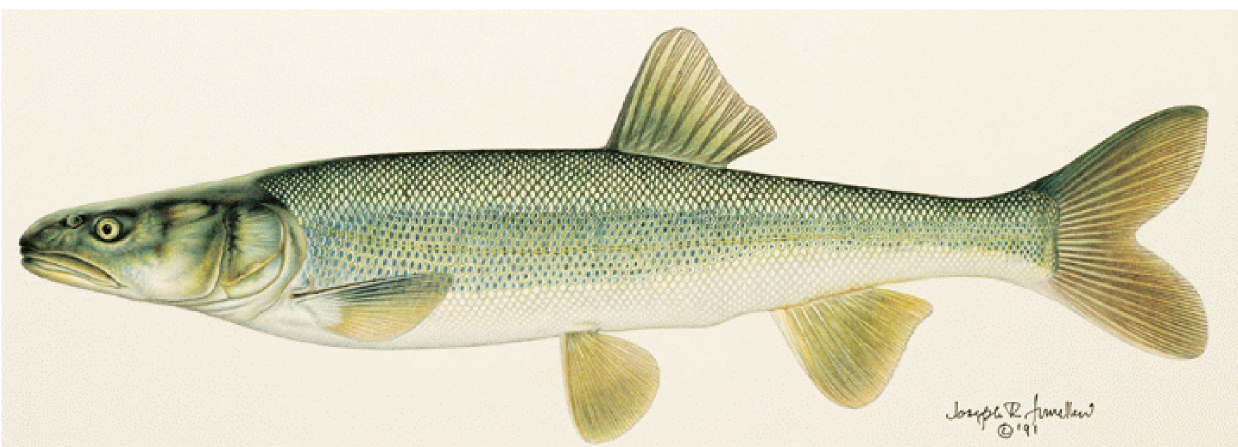
COLORADO PIKEMINNOW
(*Ptychocheilus lucius*)
RECOVERY GOALS



COLORADO PIKEMINNOW (*Ptychocheilus lucius*)

RECOVERY GOALS

Amendment and Supplement to the Colorado Squawfish Recovery Plan

U.S. Fish and Wildlife Service
Mountain-Prairie Region (6)
Denver, Colorado

Approved: Ralph O. Morgenweck
Regional Director, Region 6, U.S. Fish and Wildlife Service

Date: 8/1/02

DISCLAIMER PAGE

These recovery goals amend and supplement the 1991 Colorado Squawfish Recovery Plan. Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. The U.S. Fish and Wildlife Service publishes these plans, which may be prepared with the assistance of recovery teams, contractors, State agencies, and others. Attainment of the objectives and provision of any necessary funds are subject to priorities, budgetary, and other constraints affecting the parties involved. Recovery plans do not necessarily represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than the U.S. Fish and Wildlife Service. Recovery plans represent the official position of the U.S. Fish and Wildlife Service **only** after they have been signed by the Regional Director or Director as **approved**. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

CITATION FOR THESE RECOVERY GOALS

These recovery goals should be cited as follows:

U.S. Fish and Wildlife Service. 2002. Colorado pikeminnow (*Ptychocheilus lucius*) Recovery Goals: amendment and supplement to the Colorado Squawfish Recovery Plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

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A total of 69 comment letters from 66 individuals representing State, Federal, and private interests was accepted and considered by the U.S. Fish and Wildlife Service (Service) pursuant to the public review of the September 7, 2001, draft recovery goals for the four endangered fishes of the Colorado River Basin through the *Federal Register* Notice of Availability (66 FR 47033) and Notice of Reopening (66 FR 58748). The Service thanks those individuals for submitting comment letters and appreciates the valuable input. The Service also appreciates the input received through meetings with basin States, recovery or conservation programs, water and power interests, environmental groups, American Indian tribes, and other stakeholders.

EXECUTIVE SUMMARY

This document amends and supplements the Colorado Squawfish Recovery Plan of 1991. The common name for this species was changed to Colorado pikeminnow by the American Fisheries Society in 1998. The purpose of this document is to describe site-specific management actions/tasks; provide objective, measurable recovery criteria; and provide an estimate of the time to achieve recovery of the endangered Colorado pikeminnow (*Ptychocheilus lucius*), according to Section 4(f)(1) of the Endangered Species Act of 1973, as amended. Recovery programs that include the Colorado pikeminnow will direct research, management, and monitoring activities and determine costs associated with recovery.

Current Species Status: The Colorado pikeminnow is listed as endangered under the Endangered Species Act of 1973, as amended. The species is endemic to the Colorado River Basin of the southwestern United States. Adults attain a maximum size of about 1.8 m total length (TL) and 36 kg in weight. Wild, reproducing populations occur in the Green River and upper Colorado River subbasins of the Upper Colorado River Basin (i.e., upstream of Glen Canyon Dam, Arizona), and there are small numbers of wild individuals (with limited reproduction) in the San Juan River subbasin. The species was extirpated from the Lower Colorado River Basin in the 1970's but has been reintroduced into the Gila River subbasin, where it exists in small numbers in the Verde River.

Habitat Requirements and Limiting Factors: The Colorado pikeminnow is a long-distance migrator; moving hundreds of kilometers to and from spawning areas. Adults require pools, deep runs, and eddy habitats maintained by high spring flows. These high spring flows maintain channel and habitat diversity, flush sediments from spawning areas, rejuvenate food production, form gravel and cobble deposits used for spawning, and rejuvenate backwater nursery habitats. Spawning occurs after spring runoff at water temperatures typically between 18 and 23°C. After hatching and emerging from spawning substrate, larvae drift downstream to nursery backwaters that are restructured by high spring flows and maintained by relatively stable base flows. Threats to the species include streamflow regulation, habitat modification, competition with and predation by nonnative fish species, and pesticides and pollutants.

Recovery Objective: Downlisting and Delisting.

Recovery Criteria: Objective, measurable criteria for recovery of Colorado pikeminnow in the Colorado River Basin are presented for the Upper Colorado River Basin (including the Green River, upper Colorado River, and San Juan River subbasins). Recovery of the species is considered necessary only in the upper basin because of the present status of populations and because existing information on Colorado pikeminnow biology support application of the metapopulation concept to extant populations. The need for self-sustaining populations in the lower basin and associated site-specific management actions/tasks necessary to minimize or remove threats will be reevaluated at the status review of the species, which is conducted at least once every 5 years (provisional recovery criteria for the lower basin are appended). The Colorado pikeminnow was listed prior to the 1996 distinct population segment (DPS) policy. If lower basin populations are determined necessary for recovery, the Service may conduct an evaluation to designate DPSs in a future rule-making process. If DPSs are designated, these recovery criteria will need to be reevaluated. These recovery goals are based on the best available scientific information, and are structured to attain a balance between reasonably achievable criteria (which include an acceptable level of uncertainty) and ensuring the viability of the species beyond delisting. Additional data and improved understanding of Colorado pikeminnow biology may prompt future revision of these recovery goals.

<u>Downlisting</u> can occur if, over a 5-year period, the upper basin metapopulation is maintained such that: (1) a genetically and demographically viable, self-sustaining population is maintained in the Green River subbasin such that — (a) the trends in separate adult (age 7+; ≥450 mm TL) point estimates for the middle Green River and the lower Green River do not decline significantly, and (b) mean estimated recruitment of age-6 (400–449 mm TL) naturally produced fish equals or exceeds mean annual adult mortality for the Green River subbasin, and (c) each population point estimate for the Green River subbasin exceeds 2,600 adults (2,600 is the estimated minimum viable population [MVP] needed to ensure long-term genetic and demographic viability); and (2) a self-sustaining population of at least 700 adults (number based on inferences about carrying capacity) is maintained in the upper Colorado River subbasin such that — (a) the trend in adult point estimates does not decline significantly, and (b) mean estimated recruitment of age-6 naturally produced fish equals or exceeds mean annual adult mortality; and (3) a target number of 1,000 age-5+ fish (≥300 mm TL); number based on estimated survival of stocked fish and inferences about carrying capacity) is established through augmentation and/or natural reproduction in the San Juan River subbasin; and (4) when certain site-specific management tasks to minimize or remove threats have been identified, developed, and implemented.

<u>Delisting</u> can occur if, over a 7-year period beyond downlisting, the upper basin metapopulation is maintained such that: (1) a genetically and demographically viable, self-sustaining population is maintained in the Green River subbasin such that — (a) the trends in separate adult point estimates for the middle Green River and the lower Green River do not decline significantly, and (b) mean estimated recruitment of age-6 naturally produced fish equals or exceeds mean annual adult mortality for the Green River subbasin, and (c) each population point estimate for the Green River subbasin exceeds 2,600 adults; and (2) either the upper Colorado River subbasin self-sustaining population exceeds 1,000 adults **OR** the upper Colorado River subbasin self-sustaining population exceeds 700 adults and San Juan River subbasin population is self-sustaining and exceeds 800 adults (numbers based on inferences about carrying capacity) such that for each population — (a) the trend in adult point estimates does not decline significantly, and (b) mean estimated recruitment of age-6 naturally produced fish equals or exceeds mean annual adult mortality; and (3) when certain site-specific management tasks to minimize or remove threats have been finalized and implemented, and necessary levels of protection are attained.

Conservation plans will go into effect at delisting to provide for long-term management and protection of the species, and to provide reasonable assurances that recovered Colorado pikeminnow populations will be maintained without the need for relisting. Elements of those plans could include (but are not limited to) provision of flows for maintenance of habitat conditions required for all life stages, regulation and/or control of nonnative fishes, minimization of the risk of hazardous-materials spills, and monitoring of populations and habitats. Signed agreements among State agencies, Federal agencies, American Indian tribes, and other interested parties must be in place to implement the conservation plans before delisting can occur.

Management Actions Needed:

1. Provide and legally protect habitat (including flow regimes necessary to restore and maintain required environmental conditions) necessary to provide adequate habitat and sufficient range for all life stages to support recovered populations.
2. Provide passage over barriers within occupied habitat to allow adequate movement and, potentially, range expansion.
3. Investigate options for providing appropriate water temperatures in the Gunnison River.
4. Minimize entrainment of subadults and adults in diversion canals.
5. Ensure adequate protection from overutilization.
6. Ensure adequate protection from diseases and parasites.
7. Regulate nonnative fish releases and escapement into the main river, floodplain, and tributaries.
8. Control problematic nonnative fishes as needed.
9. Minimize the risk of hazardous-materials spills in critical habitat.
10. Remediate water-quality problems.
11. Provide for the long-term management and protection of populations and their habitats beyond delisting (i.e., conservation plans).

Estimated Time to Achieve Recovery: Reliable population estimates, based on a multiple mark-recapture model, are needed for all populations over a 5-year monitoring period for downlisting and over a 7-year monitoring period beyond downlisting in order to achieve delisting. The accuracy and precision of each point estimate will be assessed by the Service in cooperation with the respective recovery or conservation programs, and in consultation with investigators conducting the point estimates and with qualified statisticians and population ecologists. First point estimates were completed for all populations in 2001. The Service is reviewing those estimates for reliability, and, if they are accepted by the Service and all recovery criteria are met, downlisting could be proposed in 2006 and delisting could be proposed in 2013. This estimated time frame is based on current understanding of the status and trends of populations and on the monitoring time required to meet the downlisting and delisting criteria.

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1.0 INTRODUCTION

1.1 Background

The Colorado pikeminnow (*Ptychocheilus lucius*) is the largest cyprinid fish endemic to the Colorado River Basin (Tyus 1991). The common name for this species was changed from Colorado squawfish by the American Fisheries Society (Nelson et al. 1998). Adults attain a maximum size of about 1.8 m total length (TL) and 36 kg in weight (Miller 1961). The Colorado pikeminnow is currently listed as “endangered” under the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 *et. seq.*). It was first included in the List of Endangered Species issued by the Office of Endangered Species on March 11, 1967 (32 FR 4001) and was considered endangered under provisions of the Endangered Species Conservation Act of 1969 (16 U.S.C. 668aa). The Colorado squawfish (pikeminnow) was included in the United States List of Endangered Native Fish and Wildlife issued on June 4, 1973 (38 FR No. 106), and it received protection as endangered under Section 4(c)(3) of the original ESA of 1973. The latest revised Colorado squawfish (pikeminnow) recovery plan was approved on August 6, 1991 (U.S. Fish and Wildlife Service 1991). The final rule for determination of critical habitat was published on March 21, 1994 (59 FR 13374), and the final designation became effective on April 20, 1994.

The Colorado pikeminnow is a member of a unique assemblage of fishes native to the Colorado River Basin, consisting of 35 species with 74% level of endemism (Miller 1959). It is one of four mainstem, big-river fishes currently listed as endangered under the ESA; others are the humpback chub (*Gila cypha),* bonytail (*Gila elegans*), and razorback sucker (*Xyrauchen texanus*). The native fish assemblage of the Colorado River Basin is jeopardized by large mainstem dams, water diversions, habitat modification, nonnative fish species, and degraded water quality (Miller 1961; Minckley and Deacon 1991).

1.2 Purpose and Scope

This document amends and supplements the Colorado Squawfish Recovery Plan of 1991 (Recovery Plan; U.S. Fish and Wildlife Service 1991). The purpose and scope are to assimilate current information on the life history of the species and status of populations to develop recovery goals associated with the five listing factors that [as specified under Section 4(f)(1) of the ESA] identify site-specific management actions necessary to minimize or remove threats; establish objective, measurable recovery criteria; and provide estimates of the time and costs required to achieve recovery. In developing the recovery goals, the full body of available information pertinent to issues related to species life history and conservation was considered. However, it is not the intent of this document to provide a comprehensive treatise of information on Colorado pikeminnow; a synopsis of the life history that includes a description of habitat requirements is provided in Appendix A. Additional and more detailed information can be found in literature cited in this document and in reports and publications referenced in those citations.

These recovery goals were developed as an amendment and supplement to the Recovery Plan to focus on the requirements of Section 4(f)(1)(B) of the ESA, which requires that the Secretary of the Interior incorporate into each plan site-specific management actions; objective, measurable criteria; and estimates of the time and costs to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal. The Recovery Plan did not contain those key requirements of the ESA; therefore, these recovery goals take precedence over the Recovery Plan. Recovery programs that include the Colorado pikeminnow (see section 1.3) will direct research, management, and monitoring activities and determine costs associated with recovery. The recovery goals are not intended to include specifics on design of management strategies nor are they intended to prescribe ways that management strategies should be implemented. Those details (and associated costs) need to be developed by the respective recovery programs in their implementation plans.

An important aspect in development of these recovery goals was to attain a balance between reasonably achievable criteria and ensuring the viability and security of the species beyond delisting. Reasonably achievable criteria considered demographic and genetic requirements of self-sustainability in balance with available estimates of carrying capacity. These recovery goals are intended to be used by the U.S. Fish and Wildlife Service (Service) in rule-making processes to downlist and/or delist the Colorado pikeminnow. The Service intends to review, and revise as needed, these recovery goals at least once every 5 years from the date they are made public through a Notice of Availability published in the *Federal Register*, or as necessary when sufficient new information warrants a change in the recovery criteria. Review of these recovery goals will be part of the review of listed species as required by Section 4(c)(2)(A) of the ESA, *"The Secretary shall ... conduct, at least once every five years, a review of all species..."*.

1.3 Recovery or Conservation Programs

Two of the five major endangered-species recovery or conservation programs in the Colorado River Basin include the Colorado pikeminnow (highlighted in Box 1). These are the Upper Colorado River Endangered Fish Recovery Program (UCRRP) and the San Juan River Basin Recovery Implementation Program (SJRRIP). The UCRRP is a recovery program that was initiated under a Cooperative Agreement signed by the Secretary of the Interior on January 22, 1988, as a coordinated effort of State and Federal agencies, water users, energy distributors, and environmental groups to recover the four endangered fishes in the upper basin downstream to Glen Canyon Dam, excluding the San Juan River (U.S. Department of the Interior 1987; Wydoski and Hamill 1991; Evans 1993). It functions under the general principles of adaptive management (see section 5.1.2) and consists of seven program elements, including instream flow protection; habitat

Box 1. Recovery or Conservation Programs

1. ***Upper Colorado River Endangered Fish Recovery Program (UCRRP)***
2. ***San Juan River Basin Recovery Implementation Program (SJRRIP)***
3. Glen Canyon Adaptive Management Program (GCDAMP)
4. Native Fish Work Group (NFWG)
5. Lower Colorado River Multi-Species Conservation Program (MSCP)

restoration; reduction of nonnative fish and sportfish impacts; propagation and genetics management; research, monitoring, and data management; information and education; and program management. The SJRRIP is a similar recovery program, established under a cooperative agreement signed in 1992, to conserve populations of Colorado pikeminnow and razorback sucker in the San Juan River Basin (U.S. Department of the Interior 1995a). As stated in the governing documents of the UCRRP and SJRRIP, the goal is to recover the endangered fishes while water development proceeds in compliance with State and Federal laws, including the ESA, State water law, interstate compacts, and Federal trust responsibilities to American Indian tribes. Funding for the UCRRP and SJRRIP will continue through 2011 under legislation passed in October 2000 (P.L. 106-392); Congress will review the UCRRP and SJRRIP to determine if funding should be authorized beyond 2011.

2.0 THE RECOVERY PROCESS

2.1 Definition of Recovery

Understanding the Service's strategy for recovery of the Colorado pikeminnow, as provided in the ESA and implementing regulations, first requires an understanding of the meaning of "recover" and "conserve". The ESA does not specifically define recover, and the term "recovery" is used with respect to recovery plans *"...for the conservation and survival..."* of listed species. An endangered species, as defined in Section 3(6) of the ESA, means *"any species which is in danger of extinction throughout all or a significant portion of its range."* A threatened species is defined in Section 3(19) of the ESA as *"any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."* According to Service policy (U.S. Fish and Wildlife Service 1990), *"Recovery is the process by which the decline of an endangered or threatened species is arrested or reversed, and threats to its survival are neutralized, so that its long-term survival in nature can be ensured. The goal of this process is the maintenance of secure, self-sustaining wild populations of species with the minimum necessary investment of resources."* The ESA's implementing regulations (50 CFR § 402.02) further define recovery as *"...improvement in the status of listed species to the point at which listing is no longer appropriate under the criteria set out in section 4(a)(1) of the Act."* The policy and regulations use the word recovery a narrow ESA sense, giving it meaning that is different from returning a species to its normal position or condition.

The definition provided for recovery in the implementing regulations and the definition provided for conserve in the ESA have essentially the same meaning. Section 3(3) of the ESA states: *"The terms "conserve," "conserving," and "conservation" mean to use and the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this Act are no longer necessary."* Hence, recovery and conserve both mean to bring a species to the point at which it no longer needs the protection of the ESA, because the species is no longer in danger of extinction throughout all or a significant portion of its range. This definition of recovery falls far short of requiring that a species must be restored to its historic range and abundance before it can be considered recovered or delisted. It also falls short of requiring the restoration of a species to all the remaining suitable habitat, unless this is necessary to sufficiently reduce the species' susceptibility to threats to a level at which the species is no longer threatened or endangered.

The phrase "throughout all or a significant portion of its range" is used in both definitions of endangered and threatened. Neither "significant" nor "range" are defined in the ESA or implementing regulations. Hence, the ESA provides the Service with latitude to use its discretion, based on the best scientific information available, to develop recovery goals and implement recovery plans designed to conserve and recover species. The ESA clearly does not use the term significant in a statistical sense. Significance cannot be reliably and safely applied in any strictly quantitative framework, because of the great variety of organisms, habitats, and threats that must be evaluated for protection under the ESA.

Given that the ESA is intended to avoid species extinction, the Service avoids the pitfalls of a purely quantitative approach by instead viewing significant in the context of a species' long-term survival needs. The term becomes logical, meaningful, and useful if applied in this context. A significant portion of the range is that area that is important or necessary for maintaining a viable, self-sustaining, and evolving population or populations, in order for a taxon to persist into the foreseeable future. That "significant portion" may constitute a large portion of the historic range of a species or a relatively small portion of the historic range. Other parts of a species' range (regardless of whether it is historical, current, or potential range) may not be significant to its long-term survival, regardless of its geographic extent. Therefore, a species extirpated from such areas does not necessarily mean it is threatened or endangered, regardless of the geographic extent of those areas.

Implicit in the ESA definitions of threatened and endangered and in the principles of conservation biology is the need to consider genetics, demographics, population redundancy, and threats (as identified by the listing factors). The ESA is mandated to recover species to the point that they are "not likely" to be in danger of extinction for the foreseeable future throughout all or a significant portion of their range. The Service believes that the "not likely" standard is exceeded by the requirement of the recovery goals to maintain multiple widespread populations that are independently viable, because it is unlikely that future singular threats will endanger widely separated multiple populations. Viable populations have sufficient numbers of individuals to counter the effects of deleterious gene mutations as a result of inbreeding, and to counter the effects of deaths exceeding births and recruitment failure for periods of time. Thus, the conservation biology principle of redundancy is satisfied by the required multiple genetically and demographically viable, self-sustaining populations (section 3.1.3). Furthermore, the principle of resiliency is satisfied with sufficiently large populations to persist through normal population variations, as well as through unexpected catastrophic events (section 3.1.4).

The principles of recovery and conservation as defined in the ESA, implementing regulations, and Service policy demonstrate the strong relationship between the delisting criteria used for recovery and the five listing factors in Section 4(a)(1) of the ESA. These five listing factors must be addressed in any reclassification of a species [ESA Section 4(c)(2)(B); section 4.0 of this document], and are:

> "*(A) The present or threatened destruction, modification, or curtailment of its habitat or range;*
> *(B) overutilization for commercial, recreational, scientific, or educational purposes;*
> *(C) disease or predation;*
> *(D) the inadequacy of existing regulatory mechanisms; and*
> *(E) other natural or manmade factors affecting its continued existence.*"

Recovery is based on reduction or removal of threats and improvement of the status of a species during the period in which it is listed, and not just from the time a listed species is proposed for reclassification. Environmental conditions and the structure of populations change over time, and threats recognized at listing or in subsequent recovery plans may no longer be directly applicable when reclassification is considered. Management actions and tasks conducted by recovery or conservation programs for listed species are expected to minimize or remove threats and improve the species' status.

When delisting a species, the Service must determine that the five listing factors no longer apply, e.g., the habitat is no longer threatened with destruction or modification, the current abundance and range is adequate, and the habitat needed to sustain recovered populations is present. Therefore, the recovery goals (section 5.0) include management actions and tasks, as well as downlisting and delisting criteria, presented by "recovery factor". These recovery factors were derived from the five listing factors and state the conditions under which threats are minimized or removed.

Recovery is achieved when management actions and associated tasks have been implemented and/or completed to allow genetically and demographically viable, self-sustaining populations to thrive under minimal ongoing management and investment of resources. Achievement of recovery does not mandate returning a species to all or a significant portion of its historic range, nor does it mandate establishing populations in all possible habitats, or everywhere the species can be established or reestablished. Removing a species from protection of the ESA remands the primary management responsibility of that species to the States, who may choose to further expand its range and populations. The standard of establishing and protecting viable, self-sustaining populations is applied to the recovery of Colorado pikeminnow, and was used in developing recovery goals for the other three endangered fishes of the Colorado River Basin (U.S. Fish and Wildlife Service 2002a, 2002b, 2002c). This approach is consistent with recovery of other vertebrate species, such as the bald eagle (*Haliaeetus leucocephalus*; 64 FR 36453), peregrine falcon (*Falco peregrinus*; 64 FR 46541), desert tortoise (*Gopherus agassizii*; Berry 1999), Pacific salmon (*Oncorhynchus spp.*; Allendorf et al. 1997), and southern sea otter (*Enhydra lutris nereis*; Ralls et al. 1996).

