consistency in estimating age using teeth from New Mexico black bears. A second objective was to determine the comprehensiveness of the NMDGF harvest data and to document any error with regard to reporting of sex.

METHODS

Harvest-data

We tested the completeness and accuracy of reported sex for the NMDGF hunter-kill (pelt tag) harvest records. These records were tested by comparing them to known hunter-kills of study bears, verified by radio-telemetry monitoring and direct reports from NMDGF personnel.

Cementum Annuli Data

An upper premolar tooth was extracted from most study bears ≥1 year of age during initial capture, and a second tooth was collected from some bears during recapture or den investigations, particularly during the final year of fieldwork (see Chapter 4). For hunter-killed study bears, a second tooth also was collected by NMDGF as part of the mandatory check program (see Chapter 11). During 1993, NMDGF personnel removed 2 teeth from each hunter-killed black bear specifically for examining consistency in aging black bear teeth.

All collected teeth, from study bears and hunter-killed bears, were processed by Matson Laboratory (Milltown, Montana) for age determination using cementum annuli counts. Pairs of teeth from the same bears were assigned different numbers to create a blind sample. Date of extraction, sex of bear, and comments relevant to tooth condition (e.g., broken or rotten) were reported to Matson's Laboratory for most tooth samples.

Matson's Laboratory provided us with age estimates with corresponding accuracy limits. These accuracy limits were based on the determined age of the bear and the condition of the tooth sample. In general, they found that error increased with age. Thus, determined ages were grouped into 1-7 years, 8-15 years, and ≥16 years. "Certainty codes", based on tooth condition, were superimposed on these age groupings. Assigned certainty codes were (A) result nearly certain, (B) some error possible, and (C) error likely. The combination of the tooth age grouping and the certainty code resulted in an age estimate with a corresponding range of error in years.

We tested the consistency of the aging technique by comparing 2 or more age estimates obtained for a single individual. Two samples were used for consistency analysis: (1) paired teeth collected from hunter-killed bears on the same day, and (2) pairs of teeth collected from study bears on different dates (often years apart). We tested accuracy of the aging technique by obtaining age estimates from known-age study bears. The sample of known-age bears consisted of individuals handled as cubs or yearlings in the den, and individuals confidently aged from tooth eruption when captured as cubs or yearlings.

Using Chi-square tests and Pearson's correlation, we evaluated consistency relative to estimated age class (or mean age class of pairs), sex, tooth condition, certainty code, and season of extraction (den = January-April, active = May-October). Probability levels are reported for all test outcomes reported.

RESULTS

Harvest Data

From 1992-1999, 42 marked study bears were known harvested by hunters, including 16 radio-transmittered bears and 26 marked bears. Three bears (7%) were not included as records in the NMDGF harvest database. In all instances, the bears were known to have been checked by a NMDGF officer, however record of the kill was not present in the central database. Sex was accurately recorded for all study bears present in the harvest database.

Cementum Annuli Aging

Age estimates were obtained for 236 pairs of teeth collected by NMDGF personnel in 1993. All teeth were collected during the mast season. Most age estimates (83%, n = 472) were assigned a certainty code of A (result nearly certain), while 16% were assigned as B (some error possible) and 1% were assigned C (error likely). Among the 96 teeth that were broken (20% of total), most were assigned a certainty code of B (61%), while 32% were assigned as A and 6% were assigned as C.

Teeth were consistently aged for 74% of pairs (n = 236). Among pairs inconsistently aged (n = 96), discrepancies ranged from 1-6 years, with a mean of 1.6 years. Percent inconsistency among pairs differed by certainty code (X^2 = 28.7, df = 2, n = 236). Among pairs with both age estimates assigned A, 83% of pairs were consistently aged (n = 168). Only 52% and 33% of pairs were consistently aged when $\geq$1 assignment was B (n = 62) or C (n = 6), respectively.

Discrepancy in estimated age, in years, was positively associated with mean estimated age of the pair (Pearson r = 0.51, P = 0.001, n = 236). Compared to intermediate groups, percent inconsistency was significantly lower (9%) for pairs with a mean estimated age of 1 and significantly higher (46%) for pairs with a mean estimated age of $\geq$5 (X^2 = 34.7, df = 4, n = 236).

Percent consistency also was lower when teeth were broken (50% vs. 83%, X^2 = 27.8, df = 1, n = 236), however percent tooth breakage was positively associated with estimated age class (X^2 = 29.3, df = 5, n = 472) and with higher certainty codes (X^2 = 214.4, df = 2, n = 472). Only 8% of ages designated with A (n = 392) were broken, while 88% and 100% of ages designated with B (n = 62) or C (n = 6) were broken.

Percent consistency differed by sex (X^2 = 6.6, df = 1, n = 231). Percent consistency was 65% for females and 80% for males. However, mean estimated age of tooth pairs was higher for females than for males (t = 4.8, df = 174, P < 0.001, n = 231).

Extraction of improper teeth (e.g., molars, incisors) did not appear to affect consistency, however sample size was very low. Inconsistency in estimated ages was 33% for these teeth (*n* = 6), however the patterns of inconsistency relative to estimated age and certainty codes appeared similar to other teeth.

The observed inconsistencies in aging did not appear to affect the estimated age composition of the harvest (Table 12-1). Comparing the 2 blind samples (obtained independently), estimated age composition of the harvest did not differ statewide ($X^2 = 1.4$, df = 5, $P = 0.92$, $n = 472$) or for any region ($P \geq 0.55$).

Table 12-1. Estimated age composition of hunter-killed black bears, by region, using the cementum annuli technique applied to 2 blind samples of premolar teeth in New Mexico, 1993.

			Percent composition by age category[a]					
Region	Sample	*n*	Cub	1 year	2 years	3 years	4 years	≥5 years
Statewide	1	236	0	14	26	13	5	42
	2	236	0	14	28	12	6	41
San Juan complex	1	55	0	11	26	18	7	38
	2	55	0	13	24	18	11	35
Sangre de Cristo complex	1	77	0	14	22	9	3	52
	2	77	0	14	23	8	3	52
Zuni and Mt. Taylor regions	1	20	0	10	20	0	0	70
	2	20	0	10	20	10	0	60
Sandia/Manzano region	1	10	0	20	0	0	20	60
	2	10	0	20	0	0	20	60
Gila complex	1	29	3	14	35	14	3	31
	2	29	0	17	35	14	3	31
Sacramento region	1	56	0	16	29	14	5	36
	2	56	0	14	34	11	5	36

[a] Percent composition did not differ between samples for any region ($P \geq 0.55$).

We obtained age estimated for 61 pairs of teeth from study bears (actual ages not known). Most age estimates (85%, *n* = 122) were assigned a certainty code of A, while 11% were assigned as B and 3% were assigned C. Among the 20 teeth that were broken (16% of total), most were assigned a certainty code of A (80%), while 10% were assigned as B and 10% were assigned as C. Pairs of teeth were extracted 0-9 years apart, with a mean of 4.0 years (*n* = 61).

Teeth were consistently aged for only 46% of pairs (*n* = 61). Among pairs inconsistently aged (*n* = 33), discrepancies ranged from 1-12 years, with a mean of 2.8 years. Percent inconsistency among pairs did not differ by certainty code (X^2 = 1.0, df = 2, *n* = 61). Discrepancy in estimated age, in years, was positively associated with mean estimated age of the pair (Pearson *r* = 0.50, *P* < 0.001, *n* = 61).

Percent consistency was lower when teeth were broken (46% vs. 80%, X^2 = 5.4, df = 1, *P* = 0.04, *n* = 61), however percent tooth breakage was positively associated with higher certainty codes (X^2 = 21.9, df = 3, *n* = 122). Only 13% of ages designated with A (*n* = 103) were broken, while 21% and 100% of ages designated with B (*n* = 14) or C (*n* = 4) were broken. Percent consistency was lower for tooth pairs when 1 or both teeth were removed in the den (34% vs. 62%, X^2 = 4.5, df = 1, *P* = 0.04, *n* = 61). Percent consistency did not differ by sex (X^2 = 1.0, df = 1, *P* = 0.40, *n* = 61).

For 26 of 31 (84%) inconsistent pairs of teeth extracted during different years, the age estimate from the tooth extracted at an older age was lower than the age estimate for the tooth extracted at a younger age (accounting for the difference in years). In other words, compared to earlier ages estimated, older ages were underestimated most of the time.

Accuracy Analyses

We obtained age estimates for 29 known-age bears, including 15 yearlings, 10 subadults, and 4 adults. Twenty-eight of 29 age estimates (97%) were assigned a certainty code of A, and 1 age estimate (3%) was assigned B. No teeth were broken among this sample.

Most of these teeth (83%) were accurately aged (*n* = 29). Among age estimates designated with A, 86% were accurate, but the single age estimate designated with B was inaccurate. Difference between estimated age and actual age ranged from 1-2 years, with a mean of 1.2 years (*n* = 5). All inaccurate age estimates were underestimates.

Percent accuracy differed by age class (X^2 = 6.9, df = 2, *P* = 0.03). All yearlings were aged accurately, while 60% of subadults and 75% of adults were aged accurately. Percent accuracy did not differ by sex (X^2 = 0.08, df = 1, *P* = 1.0).

Accuracy of age estimates differed by season (X^2 = 13.4, df = 1, *P* = 0.001). Estimates from teeth extracted during the active season were 100% accurate, while estimates from those extracted during the den season were only 55% accurate, however only sub-adult and adult teeth were extracted during the den season.

DISCUSSION

Harvest Data

Results revealed both negative and positive aspects regarding usefulness of the harvest data obtained by the NMDGF. Our analyses indicated the harvest data were incomplete, underestimating the annual bear kill by as much as 7%. This proportion not only limits the usefulness of these data for monitoring total kill, but also hinders reliable estimation of sex-age composition of the kill.

On the other hand, analyses indicated age estimates using the cememtum annuli method were relatively accurate and consistent for New Mexico bears. Accuracy and consistency were negatively associated with age and tooth breakage, however these 2 factors were correlated. These results supported earlier findings that consistency and accuracy declined with age (Willey 1974, McLaughlin 1990, and Harshyne et al. 1998). Sauer et al. (1966) suggested cementum annuli were more difficult to count in older teeth because annuli become thinner as the tooth ages.

Differences in the patterns of annuli deposition have been noted for male and female black bears (Coy and Garshelis 1992). Cross-sections of male teeth have displayed dark accessory lines that can be confused with annuli, especially in late summer and fall. On teeth from female bears, narrow bands associated with cub rearing can make distinction of adjacent annuli difficult to observe, leading to miscounts. Despite these potential differences, our analyses did not indicate sex affected accuracy or consistency of aging, and these findings were consistent with Harshyne et al. (1998). Although female teeth were less consistently aged in the sample of study bears, evidence indicated age was the factor likely causing the difference.

Accuracy and inconsistency were also affected by season. Age estimates from teeth extracted in the den were less consistent than those from teeth extracted during the active season. When the den-extracted teeth were removed from the known-age sample, accuracy improved to 100%. This may have been due to the fact that black bears deposit annuli during the winter and new annuli may not appear visibly until late spring (Sauer et al.1966, Coy and Garshelis 1992).

MANAGEMENT IMPLICATIONS

Accuracy and consistency of the cementum annuli method appeared adequate for estimating age of New Mexico black bears. Among adult bears, our findings indicated the cementum annuli method was not precise enough to identify specific age cohorts. However, accuracy and consistency was relatively high for bears with known or estimated ages <5 years old. Identification of specific cohorts is only required for these younger age classes, therefore the method appeared adequate to classify bears into age classes and to estimate the age composition of the kill.

According to Matson Laboratory, 2 types of tooth breakage occurred. The first occurred when the root tip was broken off during extraction. The second occurred when the tooth was removed intact, but the tools used for extraction damaged the cementum annuli. Breakage probably cannot be completely avoided, especially when extracting teeth from older bears. However, extra care in tooth extraction, use of proper tools, and improved training of personnel responsible for tooth extraction will aid in the consistency of aging teeth.

CHAPTER 13

PATTERNS IN HARVEST DATA

INTRODUCTION

New Mexico has more than 2 decades of black bear harvest data, a rich information resource. Harvest data document harvest numbers and provide a historical perspective on new information accumulating year by year. Relationships among harvest, regulations, effort, and environmental conditions provide valuable insight for managers that is useful for regulating harvest numbers and composition.

Black bear harvest data alone do not provide a window onto populations; changes in harvest size and composition do not indicate trends in the living resource population (Garshelis 1990). This study provides an opportunity for limited comparisons of live populations and harvests.

Our objective in this chapter is to describe relationships between the harvest sample and the sex-age composition of study populations. We do this from the standpoint of hunter supplied information, kill records, and results of field investigations.

METHODS

Harvest Data

Tagging of bear pelts and reporting of all hunter-killed bears has been mandatory in New Mexico since 1978. NMDGF officers have recorded proof of sex and collected a tooth for estimating age of bears since 1985. Other information recorded included date and Game Management Unit (GMU) of kill, use or nonuse of dogs, and use or nonuse of guides. Pelt tag records were complete through 1999.

A card survey has been mailed to all licensed bear hunters with usable mailing addresses since 1990. Information requested included whether they hunted, used guides or used dogs, days hunted in up to 3 different GMUs, killed a bear, and sex and GMU location of kill. Statewide effort and success projections by hunt method were based on individual responses with use or nonuse of guides and dogs reported. For the 1994 survey, use of guides and use of dogs could not be separated, so projections were made for using aids (guides or dogs or both) and no aids (neither).

Hunt regulations and license costs were obtained from annual NMDGF Proclamations. Numbers of licenses sold were obtained from NMDGF fiscal records.

Regional summaries were compiled for contiguous game management units including mountain ranges. The Gila complex, containing the SSA, consists of GMUs 13, 15-17, 21-24, 26, and 27. The Sangre de Cristo complex, containing the NSA, consists of GMUs 41-49 and 53-58.

Years in summary tables are calendar years of hunting seasons, not fiscal year or license year designations. Harvest numbers in summaries are derived from pelt tag reports, considered more reliable than projections from the hunter card survey. Correlation coefficients were calculated from annual statewide total harvest numbers and license sales.

Effort, Success, and Hunting Method

Estimates of hunter success were based on reported numbers of hunters and kills by GMU from card survey returns for each year. Hunters reporting days in multiple GMUs were included in each unit reported. Unit hunter and bear harvest numbers using guides, dogs, both, or neither, were summed over GMUs for regional totals. Success by year and method was calculated as total reported harvest divided by total reported hunters for each region.

Proportions of hunters or harvests by hunting method were based on the subset of records with hunting methods known. Numbers of hunters or harvests by hunting method were calculated as the product of total hunters or harvests and calculated proportions. Most pelt tag and hunter card survey records contained information on hunting methods used.

Regional harvests and resident study populations were compared for 1993-1997; later years are excluded because hunt regulations and effort changed substantially in 1998, potentially confounding any change in the relationship of live and harvest sample composition. We looked at age composition of females only, because reproductive females are important to population trends, and migrant subadult males may confound male age structure and sex ratios. Study area live population proportions were recalculated excluding cubs, because cubs do not appear in harvest data. We examined proportions of yearlings of all females, yearlings and subadults of all females, and subadults of all females aged ≥2 years.

Years of mast failure were determined from combined oak mast index measured on the study areas (see Chapter 5).

Age and Sex Composition

Ages of hunter-killed bears were based on cementum annuli analysis of collected teeth (see Chapter 12). Age class proportions were calculated only from records with age estimates. For total numbers by age class, the un-aged subset was prorated among age classes using the proportions derived from the aged subset for each sex. Most pelt tag records had associated age estimates. Year of birth for hunter-killed bears was calculated from age estimates. Virtually all pelt tag records included sex of kill.

Age and sex composition of study area live populations was based on population reconstructions (see Chapter 10). Year of birth for study area bears aged ≥1 year was known from den observations or calculated from tooth age estimates. Sex was known for all study area bears.

Relative numbers of bears by year of birth were compared for the study area populations and hunter-killed bears from the surrounding regions. From live population data, bears were counted by cohort year. All study bears observed at age ≥1 were included, regardless of age at first observation, date of capture, or den observation. Individual study bears were counted only once, regardless of frequency of observation. For harvest data, bears from a cohort year were represented by kills during the 3 hunt years following the birth year of the cohort. Proportions of 1, 2, or 3-year-olds of all-aged hunter-killed bears were calculated for the appropriate hunt year, to eliminate distortion from annual variation in total harvests. An index of harvest abundance for each cohort was calculated as the sum of its representative year class proportions at ages 1-3. For example, the index for bears born in 1991 was the sum of the proportion of 1-year-olds in the 1992 harvest, 2- year-olds in the 1993 harvest, and 3-year-olds in the 1994 harvest.

RESULTS

Patterns in Harvest, Effort, and Success

Statewide bear harvest fluctuated (Figure 13-1). The largest annual number of hunter kills for both sexes was reported in 1994, with declining numbers in each of the following 4 years. Year to year variation in statewide harvest numbers was similar for the sexes. Detailed statewide and regional information from pelt tag reports and card survey projections is presented in the Pelt Tag Notebook (Appendix D) that describes black bear harvest data history through 1999. Fall and spring hunts occurred in New Mexico from 1978-1991. Early fall hunts, beginning by 1 September and ending 31 October, occurred from 1992-1997. Late fall hunts, beginning 1 or 15 October and ending 15 December, occurred from 1998-2000.

