Final

Revised

GENETICS MANAGEMENT PLAN

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Recovery Implementation Program
for
Endangered Fishes
in the
Upper Colorado River Basin

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ACKNOWLEDGEMENTS

The "Genetics Management Guidelines" (Williamson and Wydoski 1994) and "Coordinated Hatchery Facility Plan: Need for Captive-Reared Endangered Fishes and Propagation Facilities" (Wydoski 1994) provided much of the information for this plan. Section VIII "Management of Captive Broodstocks" and Section IX "Guidelines for Stocking and Disposition of Captive-Reared Endangered Fishes in the Upper Colorado River Basin" were slightly revised from the document by Williamson and Wydoski (1994).

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I. EXECUTIVE SUMMARY

This "Genetics Management Plan" for endangered fishes in the Upper Colorado River Basin (Upper Basin) (1) identifies and classifies endangered fish stocks, (2) describes criteria for decisions related to genetics management, (3) establishes priorities for effective and rational genetics management for species and stocks, and (4) recommends management actions by species and stocks (such as, identified needs in stocking plans).

Eleven presumptive stocks of endangered fishes have been recognized in the Upper Colorado River Basin based on criteria involving geographic distribution, suspected or identified spawning sites, and movement or interaction. Criteria of genetic identification and characterization have been based on specific projects. The assignment of presumptive stocks for the Upper Basin is conservative to ensure preserving their genetic diversity because all stocks may be important in the recovery effort. Adaptive management will be employed by the Biology Committee to annually evaluate the plan and make appropriate revisions if warranted from new information.

Three presumptive stocks of razorback suckers, five stocks of humpback chub, and three stocks of Colorado pikeminnow were identified for the upper basin. Bonytails are rarely captured in the upper basin**,** the probability of obtaining sufficient adults to develop a broodstock is remote. Therefore, restoration stocking efforts of this species will depend upon broodstock development from captive fish of Lake Mohave stock.

Each presumptive stock is treated separately using the criteria for stock identification and is discussed by status, trend, and priority for upper basin. Management recommendations for endangered fish stocks from the Upper Colorado River Basin are provided in Section VII "Recommended Management Actions for Endangered Fish Stocks in the Upper Colorado River Basin".

The status and trends of presumptive endangered fish stocks in the upper basin were reviewed by the Biology Committee. The status of razorback sucker is considered critical in the upper basin because old individuals in current presumptive stocks are declining rapidly and the stocks are in danger of immediate extinction. Some recruitment occurs in the middle Green River stock but is probably not sufficient to maintain a self-sustaining population in that river reach. The bonytail is nearly extirpated in the upper basin and individual fish are captured very infrequently. Because of low numbers, a stock was not identified in the upper basin and it is recognized that broodstocks will have to be developed from Lake Mohave stock. The humpback chub stocks are apparently stable but the stocks are small and located in isolated deep canyon areas of the upper basin. Stocks in Desolation-Gray Canyons and in the Yampa River exhibit large variations in phenotypes and may be at risk from hybridization with roundtail chubs. The Colorado pikeminnow is considered stable for most presumptive stocks. The Upper Colorado River stock (upstream from Westwater Canyon) is very low in number and has been extirpated above irrigation diversion dams upstream from Palisade, Colorado. A presumptive stock in the Gunnison River above Redlands Irrigation Diversion Dam is extremely low in numbers and is declining. Successful use by subadult and adult Colorado pikeminnow of the Redlands fish ladder during the summers of 1996 and 1997 has demonstrated the utility of fish passage projects. The Colorado pikeminnow in the Gunnison may now be supplemented by the fish using the ladder.

Species priorities for propagation needs (including broodstock development, stocking plans, stocking of fish and hatchery facilities) were assigned on the basis of their current status and trends: razorback sucker - 1; bonytail - 2; humpback chub - 3; and Colorado pikeminnow - 4. Priority "1" indicates the highest priority and "4" the lowest priority. The assignment of priority 1 to the razorback sucker was based on the recovery potential of upper basin stocks. Assignment of priority 2 to the bonytail was based on the fact that only occasional captures of this species are made infrequently and broodstock development will rely on Lake Mohave stock. The humpback chub was assigned priority 3 because limited information on the status and trends of the various identified stocks suggests the stocks are small but stable in localized river reaches. Finally, priority 4 was assigned to the Colorado pikeminnow because most stocks are considered stable and recruitment has been documented for most stocks.