2.2 Recovery Units

Recovery of Colorado pikeminnow in the Colorado River Basin is considered necessary only in the Upper Colorado River Basin because of the present status of populations and because existing information on Colorado pikeminnow biology support application of the metapopulation concept to extant populations (see section 3.1.4). For the purpose of these recovery goals, the upper basin is upstream of Glen Canyon Dam, Arizona, including the San Juan River. The need for self-sustaining populations in the lower basin (i.e., downstream of Glen Canyon Dam) and associated site-specific management actions/tasks necessary to minimize or remove threats will be reevaluated at the status review of the species. The upper basin encompasses two management areas under different and separate recovery programs (i.e., UCRRP and SJRRIP; see section 1.3 for description of geographic coverage by each of the programs). Designation of the recovery units is consistent with goals established by these programs. For example, the governing document for the UCRRP (U.S. Department of the Interior 1987) states: *"Since the recovery plans* [for the Colorado pikeminnow, humpback chub, and bonytail; razorback sucker was not federally listed in 1987, but was included in the UCRRP] *refer to species recovery in both the upper and lower basins, these goals* [recovery/management goals in the original recovery plans] *also apply to both basins, until revised for the upper basin, through implementation of this recovery program. However, the goal of this program for the three endangered species is recovery and delisting in the upper basin. In general, this would be accomplished when the habitat necessary to maintain self-sustaining populations has been determined and provisions are in place to maintain and protect that habitat and these species. The Implementation Committee will be expected to revise these goals for the upper basin as the program develops. Attainment of these goals will result in recovery and delisting of the listed species in the upper basin."* Parties to the UCRRP agreed that the four endangered species could be downlisted and delisted separately in the upper basin. However, the document also states: *"... this program can not, and does not in anyway, diminish or detract from or add to the Secretary's ultimate responsibility for administering the Endangered Species Act."*

The Colorado pikeminnow was listed prior to the 1996 distinct population segment (DPS) policy, and the Service may conduct an evaluation to designate DPSs in a future rule-making process if, in the future, lower basin populations are determined necessary for recovery. In the Policy Regarding the Recognition of Distinct Vertebrate Population (61 FR 4721–4725), the U.S. Fish and Wildlife Service and the National Marine Fisheries Service clarified their interpretation of the phrase *"distinct population segment of any species of vertebrate fish or wildlife"* for the purposes of listing, delisting, and reclassifying species under the ESA. Designation of DPSs is a separate listing process that is different from recovery plans/goals, and is accomplished by a rule-making process. A DPS is a segment of the population and includes a part of the range of a species or subspecies. Like all listings, the DPS is described geographically, but it is important to retain the purpose of the ESA *"...to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved..."*. The elements considered for designation of DPSs are: *"1) Discreteness of the population segment in relation to the remainder of the species to which it belongs; 2) The significance of the population segment to the species to which it belongs; and 3) The population segment's conservation status in relation* *to the Act's standards for listing (i.e., is the population segment, when treated as if it were a species, endangered or threatened?).”*

Species listed prior to the DPS policy may be reconsidered for DPS designation at the time of reclassification or at the 5-year status review. The DPS policy states: *“Any DPS of a vertebrate taxon that was listed prior to implementation of this policy will be reevaluated on a case-by-case basis as recommendations are made to change the listing status for that distinct population segment. The appropriate application of the policy will also be considered in the 5-year reviews of the status of listed species required by section 4(c)(2) of the Act.”* Section 4(c)(2)(A) of the ESA requires a review of listed species *“at least once every five years”*. If DPSs are designated, these recovery criteria will need to be reevaluated.

2.3 Development of Recovery Goals

Development of recovery goals for the Colorado pikeminnow followed a specific process. First, current data on the life history of the species and on existing populations were assimilated (Appendix A; section 3.0). Second, the assimilated data were used to evaluate population viability and self-sustainability (section 3.0). Third, past and existing threats were identified according to the five listing factors (section 4.0). Finally, site-specific management actions were identified to minimize or remove threats, and objective, measurable recovery criteria were developed based on the five factors (section 5.0). The process of developing the recovery goals was interactive and iterative, and the recovery goals are the product of considerable input from stakeholders and scientists from throughout the Colorado River Basin and from rigorous peer review. Input from biologists and managers throughout the basin was received through meetings with the Colorado River Fishes Recovery Team; Biology, Management, and Implementation committees of the UCRRP; Biology and Coordinating committees of the SJRRIP; Colorado River Fish and Wildlife Council; American Indian tribes; State game and fish agencies; water and power interests; and appropriate Federal agencies. Input was also received through independent reviews of previous drafts (see acknowledgments). Development of these recovery goals considered the approach taken by Lentsch et al. (1998) to develop interim management objectives, and paralleled similar efforts by the Colorado Division of Wildlife and benefitted from exchange of information with the principal author (Nesler 2000).

The process of downlisting and delisting described in this document is consistent with provisions specified under Section 4(b), Basis For Determinations, and Section 4(f)(1), Recovery Plans, of the ESA. Under Section 4(b), the Secretary of the Interior shall determine if a species is endangered or threatened *“...solely on the basis of the best scientific and commercial data available...”*. Specifically, under Section 4(f)(1)(B), each recovery plan must incorporate (i) *“a description of such site-specific management actions as may be necessary to achieve the plan's goal for conservation and survival of the species”*; (ii) *“objective, measurable criteria which, when met, would result in a determination, in accordance with the provisions of this section, that the species be removed from the list”*; and (iii) *“estimates of the time required and cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal.”* Objective, measurable recovery criteria identify downlisting and delisting requirements for each management action, and define viable, self-sustaining populations consisting of target numbers of adults and subadults for wild populations. Under Section 4(c)(2)(B) of the ESA, each determination of reclassification of a species shall be made in accordance with provisions of Sections 4(a) and 4(b).

3.0 POPULATION VIABILITY AND SELF-SUSTAINABILITY

Population viability and self-sustainability are the cornerstones to defining a recovered species. Factors that determine population viability and self-sustainability are demographics (size and age structure of populations), population redundancy (number and distribution of populations), habitat carrying capacity (resource limitations), and genetic considerations (inbreeding and genetic viability). This section discusses the development of genetic and demographic viability standards for achieving the primary objective of the Recovery Plan, i.e., *"To recover the Colorado squawfish ...by establishing naturally self-sustaining populations..."* (U.S. Fish and Wildlife Service 1991). Guidelines for population viability and self-sustainability are stated in Box 2 (Franklin 1980; Soulé 1980; Shaffer 1987; Allen et al. 1992).

Box 2. Guidelines for Population Viability and Self-Sustainability

- A viable, self-sustaining population has negligible probability of extinction over a 100- to 200-year period.
- A population should be sufficiently large to survive historically observed environmental variation.
- A population should be sufficiently large to maintain long-term genetic diversity and viability.
- Multiple demographically viable (redundant) populations greatly reduce the probability of extinction if the populations are independent in their susceptibility to catastrophic events.
- A viable, self-sustaining population must have positive recruitment potential sufficient to replace adult mortality near carrying capacity, and on average, exceed adult mortality when the population is below carrying capacity.
- Carrying capacity is not expected to be the same for different populations, because physical habitat, water quality, and biological components are likely to vary.

3.1 Demographic Viability

3.1.1 Demographic characteristics, environmental uncertainty, and catastrophic events

Demographic or population viability refers to the persistence of a species over time, as affected by uncertainties in population dynamics. A viable, self-sustaining population has negligible probability of extinction over a 100- to 200-year time frame (Franklin 1980; Soulé 1980).

Population viability can be affected by demographic characteristics, environmental uncertainty, and catastrophic events (Shaffer 1987; Allen et al. 1992). Demographic characteristics relate to random changes in birth and death rates, primarily reflecting differences at the population level. Persistence time for a population faced only with demographic variability increases geometrically as the population increases, and only populations with individuals that number in the "10s to 100s" are vulnerable to extinction due simply to demographic variability (Shaffer 1987). Hence, demographic viability is generally considered to be an issue only with severely depleted populations (Goodman 1987; Allen et al. 1992). Wild populations of Colorado pikeminnow in the Green River and upper Colorado River subbasins are not considered to be severely depleted, and a population-viability analysis conducted by Gilpin (1993) indicated that the species is unlikely to go to extinction. However, the current status of the species is being evaluated through population estimates.

In contrast, population persistence decreases linearly with environmental uncertainty (Shaffer 1987), and thus is of more concern for population viability of Colorado pikeminnow. Environmental uncertainty results from changes in environmental factors such as variability in food supply; weather; population dynamics of predators, competitors, and parasites; and in the case of riverine fishes, variability in seasonal flow characteristics. Many of these environmental factors may be highly correlated to population demographics, such as reproductive success, survival, and recruitment. Population sizes necessary for persistence under environmental variability reflect the resulting variability in birth and death rates (Allen et al. 1992). Specifically linking environmental variability to birth and death rates is difficult (Ewens et al. 1987), and use of a demographic model for Colorado pikeminnow is limited because of the lack of reliable empirical data on these life-history parameters. Population viability analyses (PVA; Gilpin 1993; Soulé 1987; Shaffer 1987) were considered but not employed because of a lack of conclusive data on state and rate variables for the species.

As an alternative to demographic models, the concept of carrying capacity can be used to approximate population sizes and potential. Populations can be viewed as having some potential with respect to resource limitations or theoretical carrying capacity. The variance (V) in potential growth rate (r), without limitations of carrying capacity, has to be sizably greater than r ($V > 2r$) before the population is susceptible to extinction, otherwise the population tends toward the carrying capacity (Roughgarden 1979). For the Colorado pikeminnow, increasing population sizes of adults suggests that recruitment is greater than adult mortality for this species. It is doubtful that environmental uncertainty will affect Colorado pikeminnow populations that meet genetic considerations if the environment is protected and secured against changes that exceed environmental stochasticity for the species; e.g., anthropogenic changes such as dams and introductions of nonnative fish species can impose environmental conditions that exceed the range of conditions experienced by the species historically.

Catastrophic events, however, could dramatically impact Colorado pikeminnow populations. Catastrophic events are rare incidents that may cause sizable mortality in one or more age groups. A catastrophe is an event that would, with a single act, eliminate one or more ages of Colorado pikeminnow in a reach of river. This may include such factors as dramatic and extensive alteration of riverine habitat, invasion of nonnative fishes as highly successful predators or competitors, or spills of toxic substances. Abundance and distribution of Colorado pikeminnow were greatly reduced by the 1930's as a result of land-use practices, degraded water quality, and nonnative fishes (Dill 1944; Miller 1961). Colorado pikeminnow were extirpated from the Lower Colorado River Basin shortly after construction of major mainstem dams because direct and indirect effects of these dams affected specific life-history events by impeding passage to spawning, feeding, and nursery areas; causing reproductive failure from cold-water releases; and reducing survival through the introduction of successful nonnative predators and competitors. A rotenone treatment in Flaming Gorge Canyon in the early 1960's killed unknown numbers of Colorado pikeminnow (Holden 1991) but did not extirpate the species from the Green River, nor did an oil spill on the Yampa River in 1987. In order for the Colorado pikeminnow to be extirpated from a large portion of its existing range, a catastrophe would have to be of the magnitude where the entire ecosystem is fragmented and altered.

The Colorado pikeminnow is a long-lived fish (40+ years; Osmundson et al. 1997) that evolved in a variable system, with high adaptability to natural environmental variability and resilience to natural catastrophes. This evolution has become manifest as pulsed recruitment from periodic strong year classes, great longevity of adults, and low vulnerability of adults to environmental influences. Great longevity and stability of adults provides a "storage effect" for populations, into which periodic recruitment from strong year classes allows fish to become stored (Gilpin 1993). This is seen as a way that Colorado pikeminnow maintain long-term population viability and stability under environmental variation.

A critical aspect of recovery is increased frequency of strong year classes. Strong year classes of Colorado pikeminnow have been linked to years immediately following wet hydrologic conditions resulting in high spring-runoff flows (McAda and Ryel 1999; Valdez et al. 1999). High to moderate spring flows rework sediment deposits, which seems to increase larval survival and results in a strong year class (Van Steeter and Pitlick 1998; Osmundson 1999). Characteristically, two or three strong year classes occur in consecutive years, with a recurrence interval of 7–10 years. Shortening this recurrence interval by increasing the frequency of high spring flows increases the likelihood of greater recruitment, population expansion, and long-term stability. Mid-summer, rain-induced flow spikes have been linked to spawning cues (Nesler et al. 1988) and may stimulate reproduction and add to the success of strong year classes.

3.1.2 Existing populations of Colorado pikeminnow

Three wild populations of Colorado pikeminnow are found in about 1,753 km of riverine habitat in the Green River, upper Colorado River, and San Juan River subbasins (Table 1, Figure 1; Appendix A). Occupied habitat occurs in the Green River from Lodore Canyon to the confluence of the Colorado River (Tyus 1991; Bestgen and Crist 2000); the Yampa River downstream of Craig, Colorado (Tyus and Haines 1991); the Little Snake River from its confluence with the Yampa River upstream into Wyoming (Marsh et al. 1991; Wick et al. 1991); the White River downstream of Taylor Draw Dam and Kenney Reservoir (Tyus and Haines 1991); the lower 143 km of the Price River (Cavalli 1999); the lower Duchesne River; the upper Colorado River from Palisade, Colorado, to Lake Powell (Valdez et al. 1982a; Osmundson et al. 1997, 1998); the lower 54 km of the Gunnison River (Valdez et al. 1982b; Burdick 1995); the

Table 1. Occupied habitat of wild Colorado pikeminnow in the Upper Colorado River Basin and limits to distribution.

River	Occupied Habitat	Limits to Distribution
Green River Subbasin		
1. Green River	Lodore Canyon to Colorado River confluence (580 km)	Cold releases from Flaming Gorge Dam have been warmed and species has naturally expanded upstream into Lodore Canyon; species distributed continuously downstream to Colorado River confluence
1a. Yampa River	Craig, Colorado, to Green River confluence (227 km)	Present distribution similar to historic
1b. Little Snake River	Wyoming to Yampa River confluence (80 km)	Habitat is marginal; flows are reduced; historic distribution unknown
1c. White River	Taylor Draw Dam to Green River confluence (100 km)	Upstream distribution blocked by Taylor Draw Dam
1d. Price River	Lower 143 km above Green River confluence	Streamflow reduced; barriers occur above current distribution
1e. Duchesne River	Lower 10 km above Green River confluence	Streamflow reduced; barriers occur above current distribution
Upper Colorado River Subbasin		
2 Upper Colorado River	Palisade, Colorado, to Lake Powell inflow (298 km)	Passage by Grand Valley Diversion completed in 1998; Price-Stubb and Government Highline diversion dams restrict upstream distribution; Lake Powell inflow defines downstream distribution
2a. Gunnison River	Lower 54 km above Colorado River confluence	Redlands Fishway allowed passage in 1996; upstream distribution is limited by Hartland Diversion Dam and possibly cold-water releases from the Aspinall Unit
2b. Dolores River	Lower 2 km above Green River confluence	Streamflow altered; no barriers in potential historic habitat
San Juan River Subbasin		
3. San Juan River	Shiprock, New Mexico, to Lake Powell inflow (241 km)	Irrigation diversions block upstream movement; Lake Powell defines downstream distribution

lower 2 km of the Dolores River (Valdez et al. 1992); and 241 km of the San Juan River downstream from Shiprock, New Mexico, to the Lake Powell inflow (Jordan 1891; Koster 1960; Olson 1962; Holden 1999; Propst 1999). Natural reproduction of Colorado pikeminnow is currently known from the Green, Yampa, upper Colorado, Gunnison, and San Juan rivers.

Recent preliminary estimates of abundance summed for the three Colorado pikeminnow populations range from about 6,600 to 8,900 wild adults. The precision and reliability of these estimates vary, and approximate numbers are provided as a general indication of the size of populations in the basin. Estimates of subadults are not currently available for all populations, and precise estimates of adults and subadults will be developed in order to determine if demographic criteria are met for downlisting and delisting. Estimates of adults for the three subbasins are: Green River, 6,000–8,000 (Nesler 2000; personal communication, K. Bestgen,

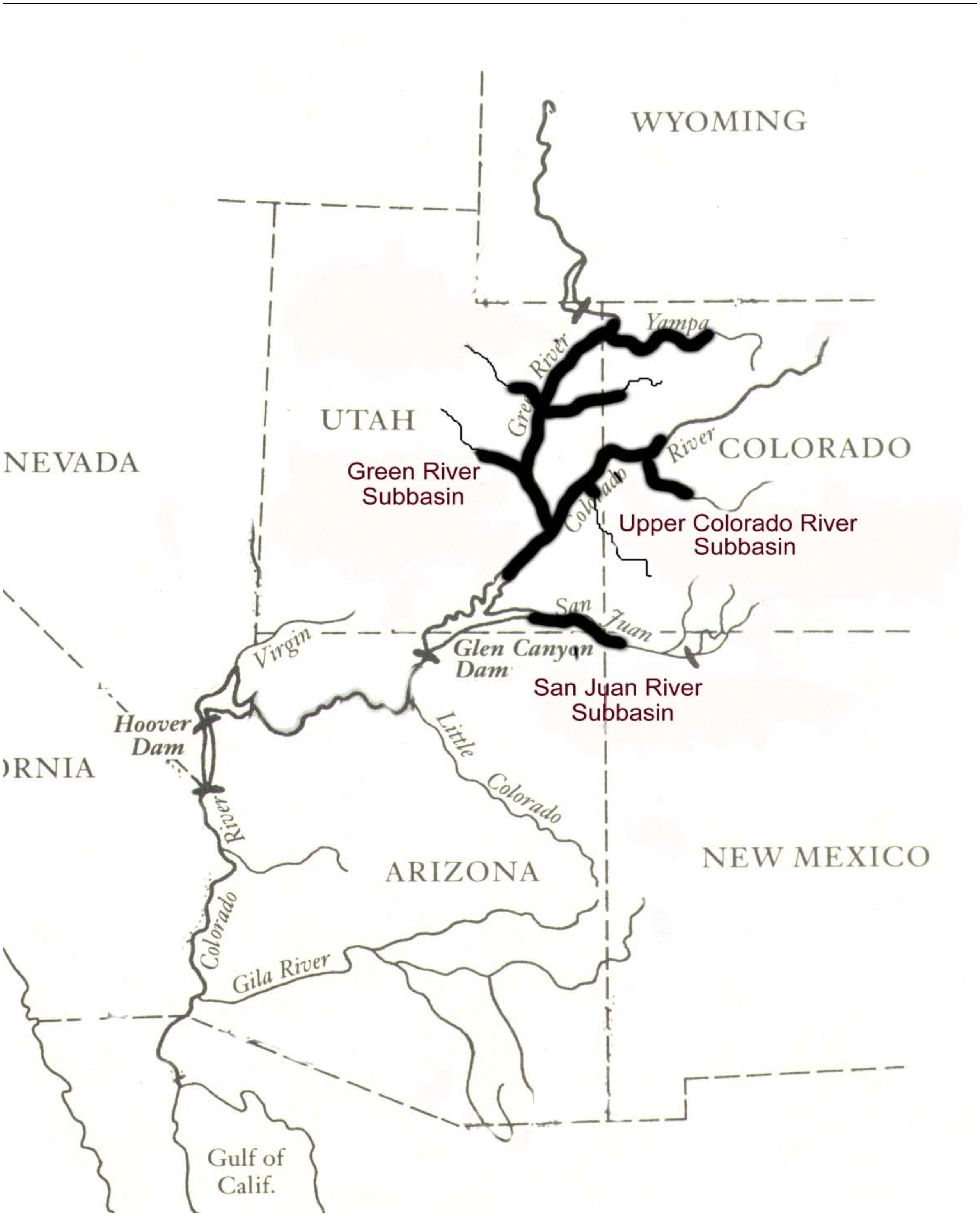

Figure 1. Distribution of wild Colorado pikeminnow in the Colorado River Basin.

Colorado State University); upper Colorado River, 600–900 (Nesler 2000; Osmundson 2002 [includes some subadults]); and San Juan River, 19–50 (Holden 1999; personal communication, D. Ryden, U.S. Fish and Wildlife Service).

Two principal spawning sites have been identified in the Green River subbasin (Tyus 1990). Crowl and Bouwes (1998) estimated that 1,000 adults were associated with the spawning site near Three Fords Canyon in Gray Canyon of the lower Green River, and 1,400 adults were associated with the spawning site in the lower 32 km of the Yampa River. Fish associated with the two spawning sites may be demographically independent with individual stock-recruitment characteristics (personal communication, T. Modde, U.S. Fish and Wildlife Service), but overlap in adult and juvenile distributions and no significant differences in allele frequencies suggest essential panmixia or mixing of these two stocks (Ammerman and Morizot 1989; Williamson et al. 1999; Morizot et al. 2002). Fish in the upper Colorado River subbasin are believed to spawn near Grand Junction, Colorado, and in the lower Gunnison River (personal communication, C. McAda, U.S. Fish and Wildlife Service).

In addition to adults, age-0 fish and juveniles are found in the lower Yampa River; Green River downstream of the Yampa River confluence; upper Colorado River downstream of Palisade, Colorado, to the Lake Powell inflow, Utah; and lower 40 km of the Gunnison River. Small numbers of age-0 Colorado pikeminnow have been collected in the San Juan River (Holden 1999). Subadults and small adults have also been found in the lower Price, Duchesne, and White rivers (Tyus and Haines 1991; Cavalli 1999; Muth et al. 2000). The Interagency Standardized Monitoring Program (ISMP) of the UCRRP (McAda et al. 1994a, 1994b, 1995, 1996, 1997) has determined catch-rate indices of age-0 and subadult fish in the Green and upper Colorado rivers since 1988. Average of geometric mean catch-per-effort (CPE) during 1986–1997 for Reach 1 (lower Colorado River), Reach 2 (upper Colorado River), Reach 3 (lower Green River), and Reach 4 (upper Green River) are approximately 0.4, 0.03, 1.5, and 0.4 fish/10 m^2, respectively. Numbers of age-0 and subadult fish in the other rivers are low, but with no extensive surveys, except for the San Juan River. All data collected under ISMP for age-0 are catch-rate indices, with a few mark-recapture estimates in backwaters (Haines et al. 1998).

Efforts to reestablish populations of Colorado pikeminnow have taken place in the Lower Colorado River Basin and the San Juan River. Over 623,000 Colorado pikeminnow were reintroduced into the Salt and Verde rivers, tributaries of the Gila River subbasin in Arizona, during 1981–1990 (Hendrickson 1994). These reintroductions were part of conservation efforts and considered nonessential experimental populations [Section 10(j) of the ESA]. Long-term survival was not reported as a result of these releases (Maddux et al. 1993), but some of these stocked fish still persist in the Verde River. Also, over 300,000 hatchery-produced Colorado pikeminnow have been released in the mainstem as part of the SJRRIP (Ryden and Ahlm 1996; Holden 1999; personal communication, F. Pfeifer, U.S. Fish and Wildlife Service).

3.1.3 Populations of Colorado pikeminnow as redundant units

Maintaining several populations with relatively independent susceptibility to threats is an important consideration in the long-term viability of a species (Shaffer 1987; Goodman 1987).

These redundant populations provide security in case of a catastrophic event or repeated year-class failure. The positive effect of relatively independent populations can be demonstrated by the following examples. Consider that a single population has a probability of extinction from a catastrophic event of 10% in 200 years. If two populations are independent, the probability of both going extinct is 1% (0.1^2). For three populations, the probability reduces to 0.1% (0.1^3). Even with an extinction probability of 25% for one population, the probability of extinction for two and three populations is 6.3% and 1.6%, respectively. Maintenance of Colorado pikeminnow populations in discrete subbasins contributes to redundancy as protection against threats and catastrophic events simultaneously affecting all or most populations. The migratory nature of the species and connectedness of the riverine system allows individuals to repopulate patches in the event of local extirpation.