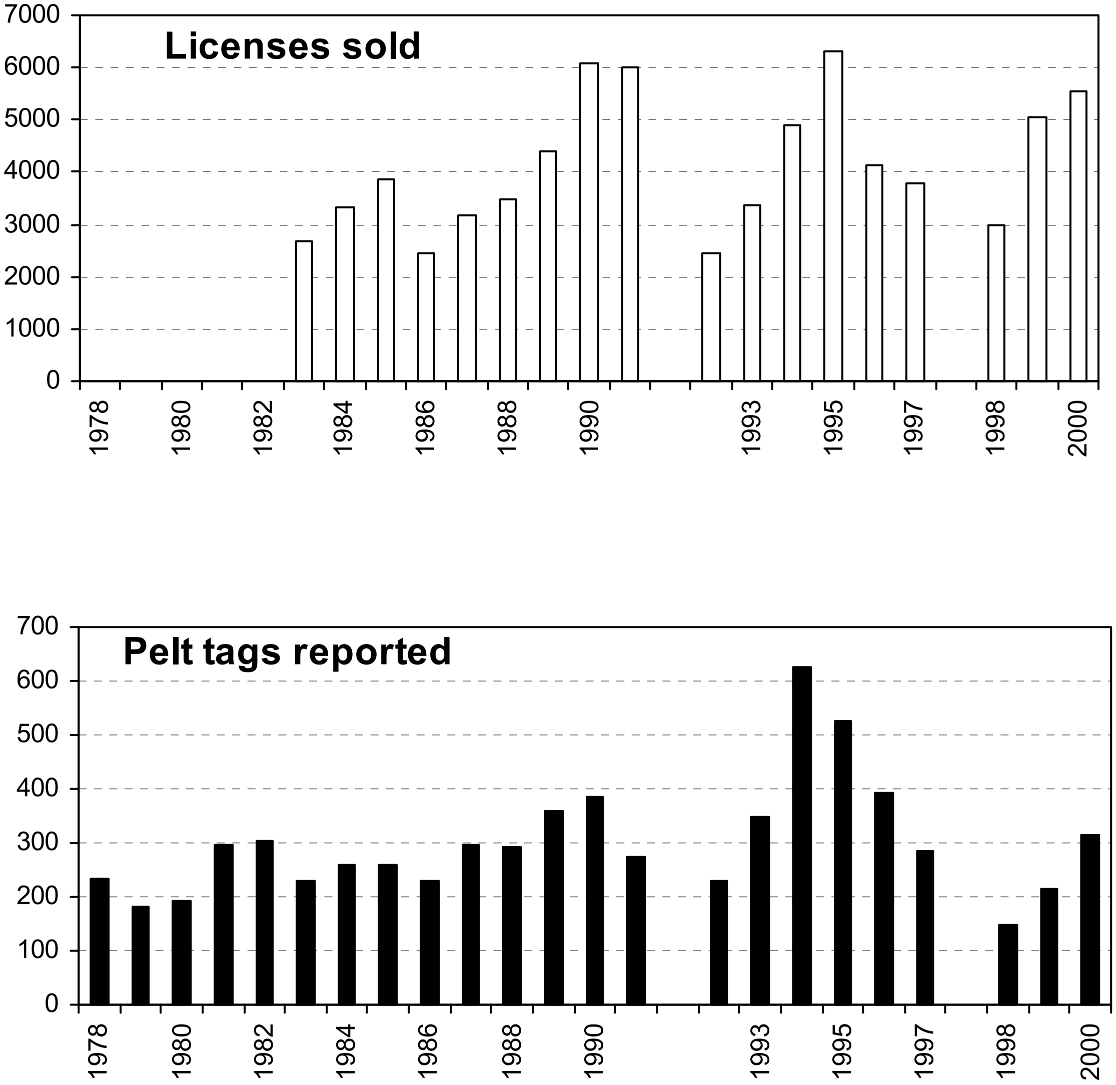


Figure 13-1. Numbers of black bear hunting licenses sold and pelt tags reported in New Mexico for years with both spring and fall hunts (1978-1991), early fall hunts only (1992-1997), and late fall hunts only (1998-2000).

License sales and statewide harvests increased during the 1990s (Table 13-1). Average license sales and average total females harvested for 1990-2000 were 38% greater than for 1983-1989. Because of the peak harvest in 1994, average harvests increased out of proportion to license sales for 1994-1997 compared to previous 4-year averages, both regional and statewide. Average harvests decreased for 1998-2000 because of the shift to late fall hunt dates.

Table 13-1. Average license sales and harvest reports for female (F) and male (M) black bears in New Mexico for 1978-2000.

		Harvests reported					
		Statewide		Sangre de Cristo complex		Gila complex	
Years	Licenses sold statewide	F	M	F	M	F	M
1978-1981[a]	not available	87	139	33	57	19	43
1982-1985	3290[b]	99	162	31	49	23	41
1986-1989	3381	98	195	33	63	27	65
1990-1993	4471	123	185	39	63	26	43
1994-1997	4782	188	267	51	75	50	71
1998-2000	4529	70	154	22	56	20	29

[a] 4-year averages make long-term changes easier to see;
[b] averaged over 1983-1985

Bear hunters in New Mexico consistently harvested more males than females (Table 13-2). The female proportion of annual statewide harvest ranged from 29 to 46%. The proportion of females averaged 37% during the years of combined spring and fall hunts, 41% during early fall hunts, and 36% for late fall hunt years.

Harvest patterns differed by region (Figure 13-2). Harvests in the Gila and Sangre de Cristo complexes fluctuated, but Gila numbers were more variable. The 1994 female harvest in the Gila complex was 4 times the average from previous years, and more than twice the harvest from any other year. In contrast, Sangre de Cristo regional female harvests were elevated for 1993-1995, at about twice the average from previous years.

From 1983-2000, annual statewide license sales varied more than 2-fold (Appendix D, Table 2). License sales decreased in years with regulation or cost changes. License sales dropped 36% and total black bears harvested dropped 11% in 1986, when spring season dates were shifted 1 month earlier and the fall season was closed during elk firearm hunts. License sales decreased 59% and total harvest decreased 17% in 1992, when spring hunting was discontinued and the fall season was shortened to September and October only. License sales decreased 35% and harvest decreased 25% in 1996, when license cost for residents increased from $10 to $30. License sales decreased 22% and total harvest decreased 52% in 1998, when the fall season dates were shifted 6 weeks later and no licenses were sold after the hunting season began.

Table 13-2. Numbers and mean ages of female (F) and male (M) black bears harvested statewide and in 2 regions of New Mexico where study areas were located, 1985-1999.

	Statewide				Sangre de Cristo complex				Gila complex			
	No. kills		Mean age		No. kills		Mean age		No. kills		Mean age	
Year	F	M	F	M	F	M	F	M	F	M	F	M
1985	94	160	5.2	4.4	21	49	5.4	3.5	27	39	5.0	5.4
1986	84	145	5.5	4.6	28	72	6.3	4.8	22	26	6.0	4.8
1987	104	192	5.6	4.6	43	62	5.8	4.8	27	68	5.8	4.8
1988	101	188	5.0	4.2	39	62	5.6	4.8	24	49	4.8	4.6
1989	103	254	6.2	5.0	21	57	5.3	5.8	36	115	7.5	5.5
1990	151	232	5.9	5.3	40	67	5.9	6.3	47	64	6.9	4.9
1991	99	176	6.4	5.9	26	62	5.3	5.5	23	47	7.7	7.1
1992	91	137	6.4	4.8	29	55	7.0	4.6	16	30	6.9	5.0
1993	152	196	6.3	4.0	61	67	6.9	4.1	18	30	5.8	3.7
1994	259	364	7.0	5.3	60	75	6.3	5.3	103	138	6.8	5.9
1995	213	313	7.0	5.0	62	114	6.7	5.0	39	49	8.4	6.1
1996	171	216	6.7	5.7	43	72	6.2	5.5	36	50	8.0	6.1
1997	110	175	6.3	5.6	38	52	7.0	5.3	22	48	5.9	6.3
1998	51	97	5.3	4.4	20	50	5.8	4.0	10	12	7.4	7.4
1999	60	150	6.1	4.5	20	59	5.4	5.8	14	26	7.1	2.4

Total hunt effort influenced total harvest. Correlations between statewide annual total legal kills and total licenses sold were 0.68 for 1983-1991 with both spring and fall seasons, 0.82 for 1992-1997 with early fall seasons, and 0.90 for 1998-2000 with late fall seasons.

Success rates for all black bear license buyers were relatively low, ranging from 5-9% for years with spring and fall hunts, from 7-10% for early fall hunts except for 13% in 1994, and from 4-6% for late fall hunts. The exceptional success rate in 1994 coincided with the largest statewide annual harvest.

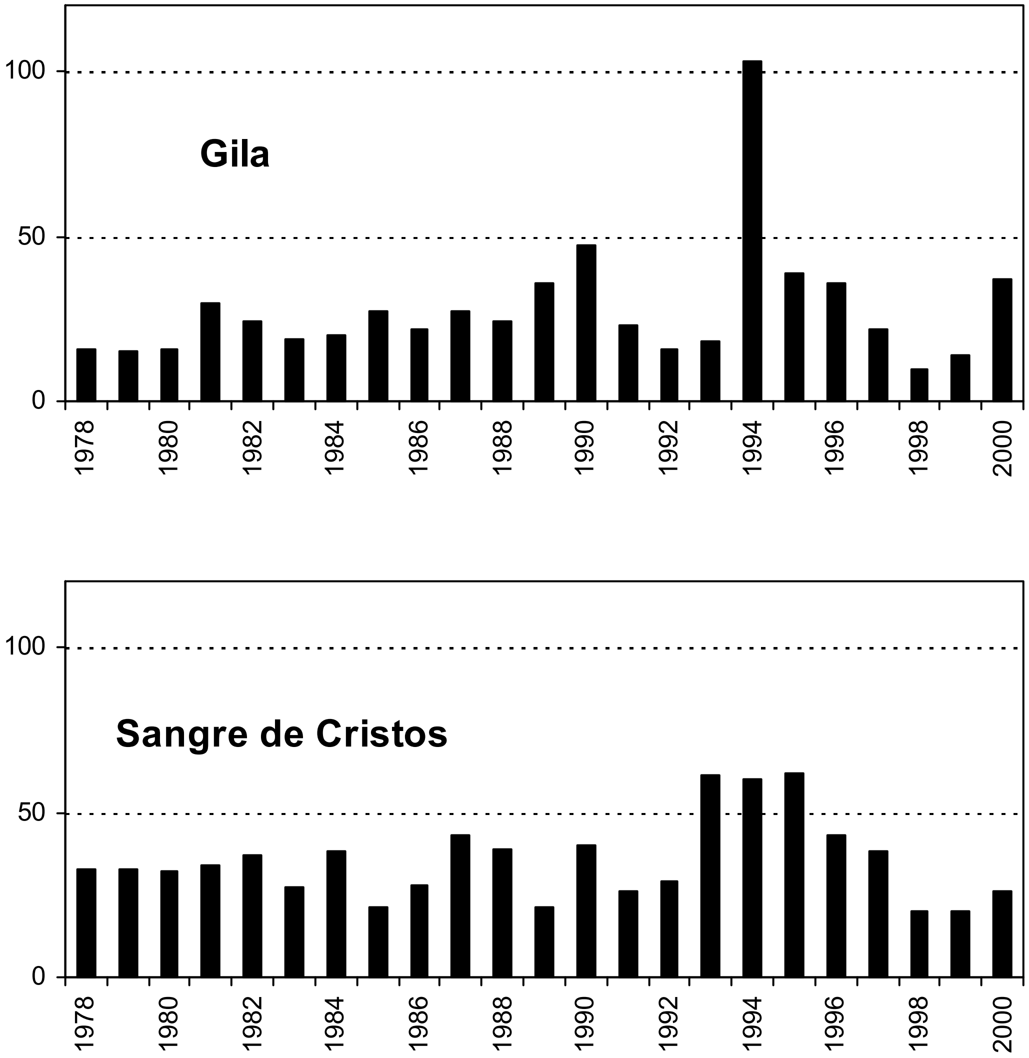


Figure 13-2. Number of female hunter-killed black bears reported from the Gila and Sangre de Cristo complexes of New Mexico, 1978 – 2000.

Patterns by Hunting Method and Season Timing

Hunters using dogs were about 3 times as successful as hunters not using dogs (Table 13-3). Using dogs doubled success for unguided hunters, and increased success 2 to 5 fold for guided hunters. Using dogs increased success more in spring and late fall hunts than in early fall hunts.

Table 13-3. Average annual participation and hunter success by hunting method and season timing from card survey data and pelt tag reports from black bear hunting in New Mexico, 1990-1999.

	Hunt season timing			
Comparison by hunting method	Spring 1990-1991	Early fall 1990-1993 1995-1997	Early fall 1994	Late fall 1998-1999
Percent of hunters using each method, from hunter card survey				
Guides and dogs	17	8		7
Guides only	2	4		10
Dogs only	19	10		10
Neither	63	78	73	74
Percent success by method, from hunter card survey				
Dogs	22	28		21
No dogs	3	9		6
Percent of females in harvest by method, from pelt tag reports				
Dogs	23	46	40	35
No dogs	22	37	43	30

Fall season hunters using dogs took a higher proportion of females than hunters not using dogs, except for 1994 when hunters not using dogs took an unusually high proportion of females (Table 13-3). Hunters using dogs took about 4 times as many female bears per hunter as hunters not using dogs (Table 13-4).

Most hunting effort was without dogs (Table 13-3). In fall hunts, an average of 18% of all hunters used dogs; in spring, 36% used dogs. However, hunters using dogs took 45% of the female bears killed during fall hunts and 71%

of the few females killed during spring hunts, because of higher success rates and higher percentages of females taken with dogs.

The proportion of females in early fall hunter kills was double that in spring kills. Overall, 41% of early fall harvests, 32% of late fall harvests, and 21% of spring harvests were female. The same pattern held for all hunting methods (Table 13-3).

For all hunting methods, success rates were higher for early fall hunts than for late fall or spring hunts (Table 13-3). Overall success from card survey reports was 13% for early fall hunts (except for 1994 with 48% success reported), 11% for spring hunts, and 9% for late fall hunts.

Table 13-4. Relationships of hunting method and season timing to female black bear harvest in New Mexico, 1990-1999.

	Hunt season timing			
Comparison by hunting method	Spring 1990-1991	Early fall 1990-1993 1995-1997	Early fall 1994	Late fall 1998-1999
Average no. females killed / 100 hunters / year				
Guides and dogs	7.7	21.6		11.2
Guides only		7.8		3.1
Dogs only	2.1	7.2		4.2
Neither	0.8	3.3	17.2	1.8
Dogs	4.8	12.9		7.4
No dogs	1.1	3.3		1.8
Average percent of all F bear kills taken by each method				
Guides and dogs	59	32		28
Guides only		6		11
Dogs only	18	13		15
Neither	23	48		47
Dogs	71	46		45
No dogs	29	54		55

Patterns by Mast Availability

The NSA did not experience a mast failure during the late fall season hunt years 1998-2000, and experienced only a single year of mast failure during the early fall hunt season years from 1993-1997. The SSA experienced mast failure in 2 of the 5 early fall hunt season years and in 2 of the 3 late fall hunt season years.

In the Gila complex, more bears were killed in years of mast failure during early and late fall seasons (Table 13-5). This pattern was observed with or without guides and dogs. In the Sangre de Cristo complex early fall hunts, the proportion of females in the total harvest was higher during the mast failure year. In the Gila complex, hunters using dogs or guides killed the same proportion of females in mast failure years as other years. However, on average 78% of the hunting effort in the Gila complex was by hunters not using aids, who took a higher proportion of females in mast failure years. Statewide, the largest bear harvest in early fall hunts occurred in 1994, and the largest harvest in late fall hunts occurred in 2000, both probably years of widespread mast failure.

Table 13-5. Hunter success, sex composition, and total harvest of black bears in New Mexico by hunting method for years with and without mast failures, 1993-1999.

	Early fall hunts				Late fall hunts	
	Sangre de Cristo complex		Gila complex		Gila complex	
	Oak on NSA		Oak on SSA		Oak on SSA	
Parameter by hunting method	Fail	Not fail	Fail	Not fail	Fail	Not fail
Average percent hunter success from card survey						
Guides or dogs or both	46	34	24	18	12[a]	5
No aids	13	14	16	10	4[1]	4
Average percent females in harvest from pelt tag reports						
Guides or dogs or both	54	42	44	44	40	56
No aids	44	36	37	33	27	38
Average annual bear kills from pelt tag reports						
Guides or dogs or both	48	61	57	34	29	9
No aids	80	68	106	34	34	13
Total	**128**	**129**	**163**	**68**	**63**	**22**
Years included	1993	1994 1995 1996 1997	1994 1996	1993 1995 1997	1999 2000	1998

[a]Value for 1999 only; card survey projections for 2000 not yet available

For the Gila complex, the contrast in average harvest was exaggerated by an exceptionally high harvest in the mast failure year 1994 (with 242 bears reported), and an exceptionally low harvest in the non-failure year 1998 (with 22 pelts reported) when regulations changed significantly and effort and harvest decreased statewide.

Live Population and Harvest Age Composition

More individual bears born in 1991 were captured on both study areas than bears born in 1990 or 1992; bears born in 1988-1990 were observed less frequently than those born in 1987 or 1991. A similar pattern occurred in hunter-killed bears from the surrounding regions (Figure 13-3). The 1994 cohort in the SSA and Gila region, and the 1995 cohort in the NSA and Sangre de Cristo complex, were relatively small in harvests and live captures. No yearlings were observed in dens from the 1992 and 1994 cohorts on the NSA, and only 1 yearling was observed from the 1993-1995 cohorts on the SSA (Table 13-6).