The recommended target breeding strategy for propagation of the endangered Colorado River fishes is to mate 25 females with 25 males to produce 25 pedigreed family lots if sufficient adults are available and removal of adults from the wild will not jeopardize the genetic characteristics of the founder stock. An inbreeding rate of 1% was estimated for an effective population size of 50 fish. That is acceptable for maintaining the genetic diversity of wild fish stocks used as founders. If significant differences in genetic diversity do not exist among stocks of endangered fish species, the recommended approach is to develop 25x25 paired matings first from local populations, then nearest neighboring populations, then from other centralized populations. When stocks are low, a minimum breeding strategy using a 5 X 5 di-allele cross will be used to develop broodstocks. A 5 X 5 breeding strategy has an effective population size of 10 and estimated inbreeding rate of 5%. In the event that 5 males and 5 females are not available, a factorial mating will be used to capture the genetic contribution of the least numerous sex. However, additional wild adults will be used to supplement the broodstocks that are developed from either the 5 X 5 di-allele cross or factorial crosses when they are available to increase the effective population size and to reduce the risk of inbreeding.

Immediate broodstock development for four presumptive stocks is ongoing: 2 for razorback suckers (Middle Green River and Upper Colorado River stocks), 1 for bonytail (Lake Mohave stock), and 1 for Colorado pikeminnow (Upper Colorado River stock). The Escalante Ranch-Green River razorback sucker broodstock is being developed at the Ouray Endangered Fish Facility in Utah. The Upper Colorado River razorback sucker broodstock is being developed at the Grand Valley Endangered Fish Facility, Grand Junction, Colorado. The Lake Mohave bonytail broodstock will be cultured at Dexter National Fish Hatchery and Technical Center, Dexter, New Mexico. The Upper Colorado River Colorado pikeminnow broodstock (17 family lots) is being maintained at the Horsethief State Wildlife Area and in a backup refuge at Dexter National Fish Hatchery, New Mexico. An estimate of about 10.3 acres of active ponds and 144 acre-feet of water annually will be needed to maintain these broodstocks.

Currently our broodstock needs in razorback sucker is not meeting the 25x25 mated pairs. It has been difficult to get older fish held over a year at the hatchery to spawn. In addition, collections of adults from the spawning bar has been limited and when possible difficult. Recent attempts at collecting adults has resulted in four females and 17 males; only 2 of the females produced sufficient eggs for brood stock development. Bonytail are currently supplied from the Dexter National Fish Hatchery and Technical Center, but are based on a relatively few adults. Humpback do not currently have a broodstock development plan in place. The humpback chubs are considered to be sufficiently stable. To enhance the population of pikeminnow, at least in the upper Colorado River reach, the purposed method is to use stream side spawned progeny and grow out, without the further development of a broodstock.

II. INTRODUCTION

Four endemic fishes in the Upper Colorado River Basin (razorback sucker, *Xyrauchen texanus*; bonytail, *Gila elegans*; humpback chub, *Gila cypha*; and Colorado pikeminnow, *Ptychocheilus lucius*) are listed as "endangered" under the Endangered Species Act of 1973, as amended. These species declined in numbers from various biological and environmental changes in the upper basin including changes in the historic streamflow regime, altered habitats, changes in water temperature, water diversions (i.e., water depletions), barriers to fish passage, and increased predation or competition from nonnative fishes (U.S. Fish and Wildlife Service 1987a, 1987b, 1990a, 1990b, 1991).

The U.S. Fish and Wildlife Service coordinated an effort to develop a Recovery Implementation Program (Program) for recovery of these endangered fishes while allowing water development to continue in the Upper Colorado River Basin (Figure 1) that would meet the needs of society. Participants in the Program include the States of Colorado, Utah, and Wyoming; U.S. Bureau of Reclamation; U.S. Fish and Wildlife Service; Western Area Power Administration; water development interests; and environmental organizations. The Program consists of five elements that are directed toward the recovery of the endangered fishes in the upper basin. One Program element includes the propagation and stocking of captive-reared fish. The evolution of this Program is described by Wydoski and Hamill (1991). Effective genetics management is an integral component in the propagation and stocking of captive-reared endangered fish and exerts significant influence on decisions regarding instream management of existing wild stocks.

A. Program Philosophy, Mission, and Goals for Genetics Management. The Program philosophy, mission, and goals are to maintain the genetic integrity of wild endangered fish stocks in the upper basin and to maintain genetic diversity in captive broodstocks that is similar to the stock used as founders (Box 1; Echelle 1991; Meffe 1986). The recovery of these endangered fishes will be accomplished through all program elements; however, those dealing with genetic preservation and conservation through propagation are described here. In regards to propagation, two principle avenues are realized: natural and artificial (or captive).