3.1.4 Colorado pikeminnow as a metapopulation

The metapopulation concept is a natural phenomenon that should be considered when evaluating species persistence. A metapopulation is defined as a network of populations or subpopulations that have some degree of intermittent or regular gene flow among geographically separate units occupying habitat patches (Meffe and Carroll 1994). Populations that make up a metapopulation exist along a continuum of connectedness, with no clear break points, from totally isolated units to those that experience regular and high gene flow (Ehrlich and Murphy 1987; Harrison et al. 1988). Connectedness among units of a metapopulation may vary seasonally or annually (U.S. Fish and Wildlife Service 1995), and the best way to identify population units is that they have some ecological and evolutionary significance (Hanski and Gilpin 1997). Under metapopulation dynamics, habitat patches that become unoccupied due to local extirpations may become repopulated by dispersing individuals from other subpopulations. Metapopulations depend on the ability of individuals to disperse and repopulate empty patches in a manner timely enough to ensure that sufficient numbers of patches always contain viable subpopulations.

Colorado pikeminnow in the Upper Colorado River Basin are distributed in three geographically separate subbasins, where the migratory nature of the species and documented mixing of stocks indicate that Colorado pikeminnow function as a metapopulation (see section 3.1.2 and Appendix A). The largest self-sustaining population occurs in the Green River subbasin with direct and unimpeded riverine connection to a smaller self-sustaining population in the upper Colorado River subbasin. Colorado pikeminnow in San Juan River subbasin are separated from the other two subbasins by about 320 km across Lake Powell, habitat not normally inhabited by Colorado pikeminnow, but through which passage is possible. Several adults have been captured in this reservoir (Valdez 1990); most recently near Bullfrog, Utah (personal communication, W. Gustaveson, Utah Division of Wildlife Resources), a midpoint between the San Juan River and upper Colorado River, but movement of Colorado pikeminnow between these subbasins has not been documented. Several tagged adults have been recaptured to substantiate exchange of Colorado pikeminnow between the Green and upper Colorado rivers (personal communication, C. McAda, U.S. Fish and Wildlife Service). Gilpin (1993) hypothesized that mixing of Colorado pikeminnow from the Green River and upper Colorado River subbasins also occurs when young fish in downstream areas begin to mature and return randomly to upstream feeding and spawning areas. High densities of age-0 Colorado pikeminnow have been found below the confluence of the Green and Colorado rivers and in the Lake Powell inflow (Valdez 1990), suggesting that fish from both systems are transferred passively or move actively downstream and mix in these regions. Longitudinal distributions show decreasing sizes of fish with distance downstream, and tag-recapture data show fish moving back upstream as they mature (Valdez et al. 1982a; Osmundson et al. 1998). Gilpin (1993) hypothesized that this upstream return by subadults provides connectivity and gene flow between the Green and upper Colorado rivers, resulting in a panmictic population for the entire upper basin with evidence of source/sink dynamics. Although Colorado pikeminnow show fidelity to four primary spawning locales (Tyus 1985, 1991), fish in the Green River and upper Colorado River subbasins are linked genetically, based on movement throughout the system and lack of genetic separation (Ammerman and Morizot 1989; Gilpin 1993). Williamson et al. (1999) and Morizot et al. (2002) reported that Colorado pikeminnow from the San Juan River are genetically similar to fish from the Green River and upper Colorado River subbasins, and they suggested that exchange of genes occurred historically and may continue today.

Populations of Colorado pikeminnow within the Green River and upper Colorado River subbasins consist of separate spawning stocks, whose progeny and adults mix (see section 3.1.2 and Appendix A). Two spawning stocks are recognized in the Green River subbasin; fish spawn in the lower Yampa River (i.e., Cleopatra's Couch) and in lower Desolation/Gray Canyons (i.e., Three Fords). Radio telemetry studies show considerable fidelity of adults to respective spawning locations, but with some exchange of adults between these spawning locations on different years. Young produced in the lower Yampa River drift downstream and nurse primarily in alluvial backwaters upstream of Desolation/Gray Canyons, and young produced in lower Desolation/Gray Canyons nurse primarily in alluvial backwaters downstream of Desolation/Gray Canyons. There is considerable downstream transport and movement of these young fish and, eventually, there is mixing of these age-0 fish, as well as the juveniles, such that the progeny of the two stocks become mixed and indistinguishable. Hence, although there are two separate and distinct spawning stocks in the Green River subbasin, there is only one mixed population. A similar situation exists for the upper Colorado River subbasin, where spawning occurs in the mainstem Colorado River and the Gunnison River. Although stock recruitment dynamics are not well documented, exchange of adults between the upper Colorado and Gunnison rivers is documented through a selective fish passage structure in the lower Gunnison River.

3.2 Carrying Capacity

Carrying capacity is the theoretical size of a population that can be sustained by the existing environment, and is determined by population demographics and resource limitations (i.e., limiting factors), including habitat. Functional carrying capacity is the population at its equilibrium state in the presence of resource limitations, and is determined as the level where births equal deaths, or lambda (λ) is equal to 1.0 (Begon et al. 1990). Potential carrying capacity is the maximum possible population size with resource limitations minimized or removed.

Carrying capacity of Colorado pikeminnow is not expected to be the same for different populations because physical habitat (e.g., river channel, flow, and cover), chemical constituents (water quality), and biological components (e.g., food and predators) are likely to vary among river reaches. Hence, the same or even similar numbers and densities of fish in each population should not be expected for recovery. Carrying capacity, as a function of recovery, must be considered on its own merits for each population.

3.2.1 Green River

For the period 1986–1997, the catch of adult Colorado pikeminnow per hour of electrofishing in the Green River steadily increased (McAda et al. 1998; Figure 2). Catch rates from the 1986–1988 period to the 1996–1997 period increased by three-fold from about 0.8 fish/hour to about 2.5 fish/hour. Relative condition of adult Colorado pikeminnow in the Green River declined between these two time periods, suggesting that the population was at or near carrying capacity under existing conditions. Recently, small adult Colorado pikeminnow have moved into the Price River, where they were not reported from surveys in the 1970's (Cavalli 1999), also suggesting dispersal as a result of carrying capacity.

3.2.2 Upper Colorado River

Preliminary estimates of Colorado pikeminnow carrying capacity in the upper Colorado River were provided by Osmundson (1999). These estimates are based on existing population abundance, prey abundance and distribution, and water temperature regime for 298 km of the upper Colorado River from the Green River confluence to the Grand Valley Diversion near Palisade, Colorado. Estimates of Colorado pikeminnow (includes some subadults) in the uppermost 98 km (upstream of Westwater Canyon) increased from 205 in 1991 to 332 in 1994 and 435 in 1998 (Osmundson and Burnham 1998; Osmundson 1999), an increase of 112% during the 8-year period. Relative condition of adult Colorado pikeminnow in this upper reach remained constant during 1991–1994 but declined significantly with higher numbers in 1998 (Osmundson 1999), suggesting that carrying capacity had been reached or exceeded at about 435 Colorado pikeminnow, or about 4 fish/km. One possible explanation for increased dispersal, as indicated by increased numbers of adults migrating into the Gunnison River through the Redlands Fishway (1 in 1996, 18 in 1997, and 23 in 1998), is density-dependent dispersal from populations at or near carrying capacity under existing conditions.

Estimates of adult Colorado pikeminnow (includes some subadults) in 180 km of the upper Colorado River downstream of Westwater Canyon increased from 224 in 1992 to 512 in 1993 but decreased to 297 in 1994, for an average of 344 fish, or about 2 fish/km. Condition of Colorado pikeminnow declined following the 1991–1994 period, suggesting that the population was also at or near carrying capacity at current conditions (Osmundson 1999). In 1998, the estimates of Colorado pikeminnow upstream and downstream of Westwater Canyon were 435 and 330, respectively for a total of 765. Total estimates in 1999 and 2000 were 768 and 801 fish, respectively. Concurrent with these increases in population estimates, catch of adult Colorado pikeminnow per hour of electrofishing increased steadily for the period 1986–1997 (McAda et al. 1998; Figure 3). Catch rates from the 1986–1990 period to the 1995–1997 period increased by over ten times from about 0.1fish/hour to about 1.2 fish/hour.

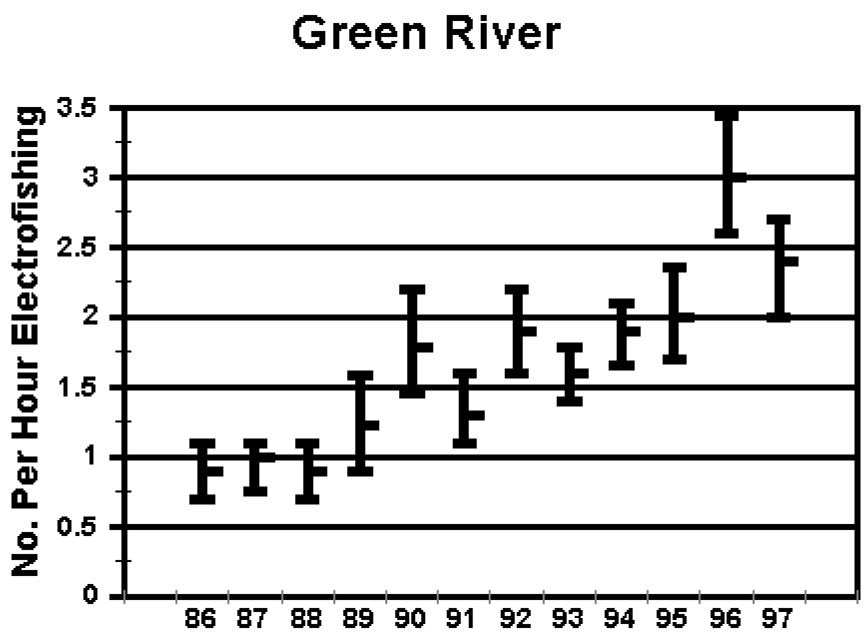

Figure 2. Mean catch rate (fish per hour of electrofishing) for Colorado pikeminnow in the Green River during spring ISMP sampling in 1986–1997. Bars indicate ± 1 standard error.

Osmundson (1999) estimated a carrying capacity of 700 adult Colorado pikeminnow for the Colorado River from the Grand Valley Diversion Dam to the Green River confluence and the lower 3.5 km of the Gunnison River based on forage base, thermal units, and fish condition. He also hypothesized that carrying capacity could be increased to 1,000 adults through range expansion by providing fish passage into a total of 22 km of the upper Colorado River (past the Grand Valley, Price-Stubb, and Government-Highline diversions) and into a total of 54 km of the lower Gunnison River from the recent Redlands Fishway. This range expansion constitutes year-around home-feeding range for adult Colorado pikeminnow, based on prey supply and a threshold of 40 annual thermal units (ATU; Kaeding and Osmundson 1989). Water-temperature augmentation in the Gunnison River, by modifying penstocks at Aspinall Unit dams, could expand the ATU threshold upstream about 40 km and hypothetically increase carrying capacity to 1,200 adults. This translates to densities of about 4 adults/km for the upper reach and about 3 adults/km (present density) for the lower reach. Penstock modification at Aspinall Unit dams has not been investigated to determine if water-temperature augmentation is feasible.

3.2.3 San Juan River

Under the current conditions, carrying capacity of Colorado pikeminnow in the San Juan River is estimated at 800 adults, based on a majority opinion of members of the San Juan Biology Committee. This estimate of carrying capacity is preliminary and subject to revision.

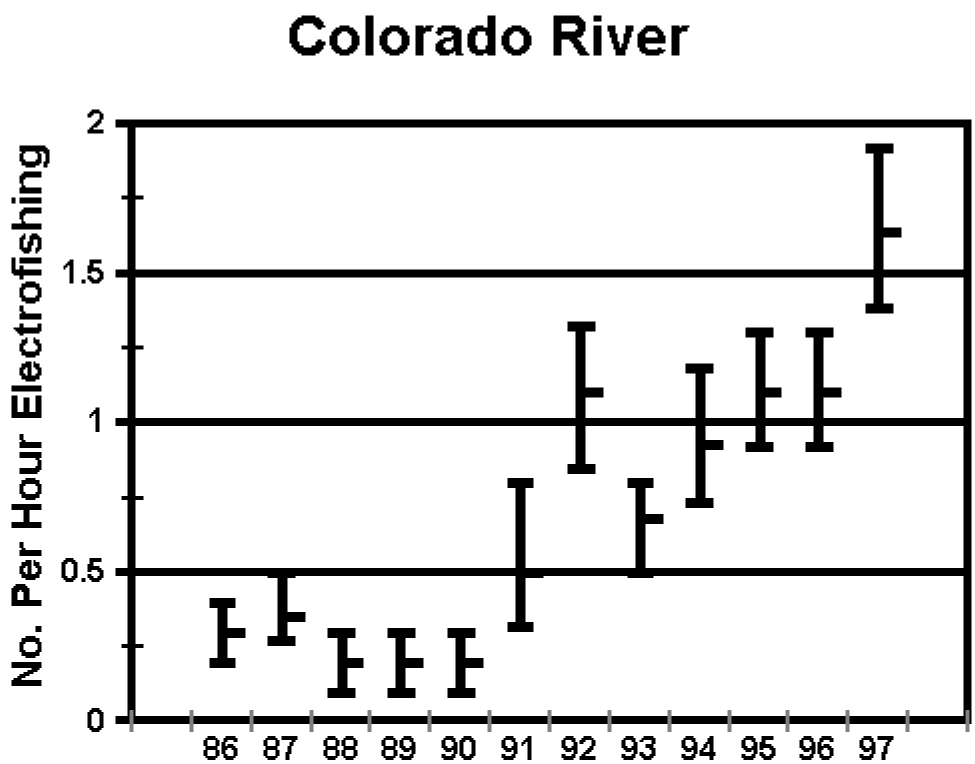

Figure 3. Mean catch rate (fish per hour of electrofishing) for Colorado pikeminnow in the Colorado River during spring ISMP sampling in 1986–1997. Bars indicate ± 1 standard error.

3.3 Genetic Viability

Genetic viability describes the pool of genetic diversity adequate to allow a population of animals to survive environmental pressures that may exceed the limits of developmental plasticity (Frankel 1983). Genetically viable populations maintain 90% of the genetic diversity present in the ancestral (pre-disturbance) population for 200 years (Soulé 1980; Soulé and Wilcox 1980; Soulé and Simberloff 1986). Ammerman and Morizot (1989) reported that Colorado pikeminnow maintain a high level of heterozygosity throughout their natural range. Genetic variability consists of within-population genetic diversity and genetic variation found among linked populations or stocks (Meffe 1986; Meffe and Carroll 1994), such as populations in the Green River and upper Colorado River subbasins. Genetic concepts that were considered are summarized in Box 3.

3.3.1 Genetic effective population size

One way to judge genetic viability is through consideration of "genetic effective population size" (N_e), which is the number of individuals contributing genes to the next generation (Crow and Kimura 1970; Gilpin and Soulé 1986; Soulé 1987; Allendorf et al. 1997). N_e was derived in

Box 3. Genetics Concepts and Considerations

- Genetic viability describes the pool of genetic diversity adequate to allow a population of animals to survive environmental pressures that may exceed the limits of developmental plasticity.
- Genetic variability consists of within-population genetic diversity and genetic variation found among linked populations.
- Genetic effective population size (N_e) is the number of individuals contributing genes to next generation.
- Rate of inbreeding is an index of the amount of genetic exchange among closely related individuals and is of particular importance because it may result in offspring that are sterile or inviable after one to several generations.
- N_e of at least 50 adults avoids inbreeding depression and is necessary for conservation of genetic diversity in the short-term; N_e of 500 is needed to avoid serious long-term genetic drift; N_e of 1,000 provides a conservative estimate beyond which significant additional genetic variation is not expected.
- Minimum viable population (MVP) is defined as a population that is sufficiently abundant and well adapted to its environment for long-term persistence without significant artificial demographic or genetic manipulations.

order to gauge the number of adults needed in a population to maintain genetic viability. The concept of N_e was defined by Wright (1931) as the size of an ideal population whose genetic composition is influenced by random processes in the same way as the real population. Low heterozygosity is the dynamic result of low N_e, and N_e likely differs by species (Meffe 1986). The concept of N_e was used to determine if wild populations are at risk genetically, but lack of genetic structural characterization with functional relationships for Colorado pikeminnow precludes a specific determination of N_e at this time. In the absence of this information, N_e for Colorado pikeminnow was derived from principles in conservation genetics by using the "50/500 rule" (Franklin 1980). It has been suggested that a minimum genetic effective population size of 50 is required to avoid inbreeding depression (Soulé 1980), and a minimum genetic effective population size of 500 is required to reduce long-term genetic drift (Franklin 1980). Lynch (1996) suggested an N_e of 1,000 as the number of adults beyond which significant additional genetic variation is not expected. An N_e of 500 is commonly used for fishes (Waples 1990; Bartley et al. 1992; Allendorf et al. 1997) and other vertebrate species (Mace and Lande 1991; Ralls et al. 1996), therefore an N_e of 500 was used to derive an estimate of the number of adults needed to maintain genetic viability of a population of Colorado pikeminnow. Recent research by fish geneticists support use of the 50/500 rule (Reiman and Allendorf 2001). An important consideration to genetic viability is maintaining natural connectedness and potential for gene flow among populations, regardless of size (Reiman and Dunham 2000). For Colorado pikeminnow populations in the Green River and Colorado River subbasins, natural connection is maintained and gene exchange indicates panmixis (Morizot et al. 2002).

It is important to note that the number of individuals in a population required to achieve a genetic effective population size of 500 may be several times greater than 500 (Frankel and Soulé 1981). Sex ratio and proportion of breeding individuals in the population are two important considerations in deriving the number of individuals necessary to support N_e. A 3:1 male to female ratio is used as the effective sex ratio for Colorado pikeminnow based on a consensus decision of biologists (Lentsch et al. 1998). To maintain an N_e of 500 with a 3:1 sex ratio the total number of breeding adults (N_b) must be increased according to the following relationship:

$$N_e = 4M_bF_b/M_b+F_b \quad [1]$$

where: M_b = number of breeding males,
F_b = number of breeding females, and
$N_b = M_b + F_b$.

The number of breeding males (M_b) needed is 499 and the number of breeding females (F_b) is 167 for a total of 666 adults needed to maintain an N_e of 500. Hence, according to Equation [1]:

$$N_e = 4(499)(167)/666 = 500 \quad [2]$$

If all adults in a population breed every year and contribute genes to the following generation, some minimum number of adults (N_g) would equal N_e. However, as with most populations, it is believed that not all Colorado pikeminnow spawn every year or contribute genes to the following generation, and hence, N_g is not equal to N_e. It is important to determine a ratio of genetic effective population size (N_e) to minimum population size (N_g), or N_e/N_g.

For various fish species (rainbow trout, *Oncorhynchus mykiss*; chinook salmon, *O. tshawytscha*; white seabass, *Atractoscion nobilis*), the ratio N_e/N_g varies from 0.013 to 0.90 (Table 2; Bartley et al. 1992; Avise 1994; Hedrick et al. 1995; Allendorf et al. 1997) for an overall average of about 0.30, which is the ratio reported for chinook salmon (McElhany et al. 2000) and other Pacific salmon species (Waples et al. 1990a, 1990b). This overall average ratio for fishes of 0.30 was used to determine the number of adult Colorado pikeminnow needed to support an N_e of 500. Mace and Lande (1991) reported that the genetic effective population size is typically 20–50% of the actual population size.

Table 2. Estimates of effective/actual population size (N_e/N_g) ratios for various fish species.

Species	N_e/N_g	Reference
Sea bass (*Atractoscion nobilis*)	0.27–0.40	Bartley et al. (1992)
Coho salmon (*Oncorhynchus kisutch*)	0.24	Simon et al. (1986)
Rainbow trout (*Oncorhynchus mykiss*)	0.90	Bartley et al. (1992)
Chinook salmon (*Oncorhynchus tshawytscha*)	0.013–0.043	Bartley et al. (1992)
Chinook salmon (*Oncorhynchus tshawytscha*)	0.30	McElhany et al. (2000)

Using an N_e of 500, a 3:1 sex ratio, and an N_e/N_g ratio of 0.30, an estimated N_g of 2,217 was derived as the estimated number of adult Colorado pikeminnow necessary to maintain a genetic effective population size. This approach does not imply that existing populations should be allowed to decrease to this level; the estimate of 2,217 is used as a gauge to evaluate genetic viability of isolated populations.

3.3.2 Minimum viable population

Genetic effective population size provides a gauge for genetic viability but does not necessarily account for demographic viability. The concept of a minimum viable population (MVP) is defined as a population that is sufficiently abundant and well adapted to its environment for long-term persistence without significant artificial demographic or genetic manipulations (Shaffer 1981; Soulé 1986, 1987; Soulé and Simberloff 1986). Meffe and Carroll (1994) define an MVP as *"the smallest isolated population size that has a specified percent chance of remaining extant for a specified period of time in the face of foreseeable demographic, genetic, and environmental stochasticities, plus natural catastrophes."* Use of MVP does not mean that populations should be allowed to drop to these levels, but is used to assess their genetic and demographic viability. It must be recognized that some populations of any wild animal species may be below an MVP, as dictated by carrying capacity. It cannot be expected that every population will exceed an MVP; linkages to other populations help to keep smaller populations viable. As stated by Thomas (1990), *"There is no single 'magic' population size that guarantees the persistence of animal populations."* Thomas (1990) also stated that MVPs are rarely lower than a few 100 individuals and often correspond to an actual population count of about 1,000.

A minimum viable population size of 2,600 adults was derived by adding 15% to the N_g of 2,220 to account for an estimate of the average annual mortality of adult Colorado pikeminnow (2,220 x 1.15 = 2,553 or about 2,600; Box 4; Osmundson and Burnham 1998). An average annual adult mortality factor was added to buffer against an event that may result in recruitment failure for a year. The concept of adding a mortality factor to a genetically viable population as demographic security is taken from recovery criteria established for the southern sea otter, in which the estimated mortality from exposure to simulated oil spills was added to the estimate of N_g, based on an N_e of 500 (Ralls et al. 1996).

<u>Box 4. Computation of Minimum Viable Population (MVP)</u>

$$N_g = N_e/(N_e/N_g)$$

where: N_e = genetic effective population size, 666
N_e/N_g = proportion of adults contributing genes to next generation; ~0.30 for most fish
therefore: N_g = 666/0.30
N_g = 2,220
hence: MVP = 2,220 x 1.15 = 2,553 (rounded to 2,600)
where: 1.15 compensates for annual adult mortality of 15%

The population of Colorado pikeminnow in the Green River subbasin is the largest and most important unit of the upper basin metapopulation. It contains sufficient numbers of adults to ensure genetic and demographic viability, and subadult numbers show that reproduction and recruitment provide self-sustainability (see Appendix A). Maintenance of the Green River subbasin population is vital for the upper basin metapopulation that includes the upper Colorado River subbasin and potentially the San Juan River subbasin.

4.0 THREATS TO COLORADO PIKEMINNOW BY LISTING FACTOR

The Colorado pikeminnow was designated as an endangered species prior to enactment of the ESA, and a formal listing package identifying threats was not assembled. Construction and operation of mainstem dams, nonnative fish species, and local eradication of native minnows and suckers in advance of new human-made reservoirs in the early 1960's were recognized as early threats (Miller 1961; Holden 1991), and the species was included in the United States List of Endangered Native Fish and Wildlife on June 4, 1973 (38 FR No. 106). A description of Threatened Wildlife of the United States compiled by the Office of Endangered Species and International Activities (U.S. Bureau of Sports Fisheries and Wildlife 1973) identified the reasons for decline of the Colorado pikeminnow as:

> *"Modification of habitat by man through construction of large reservoirs. The species will not reproduce in cold tailwaters below high dams nor in reservoirs behind these dams. The species is adapted to life in turbid, swift, warm rivers. Introduced fishes may have a decimating effect in waters not affected by dams."*

Although habitat losses were documented, the threats were poorly understood and distribution and abundance of the species were not well known. Threats were further identified in the Recovery Plan (U.S. Fish and Wildlife Service 1991):

> *"In summary, the absolute cause for the decline of Colorado squawfish is not fully understood but is probably related to a combination of factors, including direct loss of habitat, changes in flow and temperature, blockage of migration routes, and interaction with introduced fish species."*

Hence, the primary threats to Colorado pikeminnow populations are streamflow regulation and habitat modification (including cold-water dam releases, habitat loss, and blockage of migration corridors); competition with and predation by nonnative fish species; and pesticides and pollutants (Box 5). These threats are associated with the five listing factors (see section 2.1), and a summary of each is presented in the following sections. Site-specific management actions and objective, measurable criteria associated with five recovery factors to minimize or remove threats are provided in section 5.0.