Table 13-6. Yearlings per adult female (F, aged ≥5 years) from den observations on the Northern Study Area (NSA) and Southern Study Area (SSA) in New Mexico, 1993-2000.

		NSA		SSA	
Year of observation	Cohort year	No. adult F dens observed	Yearlings / adult F	No. adult F dens observed	Yearlings / adult F
1993	1992	5	0		
1994	1993	8	0.63	6	0
1995	1994	12	0	9	0.11
1996	1995	16	0.63	15	0
1997	1996	23	0.22	15	0.67
1998	1997	27	0.48	18	0.33
1999	1998	23	0.59	19	0.58
2000	1999	21	0.52	16	0.56

In both live study populations, adults comprised 54% of resident females ≥1 year old on average (Table 13-7). Adults comprised 58% of female harvests in the Sangre de Cristo complex and 70% of female harvests in the Gila complex on average for 1993-1999 (Table 13-7). Both live populations averaged 65% females of all resident bears, with little annual variation, from 1993-1999.

Regional harvests varied from 26 to 48% females in the Sangre de Cristo complex, and from 31 to 48% female in the Gila complex.

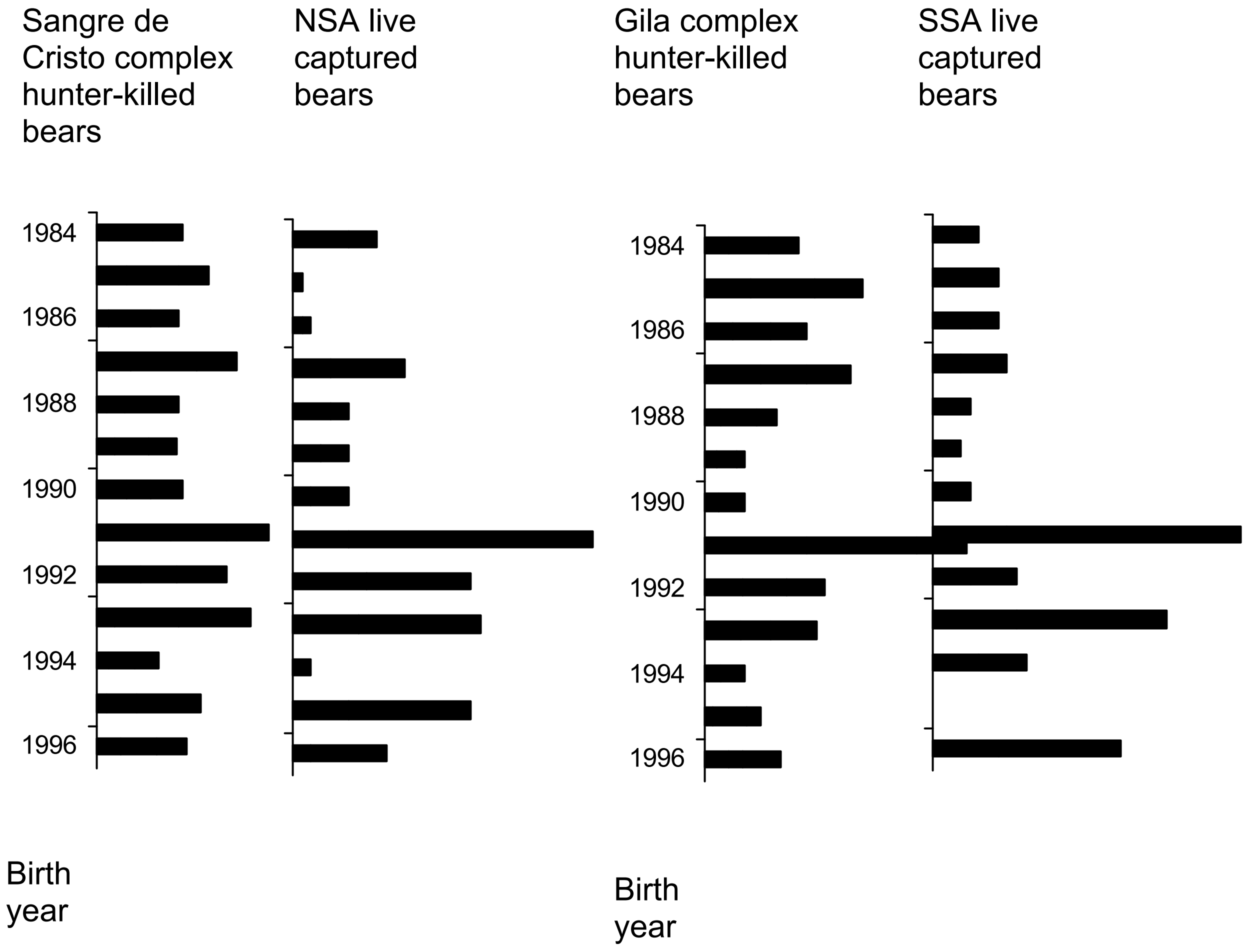


Figure 13-3. Relative numbers of black bears born in the indicated years and subsequently killed by hunters at ages 1-3 in the Sangre de Cristo and Gila complexes of New Mexico, 1985-1999, or captured live at any age on the New Mexico black bear study areas within the regions, 1993-1999.

Yearling proportions of females were higher in study area live populations than in early fall season harvests from the surrounding regions. From 1994-1997 subadults comprised 42% of live population resident females aged ≥2 years on the NSA and 44% on the SSA. In contrast, subadults comprised 38% of reported female hunter kills aged ≥2 in the Sangre de Cristo complex, but only 27% in the Gila complex, during the same years. In 1993, the NSA live population had 43% subadults, but the Sangre de Cristo harvest had only 24%; both SSA and the Gila harvest had 44% subadults.

Table 13-7. Proportions of adults (≥5 years old), subadults (2-4 years old), and yearlings (1 year old) in black bear harvests from the Sangre de Cristo and Gila complexes of New Mexico, 1993-1999.

			Year							All
Region	Sex	Age class	1993	1994	1995	1996	1997	1998	1999	Years
Sangre de Cristo	F	Adult	0.32	0.25	0.18	0.21	0.25	0.14	0.10	0.21
		Subadult	0.12	0.16	0.16	0.14	0.12	0.09	0.13	0.13
		Yearling	0.04	0.02	0	0.02	0.01	0.05	0.03	0.02
		Total	0.48	0.43	0.34	0.37	0.39	0.28	0.26	0.36
	M	Adult	0.18	0.32	0.24	0.29	0.32	0.23	0.33	0.27
		Subadult	0.24	0.20	0.39	0.33	0.23	0.33	0.30	0.29
		Yearling	0.11	0.05	0.04	0.01	0.07	0.16	0.11	0.08
		Total	0.52	0.57	0.66	0.63	0.61	0.72	0.74	0.64
Gila	F	Adult	0.18	0.28	0.29	0.30	0.21	0.48	0.26	0.28
		Subadult	0.16	0.12	0.14	0.12	0.06	0	0.06	0.10
		Yearling	0.02	0.05	0	0.01	0.03	0	0.03	0.02
		Total	0.36	0.44	0.43	0.44	0.31	0.48	0.35	0.40
	M	Adult	0.18	0.26	0.29	0.34	0.45	0.38	0.10	0.28
		Subadult	0.36	0.22	0.27	0.21	0.19	0.10	0.26	0.23
		Yearling	0.11	0.08	0.01	0.01	0.05	0.05	0.29	0.09
		Total	0.64	0.56	0.57	0.56	0.69	0.52	0.65	0.60

DISCUSSION

Harvest Patterns

In 1994, statewide harvest jumped to a record peak, and then dropped steadily during the following 4 years. Harvests for 1994-1998 differed from the fluctuating, but gradually increasing, pattern of harvests from previous years. Such a dramatic change should get the attention of managers. We cannot determine from harvest data alone whether the 1994-1998 numbers reflect overharvest and subsequent population decline. Examination of factors associated with the pattern can illuminate the information that is embedded in harvest data.

Higher harvests in the 1990s than the 1980s were associated with increased license sales. The record harvest in 1994 was not a statewide phenomenon, but derived from an anomalous harvest from the Gila complex, large enough to affect the statewide total. Return to a normal harvest size in the Gila complex in 1995 accounted for most of the decrease in statewide harvest for that year. License sales were lower in 1996-1997 than in 1994-1995, probably accounting for some of the reduction in total harvest. The decrease in statewide harvest in 1998 likely resulted from a change in hunt season from early to late fall, and an associated reduction in license sales. While these observations do not rule out a population change as the reason for decreasing bear harvests, they do suggest reasonable alternative explanations.

Harvest data history for the Gila complex implied that the impact of the 1994 hunt on the black bear population was unusual, but its effect on the population trend is not known. The high number of females removed from the population is a significant management consideration. The harvest data can provide useful indicators for managers, even without providing certainty about populations.

Why was the 1994 harvest in the Gila complex so large? Regional hunter numbers were not unusual, but success rates were extraordinary. Cub survival on the SSA was very low in 1994, and many adult females may not have been accompanied by cubs, thus not protected from hunting. Oak mast failed in 1994, and a dry summer and wildfires may have increased food stress. Bears moved longer distances during years of oak failure (see Chapter 9), and may have been more likely to encounter hunters as a result. Average annual harvest totals, hunter success rates, and percent of females harvest by unaided hunters were higher in years of oak mast failure in the Gila complex during both early and late fall hunt seasons. The proportion of females in the total harvest was also higher during the mast failure year in the Sangre de Cristo early fall hunts. Hunter success, percent of females in the kill, and mean age of females killed were inversely related to fall food abundance in Minnesota (Noyce and Garshelis 1997). Higher harvest levels also were associated with shortages of natural foods in Massachusetts (McDonald et al. 1994).

Patterns of harvest over time differed by mountain range region for New Mexico. Environmental conditions may not be uniform statewide in any given year. Harvest data should be examined by region, and regional differences in management objectives and strategies are appropriate.

The timing of hunt seasons influenced the size and composition of the harvest. Early fall hunts in New Mexico resulted in higher effort, success, and proportion of females in the harvest compared to late fall or spring hunts, and produce larger total harvests and female harvests.

Hunters using dogs harvested more bears per hunter, and proportionally more female bears, than hunters not using dogs. Most hunters in New Mexico did not use dogs. In early fall hunts, about 20% of hunters used dogs, but took almost 50% of the females harvested. The influence of hunting method on harvest depends on the combination of effort, success, and proportion females taken by different hunting methods, and is not simple to predict.

Live Population and Harvest Comparisons

In the study design, we planned to relate the live population sample represented by study bears to the killed sample represented by harvests, to explore what harvests could indicate about populations. This proved difficult in practice. Ideally, the size and composition of harvests from the study populations would be compared to the size and structure of the study populations over time. However, too few study bears were killed by hunters for meaningful comparisons.

As an alternative, harvests from the mountain range regions surrounding the study areas were used for the killed samples. The study area populations were used to represent the population structures for the larger regions, a problematic assumption. The unhunted status of the NSA during much of the study weakened its comparison with the hunted Sangre de Cristo complex. During the record high 1994 harvest in the Gila complex, no SSA hunting mortalities were observed, suggesting that hunting on the study area was not typical of hunting in the larger surrounding region. These limitations apply to the remaining discussion.

Relative Cohort Sizes

Examination of year classes of hunter-killed bears over time revealed striking and persistent differences in relative numbers by year of birth. Some cohorts were virtually absent from the harvest records. Bears born in 1988-1990 were relatively scarce in New Mexico harvest data, reflective of the decrease in proportion of subadults in the early 1990s and part of the concerns that prompted this study.

Age distributions from harvests (killed samples) and study area captures (live samples) showed similar variation in apparent cohort size from year to year (Figure 13-3). Because live captures began in 1993, cohorts born in earlier years were represented on the study areas only by older survivors and residents, and more recent cohorts were exaggerated in number compared to earlier ones in the live samples. Because harvest age collection began in 1985, pelt tag records contained information on cohorts born since 1984.

Apparent cohort size variation suggested underlying reproductive variation. A pattern of alternating larger and smaller cohorts appeared in the harvest data for the 1980s and 1990s, and from the live sample for the 1990s, consistent with moderately synchronized reproduction. In both the NSA and SSA samples, the alternating year pattern failed in 1989, with a small cohort where a larger one would be expected. The cohorts from 1988-1990 were smaller than the 1987 and 1991 cohorts. This combination suggested that bear reproduction may have been lower than normal during the late 1980s.

Correspondence between apparent relative cohort size and natality can be examined for the years of the study. The 1992 NSA cohort and the 1993 SSA cohort were missing in den observations (Table 13-6) but not in study live captures or regional harvests. The discrepancy may be attributable to the very small sample sizes for natality observations for the first year on each study area. Cohorts on the NSA from 1994 and 1996 appeared small relative to 1993 and 1995 in den observations, live captures, and harvests. The same was observed for cohorts on the SSA from 1994 and 1995 compared to 1996. For years with higher sample sizes, study natality data were consistent with apparent cohort size differences in the harvest.

The relative proportions of bears from different birth years in harvest data appeared to reflect the relative proportions of bears from different birth years in the study area live populations. The patterns of variation do not imply the causes of variation. Cohorts may appear relatively large when they are not absolutely large if mortality in adjacent cohorts was high. But absence of a cohort in harvest records for several years may indicate low reproductive success for that birth year. A missing cohort is a flag indicating possible poor reproduction; other evidence such as associated mast abundance must be considered. Missing cohorts in harvest data records are more useful for interpreting historical records than for evaluating current populations, because several years of data collection are needed to detect the differences in cohort representations in the harvest.

MANAGEMENT IMPLICATIONS

Harvest patterns and environmental conditions differ among mountain range regions in New Mexico. Analysis of harvest data and related factors on a regional basis is appropriate.

Changes in black bear populations cannot be detected from harvest data alone. However, patterns in harvest data may flag areas of concern to managers. Missing cohorts and associated decreases in proportions of subadults in the harvest over several years suggest poor reproduction. Other evidence such as mast availability should be examined, and the possible population consequences can be factored into management considerations.

Hunting method appears to affect proportion of females in the kill. During 1990-1999, hunters using dogs were 3 times more successful and took 4 times as many female bears per hunter than those not using dogs. However, the impact of hunting with dogs on the total harvest for a region depends on the proportion of hunters using dogs.

Timing of hunting seasons influences the total black bear harvest and the proportion of females in the harvest. During 1990-1999, later fall seasons were associated with lower total harvest and lower proportions of females in the harvest, compared to earlier fall seasons and spring seasons.

Environmental conditions can influence the effect of a hunt on harvest magnitude and composition. During 1993-1999, failures in oak production were associated with increases in hunter effort, hunter success, and the proportion of females in the kill.

CHAPTER 14

THE BLACK BEAR POPULATION MODEL

Our objective in this chapter is to develop and describe the bear population model as a tool for integrating harvest and biological information, and forming interpretations that are consistent with existing knowledge. This approach is intended to help managers to interpret harvest data in the context of bear population biology, make inferences about bear population size and status consistent with available harvest and biological information, and evaluate consequences of management options to bear populations. The model is designed to simulate population behaviors that are realistic for conditions in New Mexico.

CONCEPTUAL BACKGROUND

Information available to managers about black bears in New Mexico has traditionally been limited to data from hunter-killed bears. This study augments management information with biological data on New Mexico's black bear populations, improved understanding of the influence of annual variation in mast abundance, and estimates of potential bear density in different habitats. How can a manager use this diverse information to make inferences about the status of regional black bear populations and the potential consequences of harvest regulations? The population model is the tool for integrating harvest numbers, vital rates, and environmental relationships into a coherent whole.

Models of bear populations have been used for estimating population parameters, projecting population trends from vital rates, determining upper limits on sustainable mortality, and demonstrating various relationships between population and harvest composition. Treatment of biological detail and temporal variability has differed, depending on modeling objectives and information available.

Taylor et al. (1987) developed the ANURSUS model for estimating natality rates for polar bear populations from age specific litter size and family group observations. They emphasized the importance of accounting for the effect of whole litter loss on reproductive eligibility and litter intervals for animals with multi-year reproductive cycles.

Whether a population is increasing or decreasing, and why, are more important to management than population size (Eberhardt and Knight 1996). Assessment of population trends for Yellowstone grizzlies has been approached though comparison of female survival before and after sexual maturity, age of first reproduction, and reproductive rates, rather than through direct population size estimation (Eberhardt 1990, Eberhardt et al. 1994). These models use detailed biological information, and infer trends from average rate estimates. For small populations, perturbations of age and sex structure influence dynamics for many years (Knight and Eberhardt 1985). Such perturbations can affect estimates of and projections from vital rates.

A simple model with detailed reproduction (average age of first reproduction, litter size, breeding interval) and constant mortality was described by Bunnell and Tait (1981). They related maximum sustainable mortality to reproductive characteristics for several documented populations of grizzly, polar, and black bears, and aided other insights into bear population dynamics.

Consequences of food related variation in natality, particularly synchronized or alternating reproductive schedules, were modeled by McLaughlin (1998). He imposed patterns of variable parturition on an individual based, stochastic simulation model with detailed reproductive biology and density dependent mortality, and found a substantial impact on sustainable mortality rates for females.

Population viability assessment models (e.g., Weigand et al. 1998) and other stochastic, individual based models (Knight and Eberhardt 1985) are useful for small or endangered populations where chance is a significant contributor to population variability and probability of extinction is a management concern.