Box 1. Philosophy, mission and goals of the Recovery Implementation Program for genetics management of endangered fishes in the Upper Colorado River Basin.

PHILOSOPHY AND MISSION

To maintain the genetic integrity of wild and captive-reared endangered fishes in the Upper Colorado River Basin and to prevent irreversible losses of genetic diversity that may result from management interventions or lack of action.

GENETICS MANAGEMENT GOALS

1. To prevent immediate extinction of any endangered Colorado River fish stocks.
2. To conserve genetic diversity of wild endangered fish stocks through recovery efforts that will reestablish viable wild stocks by removing or significantly reducing factors that caused population declines.
3. To maintain genetic diversity in captive-reared endangered fish broodstock that is similar to that of the wild stock used as founders.
4. To produce genetically diverse fish for augmentation efforts.

B. Program Documents Related to Genetics. Genetic conservation of endangered fishes in the upper basin will be accomplished in phases that are described in separate Program documents.

1. Genetics Management Guidelines. The conceptual framework of genetics management and rationale for maintaining genetic diversity of endangered fish stocks in the upper basin are described in "Genetics Management Guidelines" (Williamson and Wydoski 1994). The guideline document (1) discusses genetic risks associated with captive propagation (Box 4 in Williamson

Figure 1. Map of the Upper Colorado River Basin.

and Wydoski 1994), (2) describes criteria for holding, rearing and stocking captive-reared endangered fish (Box 6 in Williamson and Wydoski 1994), (3) outlines guidelines for preparation of stocking plans (Box 7 in Williamson and Wydoski 1994), (4) provides an estimate of the number of endangered adults required to develop a broodstock based on current estimates of attrition rates, and (5) provides protocol for disposition of captive-reared endangered fish. The document describes rationale for genetic conservation (i.e., “why” and “how”), genetics concepts, and genetic risks to be considered in planning and management involving recovery of endangered fishes in the upper basin.

2. Genetics Management Plan (Revised as needed). This document (1) provides justification for the identification and classification of endangered fish stocks in the upper basin, (2) describes rationale for decisions related to genetics management of specific stocks, (3) establishes priorities for effective and rational genetics management for species and stocks by river reach, and (4) recommends management actions by species and stocks. Implementation of this plan is through the Annual Operations Plan, broodstock, stocking and facilities plans.

3. Annual Operation Plan (accepted by 12/1 each year). Describes the broodstock development expected over the next year as well as production number for stocking plans that can be meet.

4. Broodstock Plan. Identified in the Genetics Management Plan and implemented in the Annual Operation Plan.

5. Stocking Plans. A "Stocking Plan" will be prepared on a case-by-case basis with justification for stocking. Although priorities for which stocks to augment or restore are identified in this Genetics Management Plan (Tables 3 and 4) and the circumstances in which the use of stocking to contribute to the recovery of these fish populations are also discussed in this plan (just below), the more specific uses and priorities are in the hands of the Program committees using adaptive management and consensus of opinion in the approval and implementation of individual stocking and monitoring plans. The recently accepted stocking plan for the State of Colorado (Nesler 1998) serves as an example of a specific plan that is consistent with the consensus identified in Tables 3 and 4 of this plan.

6. Facilities Operations Plan (reviewed annually by January of each year). Describes the necessary facilities to meet the productivity objectives of stocking plans.

Conservation of natural genetic diversity is fundamental to both short-term ecological adaptation to various environmental conditions and the long-term evolution of a species through natural selection. The extinction of indigenous fish stocks is generally preceded by the loss of genetic diversity within and among populations. As species decline to the point where they are listed as threatened or endangered, each remaining stock could play an important role in increasing the probability for recovery (Rohlf 1991). Natural reproduction is the goal in the recovery of endangered fishes in the Upper Colorado River Basin so that the stocks will become self-sustaining. Efforts will be made to protect or restore viable wild stocks by removing or significantly reducing limiting factors that caused the declines in numbers and range (Box 1).