Box 5. Primary Threats To Colorado Pikeminnow

- Streamflow regulation.
- Habitat modification.
- Competition with and predation by nonnative fish species.
- Pesticides and pollutants.

4.1 Listing Factor (A): The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range

Streamflow regulation and associated habitat modification are identified as primary threats to Colorado pikeminnow populations. Regulation of streamflows in the Colorado River Basin is manifested as reservoir inundation of riverine habitats and changes in flow patterns, sediment loads, and water temperatures. For example, streamflow regulation has generally reduced the magnitude of spring peak flows and increased the magnitude of summer–winter base flows. Since 1950, annual peak flows of the Colorado River in occupied Colorado pikeminnow habitat upstream of Westwater Canyon have decreased by 29–38% (Van Steeter and Pitlick 1998). Flows of the Green River at Jensen, Utah, upstream of principal Colorado pikeminnow nursery habitat, have decreased by 13–35% during spring and increased by 10–140% during summer through winter due to regulation by Flaming Gorge Dam (Muth et al. 2000). Peak discharge of the San Juan River during the post-dam period (1962–1991) averaged 54% of the spring peak during the pre-dam period (1929–1961), and median monthly flow for the base-flow months of August through February averaged 168% of the pre-dam period (Holden 1999). The effect of flow modifications on Colorado pikeminnow includes reduction in high-velocity flows that flush sediments from spawning cobbles (Van Steeter and Pitlick 1998), reduced channel and habitat complexity and concomitant losses in food production (Osmundson 1999), reduced availability and quality of backwater nursery habitats (Tyus and Karp 1989), and loss of flooded bottomlands during spring runoff as feeding areas and as thermal refugia for maturation of gonads (Tyus 1990).

The Colorado pikeminnow was first listed as endangered following a period of dam construction throughout the Colorado River Basin. Starting with Hoover Dam in 1935, numerous dams were constructed that fragmented and inundated riverine habitat; released cold, clear waters; altered ecological processes; affected seasonal availability of habitat; and blocked fish passage. Reservoirs formed by these dams were stocked with a variety of nonnative fishes for recreational fisheries, and these fishes preyed upon and competed with the native fishes. In the 1960's, major dams were also constructed in the upper basin, primarily through the Colorado River Storage Project (CRSP) Act, including Flaming Gorge Dam (1962) on the Green River, Navajo Dam (1962) on the San Juan River, the Aspinall Units (1963) on the Gunnison River, and Glen Canyon Dam (1963) on the Colorado River. These dams had similar effects as seen in the lower basin, but there remained large undammed reaches in which the Colorado pikeminnow could complete its life cycle. The decline of the species throughout the basin and its extirpation from the lower basin is attributed largely to extensive habitat loss, modification, and fragmentation and blocked fish passage associated with dam construction and operations. Following the dams of the CRSP, fewer and smaller dams were constructed on tributaries, including McPhee Dam (1985) on the Dolores River and Taylor Draw Dam (1987) on the White River. Dams have not been constructed within occupied habitat of Colorado pikeminnow since 1987, and the threat of dam construction has been minimized considerably.

Total Colorado pikeminnow habitat lost to reservoir inundation in the upper basin is about 700 km, including Flaming Gorge Reservoir on the Green River (160 km), Lake Powell (320 km on the Colorado River and 120 km on the San Juan River), and Navajo Reservoir on the San Juan River (100 km). Much of the habitat lost to reservoir inundation cannot be reasonably regained in the near future. Inundated habitat still occupied by Colorado pikeminnow includes the Colorado River and San Juan River inflows to Lake Powell. Large numbers of age-0 and juvenile Colorado pikeminnow are found seasonally in the Colorado River inflow and fewer numbers are reported in the San Juan River inflow, but adults are rarely caught in the reservoir; Colorado pikeminnow do not survive well in reservoirs and are not known to reproduce in lentic habitats.

Cold-water releases have eliminated most native fishes from river reaches immediately downstream of dams, except for small numbers of flannelmouth sucker (*Catostomus latipinnis*), bluehead sucker *(C. discobolus*), and speckled dace (*Rhinichthys osculus*) that remain in some tailwaters. River temperatures have been modified from seasonal lows of near freezing and highs of nearly 30°C to relatively constant dam releases of about 4–13°C. Depending on dam elevation, time of year, and river volume, river temperatures may not equilibrate with atmospheric temperatures for nearly 400 km downstream (as in the Colorado River below Glen Canyon Dam). These cold releases have caused reproductive failure and slowed growth of the warm-water native fishes. Colorado pikeminnow were last reported in Grand Canyon below Glen Canyon Dam in the early 1970's, as dam release temperatures became constant; a proposed temperature modification on Glen Canyon Dam (U.S. Bureau of Reclamation 1998) is not expected to restore Colorado pikeminnow in the region because of the lack of a full complement of habitats. The species was last reported in the San Juan River below Navajo Dam shortly after dam construction, but is currently found only in the reach starting 105 km downstream of the dam. Penstock modifications on Flaming Gorge Dam in 1976 (Holden and Selby 1979; Holden and Crist 1981) allowed for warmed releases down the Green River beginning in 1978, and Colorado pikeminnow have reinvaded Lodore Canyon, upstream of the Yampa River confluence (Bestgen and Crist 2000). In the Gunnison River, warming releases from Aspinall Unit dams could provide suitable temperatures for Colorado pikeminnow to expand their present range upstream of Delta, Colorado.

Adult Colorado pikeminnow are long distance migrators to and from spawning sites (Tyus 1990). Historically, the only physical barriers to movement were natural rapids and swift turbulent flows, which were probably only seasonal impediments to fish movement. Since 1905, numerous human-made dams have been constructed throughout the Colorado River Basin, fragmenting Colorado pikeminnow habitat and blocking migration corridors. These dams have also reduced river flow, altered water-temperature and flow regimes, trapped sediments and nutrients, changed water quality, and created reservoirs as a source of nonnative fishes (Maddux et al. 1993). In the lower basin, 14 major dams have restricted fish movement through the Colorado, Gila, Salt, and Verde rivers since completion of Hoover Dam in 1935; other dams on the Colorado River include Davis, Parker, Palo Verde Diversion, Imperial, and Laguna. Glen Canyon Dam approximately divides the lower from the upper basin and also is a barrier to fish movement.

Ten barriers are identified in the upper basin upstream of Glen Canyon Dam within occupied habitat of Colorado pikeminnow (Burdick and Kaeding 1990; Holden 1999; Table 3). Five of

Table 3. Existing dams and diversion structures within occupied Colorado pikeminnow habitat.

River	Structure	Current Status	Access to Suitable Habitat
Upper Colorado River	Grand Valley Diversion	Year-around passage completed in 1998	Passage adds 5 km additional habitat up to Price-Stubb Diversion
Upper Colorado River	Price-Stubb Diversion	Environmental Assessment to remove or modify in progress	Passage would add about 9 km additional habitat up to Government Highline Diversion
Upper Colorado River	Government Highline Diversion	No formal passage proposal	Passage would add 8 km additional habitat based on existing temperature units[a]
Gunnison River	Redlands Diversion	Fishway installed in 1996; successfully passing fish	Passage adds 50 km additional habitat based on existing temperature units[a]
Green River	Tusher Wash Diversion	Passage may be difficult at very low flows	Occupied habitat both up and downstream
Yampa River	Craig Diversion	Structure modified in 1992; successfully passing fish	Occupied habitat downstream
White River	Taylor Draw Dam	Dam completed in 1983, no current fish passage	Fish have been found downstream of dam in apparent attempt to migrate to habitat upstream of dam
San Juan River	PNM Weir	Diversion being modified to allow passage	Fish found below.
San Juan River	Cudei Diversion	Diversion has been modified to allow passage	Fish found above and below.
San Juan River	Hogback Diversion	Diversion has been modified to allow passage	Fish found below

[a]Osmundson (1999).

these barriers are classified as medium or high-head structures that are partial or seasonal barriers to fish movement or that have been modified to allow passage. The Price-Stubb Diversion presently defines the upper-most distribution of the Colorado pikeminnow in the upper Colorado River; a second structure, the Government Highline Diversion, is immediately upstream. Passage by these diversions could allow the species to expand its range by about 22 km (Osmundson 1999). The Redlands Fishway on the lower Gunnison River has allowed Colorado pikeminnow and other native fishes to move past the Redland Diversion and regain access to about 50 km of the Gunnison River. A diversion structure on the Yampa River near Craig, Colorado, was recently replaced, in part, to allow unassisted fish passage (Masslich 1993). On the San Juan River, several diversion structures are in historic habitat and act as fish barriers to limit the range of Colorado pikeminnow (Masslich and Holden 1996). The Cudei and Hogback diversions have been modified to allow fish passage and work is being done on the PNM Weir; other diversions are being evaluated. Modification of these dams and diversions could allow for considerable range expansion and increases in populations. Furthermore, water withdrawn at diversion structures can entrain Colorado pikeminnow and isolate them in canal systems where their survival is potentially low. Diversion structures should be screened (as needed) to minimize or prevent entrainment of at least subadult and adult Colorado pikeminnow.

Maintenance of streamflow is important to the ecological integrity of large western rivers (Tyus 1992; Collier et al. 1996; Poff et al. 1997; Schmidt et al. 1998). Life histories of many aquatic species, especially fish, are often specifically tied to flow magnitude, frequency, and timing, such that disruption of historic flows can jeopardize native species. The importance of flow management to the endangered fishes of the Colorado River is recognized (Tyus 1992; Stanford 1994). Enhancing natural temporal and spatial habitat complexity through flow and temperature management is the basis for benefitting the endangered fishes (Osmundson et al. 2000b).

Flow recommendations have been developed for some river systems in the Upper Colorado River Basin that identify and describe flows with the necessary magnitude, frequency, duration, and timing to benefit the endangered fish species (e.g., Modde and Smith 1995; Osmundson et al. 1995; U.S. Department of the Interior 1995b; Holden 1999; Modde et al. 1999; McAda 2000 [under revision]; Muth et al. 2000). These flows were designed to enhance habitat complexity (e.g., suitable spawning areas, inundation of floodplain areas) and to restore and maintain ecological processes (e.g., sediment transport, food production) that are believed to be important to the life history of these endangered fishes. Spring peak flows are important to the dynamic sediment processes that maintain in-channel habitat complexity, and prevent vegetation encroachment and channel narrowing. For example, cobble and gravel deposits used for spawning are relatively permanent features formed at high flows. Lower peak flows in subsequent years result in deposition of fine sediments over cobble and gravel deposits. Peak flows, whose timing coincides with the natural runoff cycle, are needed to ensure that suitable sites, cleansed of fine sediments, are available during the spawning period. Conversely, low and relatively stable base flows in summer, fall, and winter provide stable, warm, and productive nursery habitats for young fish.

Flows necessary to restore and maintain required habitats of Colorado pikeminnow mimic the natural hydrograph and include spring peak flows and summer–winter base flows. Adults utilize pools, deep runs, and eddy habitats maintained by high spring flows (see Appendix A for details on habitat requirements). These high spring flows maintain channel and habitat diversity, flush sediments from spawning areas, rejuvenate food production, form gravel and cobble deposits used for spawning, and rejuvenate backwater nursery habitats (McAda 2000; Muth et al. 2000). Spawning activity begins after spring runoff at water temperatures typically between 18 and 23°C . Increased production and recruitment have been correlated with moderate-to-high water years (Converse et al. 1999; McAda and Ryel 1999; Valdez et al. 1999). Larvae typically drift downstream from spawning areas to broad alluvial reaches where they occupy sheltered nursery backwaters, restructured by high spring flows and maintained by relatively stable base flows. High spring flows also disadvantage nonnative fishes (McAda and Kaeding 1989; Valdez 1990; Hoffnagle et al. 1999), reducing predation and competition. Low base flows also increase shoreline food production.

Flow recommendations have been developed that specifically consider flow-habitat relationships within occupied habitat of Colorado pikeminnow (see section 3.1.2; Table 1) in the upper Colorado River (Osmundson et al. 1995; McAda 2000), Gunnison River (McAda 2000), Yampa River (Modde and Smith 1995; Modde et al. 1999), Green River (Muth et al. 2000), and San Juan River (Holden 1999). These flow recommendations will be evaluated and revised (as necessary) as part of an adaptive-management process, and flow regimes to benefit the endangered fishes will be implemented through multi-party agreements or by other means (see section 4.4).

4.2 Listing Factor (B): Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Overutilization of Colorado pikeminnow for commercial, recreational, scientific, or educational purposes is not currently considered a threat to the species. This factor will be reevaluated and, if necessary, actions to ensure adequate protection will be identified before downlisting and attained before delisting.

Historically, Colorado pikeminnow were opportunistically used as food by American Indians and early explorers to the region, and were commercially harvested as "white salmon" in the early 1900's (see section A.2). Colorado pikeminnow will strike at lures and flies, and some fish are incidentally caught by recreational anglers, but the number harmed or killed is believed to be insignificant based on creel census (personal communication, T. Nesler, Colorado Division of Wildlife). All angler access points near occupied habitat are posted with signs advising anglers to release any endangered fish unharmed.

Collection of Colorado pikeminnow for scientific or educational purposes is regulated by the Service under Section 10(a) of the ESA. Scientific collecting permits are issued to investigators conducting legitimate scientific research, and "take" permits are issued where a reasonable loss of fish is expected. Permits to collect Colorado pikeminnow for educational purposes are normally not requested but are regulated by the same provisions of the ESA.

4.3 Listing Factor (C): Disease or Predation

4.3.1 Diseases and parasites

Diseases and parasites currently are not considered singly significant in the decline of the Colorado pikeminnow (see section A.11 for expanded discussion of parasites), but these factors will be reevaluated and, if necessary, actions will be identified to minimize adverse effects before downlisting. Adequate protection from deleterious diseases and parasites will be attained before delisting.

4.3.2 Nonnative fishes

Colorado pikeminnow populations in the upper basin live sympatrically with about 20 species of warm-water, nonnative fishes (Tyus et al. 1982; Lentsch et al. 1996) that are potential predators, competitors, and vectors for parasites and diseases. Backwaters and other low-velocity shoreline habitats in alluvial reaches of the upper Colorado, Green, and San Juan rivers are important nursery areas for larval and juvenile Colorado pikeminnow (Tyus 1991; Holden 1999; McAda 2000; Muth et al. 2000; see Appendix A), and researchers believe that nonnative fish species in those habitats limit the success of Colorado pikeminnow recruitment (e.g., Muth and Nesler 1993; Bestgen 1997; Bestgen et al. 1997; McAda and Ryel 1999; Valdez et al. 1999). Osmundson (1987) confirmed predation by black bullhead (*Ameiurus melas*), green sunfish (*Lepomis cyanellus*), largemouth bass (*Micropterus salmoides*), and black crappie (*Pomoxis nigromaculatus*) as a significant mortality factor of young-of-year and yearling Colorado pikeminnow stocked in riverside ponds along the upper Colorado River. Adult red shiner (*Cyprinella lutrensis*) are known predators of larval native fish in backwaters of the upper basin (Ruppert et al. 1993), and predation by nonnative fishes such as red shiner may influence within-year-class recruitment of Colorado pikeminnow (Bestgen et al. 1997). In laboratory experiments on behavioral interactions, Karp and Tyus (1990) observed that red shiner, fathead minnow (*Pimephales promelas*), and green sunfish shared activity schedules and space with young Colorado pikeminnow and exhibited antagonistic behaviors toward smaller Colorado pikeminnow. They hypothesized that Colorado pikeminnow may be at a competitive disadvantage in an environment which is resource limited and concluded that nonnative fishes could have a negative impact on growth and survival of young Colorado pikeminnow. High spatial overlap in habitat use has been documented among young Colorado pikeminnow, red shiner, sand shiner (*Notropis stramineus*), and fathead minnow (McAda and Tyus 1984; McAda and Kaeding 1989). Muth and Snyder (1995) compared the diet of young-of-year Colorado pikeminnow with the diets of other small fishes collected from backwaters of the Green River. They concluded that the potential for competition for food between Colorado pikeminnow and other fishes in backwaters appeared greatest with red shiner, which are often the most abundant fish in backwaters.

Channel catfish (*Ictalurus punctatus*) and northern pike (*Esox lucius*) have been identified as the principal nonnative threats to subadult and adult Colorado pikeminnow in the upper basin. Adult Colorado pikeminnow apparently use the same habitats as adult channel catfish and northern pike suggesting the potential for negative interactions, especially during periods of limited resource availability (Wick et al. 1985; Tyus and Karp 1989; Tyus and Beard 1990; Nesler 1995). Channel catfish were first introduced into the Upper Colorado River Basin in 1892 (Tyus and Nikirk 1990) and are now considered common to abundant throughout much of the upper basin (Tyus et al. 1982; Nelson et al. 1995). The species is one of the most prolific predators in the upper basin and, among the nonnative fishes, is thought to have the greatest adverse effect on the endangered fishes (Hawkins and Nesler 1991; Lentsch et al. 1996; Tyus and Saunders 1996), largely due to predation on juveniles and resource overlap with subadults and adults. Additionally, mortality of adult Colorado pikeminnow that prey on channel catfish has occurred due to choking on pectoral spines (McAda 1980; Pimental et al. 1985). Northern pike accidentally became established in the Yampa River in the early 1980's when individuals escaped from Elkhead Reservoir (Tyus and Beard 1990). Since then, northern pike have established a reproducing population in the Yampa River and have expanded their numbers and range in both the Yampa and middle Green rivers (Tyus and Beard 1990; Hawkins and Nesler 1991; Nesler 1995) where they pose a competitive and predatory threat to endangered and other native fishes (Wick et al. 1985; Tyus and Karp 1989; Tyus and Beard 1990; Martinez 1995; Nesler 1995).

A Strategic Plan for Nonnative Fish Control was developed for the Upper Colorado River Basin (Tyus and Saunders 1996) and implemented by the UCRRP in 1997. Some activities include mechanical removal of nonnative fishes through intensive sampling, and modification of habitats used as residential or nursery areas by nonnative fishes. Preliminary results of the control program are inconclusive as to the beneficial effects for Colorado pikeminnow. However, increases in abundances of Colorado pikeminnow during the 1980's and 1990's in both the Green and upper Colorado rivers (see section 3.2) suggest that other factors, such as restoration of naturalized river flows, may allow the species to proliferate even in the presence of nonnative species. Colorado pikeminnow are predators during their first year of life and as major predators, may have an advantage over other sympatric native species. Data from a 7-year research period on the San Juan River suggest that efforts to date were effective in reducing density of large channel catfish, but efforts were not effective in reducing overall abundance of channel catfish in the river (Holden 1999). A positive population response by native fishes to this channel catfish reduction has not been reported (personal communication, San Juan River Basin Recovery Implementation Program, Biology Committee). A strategic control program has also been recommended for Grand Canyon (Valdez et al. 1999), and a Science Plan is being developed for implementation of nonnative fish removal starting in 2003 (GCMRC 2002).

Control of the release and escapement of nonnative fishes into the main river, floodplain, and tributaries is also a necessary management action to stop the introduction of new fish species into occupied habitats and to thwart periodic escapement of highly predaceous nonnatives from riverside features. Agreements have been signed among the Service and the States of Colorado, Utah, and Wyoming to review and regulate all stockings within the Upper Colorado River Basin (U.S. Fish and Wildlife Service 1996) in order to reduce the introduction and expansion of nonnative fishes. A Memorandum of Agreement implementing these procedures was signed on September 5, 1996, by the Service and the States and remains in effect through the life of the UCRRP. This agreement regulates releases of nonnative fishes within the 50-year floodplain of the river, and provides security against State or Federal endorsed programs introducing new species into the system or increasing the numbers or distribution of existing species. The agreement also allows the States to regulate and restrict stocking of privately owned ponds. These procedures will also reduce the likelihood of new parasites and diseases being introduced through nonnative fish stockings. Similar procedures need to be developed and implemented in the San Juan River subbasin.

Annual flooding of the river can inundate riverside ponds potentially containing large numbers of green sunfish, black bullhead, largemouth bass, and other nonnative fishes that may escape to the river during high flows (Valdez and Wick 1983). Riverside features determined to be problematic must be either isolated from high river floods, designed to drain annually with the rise and fall of the river, or treated with piscicidal compounds to eradicate nonnative fishes. The Colorado Division of Wildlife is to prepare a Colorado River Fisheries Management Plan (Plan) that will implement a more detailed nonnative fish control effort. The Plan is to be reviewed and approved by the Colorado Wildlife Commission and UCRRP. The Plan will be finalized and implemented by the dates specified in the Recovery Implementation Program Recovery Action Plan (RIPRAP) of the UCRRP. One aspect of the Plan will be pond reclamation, which can include complete removal of nonnative fish, screening ponds to prevent escapement to the river, and/or reshaping ponds so that they no longer support year-round habitation by nonnative fish.

Another aspect of nonnative fish control in the upper basin is removal of bag and possession limits on nonnative fishes in designated critical habitat of Colorado pikeminnow. For example, the State of Colorado has removed bag and possession limits on all nonnative, warm-water sport fishes within critical-habitat reaches of the Colorado and Yampa rivers. Colorado also has agreed to close river reaches to angling where and when angling mortality is determined to be significant to native fishes.

Three management actions are identified to reduce the threat of nonnative fishes: high spring flows, nonnative fish control strategies, and stocking agreements. There is documented evidence that high flows temporarily disadvantage nonnative fishes in several ways, including displacement from sheltered habitats, disruption of spawning activities, increased mortality in high mainstem currents, and physical downstream transport of individuals. Studies from the Upper Colorado River (McAda and Kaeding 1989), Green River (Valdez 1990), Yampa River (Muth and Nesler 1993), and Lower Colorado River through Grand Canyon (Hoffnagle et al. 1999; Valdez et al. 2001) showed reductions in densities of small-bodied species of fish (e.g., fathead minnow, red shiner, sand shiner, plains killifish [*Fundulus zebrinus*]) following high flows. On the San Juan River, no evidence exists to support the hypothesis that high flows even temporarily disadvantage nonnatives and promote endangered fish reproduction and recruitment (Holden 1999). Strong year classes of Colorado pikeminnow have consistently occurred in 1–3 years following high runoff years, and have been attributed to cleansing of spawning gravels and short-term reduction in nonnative fishes (McAda and Ryel 1999). Hence, even a short-term reduction in nonnative fishes could allow increased survival and recruitment of native forms (Tyus and Saunders 1996). Flow recommendations include the provision of high flows, which provide these unsuitable conditions for nonnative fishes and may at least temporarily reduce numbers of these predators and competitors.

Active control programs should be implemented or continued (as needed) for problematic nonnative fishes in Colorado pikeminnow nursery habitats, northern pike in the Yampa and middle Green rivers, and channel catfish in river reaches occupied by Colorado pikeminnow. Guidance is not provided in this document with regard to target reduction levels because such criteria may be premature and unreasonable to achieve, or may be easily achieved and exceeded. Little is known with respect to responses by nonnative fish populations to overt control measures, and these must be evaluated as part of nonnative fish control programs. Another unknown aspect of nonnative fish control is the need to maintain control measures indefinitely or periodically over time. These decisions will have to be made from information gained through these control programs during the downlist monitoring period.