Abundant, detailed biological information is not available to many bear managers, but almost all have harvest data. However, inferring population trend from harvest data alone is nearly impossible (Bunnell and Tait 1980, Garshelis 1991, Miller 1990). A stable age and sex composition in both the live population and the harvest can occur when the live population is stable, but also when it is increasing or declining (Miller 1990). A predominantly male harvest is possible from a predominantly female population (Bunnell and Tait 1980). The erroneous assumption of a constant harvest mortality rate can lead to misinterpretation of harvest data (Garshelis 1991). However, models can be used to demonstrate counterintuitive relationships between simulated populations and harvest data, warning managers of the possibility of drawing false conclusions from pelt data.

Modeling with constant rates can provide useful insights on the boundaries of possible bear population behavior. However, vital rates are variable in real populations, and the particular patterns of variation influence population structure for long time periods. Stochastic modeling provides implicit variation in vital rates over time, but the time pattern of the variation is not related to observed habitat conditions, cohort size, or harvest numbers. Selected general patterns of cohort variation have been examined. The consequences of hypothetical variation in survival over time to population age structure have been used to demonstrate problems in relating harvest data to population status. However, bear models have rarely dealt with the implications of specific population histories. The perils of population assessment from harvest data alone are well documented. Modeling tools for integrating harvest data, biological information, and population history are needed.

METHODS

The bear population model was designed to simulate a black bear population through time, with biological realism, hunting, and environmental influences. Choices for population structure and for life history events accommodated population concerns, hunting patterns, and age of first reproduction for New Mexico. Input requirements were based on information anticipated from the field study for vital rates and bear densities, information routinely collected by NMDGF from hunters on effort and kills, and readily obtained environmental information important to bears. Outputs were chosen to track changes in population numbers and composition, as well as realized mortality rates and harvest predictions for comparison with observations. A set of functions with vital rates as arguments was developed to describe annual births, deaths, and age shifts. Additional functions related annual vital rate changes to environment (mast index, den entry timing) and hunting (effort and season timing). Functions for migration and population size constraints were added last.

Sets of vital rates from the study areas and regional pelt tag (hunter-kill) records were developed and stored with the model. A library of regional history simulations and teaching (hypothetical) model scenarios was developed.

Model software was programmed in APL (Array Processing Language, APL2000 APL+Win version 3.6) with a user interface in Windows Graphic User Interface (GUI) format. Installation is from CDDOM, programmed with Install Shield Express version 2.13. Automated output graphics are displayed using Microsoft Excel (version from Office 97 or later).

The model is implemented in a Windows Graphics User Interface (GUI) program, with a user shell to facilitate inputs, outputs, and scenario saves. Outputs are in both table and graphic formats. The model installation program is provided on CDROM with this report. The model CDROM also contains a library of scenarios, user manual, and documentation for the core model calculations.

The model user interface provides an assortment of aids to choosing input values, including stored characteristic rate sets for geographic regions of New Mexico, and hunt season and pelt tag (hunter-kill) report historic data sets.

RESULTS

Conceptual Model Structure

Overview. The bear population model (Appendix E) simulates a hunted bear population, tracking changes in numbers and sex-age composition over time based on births, deaths, and migrants (Figure 14-1). The initial population, characteristic vital rates, and annual variation in environment and hunting are inputs to the model. The core model equations are a calculation engine to change population numbers based on varying rates over time (Appendix F). Details of bear reproductive biology are incorporated into the model calculations. The model extrapolates population changes based on the conditions described by the full set of model inputs. Outputs are detailed population and harvest numbers and realized total mortality rates over time.

Vital rates are age and sex specific, and vary from year to year in response to environment and hunting. Vital rates are not explicit functions of density dependence or social structure. Migration of subadult males is optional and depends on threshold population sex proportions. Optional upper limits on total population and total adult females approximate density dependence at high population levels.

Population composition. The model's population age structure has separate age classes for each year from cub through 4 years, and an adult class containing ages 5 and above combined. Each age class also is separated by sex. Adult females are partitioned into groups with cubs, with yearlings, and with no offspring.

Scale. The modeled population should represent a large geographic area with a reasonably well-defined bear population, such as a mountain range. The model is not suitable for very small areas or small population subsets. Model runs typically simulate a population for 20 years or longer.

Annual variation. Mast availability index and den entry timing represent annual variation in environmental conditions. Hunting occurs in the fall, with annual variation in effort and season start dates. Fall mast index (poor, fair, or good) may be input for each year, or randomized based on input frequencies for each index level. Annual den entry is input as normal or late for each year. Hunt season dates may be loaded from historic data files; annual low, average, or high effort must be input for each year. Although the model is deterministic, it allows for unlimited patterns of variation over time.

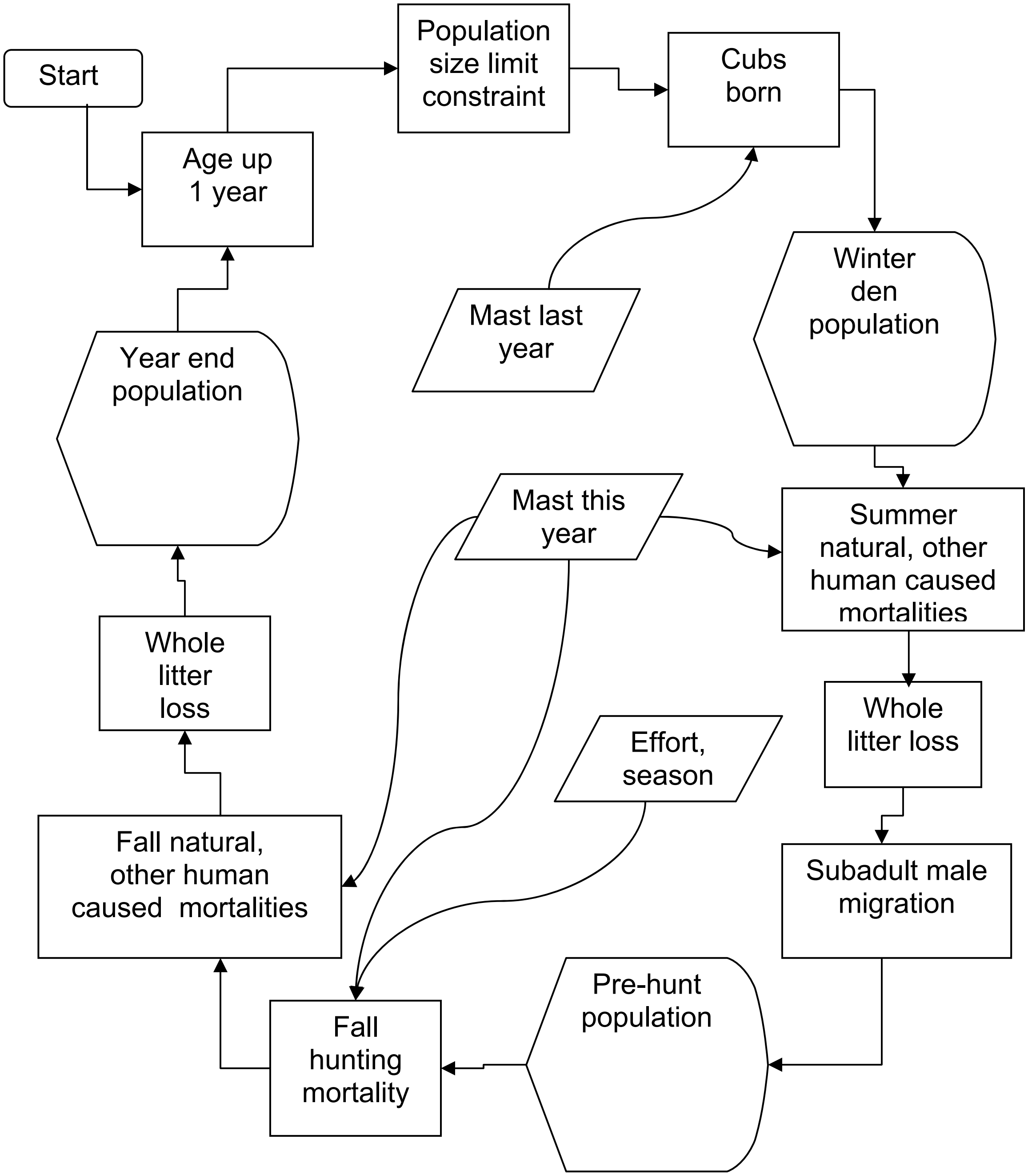


Figure 14-1. Schematic of sequence of events for a simulated year in the bear population model, New Mexico Black Bear Study, 1993-2000.

Natality. Parturition and cub survival rate inputs are step functions of poor, fair, and good mast availability and characteristic of the population being modeled. Fall mast each year determines cub survival rate for cubs born the previous winter and parturition rates for eligible adult females the following winter. Adult females with yearlings in dens do not give birth. Parturition rate is applied only to eligible adult females, defined as adult females without yearlings in dens. Cohort size variation and synchronized alternate year reproduction can be simulated. Calculated cub numbers are based on number of eligible mothers, parturition rate, and litter size frequency. Whole litter loss prior to hunting and prior to the following denning season is based on litter size frequency and cub survival. Whole litter loss in either time period classifies an adult female as eligible to give birth the next year, corresponding to the estimation of parturition rates for all adult females without yearlings in dens in this study.

Mortality. Long-term average mortality rate inputs characteristic of the population being modeled are age and sex specific, and partitioned into natural, hunting, and other human causes. Rates are additive. Hunting mortality varies as the characteristic rate is modified each year by hunt effort, season timing in relation to den entry, and mast conditions. Annual realized mortality rates, or characteristic rates modified by environmental factors, are an explicit output.

Hunting. The model can be run with hunt mortality rates as inputs, and hunter kills or pelt numbers as outputs. Alternatively it can be run with tagged pelt numbers as inputs, and the associated hunt mortality rates as outputs. The choice can be made separately for each year in the simulation. Forcing harvest numbers is useful for simulating unusual events such as the large 1994 harvest. Forcing harvest also makes explicit use of the NMDGF's long-term ongoing harvest pelt tag report data collection (see Chapter 13). Regional harvest data history files are stored with the model. Only fall hunts, the current NMDGF practice, have been implemented; a spring hunt could be added to a later version of the population model.

Scenarios. A scenario is the complete set of inputs for a model run. Scenarios may be saved and restored. Data interpretation using the model should be based on sets of scenarios, not on single runs. Sets of scenarios bracketing the range of uncertainty for inputs of interest or concern produce a set of outputs representing a plausible range of outcomes.

DISCUSSION

Limitations and Advantages of the Model

The New Mexico bear population model is deterministic. It is not suitable for assessing extinction probabilities or for modeling very small populations where chance is a significant influence. A set of runs with varied inputs is necessary to achieve a range of plausible outcomes. The model is intended for simulation of viable, hunted populations, not endangered ones.

The model does not predict vital rates or environmental variation, although it allows variation in environment to modify realized rates over time. The influence of habitat quality can be expressed by choice of characteristic vital rates. Inputs are detailed, a disadvantage when biological information is sparse, but an advantage for simulating the particular conditions experienced by a real population. Annual mast index is an explicit input, allowing use of observations when available. Mast variation can also be randomized, based on frequencies characteristic of the geographic area being modeled.

The influence of bear social structure on population dynamics is not modeled explicitly. Migration of 3-year-old males in or out of the population can be included, activated by selected threshold population sex ratios. However, interpretation of the results of simulations allowing subadult male migrants should include the plausibility of an external population source for immigrants. An upper limit on adult females and on total bears can approximate density dependence and habitat carrying capacity. The model is sensitive to upper limits, so choices should be based on habitat types and potential densities where possible.

Reproductive biology is modeled in detail. Females with cubs and probability of whole litter loss are tracked for reproductive eligibility and for hunting vulnerability. There are not separate age classes for adult females and parturition rates are average for all adult females, not age specific, because age specific reproductive rate data will not be generally available for New Mexico populations. Age at first reproduction is effectively 5 years, the approximate average for New Mexico. However, reduced parturition in mast failure years is equivalent to older age of first reproduction under poor environmental conditions. Parturition rate is not affected by adult sex ratios, since depressed reproduction due to scarce males is not a problem in New Mexico. However, no cubs are produced if there are no adult males in the simulated population.

Hunt season timing or closure and hunting effort are inputs, allowing management options to be explicit inputs for simulations. The current version allows hunting only in the fall, the current practice in New Mexico. The addition of a spring hunt option would expand the utility of the model.

The New Mexico bear model is designed to facilitate a synthesis of harvest data, population biology, and information on environmental variability. Resulting inferences about bear populations are consistent with all available information. The model cannot provide certainty, but it can rule out nonsense.

When good information is available on annual mast availability, harvest numbers with sex and age, and an upper limit or carrying capacity number of adult females for a population, in conjunction with the vital rate estimates from this study, model results can be of considerable use to managers. Scenarios with population constraints are more sensitive to the combination of harvest numbers, mast failure frequency, and carrying capacity than to rate estimates. Mast, harvest, and carrying capacity can indicate potential over harvest; vital rates can indicate potential for recovery.

Some Strategic Uses of the Model

Real population status. Use of the model to assess population status requires criteria for recognizing a plausible simulation. The criteria will combine best available information for rates and environmental inputs, and information on historic harvests to compare with outputs. To establish criteria for an acceptable simulation, (1) determine reasonable harvest and total mortality rates for the region and time period, (2) use measured mast indices, or any other indicators of mast availability for each year, or use a reasonable frequency of mast failure and randomize mast index over time, (3) note hunt season start dates and identify years with unusually low or high hunter effort, (4) from pelt records, calculate the average numbers of harvests by sex for the time period, and identify years of unusually low or high harvests, and (5) find indications of cohort size variation from harvest data records or independent observations. Run the model using the most plausible rate, environment, and hunt condition inputs. If necessary, make additional runs, varying the initial population numbers until the predicted average female harvest agrees with the observed average, to ensure a plausible initial population size. Then evaluate other outputs against criteria for a plausible simulation. Check predicted variations in cohort size and total harvest for agreement with observed patterns over time. If harvest numbers were forced (inputs) for some years, check the realized hunting and total mortality rates for those years for plausibility. A simulation with plausible inputs and with outputs consistent with observation provides a plausible assessment of population size and trend, consistent with available information.

Hypothetical population behavior. To investigate bear population behavior in general, use an arbitrary initial population with a reasonable age and sex composition, and vary characteristic rates or environmental conditions while leaving the initial population unchanged. Compare patterns in outputs over time, rather than numbers, to see how populations and harvest size and composition respond to different conditions. For example, change mast failure frequency to see the impact on population growth and harvest composition. Increase characteristic harvest and total mortality rates to find levels of over-harvest associated with population reproductive rates, and observe how harvest number and composition predictions change at the same time. Or simulate different hunting regimes over time for comparison, and include environmental variation for realism.

Examples from literature. The model can also be used to reproduce cautionary examples derived from technical literature concerning the problems of relating population status to harvest composition. An example is the counterintuitive finding that a predominantly female population is consistent with a predominantly male harvest, or that population and harvest age and sex composition can remain stable while population size is increasing, stable, or decreasing. The model user can thus be educated about the difficulties of interpreting harvest data, and avoid unwarranted deductions.

Reasonable Input Values

Characteristic vital rates. Estimating vital rates with minimal uncertainty is difficult for bear populations. Allowing rates to vary with environment and hunting is more important to model interpretations than getting average rates exactly right. The field study has produced reproductive and mortality rate estimates for New Mexico, although measured hunting mortalities are suspected to be low in some cases, providing the basis for reasonable input values for the population model (Tables 14-1 and 14-2).

Table 14-1. Black bear population model inputs for characteristic natality rates based on field study observations, New Mexico Black Bear Study 1993-2000.

Litter size frequency			Mast index frequency			
No. cubs	NSA	SSA	Model label	Mast classification	NSA	SSA
single	14	13	Poor	Fail	1	4
twins	43	24	Fair	Poor	4	2
triplets	4	1	Good	Medium or better	3	2

Mast index		Parturition rate		Cub survival	
Model label	Mast classification	NSA	SSA	NSA	SSA
Poor	Fail	0	0.39	0.50	0.43
Fair	Poor	0.71	0.67	0.50	0.85
Good	Medium or better	0.78	0.77	0.50	0.85

Choices for characteristic rate inputs have significant impact on model outputs, reflecting realistic uncertainty about bear population dynamics. Sets of simulations with different characteristic rates are needed to assess the impact of uncertainty on population inferences, and to bracket a range of plausible inferences.

Table 14-2. Observations and reasonable ranges for characteristic mortality rate inputs to the population model for female (F) and male (M) black bears on the Northern Study Area (NSA) and Southern Study Area (SSA), New Mexico Black Bear Study 1993-2000.

	Hunt mortality rate			Total mortality rate		
Population category	NSA	SSA	Reasonable range	NSA	SSA	Reasonable range
F Yearling	0	0	0.02 - 0.03	0.25	0.03	0.10 -0 .30
F Subadult	0.05	0.04	0.04 -0.08	0.06 - 0.14	0.09 - 0.11	0.05 - 0.15
F Adult	0.04	0.07	0.04 - 0.08	0.07 - 0.08	0.10	0.08 - 0.20
M Yearling	0	0	0.02 - 0.05	0.10 - 0.13	0.24	0.10 - 0.30
M Subadult	0	0	0.07 - 0.10	0.05	0 - 0.03	0.08 - 0.25
M Adult	0.02	0.07	0.07 - 0.10	0.08	0.09 - 0.18	0.10 - 0.25

Choices for characteristic rates can be used to describe conditions for a particular population. Natality rates can be adjusted to represent habitat quality differences. Mortality rates can be increased for areas with many roads or other disturbances.