4.4 Listing Factor (D): The Inadequacy of Existing Regulatory Mechanisms

Implementation of regulatory mechanisms are necessary for recovery of the Colorado pikeminnow and to ensure long-term conservation of the species. Regulatory mechanisms affect many aspects of legal protection, such as habitat and flow protection, regulation and/or control of nonnative fishes, regulation of hazardous-materials spills, and angling regulations. Flow regimes to benefit Colorado pikeminnow populations must be identified, implemented, evaluated, and revised (as necessary) before downlisting can occur (existing flow recommendations are described in section 4.1). By the time of delisting, legal protection of habitat (including flows) necessary to provide adequate habitat and sufficient range for all life stages of Colorado pikeminnow to support recovered populations must be accomplished through various means, including instream-flow appropriations, legal agreements, contracts, operating criteria, and/or other means. Additionally, certain States may issue policies that also afford flow protection. As examples, the State of Utah has instituted a policy that subordinates all future water-rights appropriations for the Green River from Flaming Gorge Dam to the Duchesne River confluence for the summer and autumn periods to provide flows to benefit the endangered fish; actions proposed under this policy would not affect pre-existing water rights (Utah Division of Water Rights 1994). Also, the State of Colorado has established two instream-flow rights on the Colorado River under its state instream-flow law.

Before delisting, the primary regulatory mechanism for protection of Colorado pikeminnow is through Section 7(a)(2) of the ESA, as administered by the Service. *"Each Federal agency shall, in consultation with and with the assistance of the Secretary, insure that any action authorized, funded, or carried out by such agency... is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species which is determined by the Secretary, after consultation as appropriate with affected States, to be critical..."* In the Upper Colorado River Basin, the UCRRP provides a mechanism for dealing with Section 7 consultations in a unified manner. The SJRRIP provides a similar consolidated effort for addressing Biological Opinions in the San Juan River, including Navajo Dam. Neither of these two programs are regulatory mechanisms that provide permanent, long-term protection for the species after delisting.

In addition to Federal protection under the ESA, Colorado pikeminnow are protected by all basin States under categories such as "endangered", "threatened", or "sensitive". This protection prohibits intentional take and keeping or harming in any way any fish captured incidentally, and may need to remain in place after the species is Federally delisted. However, the States do not address the major problem of habitat destruction, and especially streamflow modification. Most States have instream-flow laws that allow "beneficial use" of water left in streams for wildlife, but these laws typically only provide for flow that is the minimum amount necessary to maintain the fishery. With some States, there is also an inherent conflict between management of nonnative sport fish and recovery of endangered fishes. Where valued sport fisheries occur, there is an ongoing dilemma between public demands for maintenance and expansion of fisheries and management actions to conserve and recover endangered fish. There is no immediate solution to the dilemma, but predation by nonnative fishes is clearly identified as a cause for the decline of many of the native Colorado River fishes, and long-term agreements between States and the Service are essential.

After removal from the list of species protected by the ESA, the Colorado pikeminnow and its habitat will continue to receive consideration and some protection through the following Federal laws and related State statutes, and will need the provisions to protect habitat previously discussed. The National Environmental Policy Act (NEPA; 42 U.S.C. 4321–4370d) requires Federal agencies to evaluate the potential effects of their proposed actions on the quality of the human environment and requires the preparation of an environmental impact statement whenever projects may result in significant impacts. Federal agencies must identify adverse environmental impacts of their proposed actions and develop alternatives that undergo the scrutiny of other public and private organizations as a part of their decision-making process. Recovery actions identified for Colorado pikeminnow are linked to federal actions, which must undergo review under NEPA.

Section 101(a) of the Federal Water Pollution Control Act (i.e., Clean Water Act; 33 U.S.C. 1251–13287) states that the objective of this law is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters and provide the means to assure that *"...protection and propagation of fish, shellfish, and wildlife..."*. This statute contributes in a significant way to the protection of the Colorado pikeminnow and its food supply through provisions for water quality standards, protection from the discharge of harmful pollutants, contaminants [Section 303(c), Section 304(a), and Section 402] and discharge of dredge or fill material into all waters, including certain wetlands (Section 404).

The Organic Act (16 USC 1, as amended) provides for management of National Park Service areas in such a manner *"...to promote and regulate the use of the...national parks...which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."* The National Park Service is the largest single jurisdictional land owner in reaches with critical and other occupied habitats for the four Colorado River endangered fishes (Maddux et al. 1993).

The Fish and Wildlife Coordination Act (16 U.S.C. 661–666c) requires that Federal agencies sponsoring, funding, or permitting activities related to water resource development projects request review of these actions by the Service and the State natural resource management agency. These comments must be given equal consideration with other project purposes. Also, the Federal Land Policy and Management Act (43 U.S.C. 1701–1784) requires that public lands be managed to protect the quality of scientific, ecological, and environmental qualities and preserve and protect certain lands in their natural conditions to provide food and habitat for fish and wildlife.

Hazardous-materials spills are identified as a threat to Colorado pikeminnow. Although the States of Colorado, Utah, and New Mexico, where the species occurs, have state-wide hazardous-materials plans, these may not be adequate to provide protection against spills into the river. Research into the adequacy of these plans is identified as a recovery element. Hazardous-materials spills are regulated by the Hazardous Materials and Waste Management Division of the Colorado Department of Public Health and Environment; the Hazardous Waste Branch of the Utah Department of Environmental Quality; and the New Mexico Department of Environment.

The need for conservation plans and agreements was identified to provide reasonable assurances that recovered Colorado pikeminnow populations will be maintained. These plans are to be implemented after delisting and are intended to assure that relisting does not become necessary. They would be developed to ensure long-term management and protection of the species, and should include (but not limited to) provision of flows for maintenance of habitat conditions required for all life stages, regulation and/or control of nonnative fishes, minimization of the risk of hazardous-materials spills, and monitoring of populations and habitats. Signed agreements among State agencies, Federal agencies, American Indian tribes, and other interested parties must be in place to implement the conservation plans before delisting can occur.

4.5 Listing Factor (E): Other Natural or Manmade Factors Affecting Its Continued Existence

4.5.1 Pesticides and pollutants

The potential role of pesticides and pollutants in suppressing populations of Colorado pikeminnow is not well understood. Pesticides find their way to the Colorado River from agricultural runoff, and other pollutants in the system include petroleum products, heavy metals (e.g., mercury, lead, zine, copper), nonmetals (i.e., selenium), and radionucleides.

Potential spills of petroleum products threaten wild populations of Colorado pikeminnow. For example, numerous petroleum-product pipelines cross or parallel the Yampa River upstream of Yampa Canyon, most of which lack emergency shut-off valves. One pipe ruptured in the late 1980's releasing refined oil into the Yampa River during the spawning period for Colorado pikeminnow.

All States have hazardous-materials spills emergency-response plans that provide a quick cleanup response to accidental spills (see section 4.4). These responses may not be sufficiently rapid to minimize deleterious effects to fishes, especially a species like the Colorado pikeminnow with site-specific spawning areas. Quick response may, therefore, be inadequate to protect the species and preventive measures must be incorporated into these plans. These preventive measures may include safety shut-off valves on petroleum-products lines in or near the floodplain and filtration systems in case of accidental spills of hazardous materials at bridge crossings above occupied habitats. Identifying and implementing the most reasonable and prudent preventive measures will require a comprehensive review of existing State and Federal hazardous-materials spills emergency-response plans. These preventive measures must be implemented before delisting.

Another cause of degraded water quality is the Atlas Mills tailings pile located on the north bank of the Colorado River near Moab, Utah. In 1998, the Service determined in a final biological opinion that this pile *"...is likely to jeopardize the continued existence of..."* the Colorado pikeminnow and razorback sucker. This biological opinion was withdrawn on February 8, 2001, because of refusal by the Nuclear Regulatory Commission to reinitiate consultation. Section 3405 of the Floyd D. Spence National Defense Authorization Act for Fiscal Year 2001 (P.L. 106-398) requires that the Atlas Mills tailings site be transferred to the Department of Energy for remediation. Congress authorized $300 million for clean-up of the Atlas Mills tailings pile. Remediation is outside of the purview of the UCRRP.

There are two significant threats to endangered fish posed by the Atlas Mills tailings pile. The first is from toxic discharges of pollutants, particularly ammonia, through groundwater to the Colorado River. The second is the risk of catastrophic pile failure, that could bury important nursery areas and destroy other fish habitat. To address the threats posed by the discharge of toxic pollution, whether tailings are reclaimed on site or removed to another location, the groundwater must be cleaned up to the extent necessary to prevent the discharge of ammonia, uranium, and other toxic pollutants into the Colorado River and meet the State of Utah surface-water and groundwater quality standards for fish and wildlife. To assess whether such clean-up has occurred, groundwater-system compliance and measuring points must be established.

Selenium is hypothesized as contributing to the decline of the endangered fishes of the Colorado River Basin (U.S. Fish and Wildlife memorandum, December 22, 1998). It is a water-quality factor that may inhibit recovery by adversely affecting reproduction and recruitment (Hamilton and Wiedmeyer 1990; Stephens et al. 1992; Hamilton and Waddell 1994; Hamilton et al. 1996; Stephens and Waddell 1998; Osmundson et al. 2000a). Selenium concentrations in certain areas of the basin (e.g., Green River near Jensen, Utah; Gunnison River downstream from the Uncompahgre River confluence; and upper Colorado River downstream from Palisade, Colorado) exceed those shown to impact fish and wildlife elsewhere, and, although results are inconclusive as to exposure thresholds that cause specific effects, some studies suggest deleterious effects on Colorado pikeminnow and razorback sucker. The National Irrigation Water Quality Program is addressing selenium issues in the upper basin by implementing remediation projects to reduce selenium levels in areas of critical habitat. The adverse effects of selenium contamination on Colorado pikeminnow reproduction and survival of young will be reevaluated before downlisting and necessary protection will be implemented before delisting.

5.0 RECOVERY GOALS

The following are site-specific management actions and objective, measurable recovery criteria for the Colorado pikeminnow presented for the Upper Colorado River Basin (including the Green River, upper Colorado River, and San Juan River subbasins). The need for self-sustaining populations in the lower basin and associated site-specific management actions/tasks necessary to minimize or remove threats will be reevaluated at the status review of the species. The Colorado pikeminnow was listed prior to the 1996 DPS policy, and the Service may conduct an evaluation to designate DPSs in a future rule-making process if, in the future, lower basin populations are determined necessary for recovery. Provisional site-specific management actions/tasks and objective, measurable recovery criteria for the lower basin are presented in Appendix B as guidelines for conservation efforts (e.g., nonessential, experimental populations; see section 3.1.2).

Steps for downlisting and delisting presented in this section are consistent with provisions specified under Section 4(a)(1), Section 4(b), Section 4(c)(2)(B), and Section 4(f)(1) of the ESA (see section 2.0 of this document). The five recovery factors (i.e., Factor A, Factor B, etc.) were derived from the five listing factors (see section 2.1) and state the conditions under which threats are minimized or removed. For each recovery factor, management actions and tasks are identified that minimize or remove threats to the Colorado pikeminnow. Under objective, measurable recovery criteria, demographic criteria and recovery factor criteria are presented for downlisting and delisting. Generally, for each downlisting criterion there is a corresponding delisting criterion. Reclassification can be considered when appropriate recovery criteria are met.

5.1 Requirements and Uncertainties Associated with Recovery Goals

5.1.1 Demographic criteria and monitoring

Demographic criteria that describe numbers of subbasin populations and individuals (adults and juveniles) for downlisting and delisting are presented for the Upper Colorado River Basin. These criteria specify maintenance of a metapopulation, based on requirements of no significant decline in numbers of adults for each population and recruitment equal to or exceeding adult mortality. To maintain the metapopulation, these criteria require a genetically and demographically viable, self-sustaining population in the Green River subbasin; and self-sustaining populations that meet or exceed estimated carrying capacity either in only the upper Colorado River subbasin, or in both the upper Colorado River subbasin and San Juan River subbasin.

Wild populations of Colorado pikeminnow have been studied since the 1960's, and population dynamics and responses to management actions have been evaluated since the early 1980's. A 5-year monitoring period is required for downlisting, and a 7-year monitoring period beyond downlisting is required for delisting. The downlist monitoring period begins with the first reliable estimates for all populations acceptable to the Service. The downlist and delist monitoring periods are expected to be continuous, and reclassification cannot be considered until each population has been monitored for the required period of time. The total 12-year monitoring period is equivalent to approximately one generation time for Colorado pikeminnow, and is considered sufficient to determine if populations are stable, increasing, or decreasing. Generation time is equal to the mean adult age and is computed as the average age of attaining sexual maturity; i.e., $age_{sex\ maturity}$ plus (1/d), where d is equal to death rate (Seber 1982; Gilpin 1993). For Colorado pikeminnow, the age of attaining sexual maturity is 5 years and the adult survival rate is 0.85 (d=1-0.85); hence, generation time is 5 + [1/(1-0.85)] = 5 + 7 = 12. It is important to note that under Section 4(g)(1) of the ESA, *"The Secretary shall implement a system in cooperation with the States to monitor effectively for not less than five years the status of all species which have recovered to the point at which the measures provided pursuant to this Act are no longer necessary..."*. Hence, populations would be monitored for at least 5 additional years after delisting.

The Service considers a reliable estimate as one that is based on a multiple mark-recapture model. Direct enumeration of fish populations is not feasible in turbid rivers, and removal estimates are unreliable because of the difficulty of blocking reaches of large rivers to meet the model assumption of no migration. Instead, closed-population, multiple mark-recapture estimators (Otis et al. 1978; Burnham et al. 1987; Chao 1989; Osmundson and Burnham 1998) are recommended for deriving population point estimates and to guide development of sampling designs that conform to these models. The accuracy and precision of each point estimate will be assessed by the Service in cooperation with the respective recovery or conservation programs, and in consultation with investigators conducting the point estimates and with qualified statisticians and population ecologists. If, for example, an estimate is made that is considered unreliable (i.e., lacks precision and accuracy) because of poor sampling conditions or other causes, a determination will be made if an additional estimate is needed in the following year in order to accurately assess if downlisting or delisting criteria are met. Field sampling methodologies should be developed and refined to attain a balance between the need for accurate and precise population estimates while minimizing stress to fish from excessive handling.

Monitoring must be designed to determine if the demographic criteria are being met. At least three point estimates are needed for each of the Colorado pikeminnow populations to downlist, and at least five more estimates are needed to delist. Point estimates should be made in each of 3 consecutive years with 1–2 years between blocks of estimates. In order to ensure no net loss in each population, the trend in adult (age 7+; ≥450 mm TL; see section A.8) point estimates cannot decline significantly; i.e., slope is not significantly less than zero over the trend period ($p \leq 0.05$), requiring that the population is either stable or increasing during the monitoring period. Also, mean estimated recruitment of age-6 (400–449 mm TL; see section A.8) naturally produced fish in each population must equal or exceed mean annual adult mortality (i.e., ≥15%). This criterion requires that each population is reproducing, recruiting, and self-sustaining. To meet the requirement of a genetically and demographically viable, self-sustaining population in the Green River subbasin, each population point estimate must exceed 2,600 adults (MVP; see section 3.3.2). In addition to the demographic criteria, adequate habitat and sufficient range are required to support recovered populations. Recovery goals require maintenance of populations within areas of designated critical habitat (59 FR 13374).

5.1.2 Recovery factor criteria

The recovery factor criteria are directly linked to management actions/tasks. Recovery factor criteria for downlisting generally call for identification, implementation, evaluation, and revision of management tasks. Corresponding criteria for delisting call for attainment of necessary and feasible levels of protection that minimize or remove threats.

Each of the four threats identified in section 4.0 (i.e., streamflow regulation, habitat modification, competition with and predation by nonnative fishes, and pesticides and pollutants) is addressed in this section with appropriate management actions/tasks. Details of these and other management actions/tasks that contribute to recovery are or will be identified in the RIPRAP of the UCRRP and Annual Work Plan of the SJRRIP. These programs function under the general principles of adaptive management, and the plans are periodically revised. In the context of these programs, adaptive management is the process by which management actions are identified, implemented, evaluated, and revised based on results of research and monitoring.

Providing and legally protecting habitat are necessary elements in recovery of the Colorado pikeminnow. Habitat as used in these recovery goals is defined as the physical and biological components of the environment required for recovery of the species, including flow regimes necessary to restore and maintain those environmental conditions. Hence, identification, implementation, evaluation, and revision of adequate flow regimes through adaptive management are identified as criteria necessary for downlisting. By the time of delisting, flows (as well other habitat components) identified as necessary to the life history of the species must be provided and legally protected through various means, including instream-flow appropriations, legal agreements, contracts, operating criteria, and/or other means. As stated in the governing documents of the UCRRP and the SJRRIP, under these programs legal protection of flows referenced in these recovery goals for upper basin rivers and the San Juan River will be consistent with State and Federal laws related to the Colorado River system (sometimes referred to as "Law of the River"), including State water law, interstate compacts, and Federal trust responsibilities to American Indian tribes. It is recognized that flow management alone is not sufficient to ensure self-sustaining populations of the endangered fishes, and that a combination of flow and non-flow management actions will be necessary for recovery. It is anticipated that flow management actions identified in these recovery goals can be achieved in balance with non-flow management actions to improve ecosystem conditions and enhance recovery and sustainability of the endangered fish populations. Population and demographic data collected through monitoring will be used to track progress toward meeting the habitat needs of the species.

Implementation of conservation plans is required in order to provide for the long-term management and protection of Colorado pikeminnow populations after delisting. These conservation plans will be developed and implemented through agreements among State agencies, Federal agencies, American Indian tribes, and other interested parties, and may include (but are not limited to) provision of flows for maintenance of habitat conditions required for all life stages, regulation and/or control of nonnative fishes, minimization of the risk of hazardous-materials spills, and monitoring of populations and habitats.

Use of hatchery fish (progeny of cultured broodstock) may be necessary to expand or augment existing populations of Colorado pikeminnow. Provisions and recommendations of the UCRRP Genetics Management Plan (Czapla 1999) and the Policy Regarding Controlled Propagation of Species Listed Under the Endangered Species Act (65 FR 56916) should be used as guidelines for use of hatchery fish in recovery. The UCRRP is revising a facilities-needs plan based on revised State stocking plans.

5.1.3 Uncertainties

These recovery goals are based on the best available scientific information, and are structured to attain a balance between reasonably achievable criteria (which include an acceptable level of uncertainty) and ensuring the viability of the species beyond delisting. It is expected that research, management, and monitoring activities directed by the UCRRP and SJRRIP will fill information gaps and considerably narrow, if not eliminate, many of the uncertainties that affect recovery criteria. Additional data and improved understanding of Colorado pikeminnow biology may prompt future revision of these recovery goals. The Service intends to review, and revise as needed, these recovery goals at least once every 5 years from the date of their publication in the *Federal Register*, or as necessary when sufficient new information warrants a change in the recovery criteria. Review of these recovery goals will be part of the review of listed species as required by Section 4(c)(2)(A) of the ESA, *"The Secretary shall ... conduct, at least once every five years, a review of all species..."*. Uncertainties associated with these recovery goals include:

- Demographic Viability. The level of exchange of individuals between the San Juan River and populations in the Green River and upper Colorado River subbasins is unknown.
- Carrying Capacity. Inferences about carrying capacity for some Colorado pikeminnow populations have been largely drawn from recent population estimates, information on condition factor and forage base, and analyses of thermal regimes. However, the information is preliminary and hypotheses associated with carrying capacity have yet to be fully tested.
- Genetic Viability. Although determination of genetic effective population size (N_e) was based on principles in conservation genetics (i.e., "50/500 rule"), genetic information on Colorado pikeminnow was insufficient to derive a species-specific value of N_e and a ratio of N_e/N_g.
- Flow and Temperature Recommendations. Flow and temperature recommendations have been developed that specifically consider flow-habitat relationships in habitats occupied by Colorado pikeminnow. However, it is uncertain to what extent these recommendations can be met and what flow regimes will be necessary to meet the life history needs of the Colorado pikeminnow. Streamflow reduction and modification from dams and water withdrawal systems have reduced spatial and temporal variability in flow regimes, reduced available habitat, and changed ecosystem function and structure. A paradigm in river management suggests that the ecological integrity of river ecosystems is linked to their natural dynamic character (Stanford et al. 1996; Poff et al. 1997), and restoring a more natural flow regime is the cornerstone of river restoration. This paradigm and the response by endangered fishes of the Colorado River Basin is largely untested, and as these flow regimes to benefit the endangered fishes are implemented, it is important to be aware of associated uncertainties and plan for management of unanticipated results. Response of Colorado pikeminnow to flows will need to be monitored in order to identify and provide flow regimes that are necessary to restore and maintain adequate habitat and sufficient range for all life stages.
- Nonnative Fish Response. Uncertainty exists regarding the responses of nonnative fishes to active control measures and to flow regimes to benefit the endangered fishes. Many of these nonnative fishes, both warm-water and cold-water, prey on and compete with native fishes. There are indications that high spring flows have a negative effect on nonnative fishes, but the overall response of nonnative fish populations to flow recommendations is uncertain. Long-term response by nonnative fishes to mechanical removal is also an uncertainty. It is unknown if reduction in numbers of nonnatives will result in lower population numbers, altered age structure, or opening of niches for new or existing nonnative fishes. It is also unknown if reduction in nonnative fishes will result in increased numbers of native fishes.

- Efficacy of Monitoring Programs. The precision and reliability of long-term monitoring programs to accurately measure the response of Colorado pikeminnow populations to management actions is an uncertainty. Mark-recapture population estimates may reflect high variability because of population variability and/or sampling variability. This variability in estimates may exceed the level of population response to a management action, masking measurement of short-term responses and cause-effect relationships. Demographic criteria proposed in this document attempt to account for this variability and set numbers that are measurable under current conditions.
- Establishing Self-Sustaining Populations. Hatchery fish may be used to expand or augment existing populations. The survival, recruitment, and reproductive success of these fish in the wild is uncertain. This uncertainty is greater in rivers or river reaches that have been extensively modified.
- Response to Management Actions. Management actions, such as regulation of escapement of nonnative fishes, control of nonnative fishes, and minimization of the risk of hazardous-materials spills, may vary in their effectiveness to benefit Colorado pikeminnow. Tasks and recovery criteria associated with each of these management actions are intended to provide some measure of success before reclassification can occur.

5.2 Site-Specific Management Actions and Tasks by Recovery Factor

5.2.1 Factor A.—Adequate habitat and range for recovered populations provided

Management Action A-1.—Provide flows necessary for all life stages of Colorado pikeminnow to support recovered populations, based on demographic criteria.

Task A-1.1.—Identify, implement, evaluate, and revise (as necessary through adaptive management) flow regimes to benefit Colorado pikeminnow populations in the Green River, upper Colorado River, and San Juan River subbasins (see section 4.1 for discussion of existing flow recommendations to benefit the endangered fishes and for discussion of Colorado pikeminnow flow-habitat requirements; see Appendix A for a synopsis of Colorado pikeminnow life history).

Task A-1.2.—Provide flow regimes (as determined under Task A-1.1) that are necessary for all life stages of Colorado pikeminnow to support recovered populations in the Green River, upper Colorado River, and San Juan River subbasins.

Management Action A-2.—Provide passage for Colorado pikeminnow within occupied habitat to allow adequate movement and, potentially, range expansion.

Task A-2.1.—Continue to provide fish passage over Redlands Diversion and Grand Valley Diversion to allow adequate movement of Colorado pikeminnow in the upper Colorado River and Gunnison River (see section 4.1 for a discussion on barriers to fish passage).

Task A-2.2.—Modify Price-Stubb Dam and Government Highline Dam to allow adequate movement of Colorado pikeminnow in the upper Colorado River.

Task A-2.3.—Identify, evaluate, and modify (as necessary) barriers on the San Juan River (e.g., Cudei Diversion and Hogback Diversion) to allow adequate movement of Colorado pikeminnow.

Management Action A-3.—Investigate options for providing appropriate water temperatures in the Gunnison River that would allow for range expansion of Colorado pikeminnow.

Task A-3.1.—Investigate the feasibility of modifying releases from Aspinall Unit dams to increase water temperatures in the Gunnison River that would allow for upstream range expansion of Colorado pikeminnow in the Gunnison River (see section 4.1 for discussion on warm-water releases).

Task A-3.2.—Modify releases from Aspinall Unit dams to increase water temperatures in the Gunnison River, if determined feasible and necessary to achieve demographic criteria for the upper Colorado River subbasin (see section 5.3.2.1.2).

Management Action A-4.—Minimize entrainment of subadult and adult Colorado pikeminnow in diversion canals.

Task A-4.1.—Identify measures (e.g., screens, baffles) to minimize entrainment of subadult and adult Colorado pikeminnow at problematic diversion structures, such as the Green River Canal, Grand Valley Irrigation Canal, Government Highline Diversion Project, and the Redlands Canal Company Diversion (see section 4.1 for discussion on entrainment).

Task A-4.2.—Install devices and/or implement other measures (as determined under Task A-4.1) to minimize entrainment.

5.2.2 Factor B.—Protection from overutilization for commercial, recreational, scientific, or educational purposes

Management Action B-1.—Protect Colorado pikeminnow populations from overutilization for commercial, recreational, scientific, or educational purposes.

Task B-1.1.—Reevaluate and, if necessary, identify actions to ensure adequate protection from overutilization of Colorado pikeminnow for commercial, recreational, scientific, or educational purposes; not currently identified as an existing threat (see section 4.2).

Task B-1.2.—Implement identified actions (as determined under Task B-1.1) to ensure adequate protection of Colorado pikeminnow populations from overutilization for commercial, recreational, scientific, or educational purposes.

5.2.3 Factor C.—Adequate protection from diseases and predation

Management Action C-1.—Minimize adverse effects of diseases and parasites on Colorado pikeminnow populations.

Task C-1.1.—Reevaluate and, if necessary, identify actions to minimize adverse effects of diseases and parasites on Colorado pikeminnow populations; not currently identified as an existing threat (see sections 4.3.1 and A.11 for discussion of diseases and parasites).

Task C-1.2.—Implement identified actions (as determined under Task C-1.1) to ensure adequate protection of Colorado pikeminnow populations from deleterious diseases and parasites.

Management Action C-2.—Regulate nonnative fish releases and escapement into the main river, floodplain, and tributaries.

Task C-2.1.—Develop, implement, evaluate, and revise (as necessary through adaptive management) procedures for stocking nonnative fish species in the Upper Colorado River Basin (including the San Juan River subbasin) to minimize negative interactions between nonnative fishes and Colorado pikeminnow (see sections 4.3.2 and A.7 for discussion of effects of nonnative fishes).

Task C-2.2.—Finalize and implement procedures (as determined under Task C-2.1) for stocking nonnative fish species in the Upper Colorado River Basin to minimize negative interactions between nonnative fishes and Colorado pikeminnow.

Management Action C-3.—Control problematic nonnative fishes as needed.

Task C-3.1.—Develop control programs for small-bodied nonnative fishes (e.g., cyprinids and centrarchids) in backwater nursery habitats in river reaches occupied by young Colorado pikeminnow to identify levels of control that will minimize negative interactions (e.g., competition and predation; see sections 4.3.2 and A.7 discussion of effects of nonnative fishes).

Task C-3.2.—Implement identified levels (as determined under Task C-3.1) of nonnative fish control in backwater nursery habitats in river reaches occupied by young Colorado pikeminnow.

Task C-3.3.—Develop channel catfish control programs in river reaches occupied by Colorado pikeminnow to identify levels of control that will minimize negative interactions.

Task C-3.4.—Implement identified levels (as determined under Task C-3.3) of channel catfish control in river reaches occupied by Colorado pikeminnow.

Task C-3.5.—Develop northern pike control programs in reaches of the Yampa and middle Green rivers occupied by Colorado pikeminnow to identify levels of control that will minimize negative interactions.

Task C-3.6.—Implement identified levels (as determined under Task C-3.5) of northern pike control in reaches of the Yampa and middle Green rivers occupied by Colorado pikeminnow.

5.2.4 Factor D.—Adequate existing regulatory mechanisms

Management Action D-1.—Legally protect habitat (see definition of habitat in section 5.1.2) necessary to provide adequate habitat and sufficient range for all life stages of Colorado pikeminnow to support recovered populations, based on demographic criteria.

Task D-1.1.—Determine mechanisms for legal protection of adequate habitat through instream-flow rights, contracts, agreements, or other means (see section 4.4 for discussion of regulatory mechanisms).

Task D-1.2.—Implement mechanisms for legal protection of habitat (as determined under Task D-1.1) that are necessary to provide adequate habitat and sufficient range for all life stages of Colorado pikeminnow to support recovered populations.

Management Action D-2.—Provide for the long-term management and protection of Colorado pikeminnow populations and their habitats.

Task D-2.1.—Identify elements needed for the development of conservation plans that are necessary to provide for the long-term management and protection of Colorado pikeminnow populations; elements of these plans may include (but are not limited to) provision of flows for maintenance of adequate habitat conditions for all life stages of Colorado pikeminnow, regulation and/or control of nonnative fishes, minimization of the risk of hazardous-materials spills, and monitoring of populations and habitats (see section 4.4 for discussion of need for conservation plans).

Task D-2.2.—Develop and implement conservation plans and execute agreements among State agencies, Federal agencies, American Indian tribes, and other interested parties to provide reasonable assurances that conditions needed for recovered Colorado pikeminnow populations will be maintained.

5.2.5 Factor E.—Other natural or manmade factors for which protection has been provided

Management Action E-1.—Minimize the risk of hazardous-materials spills in critical habitat.

Task E-1.1.—Review and recommend modifications to State and Federal hazardous-materials spills emergency-response plans to ensure adequate protection for Colorado pikeminnow populations from hazardous-materials spills, including prevention and quick response to hazardous-materials spills (see section 4.5.1 for discussion of hazardous-materials spills).

Task E-1.2.—Implement State and Federal emergency-response plans that contain the necessary preventive measures (as determined under Task E-1.1) for hazardous-materials spills.

Task E-1.3.—Identify locations of all petroleum-product pipelines within the 100-year floodplain of critical habitat and assess the need for emergency shut-off valves to minimize the potential for spills.

Task E-1.4.—Install emergency shut-off valves (as determined under Task E-1.3) on problematic petroleum-product pipelines within the 100-year floodplain of critical habitat.

Management Action E-2.—Minimize threats from degraded water quality on Colorado pikeminnow.

Task E-2.1.—Identify actions to remediate groundwater contamination from the Atlas Mills tailings pile located near Moab, Utah, in order to restore water quality of the Colorado River in the vicinity of the pile in accordance with the State of Utah and Environmental Protection Agency (EPA) water-quality standards for fish and wildlife (see section 4.5.1 for discussion of groundwater contamination).

Task E-2.2.—Implement actions (as determined under Task E-2.1) to remediate groundwater contamination from the Atlas Mills tailings pile.

Management Action E-3.—Minimize adverse effects of selenium contamination on Colorado pikeminnow reproductive success and survival of young and reduce deleterious levels of selenium contamination, if necessary.

Task E-3.1.—Reevaluate the effects of selenium contamination on Colorado pikeminnow reproductive success and survival of young, and, if necessary, identify actions to reduce deleterious levels of selenium contamination (see section 4.5.1 for discussion of selenium effects).

Task E-3.2.—Implement identified actions (as determined under Task E-3.1) to reduce deleterious levels of selenium contamination.

5.3 Objective, Measurable Recovery Criteria

5.3.1 Downlist criteria

5.3.1.1 Demographic criteria for downlisting (population demographics in all subbasins must be met in order to achieve downlisting)

5.3.1.1.1 Green River Subbasin

1. A self-sustaining population is maintained over a 5-year period, starting with the first point estimates acceptable to the Service, such that:

    a. the trends in separate adult (age 7+; ≥450 mm TL) point estimates for the middle Green River and the lower Green River do not decline significantly, and

    b. mean estimated recruitment of age-6 (400–449 mm TL) naturally produced fish equals or exceeds mean annual adult mortality for the Green River subbasin, and

c. each population point estimate for the Green River subbasin exceeds 2,600 adults (Note: 2,600 adults is the estimated MVP number; see section 3.3.2).

5.3.1.1.2 Upper Colorado River Subbasin

1. A self-sustaining population of at least 700 adults (number based on inferences about carrying capacity) is maintained over a 5-year period, starting with the first point estimate acceptable to the Service, such that:

    a. the trend in adult (age 7+; ≥450 mm TL) point estimates does not decline significantly, and

    b. mean estimated recruitment of age-6 (400–449 mm TL) naturally produced fish equals or exceeds mean annual adult mortality.

5.3.1.1.3 San Juan River Subbasin

1. A target of 1,000 age-5+ fish (≥300 mm TL; number based on estimated survival of stocked fish and inferences about carrying capacity) is established through augmentation and/or natural reproduction.

5.3.1.2 Recovery factor criteria for downlisting

Factor A.—Adequate habitat and range for recovered populations provided.

1. Flow regimes to benefit Colorado pikeminnow populations in the Green River, upper Colorado River, and San Juan River subbasins identified, implemented, evaluated, and revised (Task A-1.1), such that:

    a. Adequate spawning habitat and appropriate spawning cues (e.g., flow patterns and water temperatures) are available to maintain self-sustaining populations, as reflected by downlisting demographic criteria in section 5.3.1.1.

    b. Adequate nursery habitat is available to maintain self-sustaining populations, as reflected by downlisting demographic criteria in section 5.3.1.1.

    c. Adequate juvenile and adult habitat (e.g., cover, resting, and feeding areas) is available to maintain self-sustaining populations, as reflected by downlisting demographic criteria in section 5.3.1.1.

2. Passage over Redlands Diversion and Grand Valley Diversion continued to allow adequate movement of Colorado pikeminnow in the upper Colorado River and Gunnison River (Task A-2.1).

3. Modification of Price-Stubb Dam and Government Highline Dam initiated to allow adequate movement of Colorado pikeminnow in the upper Colorado River (Task A-2.2).

4. Barriers on the San Juan River identified and evaluated, and modifications initiated to allow adequate movement of Colorado pikeminnow (Task A-2.3).

5. Investigations initiated on the feasibility of modifying releases from Aspinall Unit dams to increase water temperatures in the Gunnison River that would allow for upstream range expansion of Colorado pikeminnow (Task A-3.1).

6. Measures identified to minimize entrainment of subadult and adult Colorado pikeminnow at problematic diversion structures (Task A-4.1).

Factor B.—Protection from overutilization for commercial, recreational, scientific, or educational purposes.

7. Overutilization of Colorado pikeminnow for commercial, recreational, scientific, or educational purposes reevaluated and, if necessary, actions identified to ensure adequate protection (Task B-1.1).

Factor C.—Adequate protection from diseases and predation.

8. Effects of diseases and parasites on Colorado pikeminnow populations reevaluated and, if necessary, actions identified to ensure adequate protection (Task C-1.1).

9. Procedures developed, implemented, evaluated, and revised for stocking nonnative fish species in the Upper Colorado River Basin (including the San Juan River subbasin) to minimize negative interactions between nonnative fishes and Colorado pikeminnow (Task C-2.1).

10. Control programs for small-bodied nonnative fishes in backwater nursery habitats in river reaches occupied by young Colorado pikeminnow developed and implemented to identify levels of control that will minimize negative interactions (Task C-3.1).

11. Channel catfish control programs in river reaches occupied by Colorado pikeminnow developed and implemented to identify levels of control that will minimize negative interactions (Task C-3.3).

12. Northern pike control programs in reaches of the Yampa and middle Green rivers occupied by Colorado pikeminnow developed and implemented to identify levels of control that will minimize negative interactions (Task C-3.5).

Factor D.—Adequate existing regulatory mechanisms.

13. Mechanisms determined for legal protection of adequate habitat (Task D-1.1).

14. Elements of conservation plans identified that are necessary to provide for the long-term management and protection of Colorado pikeminnow populations (Task D-2.1).

Factor E.—Other natural or manmade factors for which protection has been provided.

15. State and Federal hazardous-materials spills emergency-response plans reviewed and modified to ensure adequate protection for Colorado pikeminnow populations from hazardous-materials spills (Task E-1.1).

16. Locations of all petroleum-product pipelines within the 100-year floodplain of critical habitat identified and the need for emergency shut-off valves assessed (Task E-1.3).

17. Actions identified for remediation of groundwater contamination at the Atlas Mills tailings pile located near Moab, Utah (Task E-2.1).

18. Effects of selenium contamination on Colorado pikeminnow reproductive success and survival of young reevaluated and, if necessary, actions identified to reduce deleterious levels of selenium contamination (Task E-3.1).

5.3.2 Delist criteria

5.3.2.1 Demographic criteria for delisting (population demographics in all subbasins must be met in order to achieve delisting)

5.3.2.1.1 Green River Subbasin

1. A self-sustaining population is maintained over a 7-year period beyond downlisting, starting with the first point estimates acceptable to the Service, such that:

    a. the trends in separate adult (age 7+; ≥450 mm TL) point estimates for the middle Green River and the lower Green River do not decline significantly, and

    b. mean estimated recruitment of age-6 (400–449 mm TL) naturally produced fish equals or exceeds mean annual adult mortality for the Green River subbasin, and

    c. each population point estimate for the Green River subbasin exceeds 2,600 adults (MVP).

5.3.2.1.2 Upper Colorado River and San Juan River Subbasins

1. One of the following must be met over a 7-year period beyond downlisting, starting with the first point estimate acceptable to the Service:

    A self-sustaining population that exceeds 1,000 adults (age 7+; ≥450 mm TL) is maintained in the upper Colorado River subbasin **OR** a self-sustaining population that exceeds 700 adults is maintained in the upper Colorado River subbasin and a self-sustaining population that exceeds 800 adults is maintained in the San Juan River subbasin, such that for each population (numbers of adults based on inferences about carrying capacity):

    a. the trend in adult point estimates does not decline significantly, and

    b. mean estimated recruitment of age-6 (400–449 mm TL) naturally produced fish equals or exceeds mean annual adult mortality.

5.3.2.2 Recovery factor criteria for delisting

Factor A.—Adequate habitat and range for recovered populations provided.

1. Flow regimes provided that are necessary for all life stages of Colorado pikeminnow to support recovered populations in the upper Colorado River, Green River, and San Juan River subbasins (Task A-1.2), such that:

   a. Adequate spawning habitat and appropriate spawning cues (e.g., flow patterns and water temperatures) are available to maintain self-sustaining populations, as reflected by delisting demographic criteria in section 5.3.2.1.

   b. Adequate nursery habitat is available to maintain self-sustaining populations, as reflected by delisting demographic criteria in section 5.3.2.1.

   c. Adequate juvenile and adult habitat (e.g., cover, resting, and feeding areas) is available to maintain self-sustaining populations, as reflected by delisting demographic criteria in section 5.3.2.1.

2. Passage over Redlands Diversion and Grand Valley Diversion continued to allow adequate movement of Colorado pikeminnow in the upper Colorado River and Gunnison River (Task A-2.1).

3. Modification of Price-Stubb Dam and Government Highline Dam completed to allow adequate movement of Colorado pikeminnow in the upper Colorado River (Task A-2.2).

4. Barriers on the San Juan River modified to allow adequate movement of Colorado pikeminnow (Task A-2.3).

5. Releases from Aspinall Unit dams to increase water temperatures in the Gunnison River are modified, if determined feasible and necessary to achieve demographic criteria for the upper Colorado River subbasin (see section 5.3.2.1.2) to allow for upstream range expansion of Colorado pikeminnow (Task A-3.2).

6. Devices installed and/or measures implemented at problematic diversion structures to minimize entrainment of subadult and adult Colorado pikeminnow (Task A-4.2).

Factor B.—Protection from overutilization for commercial, recreational, scientific, or educational purposes.

7. Adequate protection of Colorado pikeminnow populations from overutilization for commercial, recreational, scientific, or educational purposes attained (Task B-1.2).

Factor C.—Adequate protection from diseases and predation.

8. Adequate protection of Colorado pikeminnow populations from deleterious diseases and parasites attained (Task C-1.2).

9. Procedures finalized and implemented for stocking nonnative fish species in the Upper Colorado River Basin to minimize negative interactions between nonnative fishes and Colorado pikeminnow (Task C-2.2).

10. Identified levels of nonnative fish control to minimize negative interactions attained in backwater nursery habitats in river reaches occupied by young Colorado pikeminnow (Task C-3.2).

11. Identified levels of channel catfish control to minimize negative interactions attained in river reaches occupied by Colorado pikeminnow (Task C-3.4).

12. Identified levels of northern pike control to minimize negative interactions attained in reaches of the Yampa and middle Green rivers occupied by Colorado pikeminnow (Task C-3.6).

Factor D.—Adequate existing regulatory mechanisms.

13. Habitat necessary to provide adequate habitat and sufficient range for all life stages of Colorado pikeminnow to support recovered populations in the Green River, upper Colorado River, and San Juan River subbasins is legally protected in perpetuity (Task D-1.2).

14. Conservation plans developed and implemented, and agreements among State agencies, Federal agencies, American Indian tribes, and other interested parties executed to provide reasonable assurances that conditions needed for recovered Colorado pikeminnow populations will be maintained (Task D-2.2).

Factor E.—Other natural or manmade factors for which protection has been provided.

15. State and Federal emergency-response plans implemented that contain the necessary preventive measures for hazardous-materials spills (Task E-1.2).

16. Emergency shut-off valves installed on all problematic petroleum-product pipelines within the 100-year floodplain of critical habitat (Task E-1.4).

17. Groundwater contamination remediated at the Atlas Mills tailings pile located near Moab, Utah, and water quality of the Colorado River in the vicinity of the pile restored in compliance with the State of Utah and EPA water-quality standards for fish and wildlife (Task E-2.2).

18. Deleterious levels of selenium contamination reduced to minimize adverse effects on Colorado pikeminnow reproductive success and survival of young (Task E-3.2).

5.4 Estimated Time to Achieve Recovery of the Colorado Pikeminnow

Estimated time to achieve recovery of the Colorado pikeminnow is 5 years for downlisting and an additional 7 years for delisting. First point estimates were completed for all populations in 2001. The Service is reviewing those estimates for reliability, and, if they are accepted by the Service and all recovery criteria are met, downlisting could be proposed in 2006 and delisting could be proposed in 2013 (Figure 4). This estimated time frame is based on current understanding of the status and trends of populations and on the monitoring time required to meet the downlisting and delisting criteria.

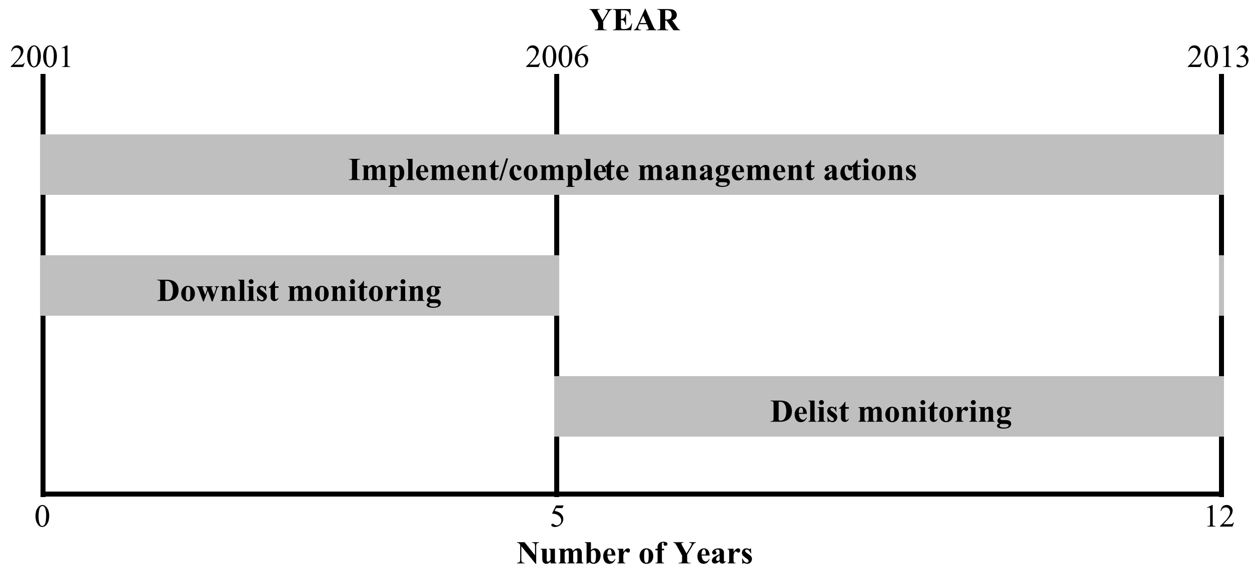

Figure 4. Estimated time to achieve recovery of the Colorado pikeminnow.

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APPENDIX A.

LIFE HISTORY OF THE COLORADO PIKEMINNOW

Following is a synopsis of Colorado pikeminnow life history. This assimilation of information represents an overview of the best scientific information available for the species at this time. Additional and more detailed information can be found in literature cited in this document and in reports and publications referenced in those citations.

A.1 Species Description

The Colorado pikeminnow is the largest member of the minnow family (Cyprinidae) in North America, with an estimated maximum total length (TL) of about 1.8 m and weight of 36 kg (Miller 1961). These large individuals were reported from the lower basin in the late 1800's and early 1900's. Largest confirmed weights are 12.2 and 15.5 kg in the 1950's from the lower basin (Wallis 1951), and about 11.4 kg in the 1990's from the upper basin (personal communication, T. Chart, U.S. Bureau of Reclamation). The species was known as the “salmon”, “white salmon”, “whitefish” (Evermann and Rutter 1895), and “Colorado River salmon” (Measeles 1981), although it was officially described as the “Colorado squawfish” (Girard (1856). The common name was recently changed to the Colorado pikeminnow (Nelson et al. 1998).

The Colorado pikeminnow is a long, slender, cylindrical fish with silvery sides, greenish back, and creamy-white belly. The tail trunk is thick with a triangular black patch at the base of the caudal fin. The head is large with a terminal mouth and thickened lips and jaws that lack teeth, and a maxillary (upper jaw) that extends past the middle of the eye. Large adults are silvery-white throughout and salmon-like in appearance. Spawning adults in June–August are tinged with light rosy-red on the head and body, with pimple-like tubercles on the head and paired fins. Dorsal and anal fins typically have 9 principal rays each. Scales are small, cycloid, and silvery with 83–87 along the lateral line. Teeth of the pharyngeal arch are spaced apart and barely hooked in a typical pattern of 2,5-4,2 (Girard 1856).

A.2 Distribution and Abundance

The Colorado pikeminnow is endemic to the Colorado River Basin, where it was once widespread and abundant in warm-water rivers and tributaries (Kirsch 1889; Jordan and Evermann 1896; Tyus 1991; Quartarone 1995). It was common in the lower basin in California and Arizona, where it was commercially harvested in the early 1900's (Minckley 1973). Numbers in the lower basin declined in the 1930's (Miller 1961), with few caught in the 1960's (Minckley 1973), and the last specimens reported in the mid-1970's (Moyle 1976; Minckley 1985).

The species was first reported in the upper basin in 1825 by Colonel William H. Ashley (Morgan 1964), and it was common to abundant in the Green and upper Colorado rivers and their tributaries (Banks 1964; Vanicek 1967; Holden and Stalnaker 1975; Seethaler 1978). It was found from Rifle, Colorado, downstream in the mainstem upper Colorado River (Beckman 1963); from Delta, Colorado, downstream on the Gunnison River (Burdick 1995); and from Paradox Valley downstream on the Dolores River (Lynch et al. 1950). In the Green River, it was reported as far upstream as Green River, Wyoming (Ellis 1914; Baxter and Simon 1970); from Craig, Colorado, downstream on the Yampa River; from Rangely, Colorado, downstream and in the White, lower Price, and Duchesne rivers (Tyus and Haines 1991; Cavalli 1999; Muth et al. 2000).