The model allows for characteristic natality rates associated with 3 levels of mast abundance. Study results indicate that only 2 levels, failure or not, are significant (see Chapters 5 and 6). To reconcile the model structure and the study findings, use the model category of poor mast abundance for failure conditions, and assign the same rates to the fair and good model categories for non-failure conditions, taking care to indicate the correct frequencies for the failure and non-failure categories. Alternatively, assign a 0 frequency to the good mast category in the model, and use the poor and fair categories to represent failure and non-failure conditions.

Initial population numbers. The model addresses changes in populations over time. Each simulation or model run requires a starting population as an input. When vital rate and environmental inputs are reasonable, but model outputs of pelt numbers or realized total mortalities are not consistent with observations, then the simulated population is not plausible, and the initial population input should be changed.

Where possible, use GIS habitat extent, quality and associated bear home range size to estimate total male and female numbers, and use those as inputs. Partition the totals by age using default proportions or use extrapolated study area population structure as a guide.

If habitat based estimates are not available, consider a manager's informed estimate of total bears in the region as a starting point. Using the model will provide a check on the plausibility of such estimates.

When there is no other basis for selecting an initial population size, the model can be used to generate ballpark initial populations from harvest data, with the following steps: (1) Select and load a set of characteristic vital rates based on geography from rates stored with the model. (2) Set mast values to average for all years, so that reproductive rates will be steady at average values. (3) Start with an arbitrary total of 1000 bears, and run the model for 20 years. (4) Use the final population from that simulation, which will have age and sex proportions consistent with the vital rates, as the initial population for the next run. This step eliminates the influence of unstable population age structure on average harvest. (5) Run the model again, and compare the average total pelts and female pelts to pelt tag observations. (6) Adjust the initial total numbers up or down until predicted average pelts are similar to observed average harvest. Then use that initial population for simulations with variations in environment and hunting.

One use of the model is testing a range of population sizes for plausibility in light of past harvest history and mast availability by repeated runs varying only initial population totals. Take care to avoid other input constraints that may invalidate the population size interpretation.

Application outside of New Mexico. The model can be applied to black bear populations in other locations by suitable choices of characteristic vital rates, litter size frequencies, and mast frequencies and mast step function values. The input details allow considerable opportunity for simulating particular conditions. In this version, simulated hunting is limited to a single fall season.

Modeling study population viability

The model was used to investigate the implications of observed natality and total mortality rates from both study areas. Natality rates from Table 14-1 were used as model inputs. Calculation of long term averages weighted by frequencies shows the NSA had an average parturition rate for eligible adult females of 0.65, and average litter size of 1.84. The SSA had lower average reproductive rates, with 0.51 for parturition rate and 1.68 average litter size. Observed total mortality rates for the study areas from Table 14-2 were entered as characteristic natural mortality, with other human and hunting mortality rates set to zero, for correct total realized mortality. Where the total mortality estimate was a range (excluding or including probable deaths), the mid point of the range was used for the input value.

Initial population age and sex composition were based on history scenarios previously developed for the surrounding mountain ranges, but total numbers were rounded to the nearest 1000 for simplicity. This analysis considers proportional population changes rather than absolute numbers, so the initial total numbers used do not affect the interpretations.

Some simulations were made with mast set to average for all years, to produce constant average natality rates. Additional runs were made with randomized mast values, using the frequencies characteristic of the study areas, so that cub production varied. Cub survival varied with mast, but total mortality rates for older bears were constant at input rates. For each study area, 1 run used mast index set to observed levels for 1993-2000. Since observed mortalities on the study areas appear unrealistic for female yearlings on both areas and subadult males on the SSA, simulations were also run with total mortalities set to the minimum, middle, and maximum of the reasonable ranges for each population category. Changes in adult female numbers from beginning to end of the simulations varied from 199% increase to 84% decrease, depending on the combination of mast conditions and mortality rates used (Table 14-3).

The interpretation of simulation results will focus on adult females, because their numbers determine the reproductive potential of the populations. Our observations of subadult male total mortality are unrealistically low, skewing the simulated male numbers and the simulated population sex composition.

These simulations are not realistic, because constant rates over time are not realistic, but they reveal the population trends implied by the observed average rates. Both populations have a built in tendency to increase, based on observed rates. The unhunted NSA has lower mortality for subadult and adult females, and higher potential reproduction because of its low frequency of mast failures, and so has potential to increase faster than the SSA.

The potential for increase is overestimated if total mortality for females has been underestimated. For both study areas, the average annual female total mortality is 10%. Model simulations with the same total mortality rate for all female age classes and average observed natality rates show that the NSA population would begin to decrease with average total female mortality above 12.5%, and the SSA population would begin to decrease with average total female mortality of 11.5%, well within the range of uncertainty for the observed rates.

Table 14-3. Percent changes in adult female numbers from bear population model runs using study area vital rates and mast observations for the Northern Study Area (NSA) and Southern Study Area (SSA), Black Bear Study in New Mexico 1993-2000.

Time frame	Constant average mortality rate	Mast	NSA female population change	SSA female population change
20 years	Study area observations	Constant at average	+117%	+49%
20 years	Study area observations	Randomized	+39 -128%	+40 - 86%
1992-2000	Study area observations	Study observations	+23%	+14%
20 years	Minimum of reasonable range	Constant at average	+199%	+129%
20 years	Middle of reasonable range	Constant at average	-16%	-34%
20 years	Maximum of reasonable range	Constant at average	-79%	-84%

The simulations with observed mast abundance indicate that both study populations have increased during the study. There were no marked bears killed from the SSA population during 1994, the year of record harvests for both sexes in the surrounding Gila region, but marking began only in 1993. If unmarked females resident on the SSA were killed in 1994, the study population may not have increased.

The pattern of mast abundance over time strongly affects simulated population trends, with all other inputs left unchanged. Routine observation of mast abundance would greatly enhance utility of the model and assessment of population status.

Modeling Pelt Tag Data Histories

In workshops held in 1998 and 1999, NMDGF area managers used the population model to assess black bear populations in 4 mountain range regions comprising most of the state's bear habitat (Table 14-4). Simulations used vital rates and mast observations from the study areas for the Gila and Sangre de Cristo complexes, and similar rates for the San Juan complex and Sacramento region with adjustments based on area managers' knowledge of local conditions. Simulations were run for 1981-1998. Outputs were evaluated for plausibility based on comparisons with observed average pelts tagged by sex for 1989-1998, timing of peak harvests, and proportions of subadults. Scenarios with reasonable matches to observed patterns provide interpretations of bear population status that are consistent with both pelt tag observations and field study findings.

Table 14-4. Regional black bear population status interpretations based on population model simulations and harvest observations in New Mexico, 1989-1998.

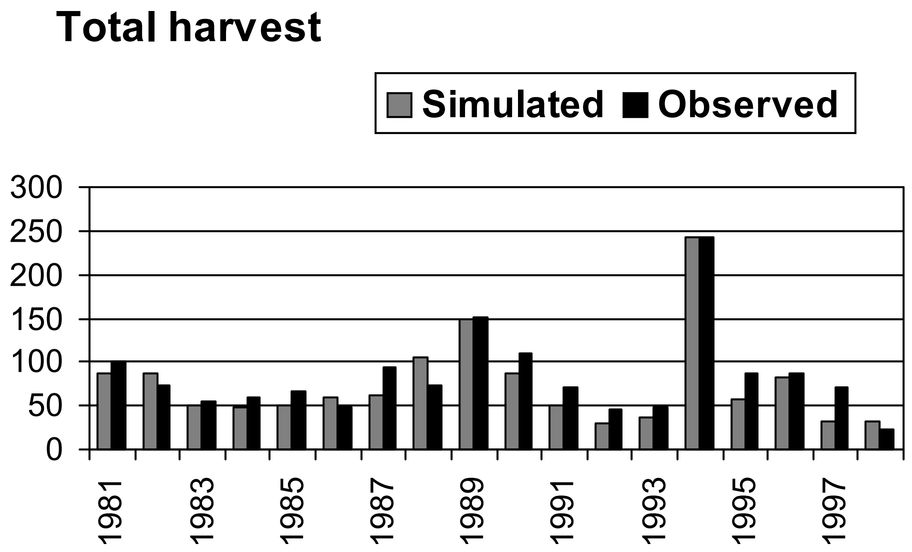
Region	Rough population estimate	Trend	Observed average no. bear kills 1989-1998		Model average no. bear kills 1989-1998		Pelt tag numbers forced	Scenario name
			F	M	F	M		
Sangre de Cristo complex	1500	Slow increase	40	67	41	56	none	SANG99D
San Juan complex	1000 hunted + 700 unhunted?	Slow increase	26	44	25	35	none	SNJN99C
Gila complex	1000	Stable	35	58	37	43	1989, 1994	GILA99B
Sacramento region	1000	Increasing	24	33	23	35	1994, 1995	SE99B

Sangre de Cristo complex. Scenarios were based on NSA rates, but with higher adult hunting and total mortality rates, because most of the region is hunted (although the study area was not). A scenario with constant hunt effort and observed mast pattern for the study years produced a slowly increasing population with reasonable harvest patterns but low average numbers, and a peak in kills for 1994. Initial population was increased to raise average pelt tag numbers, and hunt effort was specified as low for 1992 and high for 1995, consistent with card survey results. The final scenario showed a gradual increase in the live population total. Scenario average pelt numbers for males were lower than observed, suggesting that the hunt component of male mortality may have been underestimated.

San Juan complex. Scenarios were based on NSA rates, but with higher adult hunting and total mortality rates, because part of the region is hunted (although the study area was not). . Mast index inputs were based on knowledge of local conditions, not northern study area observations. Runs with slightly increasing population and a reasonable match for observed female pelt tag reports had lower male pelt tag numbers than observed. The large areas of this region protected from hunting may be a source of some of the males killed by hunters.

Gila complex. Southern study area vital rates were used, except that a higher subadult female hunt mortality (same as for adult females) was needed to match the observed proportions for subadults of females in pelt tag reports. High harvest numbers for 1989 and 1994 were forced because simulations did not produce the observed peaks. For 1994, with the harvest forced to match the high observed pelt tag report numbers, realized total mortality for the year was 22% for females, 35% for adult males, and 42% for subadult males; area managers interpreted the high mortality values as reasonable for the unusually harsh conditions of 1994. In a scenario that produced a good match to observed pelt tag numbers and proportions for females, the 1994 harvest reduced the pool of adult females in the model population, so that the population fluctuated around initial 1981 population numbers without much change over time (Figure 14-2). Scenarios that matched observed female pelts predicted too few male pelts. The discrepancy could be reduced by assuming substantial immigration of subadult males from Arizona, or by shifting all subadult male mortality from other causes into hunting, or by a higher total population with much lower female hunting mortality.

Sacramento region. A population scenario with fast turnover, both natality and mortality near the high end of reasonable ranges, is consistent with the observed high proportions of subadults in pelt tag reports. With the large 1994 and 1995 pelt tag observations forced, a scenario with a slowly increasing population predicts harvests that agree with both observed numbers and proportions. There is no likely source of immigrant subadult males for this population, and the scenario does not need 1 because these mountain ranges are isolated from sources of immigrants.



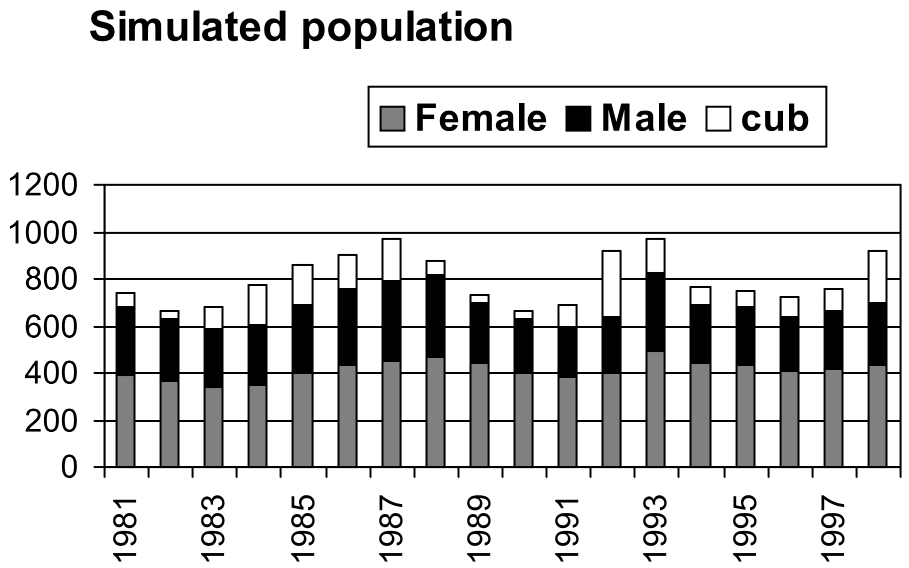


Figure 14-2. Black bear population and harvest numbers simulation

Statewide. The steady decrease in statewide hunter-killed bears from 625 in 1994 to 148 in 1998 raises concern about over-harvest. That pattern was exaggerated by the large harvest in the Gila complex in 1994; although present, the pattern is much less marked in other regions. Harvests increased again in 1999 and 2000. License sales decreased steadily from 1995 through 1998, and the 1998 season was 6 weeks later than previous years. Model population simulations with field study rates indicate that the peak harvests likely resulted from mast failure combined with an abundance of available subadults born in the early 1990s, and subsequent decreases were likely related to decreasing hunter numbers rather than to a rapid drop in bear populations.

Pelt tag reports show a higher proportion of males than do simulations based on vital rates observed during field study. The difference may result from difficulty in documenting male bear mortality rates, or from inclusion of immigrant subadult males in harvest reports, or both. Focusing on the female segment of the population for interpreting population changes avoids the problem.

Model Application to Management

Simulations used for the following model application discussions are included with the population model software in the scenario library (Table 14-5).

How fast can a population change? In simulations with all mortality rates at the high end of reasonable ranges based or study, model populations disappear in 2 or 3 decades. The persistence of bears is evidence against the plausibility of the long-term maximum mortality rate simulations. Populations with average natality like the SSA would decrease by 61 – 79% in 10 years and by 85 – 96% in 20 years with constant annual mortality rates of 20 – 25% for all population categories. Populations with average natality like the NSA would decrease by 56 – 75% in 10 years and by 80 – 94% in 20 years.

Minimum mortality simulations, while not realistic, identify an upper limit on bear population growth rates in New Mexico. Unless limited by habitat capacity, southern populations might double in 20 years, and northern populations might triple, if mortality were minimal and the pattern of mast availability remained normal. Since most New Mexico populations are hunted, the fastest population increase possible with persistent low mortality would be doubling in 20 years. With occasional years of greater mortality, population increases are reasonably expected to be slower.

Average statewide hunter kills for 1994 and 1995 were double the average for 1991-1993. This increase must be interpreted as increased hunting mortality rate, and not as a proportional increase in total population with unchanged harvest mortality, because the population could not have doubled during that time frame. Similarly, the decrease in total pelts tagged from 625 in 1994 to 148 in 1998 cannot be interpreted as evidence of a 75% reduction in population in 5 years, because such a rapid drop would be highly unlikely. Instead, other factors should be considered along with the possibility of a less rapid population decrease.

Table 14-5. Scenarios used for the black bear population model application discussion and stored in the scenario library, Black Bear Study in New Mexico, 1993-2000.

Scenario library name	Description of scenario	Interpretation section
NSAOBS01	Constant mast, NSA characteristic vital rates	Study population viability
SSAOBS01	Constant mast, SSA characteristic vital rates	Study population viability
CUBVAR1	Population varying slightly around a stable total	Synchronous reproduction
OVER0	Baseline stable population with annual variations	Characteristics of over harvest
OVER1*x*	Persistent mast and reproductive failure	Characteristics of over harvest
OVER2*x*	Increased hunt mortality	Characteristics of over harvest
OVER3*x*	Increased nonhunt mortality	Characteristics of over harvest
SANG99D	Sangre de Cristo pelts, NSA rates	Pelt tag histories
SNJN99C	San Juan pelts, modified NSA rates	Pelt tag histories
GILA99B	Gila pelts, SSA rates	Pelt tag histories
SE99B	Southeast pelts, modified SSA rates	Pelt tag histories

Cohort variation, synchronized reproduction, and pelt age composition. The baseline scenario simulates a hypothetical population varying slightly around a stable total for 20 years. Mast index and the associated natality and cub survival rates vary annually. The population age composition changes over time as variable size cohorts age. Hunt effort is held constant so that realized total mortality rates for yearling, subadult, and adult bears remain constant. Predicted hunter kills or pelt tag numbers vary slightly with population size and composition over time. The proportions of subadults in the pelts vary from 35 to 53%, with several large drops over a few years; however, total population size is essentially stable (Figure 14-3). This simulation demonstrates that shifting proportions of subadults in hunter-killed bears may indicate, and lag, cohort variations, but do not necessarily indicate population size change.