Wild populations of Colorado pikeminnow are found only in the upper basin, and the species currently occupies only about 25% of its historic range basin-wide (Table 1). Occupied habitat occurs in the Green River from Lodore Canyon to the confluence of the Colorado River (Tyus 1991; Bestgen and Crist 2000); the Yampa River downstream of Craig, Colorado (Tyus and Haines 1991); the Little Snake River from its confluence with the Yampa River upstream into Wyoming (Marsh et al. 1991; Wick et al. 1991); the White River downstream of Taylor Draw Dam and Kenney Reservoir (Tyus and Haines 1991); the lower 143 km of the Price River (Cavalli 1999); the lower Duchesne River; the upper Colorado River from Palisade, Colorado, to Lake Powell (Valdez et al. 1982a; Osmundson et al. 1997, 1998); the lower 54 km of the Gunnison River (Valdez et al. 1982b; Burdick 1995); the lower 2 km of the Dolores River (Valdez et al. 1992); and 241 km of the San Juan River downstream from Shiprock, New Mexico, to the Lake Powell inflow (Jordan 1891; Koster 1960; Olson 1962; Propst 1999).

Natural reproduction of Colorado pikeminnow is currently known from the Green, Yampa, upper Colorado, Gunnison, and San Juan rivers. Tyus (1991) and Nesler (2000) estimated an average of about 8,000 adults in the Green River subbasin, for an estimated average of about 14 and 8 adults/km for about 552 and 984 km of river, respectively. Crowl and Bouwes (1998) estimated that 1,000 adults were associated with spawning sites near Three Fords Canyon in Gray Canyon of the lower Green River, and 1,400 adults were associated with spawning sites in the lower 32 km of the Yampa River. Fish associated with the two spawning sites may be demographically independent with individual stock-recruitment characteristics (personal communication, T. Modde, U.S. Fish and Wildlife Service), but overlap in adult and juvenile distributions and panmixis of genetic material suggests the mixing of these two stocks (Ammerman and Morizot 1989; Williamson et al. 1999). Fish in the upper Colorado River subbasin total about 600–900 adults (Nesler 2000; Osmundson 2002) and are believed to spawn near Grand Junction, Colorado, and in the lower Gunnison River (personal communication, C. McAda, U.S. Fish and Wildlife Service). Although fish in the Green and upper Colorado River systems spawn at four primary locales (Tyus 1985, 1991), they are likely linked genetically, based on movement throughout the system and lack of genetic separation (Ammerman and Morizot 1989).

Biochemical genetics (Ammerman and Morizot 1989) showed no differences between fish from the Green and Colorado river systems, suggesting one panmictic upper basin population, with possible exchange occurring through unmarked subadults returning randomly to upstream areas (Gilpin 1993; Osmundson 1999). Heterozygosity of Colorado pikeminnow from the upper basin was roughly 5%, an unusually low diversity due primarily to two polymorphic loci (Ammerman and Morizot 1989). Low heterozygosity may be correlated with delayed first reproduction, low adult mortality, and with K-selected species (Mitton and Lewis 1989), and possibly with fish that return to spawn at their natal sites (Nevo 1978). Approximately 1,500 Carlin-tagged hatchery-reared juvenile Colorado pikeminnow of Green River parentage were released in the Colorado River near Moab, Utah, in February 1980 (Valdez et al. 1982a); small numbers of recaptures during annual sampling indicates that few of these fish survived and were not represented in the genetic analysis.

There are few wild fish remaining in the San Juan River; preliminary estimates range from 19 to 50 adults (Holden 1999; personal communication, D. Ryden, U.S. Fish and Wildlife Service). Over 300,000 hatchery-produced Colorado pikeminnow have been released in the mainstem as part of the San Juan River Basin Recovery Implementation Program (Ryden and Ahlm 1996; Holden 1999; personal communication, F. Pfeifer, U.S. Fish and Wildlife Service).

Over 623,000 Colorado pikeminnow were reintroduced into the Salt and Verde Rivers, Arizona, between 1981 and 1990 (Hendrickson 1994). These reintroductions are considered experimental, nonessential populations, and low survival with no successful reproduction has been documented as a result of these releases (Maddux et al. 1993).

In addition to adults, age-0 fish and juveniles are found in the lower Yampa River, the Green River downstream of the Yampa River confluence; the upper Colorado River downstream of Palisade, Colorado, to Lake Powell, Utah; and the lower 40 km of the Gunnison River. Subadults and small adults have also been found in the lower Price and Duchesne rivers (Cavalli 1999) and the lower White River (Irving and Modde 2000). The Interagency Standardized Monitoring Program (ISMP) of the Upper Colorado River Endangered Fish Recovery Program (McAda et al. 1994a, 1994b, 1995, 1996, 1997) has determined catch-rate indices of age-0 and subadult Colorado pikeminnow in the Green and upper Colorado rivers since 1988. Numbers of age-0 fish and subadults in the other rivers are believed low with no extensive surveys, except for the San Juan River. All data collected under ISMP are catch-rate indices, and there are a few mark-recapture estimates of subadults in backwaters (Haines et al. 1998).

A.3 Habitat

The Colorado pikeminnow is a long-distance migrator; adults move hundreds of kilometers to and from spawning areas, and require long sections of river with unimpeded passage. Adults require pools, deep runs, and eddy habitats maintained by high spring flows. These high spring flows maintain channel and habitat diversity, flush sediments from spawning areas, rejuvenate food production, form gravel and cobble deposits used for spawning, and rejuvenate backwater nursery habitats. Spawning occurs after spring runoff at water temperatures typically between 18 and 23°C. After hatching and emerging from spawning substrate, larvae drift downstream to nursery backwaters that are restructured by high spring flows and maintained by relatively stable base flows. Flow recommendations have been developed that specifically consider flow-habitat relationships in habitats occupied by Colorado pikeminnow in the upper basin, and were designed to enhance habitat complexity and to restore and maintain ecological processes (see section 4.1). The following is a description of observed habitat uses in the Upper Colorado River Basin.

Colorado pikeminnow live in warm-water reaches of the Colorado River mainstem and larger tributaries, and require uninterrupted stream passage for spawning migrations and dispersal of young. The species is adapted to a hydrologic cycle characterized by large spring peaks of snow-melt runoff and low, relatively stable base flows. High spring flows create and maintain in-channel habitats, and reconnect floodplain and riverine habitats, a phenomenon described as the spring flood-pulse (Junk et al. 1989; Johnson et al. 1995). Throughout most of the year, juvenile, subadult, and adult Colorado pikeminnow utilize relatively deep, low-velocity eddies, pools, and runs that occur in nearshore areas of main river channels (Tyus and McAda 1984; Valdez and Masslich 1989; Tyus 1990, 1991; Osmundson et al. 1995; Table A-1). In spring, however, Colorado pikeminnow adults utilize floodplain habitats, flooded tributary mouths, flooded side canyons, and eddies that are available only during high flows (Tyus 1990, 1991; Osmundson et al. 1995). Such environments may be particularly beneficial for Colorado pikeminnow because other riverine fishes gather in floodplain habitats to exploit food and temperature resources, and may serve as prey. Such low-velocity environments also may serve as resting areas for Colorado pikeminnow. River reaches of high habitat complexity appear to be preferred.

Because of their mobility and environmental tolerances, adult Colorado pikeminnow are the most widely distributed life stage. During most of the year, distribution patterns of adults are stable (Tyus 1990, 1991; Irving and Modde 2000), but distribution of adults changes in late spring and early summer, when most mature fish migrate to spawning areas (Tyus and McAda 1984; Tyus 1985, 1990, 1991; Irving and Modde 2000). High spring flows provide an important cue to prepare adults for migration and also ensure that conditions at spawning areas are suitable for reproduction once adults arrive. Specifically, bankfull or much larger floods mobilize coarse sediment to build or reshape cobble bars, and they create side channels that Colorado pikeminnow sometimes use for spawning (Harvey et al. 1993).

Colorado pikeminnow spawning sites in the Green River subbasin have been well documented. The two principal locations are in Yampa Canyon on the lower Yampa River and in Gray Canyon on the lower Green River (Tyus 1990, 1991). These reaches are 42 and 72 km long, respectively, but most spawning is believed to occur at one or two short segments within each of the two reaches. Another spawning area may occur in Desolation Canyon on the lower Green River (Irving and Modde 2000), but the location and importance of this area has not been verified. Although direct observation of Colorado pikeminnow spawning was not possible because of high turbidity, radiotelemetry indicated spawning occurred over cobble-bottomed riffles (Tyus 1990). High spring flows and subsequent post-peak summer flows are important for construction and maintenance of spawning substrates (Harvey et al. 1993). In contrast with the Green River subbasin, where known spawning sites are in canyon-bound reaches, currently suspected spawning sites in the upper Colorado River subbasin are at six locations in meandering, alluvial reaches (McAda 2000).

After hatching and emerging from the spawning substrate, Colorado pikeminnow larvae drift downstream to backwaters in sandy, alluvial regions, where they remain through most of their first year of life (Holden 1977; Tyus and Haines 1991; Muth and Snyder 1995). Backwaters and the physical factors that create them are vital to successful recruitment of early life stages of Colorado pikeminnow, and age-0 Colorado pikeminnow in backwaters have received much

Table A-1. Seasonal frequency (%) of use of macrohabitats in the Grand Valley of the upper Colorado River subbasin by radio-tagged adult Colorado pikeminnow, 1986–1989 (Osmundson et al. 1995). Habitats: FR = fast runs, SR = slow runs, RA = rapids, RI = riffles, ED = eddies, PO = pools, SH = shorelines, BA = backwaters, and GP = off-channel flooded gravel pits.

Months	Habitats								
	FR	SR	RA	RI	ED	PO	SH	BA	GP
April–June (Spring)	3–19	13–32	0–1	0–2	2–9	8–12	3–8	22–42	3–25
July–September (Summer)	7–26	26–55	3–5	3–10	9–16	13–16	0–4	3–7	0–4
October	0	61	0	0	4	26	0	9	0
November–February (Winter)	0	27–41	0	0	0–8	42–62	0	5–15	0
March	4	43	0	0	7	32	0	14	0

research attention (e.g., Tyus and Karp 1989; Haines and Tyus 1990; Tyus 1991; Tyus and Haines 1991; Bestgen et al. 1997). It is important to note that these backwaters are formed after cessation of spring runoff within the active channel and are not floodplain features. Colorado pikeminnow larvae occupy these in-channel backwaters soon after hatching. They tend to occur in backwaters that are large, warm, deep (average, about 0.3 m in the Green River), and turbid (Tyus and Haines 1991). Recent research (Day et al. 1999a, 1999b; Trammell and Chart 1999a, 1999b) has confirmed these preferences and suggested that a particular type of backwater is preferred by Colorado pikeminnow larvae and juveniles. Such backwaters are created when a secondary channel is cut off at the upper end, but remains connected to the river at the downstream end. These chute channels are deep and may persist even when discharge levels change dramatically. An optimal river-reach environment for growth and survival of early life stages of Colorado pikeminnow has warm, relatively stable backwaters, warm river channels, and abundant food (Muth et al. 2000).

A.4 Movement

Young Colorado pikeminnow remain near nursery areas for the first 2–4 years of life, then move upstream to recruit to adult populations and establish home ranges (Osmundson et al. 1998). In the upper Colorado River, distance moved was inversely related to fish size; displacement of fish < 550 mm TL averaged 33.6 km and displacement for fish ≥ 550 mm TL was only 7.5 km (Osmundson et al. 1998). Similar average movement of 31.8 km was observed for 43 radio-tagged adults during fall and spring in the Green River (Archer et al. 1985). Adult Colorado pikeminnow remain in home ranges during fall, winter, and spring and may move considerable distances to and from spawning areas in summer. Individuals move to spawning areas shortly after runoff in early summer, and return to home ranges in August and September (Tyus 1990; Irving and Modde 2000). Round-trip movements of up to 950 km have been reported (Irving and Modde 2000), with some fish "straying" between rivers within the Green River subbasin (Tyus 1985, 1990; Tyus and McAda 1984). Adults may return in consecutive years to overwinter in the same areas (Wick et al. 1981; Valdez and Masslich 1989).

A.5 Reproduction

The Colorado pikeminnow is an obligate warm-water species that requires relatively warm temperatures for spawning, egg incubation, and survival of young. Hatchery-reared males became sexually mature at 4 years of age and females at 5 years. Average fecundity of 24, 9-year old females was 77,400 (range, 57,766–113,341) or 55,533 eggs/kg, and average fecundity of 9 ten-year old females was 66,185 (range, 11,977–91,040) or 45,451 eggs/kg (Hamman 1986). Average-sized Colorado pikeminnow in the upper basin are 450–550 mm TL and weigh 1–2 kg. The information on sex ratio is highly variable because most observations were made from field sampling during a short interval of the total spawning event; high turbidity precludes direct observation of spawners and fish are captured with trammel nets over spawning bars. Male to female ratios reported from catches over spawning bars are 9:1 (Holden and Stalnaker 1975), 13.85:1 (Tyus 1990), and 5.6:1 (Seethaler 1978). Ratios of active males to females visually observed spawning naturally under hatchery conditions are 2:1 (Hamman 1980), and 2–3:1 (Hamman 1981, 1986). It is believed that the ratios observed under hatchery conditions more accurately reflect conditions in the wild that were not observed or reported by other investigators because sampling on spawning grounds may reflect a relatively common set of males remaining on the spawning area to service a number of transient females; hence, sampling at any one time would bias the sex ratio highly in favor of males.

Spawning activity begins after the peak of spring runoff during June–August at water temperatures typically 16°C or higher (Vanicek and Kramer 1969; Hamman 1981; McAda 2000; Muth et al. 2000). In the lower Yampa River, reproduction was initiated within days of mean daily water temperature exceeding 18°C, with water temperature at initiation ranging 16.0–22.3°C on the Yampa River and 19.8–23.0°C on the lower Green River (Bestgen et al. 1998). Colorado pikeminnow are broadcast spawners that scatter adhesive eggs over cobble substrate which incubate in interstitial spaces. Hatching success is greatest at 20–24°C with incubation time of 90–121 h (Hamman 1981; Marsh 1985). Newly hatched larvae are 6.0–7.5 mm long (Hamman 1981), which emerge from spawning cobbles 3–15 days after hatching and drift predominantly as protolarvae (Haynes et al. 1984; Nesler et al. 1988). Larvae hatched in the lower Yampa River may drift 50–120 miles downstream to nursery backwaters.

High densities of age-0 Colorado pikeminnow have been found downstream of the confluence of the Green and Colorado rivers and in the Lake Powell inflow (Valdez 1990), suggesting that fish from both systems are transferred passively or move actively downstream into these regions. Osmundson et al. (1998) showed that subadult Colorado pikeminnow in the Colorado River move back upstream as they mature. Gilpin (1993) hypothesized that this upstream return by subadults provides connectivity and gene flow between the Green and Colorado rivers, resulting in a panmictic population for the entire upper basin with evidence of source/sink dynamics. Marked fish have been recaptured to substantiate exchange of Colorado pikeminnow between the

Green and Colorado rivers, thus supporting the hypothesis of panmixis (personal communication, C. McAda, U.S. Fish and Wildlife Service).

A.6 Survival

Survival and recruitment of Colorado pikeminnow is pulsed, as a strong year class appears and is reflected in the size composition of the population over time. This "storage effect" (Gilpin 1993) enables long-lived populations to maintain themselves despite several years of failed or low reproductive success. Greatest cohort strength in the upper Colorado River (i.e., 1986, 1996) and in the Green River (1986, 1988, 1991; McAda et al. 1998) occurred 1–2 years after high river flows. High to moderate flows rework sediment deposit and this reworking seems to increase larval survival and is linked to strong year classes (Van Steeter and Pitlick 1998; Osmundson 1999). Successful cohorts during high flows may be precluded by delayed warming of the river which causes delayed spawning and age-0 fish that lack size and fat content to survive overwinter (Thompson et al. 1991; Converse et al. 1999).

Studies of overwinter survival show a significant relationship between densities of age-0 fish in fall and spring, suggesting that high spawning success and egg and larval survival by fall (i.e., 3–4 months of age) largely determine cohort strength (Valdez et al. 1999; McAda and Ryel 1999). Overwinter survival also influences cohort strength, but the linkage to environmental correlates (e.g., flow variability, river temperature and ice formation, average backwater depth, and nonnative fish density) is unclear. Overwinter survival (October–March) of age-0 fish in backwaters of the upper Green River, based on the difference between fall and spring seine catch rates for 1989, 1990, 1991, 1992, and 1993 was 96, 29, 31, 38, and 62% (mean, 51%), respectively (Valdez et al. 1999). Survival was related to backwater depth with higher survival (85%) in backwaters deeper than 120 cm and lowest survival (18%) in backwaters less than 30 cm deep. In the upper Colorado River, overwinter survival ranged 7–77% (mean, 49%; McAda and Ryel 1999). Overwinter survival of age-0 Colorado pikeminnow in Green River backwaters, based on mark-recapture population estimates, ranged 6–62% (mean, 45%), compared to catch rate estimates for the same period of 11–49% (mean, 34%; Haines et al. 1998).

Survival rates of adults ≥550 mm TL from the upper Colorado River ranged from 0.83–0.87, with the best fit at 0.85 (Osmundson et al. 1997). Similar survival rate of 0.81 was calculated by Gilpin (1993) for a population viability analysis of Colorado pikeminnow. Survival of adults in the Yampa River may be slightly lower because of incidental catch and handling from angler pressure on sympatric game species, especially northern pike (*Esox lucius*).

A.7 Predation

Nonnative fishes dominate the ichthyofauna of Colorado River Basin rivers, and certain species have been implicated as contributing to reductions in the distribution and abundance of native fishes (Carlson and Muth 1989). At least 67 species of nonnative fishes have been introduced into the Colorado River Basin during the last 100 years (Tyus et al. 1982; Carlson and Muth 1989; Minckley and Deacon 1991; Maddux et al. 1993; Tyus and Saunders 1996; Pacey and Marsh 1998). Tyus et al. (1982) reported that 42 nonnative fish species have become established in the upper basin, and Minckley (1985) reported that 37 nonnative fish species have become established in the lower basin. Many of these species were intentionally introduced as game or forage fishes, whereas others were unintentionally introduced with game species or passively as bait fish. Potential negative interactions (i.e., predation and competition) between nonnative and native fishes have been identified (reviewed by Minckley 1991; Hawkins and Nesler 1991; Lentsch et al. 1996; Tyus and Saunders 1996; Pacey and Marsh 1998).

Colorado pikeminnow populations in the upper basin live sympatrically with about 20 species of warm-water, nonnative fishes (Tyus et al. 1982; Lentsch et al. 1996) that are potential predators, competitors, and vectors for parasites and diseases. Hawkins and Nesler (1991) identified red shiner (*Cyprinella lutrensis*), common carp (*Cyprinus carpio*), fathead minnow (*Pimephales promelas*), channel catfish (*Ictalurus punctatus*), northern pike, and green sunfish (*Lepomis cyanellus*) as the nonnatives considered by Colorado River Basin researchers to be of greatest concern because of their suspected or documented negative interactions with native fishes. Sand shiner (*Notropis stramineus*), white sucker (*Catostomus commersoni*), black bullhead (*Ameiurus melas*), smallmouth bass (*Micropterus dolomieu*), and largemouth bass (*M. salmoides*) were identified by Hawkins and Nesler (1991) as nonnatives of increasing concern because of their increasing abundance, habitat preferences, and/or piscivorous habits. Lentsch et al. (1996) identified existing threats to native fishes in the upper basin from six species of nonnative fishes including red shiner, common carp, sand shiner, fathead minnow, channel catfish, and green sunfish.

Backwaters and other low-velocity shoreline habitats in alluvial reaches of the upper Colorado, Green, and San Juan rivers are important nursery areas for larval and juvenile Colorado pikeminnow (Tyus 1991; Holden 1999; McAda 2000; Muth et al. 2000), and researchers believe that nonnative fish species in those habitats limit the success of Colorado pikeminnow recruitment (e.g., Muth and Nesler 1993; Bestgen 1997; Bestgen et al. 1997; McAda and Ryel 1999; Valdez et al. 1999). Osmundson (1987) confirmed predation by black bullhead, green sunfish, largemouth bass, and black crappie (*Pomoxis nigromaculatus*) as a significant mortality factor of young-of-year and yearling Colorado pikeminnow stocked in riverside ponds along the upper Colorado River. Adult red shiner are known predators of larval native fish in backwaters of the upper basin (Ruppert et al. 1993), and predation by nonnative fishes such as red shiner may influence within-year-class recruitment of Colorado pikeminnow (Bestgen et al. 1997). In laboratory experiments on behavioral interactions, Karp and Tyus (1990) observed that red shiner, fathead minnow, and green sunfish shared activity schedules and space with young Colorado pikeminnow and exhibited antagonistic behaviors toward smaller Colorado pikeminnow. They hypothesized that Colorado pikeminnow may be at a competitive disadvantage in an environment which is resource limited and concluded that nonnative fishes could have a negative impact on growth and survival of young Colorado pikeminnow. High spatial overlap in habitat use has been documented among young Colorado pikeminnow, red shiner, sand shiner, and fathead minnow (McAda and Tyus 1984; McAda and Kaeding 1989). Muth and Snyder (1995) compared the diet of young-of-year Colorado pikeminnow with the diets of other small fishes collected from backwaters of the Green River. They concluded that the potential for competition for food between Colorado pikeminnow and other fishes in backwaters appeared greatest with red shiner, which are often the most abundant fish in backwaters.

Channel catfish and northern pike have been identified as the principal nonnative threats to subadult and adult Colorado pikeminnow in the upper basin. Adult Colorado pikeminnow apparently use the same habitats as adult channel catfish and northern pike suggesting the potential for competitive interactions, especially during periods of limited resource availability (Wick et al. 1985; Tyus and Karp 1989; Tyus and Beard 1990; Nesler 1995). Channel catfish were first introduced into the Upper Colorado River Basin in 1892 (Tyus and Nikirk 1990) and are now considered common to abundant throughout much of the upper basin (Tyus et al. 1982; Nelson et al. 1995). The species is one of the most prolific predators in the upper basin and, among the nonnative fishes, is thought to have the greatest adverse effect on the endangered fishes (Hawkins and Nesler 1991; Lentsch et al. 1996; Tyus and Saunders 1996), largely due to predation on juveniles and resource overlap with subadults and adults. Additionally, mortality of adult Colorado pikeminnow that prey on channel catfish has occurred due to choking on pectoral spines (McAda 1980; Pimental et al. 1985). Northern pike accidentally became established in the Yampa River in the early 1980's when individuals escaped from Elkhead Reservoir (Tyus and Beard 1990). Since then, northern pike have established a reproducing population in the Yampa River and have expanded their numbers and range in both the Yampa and middle Green rivers (Tyus and Beard 1990; Hawkins and Nesler 1991; Nesler 1995) where they pose a competitive or predatory threat to endangered and other native fishes (Wick et al. 1985; Tyus and Karp 1989; Tyus and Beard 1990; Martinez 1995; Nesler 1995).

In the lower basin, the recapture rate of Colorado pikeminnow stocked in the Salt and Verde rivers, Arizona, has been low. This low recapture rate has been attributed to severe predation by nonnative flathead catfish (*Pylodictis olivaris*; Hendrickson 1994). Hendrickson and Brooks (1987) documented predation by yellow bullhead (*Ameiurus natalis*) and largemouth bass on young Colorado pikeminnow stocked in the Verde River, Arizona.

A.8 Age and Growth

Oldest Colorado pikeminnow documented from scale annuli are 11 years (610 mm TL) from the Green River (Vanicek and Kramer 1969; Seethaler 1978); 16 years from the White River; 12 years from the Colorado River (Hawkins 1992); and 13 years (879 mm TL; Musker 1981) and 18 years (2 fish average of 804 mm TL; Hawkins 1992) from the Yampa River. However, Osmundson et al. (1997) cautioned that scale-based estimations are probably unreliable for Colorado pikeminnow beyond about age 10, and concluded that growth-rate data indicated that large fish (e.g., > 900 mm TL) average 47–55 years old with a minimum age of 34 years.

Larvae at hatching are 6.0–7.5 mm long (Hamman 1981) and average about 40 mm TL (range, 29–47 mm) in October at about 3 months of age (Valdez 1990; Tyus and Haines 1991). Growth under laboratory conditions averaged about 13 mm/30 days (Hamman 1981). Growth of adults in the Green River was about 10.2 mm/year (Tyus 1988). Mean annual growth rate of fish from the upper Colorado River aged 3–6 years ranged from 32.2 (age 6) to 82.0 (age 3) mm/year and declined to 19.8 mm/year for fish 500–549 mm TL (Osmundson et al. 1997); fish ≥ 550 mm grew an average of 9.5 mm/year. Preliminary evidence indicates that females grow larger and perhaps live longer than males (Vanicek 1967; Tyus and Karp 1989).

The first scale annulus apparently does not form, and the first visible annulus reflects the second winter of life (Musker 1981; Hawkins 1992). Average length at the end of the second annulus formation ranged 90–123 mm TL (Hawkins 1992). Maximum length of fish examined recently is just over 800 mm TL. Asymptotic lengths, based on scale back-calculations and derived from Walford plots, indicate that maximum potential length of Colorado pikeminnow in the upper basin is 1,152 mm TL (Hawkins 1992). Historical accounts of fish in the lower basin indicate maximum length of about 1.8 m. Kaeding and Osmundson (1989) hypothesized that growth and overall size of Colorado pikeminnow in the upper basin is limited by more restrictive temperature regimes than in the lower basin.

Age to length relationships for Colorado pikeminnow are available from several investigations (Vanicek and Kramer 1969; Seethaler 1978; Musker 1981; Hawkins 1992; Osmundson 2002; Figure A-1). Vanicek and Kramer (1969) found that nearly all fish from the Green River age 7 or older (estimated at 454 mm total length [TL] from scale back-calculated lengths; Table A-2) were sexually mature. Seethaler (1978) determined that age-7 Colorado pikeminnow from the Green and Yampa rivers averaged 451 mm TL (scale back-calculations). He also necropsied 147 Colorado pikeminnow between 184 and 652 mm TL and found that all fish longer than 503 mm TL were sexually mature, and fish less than 428 mm TL were immature; 76% of 34 fish examined between 428 and 503 mm TL were sexually mature. Hamman (1981) found that hatchery-reared Colorado pikeminnow were sexually mature at age 5 (males) and age 6 (females), at total lengths of 317–376 mm and 425–441 mm, respectively. Musker (1981) found that age-7 wild fish from all rivers of the Upper Colorado River Basin averaged 461 mm TL (scale back-calculations; recalculated by Hawkins 1992). Hawkins (1992) surmised that Colorado pikeminnow hatch in late summer and either fail to form scales in their first winter or fail to form a first annulus. He assumed that all previous studies had missed the first annulus, and determined that age-7 fish averaged 396 mm TL, and age-8 fish averaged 440 mm TL. Hawkins defined mature Colorado pikeminnow as fish over 428 mm TL, based primarily on findings of Seethaler (1978). Osmundson et al. (1997) used growth-rate data from mark-recapture information and scale back-calculations from fish of the Upper Colorado River subbasin and determined that age-7 Colorado pikeminnow averaged 456 mm TL (range, 430–479 mm TL). Mark-recapture, growth-rate data from Osmundson (2002) were also used to develop the length to age relationship shown in Figure A-1. Based on the best available information on age at sexual maturity and age to length relationships, adult Colorado pikeminnow are defined as fish that are 450 mm TL or larger. This is based on the conservative assumption that all age-7 fish are sexually mature, and average length at age 7 is 450 mm TL. Subadults (age 6) are defined as those fish that are 400–449 mm TL (Table A-2).

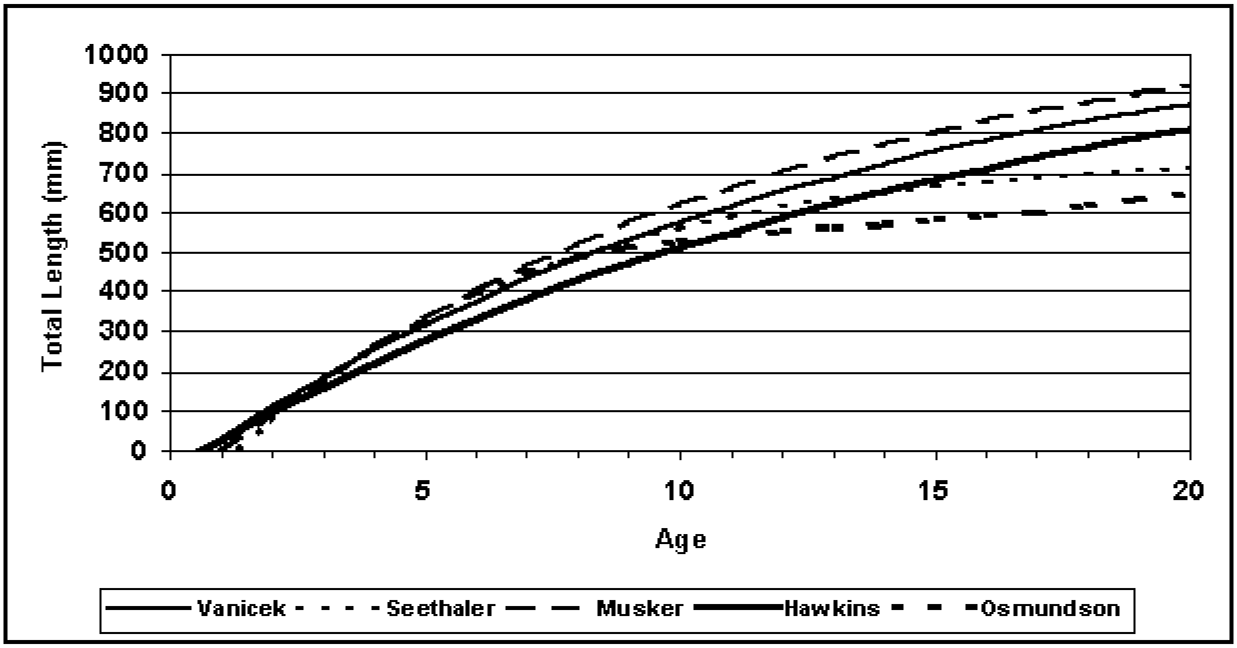

Figure A-1. Predicted length at age for Colorado pikeminnow; computed from von Bertalanffy growth functions (Vanicek and Kramer 1969; Seethaler 1978; Musker 1981; as presented in Hawkins 1992) and from growth-rate data (Osmundson 2002).

Table A-2. Lengths of adult and subadult Colorado pikeminnow as determined from scale back-calculations, mark-recapture growth data, and hatchery-reared fish.

Investigator	Area or Population	Adult		Subadult	
		Age	Total Length (mm)	Age	Total Length (mm)
Vanicek and Kramer (1969)	Dinosaur National Monument, Green River, Utah	7	454	6	391
Seethaler (1978)	Yampa and Green rivers, Colorado and Utah	7	451	6	406
Hamman (1981)	Willow Beach National Fish Hatchery	5 6	Males: 317–376 Females: 425–441		
Musker (1981)	Upper Colorado River Basin, Colorado and Utah	7	461	6	407
Hawkins (1992)	Upper Colorado River Basin, Colorado and Utah	7, 8	396, 440	6, 7	345, 396
Osmundson et al. (1997)	Upper Colorado River, Colorado and Utah	7	456 (430–479)	6	424 (375–472)

A.9 Length-Weight and Condition Factor

Length-weight relationships for Colorado pikeminnow from four rivers in the upper basin (Hawkins 1992) are:

Colorado River	$Log_{10}W = -6.384 + 3.463 * Log_{10}L$,
Green River	$Log_{10}W = -5.692 + 3.206 * Log_{10}L$,
White River	$Log_{10}W = -5.555 + 3.156 * Log_{10}L$, and
Yampa River	$Log_{10}W = -6.026 + 3.339 * Log_{10}L$,

where W is weight in grams and L is total length in millimeters. Length-weight relationships were not significantly different among rivers. Similar relationships were provided by Vanicek and Kramer (1969) and Seethaler (1978). Exponents above 3.0 suggest allometric growth in Colorado pikeminnow; i.e., the relationship of weight as a cube of the length (exponent > 3.0) changes as the fish grows (LeCren 1951; Lagler 1956), whereas exponents of $\leq$3.0 indicate isometric growth or a constant relationship between length and weight.

Mean relative condition of adult Colorado pikeminnow (>428 mm TL) ranged from about 0.92 to about 1.12 (Hawkins 1992). Highest condition usually occurred in June and was probably related to increase in fat reserves or gametes in preparation for spawning. Lowest condition occurred in July and August following pre-spawning migration and spawning activity. Condition usually increased again in fall after the migratory period returned fish to their home ranges.

A.10 Diet

Adult Colorado pikeminnow are generally considered piscivores and the main native predator of the Colorado River Basin because of their large size and large mouth (Vanicek and Kramer 1969; Minckley 1973; Holden and Wick 1982). As a member of the cyprinid family, Colorado pikeminnow lack jaw, vomerine, or palatine teeth, but possess instead large pharyngeal teeth, located on the first modified gill arch at the base of the throat. Cladocerans, copepods, and midge larvae are the principal food items of young up to 50 mm TL in nursery backwaters (Vanicek 1967; Jacobi and Jacobi 1982; Muth and Snyder 1995). Insects became important for fish up to 100 mm TL, after which fish are the main food item; Vanicek (1967) reported Colorado pikeminnow as small as 50 mm TL with fish remains in its gut, and Muth and Snyder (1995) reported fish remains in the gut of a Colorado pikeminnow 21 mm TL. Young in hatchery troughs may become cannibalistic at sizes of less than 50 mm TL (personal communication, F. Pfeifer, U.S. Fish and Wildlife Service). Adults consume primarily soft-rayed fishes, including bluehead sucker (*Catostomus discobolus*), flannelmouth sucker (*C. latipinnis*), red shiner, sand shiner, and fathead minnow (Osmundson 1999). Colorado pikeminnow have also been reported with channel catfish lodged in their throat, possibly leading to death of the fish (McAda 1980; Pimental et al. 1985). Colorado pikeminnow have been caught by anglers using various baits, including Mormon crickets (*Anabrus migratorius*; Tyus and Minckley 1988), carcasses of mice, birds, and rabbits (Beckman 1963), as well as artificial lures and spoons (Quartarone 1995).

A.11 Parasites

A survey of diseases and parasites of endangered fishes in the Upper Colorado River Basin in 1981 (Flagg 1982) revealed that Colorado pikeminnow are infected by two principal parasites (an intestinal tapeworm and an external parasitic copepod) and the protozoans *Myobolus* sp. and *Trichodina sp.*, as well as the trematode *Ornithodiplostomum* sp. Bass tapeworms (*Proteocephalus ambloplites*) were found in 65% of stomachs from fish longer than 200 mm TL in the Green River (Vanicek 1967). Vanicek (1967) also reported that P. Dotson (unpublished data, Utah Department of Fish and Game, Salt Lake City, 1962) found tapeworms in 80% of Colorado pikeminnow examined. A cestode identified as *Proteocephalus ptychocheilus* was found in Colorado pikeminnow from the upper basin (Flagg 1982). This may be the same species reported by Vanicek (1967), but further study has not been conducted to resolve the taxonomic discrepancy. Osmundson (1987) reported the first occurrence of Asian tapeworm (*Bothriocephalus achielognathii*) in hatchery-raised Colorado pikeminnow stocked in riverside ponds along the upper Colorado River. Asian tapeworms were identified in wild Colorado pikeminnow from the Colorado River downstream of Moab, Utah, in 1991 (personal communication, D. Osmundson, U.S. Fish and Wildlife Service). The parasitic copepod (*Lernaea cyprinacea*) is common in Colorado pikeminnow and has been reported by several investigators (Hagan and Banks 1963; Vanicek 1967; Flagg 1982). This parasite is believed to be alien to the Colorado River Basin, and transferred from other river basins via nonnative fishes.

APPENDIX B.

PROVISIONAL RECOVERY GOALS FOR COLORADO PIKEMINNOW IN THE LOWER COLORADO RIVER BASIN

Following are provisional site-specific management actions/tasks and objective, measurable recovery criteria presented as guidelines for conservation efforts (e.g., nonessential, experimental populations) for Colorado pikeminnow in the Lower Colorado River Basin. The need for self-sustaining populations in the lower basin and associated site-specific management actions/tasks necessary to minimize or remove threats will be reevaluated at the status review of the species. Anthropogenic changes in the lower basin have extensively modified the riverine ecosystem, including native-fish habitats. Therefore, these provisional recovery goals in the lower basin are based on a limited amount of habitat and taking aggressive actions that allow for the establishment and maintenance of populations in riverine and/or repatriated habitats (e.g., riverside habitats, such as oxbows, depressions, bottomlands, that are connected where feasible to the mainstem Colorado River).

B.1 Provisional Site-Specific Management Actions and Tasks by Recovery Factor

B.1.1 Factor A.—Adequate habitat and range for recovered populations provided

Management Action A-1.—Provide flows necessary for all life stages of Colorado pikeminnow to support recovered populations, based on demographic criteria.

Task A-1.1.—Identify, implement, evaluate, and revise (as necessary through adaptive management) flow regimes that are necessary for the establishment and maintenance of Colorado pikeminnow populations in the mainstem and/or tributaries.

Task A-1.2.—Provide flow regimes (as determined under Task A-1.1) that are necessary for all life stages of Colorado pikeminnow to support recovered populations in the mainstem and/or tributaries.

Management Action A-2.—Minimize entrainment of subadult and adult Colorado pikeminnow in diversion and/or out-take structures.

Task A-2.1.—Identify measures (e.g., screens, baffles) to minimize entrainment of subadult and adult Colorado pikeminnow at problematic diversion and/or out-take structures.

Task A-2.2.—Install devices and/or implement other measures (as determined under Task A-2.1) to minimize entrainment.

B.1.2 Factor B.—Protection from overutilization for commercial, recreational, scientific, or educational purposes

Management Action B-1.—Protect Colorado pikeminnow populations from overutilization for commercial, recreational, scientific, or educational purposes.

Task B-1.1.—Reevaluate and, if necessary, identify actions to ensure adequate protection from overutilization of Colorado pikeminnow for commercial, recreational, scientific, or educational purposes; not currently identified as an existing threat (see section 4.2).

Task B-1.2.—Implement identified actions (as determined in Task B-1.1) to ensure adequate protection of Colorado pikeminnow from overutilization for commercial, recreational, scientific, or educational purposes.

B.1.3 Factor C.—Adequate protection from diseases and predation

Management Action C-1.—Minimize adverse effects of diseases and parasites on Colorado pikeminnow populations.

Task C-1.1.—Reevaluate and, if necessary, identify actions to minimize adverse effects of diseases and parasites on Colorado pikeminnow populations; not currently identified as an existing threat (see sections 4.3.1 and A.11 for discussion of diseases and parasites).

Task C-1.2.—Implement identified actions (as determined under Task C-1.1) to ensure adequate protection of Colorado pikeminnow populations from deleterious diseases and parasites.

Management Action C-2.—Regulate nonnative fish releases and escapement into the mainstem, floodplain, and tributaries.

Task C-2.1.—Develop, implement, evaluate, and revise (as necessary through adaptive management) procedures for stocking and to minimize escapement of nonnative fish species into the mainstem, floodplain, and tributaries to minimize negative interactions between nonnative fishes and Colorado pikeminnow (see sections 4.3.2 and A.7 for discussion of effects of nonnative fishes).

Task C-2.2.—Finalize and implement procedures (as determined under Task C-2.1) for stocking and to minimize escapement of nonnative fish species into the mainstem, floodplain, and tributaries to minimize negative interaction between nonnative fishes and Colorado pikeminnow.

Management Action C-3.—Control problematic nonnative fishes as needed.

Task C-3.1.—Develop control programs for problematic nonnative fishes in the mainstem, floodplain, and tributaries to identify levels of control that will minimize negative interactions between nonnative fishes and Colorado pikeminnow.

Task C-3.2.—Implement identified levels (as determined under Task C-3.1) of nonnative fish control in the mainstem, floodplain, and tributaries.

B.1.4 Factor D.—Adequate existing regulatory mechanisms

Management Action D-1.—Legally protect habitat (see definition of habitat in section 5.1.2) necessary to provide adequate habitat and sufficient range for all life stages of Colorado pikeminnow to support recovered populations, based on demographic criteria.

Task D-1.1.—Determine mechanisms for legal protection of adequate habitat through instream-flow rights, contracts, agreements, or other means (see section 4.4 for discussion of regulatory mechanisms).

Task D-1.2.—Implement mechanisms for legal protection of habitat (as determined under Task D-1.1) that are necessary to provide adequate habitat and sufficient range for all life stages of Colorado pikeminnow to support recovered populations.

Management Action D-2.—Provide for the long-term management and protection of Colorado pikeminnow populations and their habitats.

Task D-2.1.—Identify elements needed for the development of conservation plans that are necessary to provide for the long-term management and protection of Colorado pikeminnow populations; elements of these plans may include (but are not limited to) provision of flows for maintenance of adequate habitat conditions for all life stages of Colorado pikeminnow, regulation and/or control of nonnative fishes, and monitoring of populations and habitats (see section 4.4 for discussion of need for conservation plans).

Task D-2.2.—Develop and implement conservation plans and execute agreements among State agencies, Federal agencies, American Indian tribes, and other interested parties to provide reasonable assurances that conditions needed for recovered Colorado pikeminnow populations will be maintained.

B.1.5 Factor E.—Other natural or manmade factors for which protection has been provided

No other factors have been identified as threats.

B.2 Provisional Objective, Measurable Recovery Criteria

B.2.1 Downlist criteria

B.2.1.1 Demographic criteria for downlisting

1. Two self-sustaining populations (e.g., in the mainstem and/or tributaries) are maintained over a 5-year period, starting with the first point estimates acceptable to the Service, such that for each population:

    a. the trend in adult (age 7+; ≥450 mm TL) point estimates does not decline significantly, and

    b. mean estimated recruitment of age-6 (400–449 mm TL) naturally produced fish equals or exceeds mean annual adult mortality, and

    c. each point estimate exceeds 2,600 adults (Note: 2,600 adults is the estimated MVP number, see section 3.3.2).

B.2.1.2 Recovery factor criteria for downlisting

Factor A.—Adequate habitat and range for recovered populations provided.

1. Flow regimes that are necessary for the establishment and maintenance of Colorado pikeminnow populations in the mainstem and/or tributaries identified, implemented, evaluated, and revised (Task A-1.1), such that:

    a. Adequate spawning habitat and appropriate spawning cues (e.g., flow patterns and water temperatures) are available to maintain self-sustaining populations, as reflected by downlisting demographic criteria in section B.2.1.1.

    b. Adequate nursery habitat is available to maintain self-sustaining populations, as reflected by downlisting demographic criteria in section B.2.1.1.

    c. Adequate juvenile and adult habitat (e.g., cover, resting, and feeding areas) is available to maintain self-sustaining populations, as reflected by downlisting demographic criteria in section B.2.1.1.

2. Measures identified to minimize entrainment of subadult and adult Colorado pikeminnow at problematic diversion and/or out-take structures (Task A-2.1).

Factor B.—Protection from overutilization for commercial, recreational, scientific, or educational purposes.

3. Overutilization of Colorado pikeminnow for commercial, recreational, scientific, or educational purposes reevaluated and, if necessary, actions identified to ensure adequate protection (Task B-1.1).

Factor C.—Adequate protection from diseases and predation.

4. Effects of diseases and parasites on Colorado pikeminnow populations reevaluated and, if necessary, actions identified to ensure adequate protection (Task C-1.1).

5. Procedures developed, implemented, evaluated, and revised for stocking and to minimize escapement of nonnative fish species into the mainstem, floodplain, and tributaries to minimize negative interactions between nonnative fishes and Colorado pikeminnow (Task C-2.1).

6. Control programs for problematic nonnative fishes in the mainstem, floodplain, and tributaries developed and implemented to identify levels of control that will minimize negative interactions between nonnative fishes and Colorado pikeminnow (Task C-3.1).

Factor D.—Adequate existing regulatory mechanisms.

7. Mechanisms determined for legal protection of adequate habitat (Task D-1.1).

8. Elements of conservation plans identified that are necessary to provide for the long-term management and protection of Colorado pikeminnow populations (Task D-2.1).

Factor E.—Other natural or manmade factors for which protection has been provided.

No other factors have been identified as threats.

B.2.2 Delist criteria

B.2.2.1 Demographic criteria for delisting

1. Two self-sustaining populations (e.g., mainstem and/or tributaries) are maintained over a 7-year period beyond downlisting, starting with the first point estimates acceptable to the Service, such that for each population:

   a. the trend in adult (age 7+; ≥450 mm TL) point estimates does not decline significantly, and

   b. mean estimated recruitment of age-6 (400–449 mm TL) naturally produced fish equals or exceeds mean annual adult mortality, and

   c. each point estimate exceeds 2,600 adults (MVP).

B.2.2.2 Recovery factor criteria for delisting

Factor A.—Adequate habitat and range for recovered populations provided.

1. Flow regimes provided that are necessary for all life stages of Colorado pikeminnow to support recovered populations in the mainstem and/or tributaries (Task A-1.2), such that:

   a. Adequate spawning habitat and appropriate spawning cues (e.g., flow patterns and water temperatures) are available to maintain self-sustaining populations, as reflected by delisting demographic criteria in section B.2.2.1.

   b. Adequate nursery habitat is available to maintain self-sustaining populations, as reflected by delisting demographic criteria in section B.2.2.1.

   c. Adequate juvenile and adult habitat (e.g., cover, resting, and feeding areas) is available to maintain self-sustaining populations, as reflected by delisting demographic criteria in section B.2.2.1.

2. Devices installed and/or measures implemented at problematic diversion and/or out-take structures to minimize entrainment of subadult and adult razorback sucker (Task A-2.2).

Factor B.—Protection from overutilization for commercial, recreational, scientific, or educational purposes.

3. Adequate protection of Colorado pikeminnow from overutilization for commercial, recreational, scientific, or educational purposes attained (Task B-1.2).

Factor C.—Adequate protection from diseases and predation.

4. Adequate protection of Colorado pikeminnow populations from deleterious diseases and parasites attained (Task C-1.2).

5. Procedures finalized and implemented for stocking nonnative fish species in the mainstem, floodplain, and tributaries to minimize negative interactions between nonnative fishes and Colorado pikeminnow (Task C-2.2).

6. Identified levels of nonnative fish control to minimize negative interactions between nonnative fishes and Colorado pikeminnow attained in the mainstem, floodplain, and tributaries (Task C-3.2).

Factor D.—Adequate existing regulatory mechanisms.

7. Habitat necessary to provide adequate habitat and sufficient range for all life stages of Colorado pikeminnow to support recovered populations is legally protected in perpetuity (Task D-1.2).

8. Conservation plans developed and implemented, and agreements among State agencies, Federal agencies, American Indian tribes, and other interested parties executed to provide reasonable assurances that conditions needed for recovered Colorado pikeminnow populations will be maintained (Task D-2.2).

Factor E.—Other natural or manmade factors for which protection has been provided.

No other factors have been identified as threats.