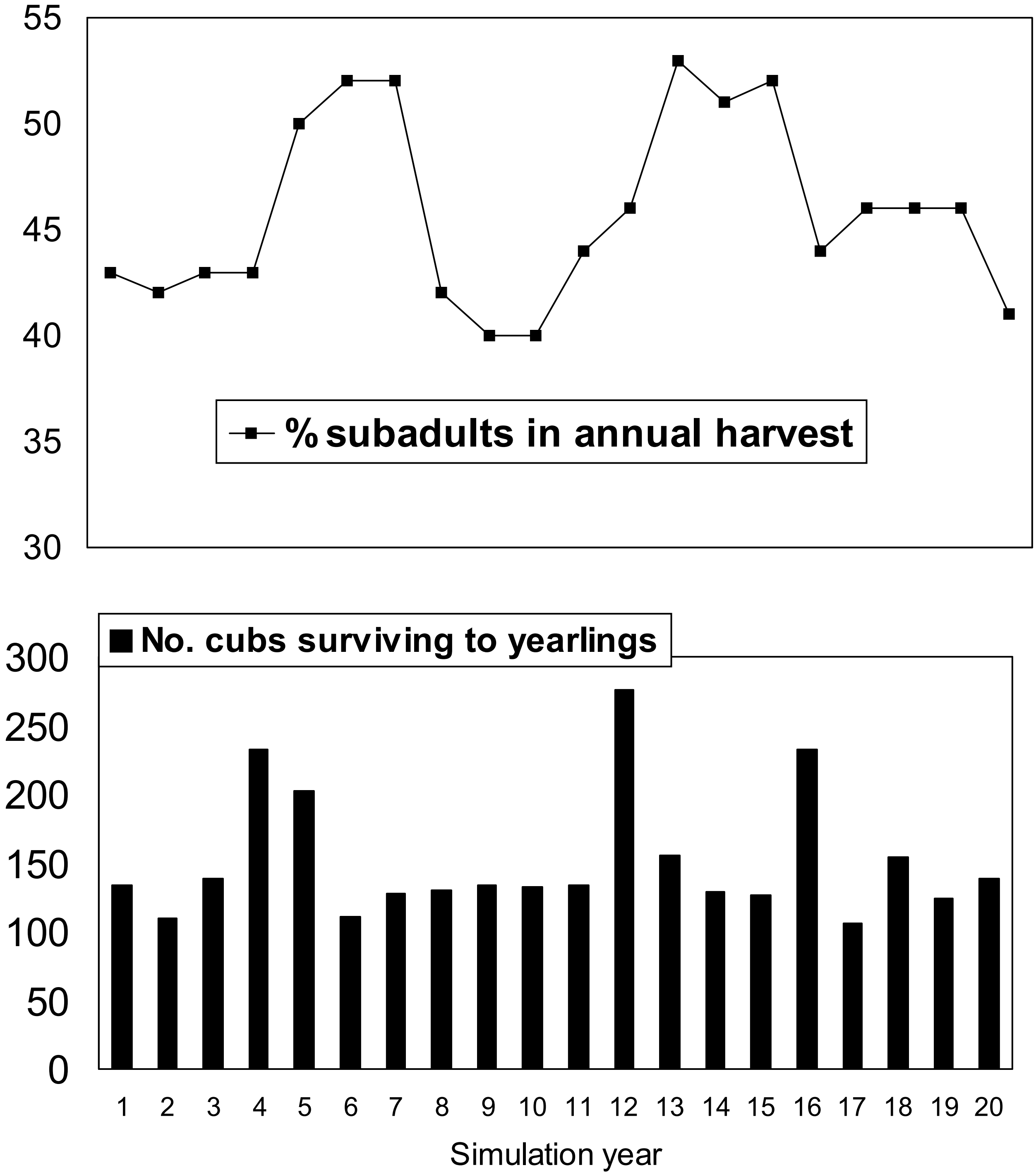


Figure 14-3. Simulation of black bear cohort size variation and its influence on harvest age composition in a 20 year stable population simulation for data applicable to black bears in New Mexico.

Synchronized reproduction can be simulated. Constant rate scenarios provide a basis for examining synchrony, by following the impact of a single mast failure over time. One year of mast failure in a simulation with NSA natality rates and otherwise all fair mast produces almost no cubs in the year following the mast failure, a very large cohort in the second year, and a smaller than normal cohort the third year. Variations continue for several more years, but with differences too small to be noticeable. A similar pattern occurs with SSA natality rates, except that the initial mast failure produces 2 cohorts about half average size since the mast failure reduces survival for cubs already born as well as parturition for the next year's cohort. A single mast failure affects cohort size for 3 or 4 years. Any single year's observation of population composition may misrepresent the longer time scale pattern. Averages over 2 to 4 years are useful for examining patterns over long time periods.

Characteristics of over-harvest. The model was used to investigate potential indicators of over-harvest and declining populations. A 20 year simulation of a hypothetical population fluctuating around a steady mean, with annual variations in mast index and 2 years each of high and low hunt effort, was used as a baseline. Declining populations were simulated by mast and reproductive failure, increased non-hunt mortality, and increased hunt mortality. For each cause of decline, runs were made with hunt mortality determining pelt numbers and with pelt numbers specified resulting in increasing hunt mortalities in the second decade. The hypothetical scenarios used for this discussion are stored in the model scenario library.

In the baseline simulation, pelt numbers fluctuated from year to year with cohort and hunt effort variations, but remained stable on average. The proportion of females varied in the range of 46-51%, and the proportion of subadults varied in the range of 34 – 44%, with no trends over time.

In all of the declining population simulations without forced pelt tag numbers, simulated harvest numbers fluctuated, but relative peaks decreased and averages clearly dropped over time. In the stable population simulation, harvest numbers were steady on average. In other simulations with increasing populations, pelt numbers increased on average. Trends in harvest numbers should indicate population trends if hunting effort remains reasonably constant and if harvest numbers are related to bear numbers, that is if hunting mortality rate has some reasonable upper limit. The problem with depending on pelt tagging report numbers as a population indicator lies in the assumptions. In New Mexico, changes in hunt season dates and substantial variation in numbers of hunters produce variations in hunt effort, so that patterns in pelt numbers must be interpreted in conjunction with patterns in hunter numbers and seasons. A persistent decrease in total pelts over 4 years or more without a related decrease in hunting effort should be investigated as a potential indication of a population decline.

Simulations with forced pelt tag numbers can represent cases of harvest numbers not related to bear numbers, so that hunt mortality increases until hunters take all bears. If hunters can kill the same numbers of bears at high and low bear population levels, then pelt number patterns are not a reliable indicator of live population trends.

The age and sex composition of pelts from populations declining due to increased mortality rates did not differ noticeably from the baseline stable population simulation. In the simulation with persistent reproductive failure, the proportion of subadults in pelts decreased by half in 6 years, and then remained low but stable. In the reproductive failure case, independent information on persistent mast failures would alert managers to a probable population decline before pelt age changes could become obvious. Changes in pelt sex and age composition are not useful indicators of population size trends. Age and sex of pelts does provide useful information on relative cohort sizes and impacts on the pool of reproductive females, however.

In the simulations of populations declining from increased hunt or nonhunt mortality rates, the population declines could be stopped or reversed by reducing hunt mortality. In the simulation of population decline from reproductive failure, the rate of the decline was slowed with reduced hunt mortality.

Declining populations are hard to recognize from pelt tag data alone. Decreased pelt numbers without decreased hunt effort would indicate a declining live population, but would take perhaps a decade to become apparent. The bear model provides a context for interpreting pelt numbers; interpretations are considerably strengthened by the incorporation of other information such as mast observations, hunter numbers, and season timing.

Focus on female harvests. Initial experiments with the model are likely to produce frustration with the difficulty of forming definitive conclusions in the face of uncertainty about vital rates. Further experience with a variety of simulations will indicate that the pool of reproductive females is critical to population trends, an outcome that is not surprising. In New Mexico there is good information on harvest numbers. Even though female mortality rates are not known with certainty, unusually high female harvest numbers (well above averages from other years) can be recognized from pelt data, and imply unusually high female mortality for the year. In New Mexico there is a well-documented relationship between mast crop success or failure and reproductive success or failure (see Chapter 6). Continuing observations of fall mast will provide a good indication of annual variation in reproduction, and the associated variability in cohort size should be detectable from pelt ages. The model provides the capability of simulating the population consequences of the real pattern of female harvest and reproduction over several years, key to assessing the potential for over-harvest. High female harvest numbers combined with poor reproduction need management attention.

MANAGEMENT IMPLICATIONS

The bear population model is a tool for integrating harvest and biological information, and forming interpretations that are consistent with existing knowledge. It helps managers to:

- Interpret harvest data in the context of bear population biology, including reproductive patterns and the influence of environmental conditions on vital rates, such as parturition and survival

- Make inferences about bear population size and status that are plausible and consistent with available harvest and biological information

- Evaluate the consequences of management options to bear populations

“Knowledge in, knowledge out” is the philosophy of bear model use. Inputs are the characteristics of the particular population to be modeled and the year-to-year changes in the conditions that affect that population. Outputs are predicted year-to-year changes in numbers and in age and sex composition of the live population and of hunter-killed bears. Model calculations link the outputs to the inputs based on knowledge of bear population dynamics. Model predictions are consistent with the inputs. Greater confidence in inputs means greater confidence that simulated population behavior is realistic.

The model simulates population behaviors that are realistic for conditions in New Mexico. There will always be considerable uncertainty in information about black bears. Because of this uncertainty, managers will not be able to use the population model for simple predictions of legal kills or population trends. The model will be useful for gaining insight about how bear populations can behave, and for discriminating between reasonable and unreasonable explanations of observed harvest trends.

The New Mexico bear model can incorporate variation in vital rates over time based on real population histories, through annual mast observations for natality variation, and annual harvest numbers for mortality variation. The consequent perturbations in live population structure and harvest composition can then be simulated and taken into account for population status interpretation.

The black bear population model can be a useful tool for understanding bear population dynamics, and educating the intuition of managers. Sufficient practice with the model is essential to appropriate interpretation.

Experimentation with the impacts of small changes in different inputs, or sensitivity analysis, will provide insight into the relative importance of different kinds of input information, allowing effort to focus on the most important variables.

When good input information is available, the black bear population model can be a useful tool for assessing population status. Continuing collection of hunt effort information though the hunter card survey and information on the number, sex, age, and location of hunter-killed bears through mandatory pelt tagging reports will be useful. Routine observation of fall mast abundance will be useful. Attention to habitat suitability, using GIS tools, will be useful.

Black bear population status appears to vary among mountain regions in New Mexico. Hunting regulations that vary among regions make sense from a population biology perspective.

Focusing the interpretation on bear population status on the female segment is useful, because the pool of adult females is critical to population maintenance. Annual variation in male harvest numbers is harder to interpret because subadult males may be migrants.

Be cautious in interpreting bear model predictions for conditions outside the range of experience from the bear study, including poorer habitats, different hunt regimes, and other climate conditions.

CHAPTER 15

MANAGEMENT TOOLS AND APPLICATIONS

It is vital that readers of this report and its appendices recognize that they are a tool for future management investigation and decision-making. Using the study results, the population and habitat models, and data collected annually by NMDGF, managers can explore the results and consequences of many management options. This product does not provide answers to all management questions; it provides the means to answer questions when used with reliable and up-to-date information.

EXISTING TOOLS

Hunter-Kill Data Records

Since 1978, the NMDGF has collected annual records of harvested bears through a mandatory tagging and reporting program. Beginning in 1985, utility of these data was improved with the requirement of proof of sex and collection of a premolar tooth for age determination with the cementum annuli method. This data set, known as the pelt tag records, also includes information on date, location, and method of kill.

Hunter Survey

Since 1989, the NMDGF also has conducted mail-in surveys of all buyers of bear hunting licenses to obtain data on hunter effort and methods to be used in conjunction with harvest records. These records, known as the card survey data, are collected and analyzed by the NMDGF Division of Wildlife.

NEW TOOLS

Bear Population Model

An important product of this study is a black bear population model that directly incorporates reproductive and survival rates observed during 8 years of field study, along with harvest data routinely collected by the New Mexico Department of Game and Fish. Utility of the model depends on continued input of data in the form of (1) annual hunter-kill (pelt tag) records and (2) annual observations of regional mast production.

Habitat Model

Another important product of this study is a model of predicted suitable habitat for black bears in New Mexico. This model is a relatively simple predictive algorithm that incorporates land cover classes (habitat types), land cover class suitability for bears, mast production potential, and distance of isolated habitat tracts from primary habitat types. The model allows for examination of bear habitat with respect to other landscape features such as roads, distribution of hunter-killed bears, proximity to human population, and other factors that a resource manager may choose to evaluate. The model is designed to incorporate and integrate with new ecological and socioeconomic information as it becomes available.

Annual Mast Survey

The mast production survey implemented during this project is a procedure conducted by NMDGF personnel using categorical criteria to distinguish annual variation in mast production. Study results indicate that documenting annual mast production, particularly occurrence and frequency of mast failures, will be an effective tool for predicting future black bear reproductive success. In addition, knowledge of mast failure may aid in interpreting harvest data, because mast failure appeared to influence amount and composition of hunter harvests.

Research Report and Data sets

The Final Report and associated data sets (on CDs) provide extensive archiving of bear project data and interpretation of that information. Some of this information is supplemental to specific uses in the bear population model and habitat model. The report materials in total are a foundation for asking additional questions about managing black bears in New Mexico and describe uses of all of the tools mentioned here.

UNDERSTANDING THE TOOLS

Hunter-Kill Data

Hunter kill data provide information only from successful hunters. Continued collection of pelt tag report data is essential for estimating population trends using the bear population model. Analyses indicate ages of hunter-killed bears, estimated using the cementum annuli method, are sufficiently accurate to support interpretation of pelt tag data. Use of the bear population model requires age-specific data on bears aged 1-4 years, and distinguishing subadult from adult bears killed by hunters. Our analysis indicated the currently used age determination technique is most accurate and consistent for young bears. Procedural improvements, such as minimizing breakage and extracting the correct tooth, also will increase accuracy.

Analysis of pelt tag records from marked study bears indicated as many as 7% of hunter-killed bears reported to NMDGF are missing from finalized pelt tag data. Improvement in the flow of data from field personnel through area offices to the Santa Fe office is necessary to ensure the most accurate data possible. Also, it is essential that UTM coordinates for locations of bear kills recorded on the pelt tag record be accurate and consistent with the GMU to maximize abilities to plot bear kill data with respect to habitat model output.

Hunter Survey

The hunter card survey collects information from unsuccessful as well as successful hunters, allowing estimation of effort and success rates. Continued collection of mail survey data is essential for knowledge of the geographic distribution of hunting effort, not available from statewide license sales or pelt tag records. Archiving raw survey response data will facilitate analysis beyond the routinely reported annual projections.

Projections of total hunter effort and harvest from card survey responses depend on total statewide license sales numbers. Because the state fiscal year is different from the regulation year, and license sales records are maintained for fiscal use, careful attention to appropriate total license numbers is important to card survey projections.

Surveys are mailed to all license holders with usable mailing addresses. Archiving mailing lists and noting undeliverable returns would improve knowledge of response rates, allow comparison of response rates by region, and facilitate follow up surveys of nonrespondents to assess bias.

Annual Mast Survey

Results of simplified surveys conducted by NMDGF officers were highly correlated with more intensive survey results, indicating quantified subjective criteria are adequate to distinguish variation in mast production. Most officers found the criteria were reasonably easy to use and could be completed during routine duties. In the future, an effort to establish general survey routes, revisited each year, may reduce unnecessary variability and ensure quality data.

Bear Population Model

The bear population model is a tool for (1) interpreting past or present conditions using real time series observations of harvest and mast, and (2) investigating demographic outcomes from hypothetical information based on realistic biological conditions and management actions. Model input variables are reproductive rates, survival rates; and mast production; outputs are predicted population composition and harvest composition. The inputs appear to be simple, but the user must be educated to the influences of factors such as hunt timing, methods, and regional differences in productivity and mortality. Information in the Final Report and interpretations from GIS habitat modeling are important resources for judging inputs for the bear population model.

Reliable information is essential for using the bear population model and interpreting its output. Continuing collection of hunt effort information though the hunter card survey and information on the number, sex, age, and location of hunter-killed bears through mandatory pelt tagging reports will be important for future management. Continued mast survey data are also essential inputs for the bear population model, because vital rates are deterministic functions of mast index in the model.

Information from this study indicated mean age of females at birth of first cubs was 5.7 years for study bears, and only 9% of 4-year-old bears produced first litters. Use of the population model assumes the adult segment of the bear population in New Mexico is bears ≥5 years old.

Sufficient practice with the model is essential to appropriate interpretation. Sensitivity analysis, or experimentation with the impacts of small changes in different inputs, will provide insight into the relative importance of different kinds of input information, allowing efforts to focus on the most important variables. Focusing interpretation of bear population status on the female segment is useful because the pool of adult females is critical to population maintenance. Annual variation in male harvest numbers is harder to interpret because subadult males may be migrants.

Caution is necessary in interpreting bear model predictions for conditions outside the range of experience from the bear study, including poorer habitats, different hunt regimes, and other climate conditions.

Habitat Model

At present, restrictions on availability of comprehensive, detailed, statewide information layers limit detailed analysis of habitat quality and potential effects of humans on bear survival. However, the model was constructed so that future, more resolved information can be easily incorporated to update model predictions. Such new data integration also applies to analytical uses of the habitat model to assess proximity to human-populated areas and other evidence of prospective human interaction with bears (e.g., traffic, recreation). The habitat model also may be useful in developing or verifying inputs to the bear population model, especially upper limits for modeled populations.

APPLYING THE TOOLS

Population Monitoring and Interpreting Hunter-Kill Data

Use of the bear population model, with the inputs described above, will (1) allow for interpretation of recent demographic trends in New Mexico bear populations, (2) provide a timely indication of potential overharvest, and (3) provide predictive scenarios useful for selecting from several management options.

Although status and trends in black bear populations cannot be detected from harvest data alone, patterns in harvest data may flag areas of concern to managers. For example, missing cohorts and associated reduction in proportions of subadults in the harvest over several years may suggest poor reproduction.

Model vital rates are deterministic functions of mast index, which can be randomized with realistic frequencies, or matched to observations. Series of scenarios with different mast patterns or characteristic vital rates can be set up easily and run in a short time by NMDGF wildlife managers and researchers investigating further and future questions about bear population management. Outputs of interest must be recorded and organized for comparison; the model does not compare results of differing scenarios automatically.

Among adult and subadult bears, most mortality was human-caused. In addition to hunting, illegal kills and depredation kills were significant sources of mortality for these bears. Illegal kills were documented on both study areas, and many of the unexplained losses were probably due to illegal kills followed by destruction of the transmitters. We were unable to verify any of these possible mortalities, therefore these possible rates should be viewed as maximum rates.

Interpretation of population trend also will be improved by actual data on bear mortalities resulting from depredation and nuisance situations. Currently, NMDGF data are incomplete and do not represent a concerted effort to assess the impact of these actions on bear populations.

Because reproductive success and recruitment are determined largely by mast production, people primarily alter black bear population growth through human-caused mortality of adult and subadult bears. Use of the bear population model with reproductive and survival rates observed during this study indicated study populations were stable (SSA) or slightly increasing (NSA) with a likely annual population increment of no more than 2-4% growth per year on average. If management goals are to maintain bear population levels, strategies that emulate demographic rates observed during this project are appropriate. If management goals are to accomplish strategic changes in numbers or redistribution of bears (e.g., reduce or increase total population, different regional population objectives), then management strategies will call for altering mortality rates up or down from those observed during this study. Options related to those goals can be explored using capabilities of the bear population model.

If annual mast surveys are continued long-term, in addition to providing annual information necessary for model inputs, they also will provide valuable information on the relative frequency of mast failures within different regions of

New Mexico. This information will be useful for determining the growth potential of distinct bear populations within the different regions of New Mexico.

Population Estimation

Two independently derived population estimates (bear population model and habitat extrapolation) put the New Mexico statewide bear population at approximately 5200-6000 bears. These estimates were for the pre-mast season (May-early August) and excluded cubs of the year.

Statewide population estimates derived from this study refute previous estimates. Our estimates indicate a statewide population of approximately twice the long-standing estimate of 3,000 bears previously used by the NMDGF. However, these estimates do not suggest a doubling of the bear population in the past decade. Rather, these estimates are based on better information including demographics, density, and habitat extent.

Population estimates must be used advisedly because each method of population estimation has intrinsic limitations and firm numbers can never be achieved. Furthermore, population estimates derived from the field study represent density in good habitat, and little is known about the relative density of bears found in less suitable habitat. With this new information NMDGF has additionally recognized latitude in bear management, but should proceed with caution regarding adjustment of harvest goals near the upper limit of new estimates without further testing of the model and predictive scenarios.

Estimates of black bear density and total population provide a reasonable estimate of the upper limit of New Mexico bear populations. As an input into the bear population model, this information is intended as a planning figure. While it is not exact, it illustrates that there is an upper limit to the possible statewide bear population and ensures a level of reality prohibiting predictions of unlimited population growth.

Hunt Management

Annual bear kill by hunters was affected by many factors including season timing, hunter effort, hunter method, and mast production, as well as underlying population composition. Hunters aided with dogs had higher success rates and harvested 4 times as many female bears per hunter as those not using dogs. Harvest was positively associated with hunter effort (higher harvest with greater effort), while harvest was negatively associated with mast production (higher harvests with lower mast abundance). Knowledge of these relationships may aid the NMDGF in selecting among various hunt management options.

During the intensive fall foraging period, study bears commonly increased activity patterns and made frequent long-range movements outside of their primary home ranges. Differences in movement patterns were observed between regions and among different sex and age categories. Movement patterns also differed relative to availability of mast, primarily acorns. Knowledge of these movement patterns may allow the NMDGF to set fall seasons at times most appropriate to accomplish various harvest objectives.

Bears entered dens as early as September and as late as February. Differences in den entry dates were observed between pregnant female and other bears and between regions of New Mexico, however much overlap occurred between sexes and varied annually. Knowledge of these differences will allow the NMDGF to influence the sex and age composition of the harvest to achieve desired management objectives, such as protection of adult females as the reproductive segment of the population. Analysis of pelt tag records indicates later timing of fall seasons reduced harvest of female bears.

Bears emerged from dens as early as March and as late as May. Slight differences in den emergence dates were observed between male and female bears, indicating careful timing of an early spring season could reduce vulnerability of female bears, especially those with new cubs. Analysis of pelt tag records showed spring harvests were dominated by male bears. However, immobility of cubs immediately following den emergence increases the potential for separation of cubs from their mothers (preventing identification of females with cubs), thus orphaning and inevitable cub mortality. Considering both factors, it appears that any spring hunting season will have the potential for reducing cub survival.

Knowledge of black bear denning dates is useful for interpreting sex and age composition of the harvest. The verified differential in den entry and emergence dates among sex and age groups has application to setting bear hunting seasons to accomplish various objectives. However, den entry and emergence dates are highly variable and generally span a period exceeding 2 months. We observed variation relative to mast production; other factors undoubtedly play a role influencing the timing from year to year. No single timing scenario is appropriate for every use.

It is important to recognize that there was no legal hunting on the NSA during 1992 through 1997. Therefore the hunting mortality rates observed may not reflect actual mortality of bears from hunting in northern New Mexico. The possibility of total mortality exceeding the rates we observed must be considered when interpreting harvest data and output from the bear population model.

Habitat Considerations

Estimated statewide bear habitat encompasses approximately 14.6 million acres, of which 75% is primary habitat. Primary habitat represents about 13.5% of the state.

Within predicted bear habitat, mast producing land cover types were found within 7 km (female mast season activity radius) of primary habitat throughout New Mexico except for about 300 km^2 in the Sangre de Cristo complex. This indicates that nearly all bears have access to habitat with important mast-producing species. However, actual abundance of oak, juniper, and pinyon is unknown within bear habitat because current data are not adequate to assess detailed distribution of potential mast production. Better information on actual mast-species abundance may allow for better interpretation of habitat quality and its potential for bear productivity.

Dens that facilitate security and energy conservation during hibernation period are of significant value to black bears, and female bears exhibit a tendency to select tree cavity dens when available. Retention of large diameter live trees, large snags, and large fallen logs may be a valuable goal in all forest management plans and programs.

Nuisance and Depredation Resolution

Approximately 17% of bear habitat is situated within 5 km of human populations. Availability of garbage and other human-related foods is associated with increased nuisance and depredation activity by bears. Despite the significant potential for conflict, analyses indicated only a minority of bears engaged in nuisance or depredation activities. Nonetheless, kills resulting from bear-human conflict represent a significant mortality factor within the bear population. Efforts to reduce accessibility of human-related foods will be instrumental in reducing the likelihood of bear problems in areas with human populations.

Translocation of bears, as a means of solving depredation and nuisance problems, has shown variable success. Observed homing behavior of adult bears indicates translocation of adult bears is merely a short-term solution, particularly if attractants are not removed from the original site. However, short- and long-term settlement was observed among translocated subadult bears, indicating relocation of subadult bears into remote areas, with little potential for human conflict, may be an effective management tool. Nonetheless, translocation of problem bears should not be done without associated attempts to eliminate or reduce accessibility to human-related attractants (e.g., garbage, pet foods, wildlife feeding, bee hives) where such attractants exist.

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APPENDICES

This section contains and references a variety of more lengthy context information regarding the black bear investigation in New Mexico. This section also identifies information in various digital formats and indicates how that information is delivered in final form.

In some cases, digital information are on CDs that reside with New Mexico Department of Game and Fish and U.S. Fish and Wildlife Service Division of Federal Aid. CDs are not provided with every copy of the final report that is printed and distributed.

APPENDIX A: BEAR HANDLING HISTORY, DENNING DATES, AND LOCATION DATA

This appendix represents a tabulation of field data regarding capture and handling histories of individual study bears (StudyBearHistory), den entry and emergence data (DenningDates), and bear locations derived from telemetry monitoring (BearLocations). This appendix is 3 extensive Excel spreadsheets with metadata that are included as data files on a CD-ROM deposited with NMDGF and USFWS as part of the electronic deliverables. A brief example of the file formats for each of the 3 files follows:

StudyBearHistory file format

Age Class	Age	Date	Event	Transmitter Status	Reproductive Status
SA	4	9/24/1992	Capture	New collar	
SA	4	9/26/1992		Shed collar	
SA	3	9/1/1992	Began monitoring	Collar OK	
SA	4	1/13/1993	Handled in den	New collar	No offspring
AD	5	3/22/1994	Observed in den	Collar OK	No offspring
AD	6	3/27/1995	Handled in den	New collar	2 cubs (F690, F691)
AD	7	2/19/1996	Handled in den	Collar OK	1 yearling (F691)
AD	8	3/23/1997	Handled in den	New collar	2 cubs (M284, F674)
AD	9	3/22/1998	Observed in den (inaccessible)	Collar fit unknown	2 yearlings (M284, F674)
AD	9	8/20/1998	Recapture	Collar OK	
AD	10	3/22/1999	Handled in den	New collar	2 cubs (F656, F657)
AD	11	2/18/2000	Handled in den	Removed collar	2 yearlings (F656, F657)
AD	8	9/1/1992	Began monitoring	Collar OK	
AD	9	3/11/1993	Handled in den	New collar	2 cubs (F513, F601)
AD	10	2/7/1994	Handled in den	Collar OK	1 yearling (F513)
AD	10	6/9/1994	Recapture	Collar OK	
AD	10	9/17/1994	Mortality (hunter kill)	Collar OK	
AD	8	9/1/1992	Began monitoring	Collar OK	
AD	9	3/13/1993	Handled in den	New collar	1 cub (M201)
AD	10	2/5/1994	Observed in den	Collar OK	1 yearling (M201)
AD	11	3/17/1995	Handled in den	New collar	2 cubs (M296, M297)
AD	12	2/20/1996	Handled in den	Collar OK	1 yearling (M296)
AD	12	9/2/1996	Mortality (hunter kill)	Collar OK	
AD	10	9/1/1992	Began monitoring	Collar OK	
AD	11	3/15/1993	Handled in den	New collar	3 cubs (M135, M136, F514)
AD	12	2/9/1994	Handled in den	Collar OK	3 yearlings (M135, M136, F514)
AD	13	3/23/1995	Handled in den	New collar	3 cubs (M295, F692, F693)
AD	13	5/12/1995	Mortality (possibly killed by bear)	Collar OK	
SA	3	9/1/1992	Began monitoring	Collar OK	

DenningDates file format

BEAR	YEAR	AREA	SEX	MAXACT	MINDEN	ENTRY DATE	DAYS1	MAXDEN	MINACT	EMERGE DATE	DAYS2	TDAYS
F502	1993	NSA	F	10/26/1992	11/6/1992	11/1/1992	11	4/12/1993	4/21/1993	4/17/1993	9	166
F502	1994	NSA	F	11/4/1993	11/9/1993	11/7/1993	5	3/24/1994	4/7/1994	4/1/1994	14	145
F502	1996	NSA	F					4/26/1996	5/5/1996	5/1/1996	9	
F502	1997	NSA	F	10/31/1996	11/11/1996	11/6/1996	11	4/27/1997	5/10/1997	5/4/1997	13	178
F502	1998	NSA	F					4/30/1998	5/9/1998	5/5/1998	9	
F502	2000	NSA	F	10/14/1999	10/21/1999	10/18/1999	7					
F503	1993	NSA	F	10/14/1992	10/26/1992	10/21/1992	12	4/5/1993	4/12/1993	4/9/1993	7	169
F503	1994	NSA	F	11/4/1993	11/9/1993	11/7/1993	5	4/18/1994	5/2/1994	4/26/1994	14	170
F504	1993	NSA	F	10/14/1992	10/26/1992	10/21/1992	12	4/30/1993	5/14/1993	5/8/1993	14	198
F504	1994	NSA	F	10/15/1993	10/22/1993	10/19/1993	7	5/2/1994	5/13/1994	5/8/1994	11	201
F504	1995	NSA	F	10/14/1994	10/28/1994	10/22/1994	14					
F504	1996	NSA	F					4/26/1996	5/5/1996	5/1/1996	9	
F505	1994	NSA	F	10/8/1993	10/15/1993	10/12/1993	7	4/7/1994	4/18/1994	4/13/1994	11	183
F506	1993	NSA	F					5/24/1993	6/2/1993	5/29/1993	9	
F506	1994	NSA	F	11/4/1993	11/9/1993	11/7/1993	5	3/24/1994	4/7/1994	4/1/1994	14	145
F506	1995	NSA	F	10/14/1994	10/28/1994	10/22/1994	14					
F506	1996	NSA	F	11/7/1995	11/14/1995	11/11/1995	7	5/5/1996	5/12/1996	5/9/1996	7	180
F506	1997	NSA	F	10/24/1996	11/2/1996	10/29/1996	9					
F506	1998	NSA	F					5/9/1998	5/28/1998	5/19/1998	19	
F510	1994	NSA	F	11/9/1993	11/18/1993	11/14/1993	9	4/18/1994	5/2/1994	4/26/1994	14	163
F510	1995	NSA	F	10/14/1994	10/28/1994	10/22/1994	14					
F510	1996	NSA	F	11/7/1995	11/14/1995	11/11/1995	7	5/5/1996	5/12/1996	5/9/1996	7	180
F510	1997	NSA	F	10/10/1996	10/24/1996	10/18/1996	14	5/28/1997	6/12/1997	6/5/1997	15	229
F510	1998	NSA	F					4/30/1998	5/9/1998	5/5/1998	9	
F511	1994	NSA	F					4/18/1994	5/2/1994	4/26/1994	14	
F512	1994	NSA	F	10/15/1993	10/22/1993	10/19/1993	7	5/13/1994	5/31/1994	5/23/1994	18	216
F512	1995	NSA	F	10/14/1994	10/28/1994	10/22/1994	14	5/4/1995	5/20/1995	5/13/1995	16	203
F512	1996	NSA	F	11/7/1995	11/19/1995	11/14/1995	12	5/5/1996	5/12/1996	5/9/1996	7	177
F512	1997	NSA	F					4/27/1997	5/10/1997	5/4/1997	13	
F516	1995	NSA	F	11/4/1994	11/10/1994	11/8/1994	6					
F516	1996	NSA	F					4/26/1996	5/5/1996	5/1/1996	9	
F516	1998	NSA	F					5/9/1998	5/28/1998	5/19/1998	19	
F516	1999	NSA	F					5/6/1999	5/22/1999	5/15/1999	16	
F516	2000	NSA	F	10/14/1999	10/21/1999	10/18/1999	7					
F517	1995	NSA	F					5/4/1995	5/20/1995	5/13/1995	16	
F517	1996	NSA	F	11/7/1995	11/14/1995	11/11/1995	7	4/26/1996	5/5/1996	5/1/1996	9	172
F517	1997	NSA	F					5/10/1997	5/28/1997	5/20/1997	18	
F517	1998	NSA	F	11/17/1997	11/30/1997	11/24/1997	13	4/30/1998	5/9/1998	5/5/1998	9	162
F517	1999	NSA	F					5/13/1999	5/22/1999	5/18/1999	9	

BearLocations file format

AREA	BEAR	SEX	DATE	YEAR	AGE	AGECL	LANDMARK	EAST	NORTH	LOCSTAT
NSA	F502	F	10/2/1992	1992	3	SA	Atmore Ranch	488000	4048200	I
NSA	F502	F	10/26/1992	1992	3	SA	Colin Neblett	486400	4047400	A
NSA	F502	F	1/1/1993	1993	4	SA		488200	4049900	DV1
NSA	F502	F	2/1/1993	1993	4	SA	Maxwell Camp	486300	4050600	D2
NSA	F502	F	4/21/1993	1993	4	SA	Colin Neblett	486300	4047500	A
NSA	F502	F	4/30/1993	1993	4	SA	Maxwell Camp	486200	4051100	A
NSA	F502	F	5/14/1993	1993	4	SA	Maxwell Camp	486200	4051100	A
NSA	F502	F	5/24/1993	1993	4	SA	California Creek	486600	4049400	A
NSA	F502	F	6/2/1993	1993	4	SA	W Atmore Ranch	486700	4049300	A
NSA	F502	F	6/8/1993	1993	4	SA	Maxwell Camp	485700	4050200	A
NSA	F502	F	6/15/1993	1993	4	SA	Maxwell Camp	486000	4050700	A
NSA	F502	F	6/23/1993	1993	4	SA	California Creek	487200	4047800	A
NSA	F502	F	6/30/1993	1993	4	SA	W Atmore HQ	487400	4048900	A
NSA	F502	F	7/9/1993	1993	4	SA	Atmore HQ	489100	4049200	A
NSA	F502	F	7/19/1993	1993	4	SA	Atmore HQ	486100	4049000	A
NSA	F502	F	7/29/1993	1993	4	SA	Maxwell Camp	485100	4049800	A
NSA	F502	F	8/5/1993	1993	4	SA	W of Atmore	485600	4049100	A
NSA	F502	F	8/24/1993	1993	4	SA	Maxwell Camp	486500	4050200	A
NSA	F502	F	9/1/1993	1993	4	SA	N Dean Canyon	504200	4045800	A
NSA	F502	F	9/16/1993	1993	4	SA	S Horseshoe Canyon	504200	4048700	A
NSA	F502	F	9/21/1993	1993	4	SA	Chase Canyon	505500	4048400	A
NSA	F502	F	10/1/1993	1993	4	SA	W Atmore HQ	487400	4049200	I
NSA	F502	F	10/8/1993	1993	4	SA	Chase Canyon	504900	4048500	A
NSA	F502	F	10/15/1993	1993	4	SA	W Johns Pond	487900	4047400	A
NSA	F502	F	10/22/1993	1993	4	SA	E Ute Creek Ranch	492100	4047700	A
NSA	F502	F	11/4/1993	1993	4	SA	E Ute Creek Ranch	491100	4049600	A
NSA	F502	F	1/1/1994	1994	5	AD		491900	4048300	DV
NSA	F502	F	4/7/1994	1994	5	AD	NE Ute Creek Ranch	491300	4048700	A
NSA	F502	F	4/18/1994	1994	5	AD	W Santa Claus Camp	491100	4049800	A
NSA	F502	F	5/2/1994	1994	5	AD	W Johns Pond	488100	4047900	A
NSA	F502	F	5/13/1994	1994	5	AD	E Ute Creek	487100	4051100	A
NSA	F502	F	5/25/1994	1994	5	AD	W Atmore HQ	486600	4048800	A
NSA	F502	F	5/31/1994	1994	5	AD	Ute Creek	487300	4049600	A
NSA	F502	F	6/17/1994	1994	5	AD	California Creek	487700	4047600	A
NSA	F502	F	6/30/1994	1994	5	AD	S California Creek	485500	4046300	A
NSA	F502	F	7/11/1994	1994	5	AD	N California Creek	487100	4047900	A
NSA	F502	F	7/29/1994	1994	5	AD	TMN Mountain	485400	4049200	A
NSA	F502	F	8/18/1994	1994	5	AD	N California Creek	488500	4047800	A
NSA	F502	F	8/26/1994	1994	5	AD	Johns Pond	488700	4047800	A

APPENDIX B. GIS AND DATA FILE LISTING AND METADATA

This is an index to the GIS coverages and data files that have been compiled for use in the bear project. The metadata for these files consists of the listing in this appendix and metadata records included with the GIS coverages or individual files identified. Metadata for GIS coverages are designed to meet Federal Geographic Data Committee standards and format. The data and metadata are available on a CD-ROM on file with NMDGF and USFWS as part of final electronic deliverables. The following table describes the directory and file structure for accessing coverages and data files.

Folder	Description	Files	File Description	FGDC Metadata Record
ArcView	ArcView projects and files			
		Model2.apr	Programming for habitat model	
		bearfigs.apr	Arc/View programming for Chapter 11 figures	
		studysites.apr	Arc/View programming for study site figures	
		fig11-x.wmf	Chapter 121 figures	

Residents	Census data			
		blk00.dbf	2000 Census block Boundaries	..\Residents\blk00.htm
		grp00.mdb	2000 Census Block-Group boundaries	..\Residents\grp00.htm
		tract00.dbf	2000 Census Tract Boundaries	..\Residents\tract00.htm
		PlaceNames.shp	Names and locations of physical and cultural geographic features located within New Mexico.	..\Residents\PlaceNames.htm
		distopop	Distance (m) to nearest human population center	..\Residents\distopop.htm
		Census2000	Tables associated with 2000 census and population projections by county	
HabitatModel	Files associated with bear habitat model.			
		statemodel2	Predicted habitat suitability for Black bear.	..\HabitatModel\statemodel2.htm
		Range2	Predicted extent (range) of black bear occurrence	..\HabitatModel\Range2

		vegattr.dbf	Habitat and Mast scores by Land cover classification	
		popcodes.dbf	Description of black bear range assignments	
HuntingFishing	Files associated with hunter and fisherman use statistics and areas of use.			
		HuntingAnglingEffort.mdb	Access files containing hunter use data by game management unit, or antelope management unit, angler survey data, and New Mexico fishing waters data. Also contains a file with metadata.	
		amu.shp	Shapefile showing boundaries of New Mexico Game and Fish antelope management units for use with antelope harvest survey data.	..\HuntingFishing\amu.htm
		fishingwaters.shp	Shapefile coverage of waters in New Mexico used by fishermen, for use with angler survey data.	..\HuntingFishing\fishingwaters.htm
		gmu98.shp	Shapefile showing boundaries of New Mexico Game and Fish game management units, for use with harvest survey data.	..\HuntingFishing\gmu98.htm
		beartag	Pont locations of bear kills in New Mexico	..\HuntingFishing\beartag.htm
Landcover	Land cover coverage			
		gaplandcover	GAP landcover file.	..\landcover\gaplandcover.htm
Metadata	Metadata for bear project			
		BearPrjMetadata.xls	This file, excel file containing bear project index and metadata.	
		citation.dbf	Citations used in metadata.	
		contact.dbf	Table of contacts used in	

			metadata.	
Ownership	Stewardship of New Mexico lands			
		PLSS	Shape file depicting stewardship of lands in New Mexico	..\landownership\PLSS.htm
Roads	Files with road locations			
		AllRoads.shp	Shapefile roads coverage containing major and minor New Mexico roads.	..\Roads\AllRoads.htm
		cfccodes.xls	Excel file explaining codes used in allroads coverage.	
		nmroads.shp	Shapefile containing major roads in New Mexico	..\Roads\nmroads.htm
		distord	Distance to nearest secondary road	..\Roads\distord.htm
		rddens7k	Total Length of road within 7k radius (female activity radius)	..\Roads\rddens7k.htm
		rddens12k	Total length of road within 12k radius (male fall activity radius)	..\Roads\rddens12k.htm
StudyData	Files specific to bear project			
		nsabounds.shp	Shapefile showing boundary of northern study area.	..\StudyData\nsabounds.htm
		nsabuff.shp	Shapefile showing buffer around northern study area.	..\StudyData\nsabuff.htm
		nsadem	Digital elevation model for northern study area.	..\StudyData\nsadem.htm
		nsahillshade	Hillshade file for use with northern study area digital elevation model.	..\StudyData\nsahillshade.htm
		ssabounds.shp	Shapefile showing boundaries of southern study area.	..\StudyData\ssabounds.htm
		ssabuff.shp	Shapefile showing buffer around southern study area.	..\StudyData\ssabuff.htm
		ssadem	Digital elevation model for southern study area.	..\StudyData\ssadem.htm
		ssahillshade	Hillshade file for use with southern study area digital	..\StudyData\ssahillshade.htm

			elevation model.	
		DenningDates	Den Entry and Emergence Information	
		BearLocations	Geographic coordinates of bear locations by date	
		StudyBearHistory	Identity and status of bears captured and handled during project.	

APPENDIX C. HABITAT MODEL AND ASSOCIATED COVERAGES

This appendix contains GIS coverages and data files associated with the habitat model generated for black bears in New Mexico and related analyses in context with human interests and population on the landscape.

The files are located on a CD-ROM and are also identified in Appendix B for file reference and metadata access.

APPENDIX D. PELT TAG NOTEBOOK

This appendix contains a year by year summary of pelt tag and hunter card survey data as they pertain to demographic modeling and simulation. This information was compiled by Katherine Green-Hammond. The appendix is included as digital files on a CD-ROM on file with NMDGF and USFWS as a final electronic deliverable.

See the following pages for an example of the Notebook format

CHANGES BEGINNING IN THE 1998 VERSION

The Central mountain range region was split into the Zuni region (units 9 and 10) and the Manzano region (units 8 and 14). Unit 18 was dropped since it is closed to bear hunting.

Ages defining adults and subadults have been changed for all data summaries. Age 4 bears have been reclassified from adults to subadults consistent with the bear study finding that age 5 is the earliest age at which females give birth in New Mexico populations. Consequently, subadults are defined as bears ages 1 to 4, and adults are defined as bears ages 5 and above, for both sexes.

Most of the interpretive comments have been removed from this notebook. Interpretations will be revised in a future revision of the notebook.

CHANGES IN THIS VERSION

Card survey results from the 1997 season, and pelt tags from the 1998 season have been added; ages are not yet available for the 1998 season pelts.

1998 AND 1999 SEASON DIFFERENCES

Prior to 1998, fall hunting began September 1 or earlier. Both 1998 and 1999 fall hunts were late, beginning and ending later than in previous years.

For the 1998 hunting season, major regulation changes were made. The season dates were October 15 - December 15, a change from the previously standard September 1 - October 31. Also, for 1998 only, hunters could not buy bear licenses after the bear hunting season began. The total bear pelt tags reported for 1998 were 148, the lowest statewide total since pelt tag record keeping began in 1978. The numbers of 1998 hunt season licenses sold, 2969, was lower than all years since 1983 except for 1986 (when bear hunting was closed during elk hunting) and 1992 (when license fees doubled for nonresidents).

In 1999, hunting season dates were October 1 - December 15, and licenses could be purchased during the hunt season. Total pelts increased to 213.

WHAT PELT DATA SUGGEST ABOUT NM BEAR POPULATIONS

Bear populations have gradually increased statewide in the last 30 years. Very high harvests in 1994 and 1995, especially of females, probably interrupted the increasing trend.

The total harvest and, presumably, the hunting mortality rate on bears, were unusually high during 1989 - 1990 and 1993 -1996, possibly because dry environmental conditions increased vulnerability to hunting.

Total statewide harvest peaked in 1994, dropped steadily through 1998, and increased again in 1999. The very low harvest in 1998 can be attributed to the change to a late fall season and very low license sales.

The high numbers and proportions of adult females harvested in recent years may represent the beginning of a period of excessive harvesting, and should be watched.

IMPORTANCE OF HARVEST DATA

Information on bears is very hard to get. Harvest data provide the only information on bears statewide and over time.

Complete pelt tag data (mandatory reporting) substantially reduces the uncertainty about bear harvests, for a reasonable cost.

Tooth age data (one tooth from each pelt) is essential for identifying subadults. Identifying subadults allows pelt data to provide information on good and bad reproductive years, and allows more useful interpretation of changes in total pelt tag numbers.

The bear hunter card survey provides the only information on the geographic distribution of hunting effort and success.

CAUTIONS ABOUT CARD SURVEY DATA

Statewide bear card survey returns number in the hundreds, but there are very few responses reporting hunting or killing a bear in many of the individual game management units. Consequently projections by unit, which are summed for the regional numbers included in this notebook, may be based on unacceptably small sample sizes. The card survey provides the only available information on geographic distribution of hunting effort, so the unit analysis results have been used in spite of the sample size problem.

The projected total statewide bear kills from the card surveys are usually higher than reported pelt tags, sometimes substantially higher. This may be a consequence of higher return rates from successful than from unsuccessful hunters (we are in the process of testing this hypothesis). Because pelt tag reports are mandatory, the pelt tag numbers are considered to be a more reliable estimate of bear kills than the survey projections. Consequently, survey results are used only for estimates of number of hunters (hunting effort) in this notebook. Number of kills, either reported directly or used in calculations of success rate, are based on pelt tag reports.

TABLE 1. Bear pelt tag numbers over time, ranked by total pelts recorded from 1978 through 1997.

Unit	Total Pelts 1978 - 1997	Annual Average # Pelts 1978 - 1992	Annual Average # Pelts 1993 - 1997
16	662	28	48
6	598	25	45
55	575	32	20
34	558	23	43
45	349	14	27
36	308	13	23
15	274	13	15
48	229	10	16
4	228	9	18
54	203	8	15
51	192	7	17
57	186	6	18
14	184	7	15
49	178	7	13
21	177	10	7
22	146	6	10
23	120	4	11
37	117	6	5
24	115	5	8
53	113	5	6
17	112	6	6
5	107	4	8
44	105	4	8
10	97	3	11

REGION	Total Pelts 1978 - 1997	Annual Average # Pelts 1978 - 1992	Annual Average # Pelts 1993 - 1997
Sangre de Cristos	1996	90	129
Gila	1631	73	107
San Juan	1188	48	92
Southeast	989	42	72
Zuni + Manzanos	340	12	31
Statewide	6195	268	435

APPENDIX E. CD-ROM WITH BEAR POPULATION MODEL SOFTWARE, SCENARIO LIBRARY, AND USER MANUAL

This appendix consists of model software and other tools associated with preparation and use of the Bear Population Model as compiled by Katherine A. Green Hammond. The information in final form is a set of electronic files on CD-ROM on file with NMDGF Santa Fe state office and USFWS Division of Federal Aid in Albuquerque.

See the following pages for an example of the format of the User Manual.

This information also is on a CD-ROM distributed with selected copies of the completion report

APPENDIX F. BEAR POPULATION MODEL CORE EQUATIONS DOCUMENTATION

This appendix contains the mathematical background for the Bear Population Model. The appendix was compiled by Katherine Green-Hammond and is contained on a CD-ROM provided as a final electronic deliverable.

An example of the text of this documentation is presented on the following pages. It is presented in Times New Roman font to preserve the format as prepared in original form. The version on the CD must be accessed for full understanding and use.

BEAR MODEL CORE EQUATIONS

POPULATION / ENVIRONMENT / HUNT MODEL DESIGN

The bear model tracks changes in population numbers and age and sex composition over time based on computed births, deaths, and migrants. Initial population, characteristic vital rates, and annual variations in mast conditions, den entry timing, and hunting regulations and effort are inputs. An upper limit on population size is optional.

Parturition and cub survival rates vary annually, as a function of mast conditions. Characteristic or average mortality rates are specified for yearlings, subadults, and adults of both sexes. Rates from natural causes, legal hunting, and other human causes are specified separately and are additive. Legal hunting mortality can vary annually, with the characteristic rate modified by hunting effort or increased by poor mast conditions. Hunting mortality for late hunting seasons (beginning in October) is also a function of den entry timing.

Birth and mortality rates are not explicit functions of density dependence or social structure in this model. Optional upper limits on total population and total adult females approximate density dependence at high population levels. Since a hunted population is being modeled, natural mortality rates will be low and hunting mortality is additive rather than compensatory. If there is a need to model long time periods without hunting, natural mortality rates in the absence of hunting should be modified. Migration is treated as a net gain or loss of 3 year old (subadult) males, and is a function of the proportions of males and females in the prehunt population. Immigration occurs when the proportion of males is below a specified threshold. Migration occurs when the proportion of males exceeds a specified threshold.

The model should be applied to a geographic area that is meaningful to bears and managers, from a game management unit to a mountain range. Migration of subadults applies to the modeled area and its surroundings, not movements within the modeled area.

The model bear population structure tracks females and males separately in age classes of cubs, yearlings, subadults (2, 3, and 4 year olds are separate age classes), and all adults (ages 5 and up) lumped. The age structure allows the influence of strong and weak cohorts to be expressed over time, and tracking of recruitment to breeding age. No maximum age is imposed or tracked in simulations; long term average total annual mortality rates determine model population longevity.

The adult female category is divided into groups with cubs, with yearlings, and with no offspring in dens. The birth rate model includes the alternate year breeding pattern of black bears; adult females with yearlings in dens are not eligible to produce cubs. The phenomenon of synchronized breeding can be simulated by the model under appropriate conditions. Adult females with cubs in the fall are partially vulnerable to legal hunting.

The effectiveness of the regulation protecting females with cubs from hunting mortality is a variable.

The model biological year has 3 parts, denning, active season spring and summer, and active season fall. Births take place during denning. Natural and other human caused mortalities occur during both active seasons. Hunting mortality occurs only during the fall season in the current model version. A spring hunting season may be added in a later version.

CORE MODEL RELATIONSHIPS: CALCULATION ENGINE

Timing and Sequence of Events

The initial population is post hunt numbers by sex and age category at the time of den entry at the end of the fall active season. The bear model year is a calendar year and begins with the winter denning season.

For age tracking throughout a simulation run, all birthdays occur at the beginning of the year, in dens, but before births. Each model year, including the first, begins with age updating; cubs at den entry become yearlings, and adult females with cubs at den entry are reclassified as adult females with yearlings at the beginning of the simulation year, and are not eligible to produce cubs that year. Bears aged 1, 2, 3, and 4 the previous year become ages 2, 3, 4 and adult (all yearlings become subadults, some subadults become adults); adults aged 5+ remain adults. New age 5 females are classified as adult females with no offspring in the den, and are eligible to produce cubs. Adult females with yearlings at the end of the previous fall are reclassified as adult females with no offspring, and are eligible to produce cubs. Adult females with no offspring at the end of the previous fall remain adult females with no offspring, and are eligible to produce cubs.

At the beginning of the year, with updated ages, there are no adult females with cubs, and the male and female cub categories are empty. All births, but no mortalities, occur during the denning season. All mortalities, but no births, occur during the early and late active seasons.

Environmental variation

The environmental condition variables of mast index, hunt effort, hunt season start date (or hunt closure), and den entry timing are inputs which may change from year to year. All vital rates are simple functions of the environmental variables modifying an underlying rate treated as a population characteristic. Variation in the environmental variables results in variation of the vital rates.

Vital rates: Characteristic rates with variation

Parturition rates and cub survival rates have input characteristic values associated with poor, fair, and good mast conditions, as well as values for special cases and long term average values. Fall mast condition (or special case or average values) is an input which may vary by year, forcing parturition and cub survival to vary by year correspondingly. Functions of mast condition involve time lags; mast index for a year influences cub survival for the same year, and parturition rate for the next year. Mortality rates have characteristic values for each combination of age, sex, and cause, which are constant and specified as inputs. Variation in mortality rates from year to year is handled by multiplying the characteristic rates by factors which are functions of mast condition, hunt effort, hunt regulations, and den entry timing.

Notation for Representing Population Numbers

F0, F1, F2, F3, F4, AF	number of females of age 0 (cubs), 1, 2, 3, 4, adult
M0, M1, M2, M3, M4, AM	number of males of age 0 (cubs), 1, 2, 3, 4, adult
CUBS = F0 + M0	number of cubs
YF = F1, **YM** = M1	numbers of yearlings for each sex
SF = F2 + F3 + F4	number of subadult females
SM = M2 + M3 + M4	number of subadult males
AFnone	number of adult females without cubs or yearlings
AFcubs	number of adult females with cubs
AFyrl	number of adult females with yearlings

AF = AFnone + AFcubs + AFyrl

CONTINUED IN THE APPROPRIATE FILE ON THE CD