Endangered fish stocks which do not have sufficient recruitment to maintain self-sustaining populations require artificial genetic recruitment from other stocks to prevent extinction or captive propagation to produce fish for experiments related to research studies and for augmentation or restoration stocking (Williams et al. 1988). Program needs for captive-reared endangered fish have been identified for (1) genetic refugia and broodstock development, (2) research and development, (3) augmentation and restoration stocking and (4) information and education (Wydowski 1994). Refuges serve a vital function in maintaining endangered fish that may become extinct in the wild due to declines in populations or from catastrophic risks; but also for broodstock development. Captive-reared endangered fish are needed for research to conduct laboratory and field experiments designed to study ecological requirements, habitat use, interactions with nonnative fishes, response to contaminants in acute or chronic bioassays, homing (e.g., olfaction and chemoreception studies), fish passage, taxonomy, anatomy, and physiology as well as performance, fitness, and hereditary traits. Endangered fish specimens can be used in public relations programs as a means to inform the public about why the fish were listed as endangered and the Program to recover these fish species. Stocking of hatchery-raised fish for both restoration and augmentation purposes will be used to establish or facilitate increases in fish populations in the following circumstances: (1) where populations no longer exist; (2) where populations are low in abundance and subject to inbreeding risks or extirpation; (3) where adult habitat is suitable but unoccupied; (4) where natural recolonization rates or recruitment is absent or impaired; and (5) where limiting factors need to be evaluated. Stocking is not appropriate, however, to sustain fish numbers indefinitely without adaptive management in response to the alleviation of the factors keeping the fish from sustaining themselves.

III. CRITERIA FOR CHARACTERIZATION OF ENDANGERED FISH STOCKS

Individuals of natural animal populations are rarely distributed randomly and their distributions may range from essentially continuous to highly clumped (Barker 1989). The term "Evolutionary Significant Unit" has been applied to natural, biological groupings of animals that exhibit patterns of diversity associated with evolutionary history, breeding isolation, unique adaptation, and production (Dizon et al. 1992).

The relationship between geographic distribution and genetic diversity varies considerably among animal populations. Avise (1989) proposed four categories of this relationship: (1) great genetic divergence and strong geographic partitioning, (2) great genetic divergence accompanied by weak geographic partitioning, (3) geographically separated assemblages characterized by little genetic differentiation, and (4) extensive gene interchange without subdivision by geographic barriers. The first three categories contain animals that have evolved independently in response to environmental variables and can be considered a stock or Evolutionary Significant Unit that may be potentially valuable to the recovery of the species. The fourth category results when there is little or no reproductive isolation and considerable intermingling on the breeding grounds that results in a panmictic population (Dizon et al. 1992). Panmictic refers to random mating within a breeding population of animals (i.e., comprises a single stock).

The Program philosophy, mission, and goals regarding genetic management of the endangered fishes are based on the recognition that stocks (i.e., Evolutionary Significant Units) or local self-sustaining populations must be considered the operational unit in the recovery effort. For example, such endangered fish stocks may contain unique genetic attributes that might have allowed these endemic Colorado River fish species to evolve and occupy habitats in the Upper Colorado River Basin that are in the northernmost part of their historic ranges (Kapuscinski and Jacobson 1987).

Criteria for Identification and Characterization of Endangered Fish Stocks. A stock is defined as a randomly breeding group of individuals that has spatial, temporal, or behavioral integrity distinct from other randomly breeding groups of that same species (Kutkuhn 1981). This definition of stock applies to multiple stocks within an individual river as well as single stock comprising fish from various rivers (Philipp et al. 1993). Stable fish stocks sustain a constant frequency of genotypes from one generation to another (Hardy-Weinberg equilibrium Booke 1981).

All available information (i.e., distribution and abundance, behavior, migration, phenotypic information, and genotypic information; Dizon et al. 1992, Ihssen et al. 1981) were considered to identify and characterize endangered fish stocks in the upper basin. Although consistency in this process is difficult, the approach used to determine the geographical, spawning site and movement information and**,** when genetic and morphometric data was available separate**,** the stocks based on all the available information. The criteria used to identify and characterize endangered fish stocks in the Upper Colorado River Basin (Wydoski 1994) were (see Appendix 2 for the use of these criteria to each of the species and stocks):

1. Identified Spawning Sites/Early Life History Habitats/Known Movements. All major large tributaries in the Upper Colorado River Basin have been sampled to determine the distribution and abundance of endemic and introduced fishes (Bestgen 1990; McAda et al. 1993; Miller et al. 1982; U.S. Fish and Wildlife Service 1990a, 1990b, 1991). Spawning sites were determined through various studies by the collection of ripe fish from specific river reaches in different years and, for some species, by the collection of larval fishes downstream from suspected spawning sites. Some

endangered Colorado River fishes are known to migrate to spawning areas but return to a home area during the remainder of the year.

2. Fidelity to Spawning Sites. Distinct spawning sites and strong fidelity to those sites is a primary factor for determining a population. Fidelity to spawning sites is extremely important to maintenance of genetically separate populations when no physical barriers exist between populations.

3. Geographic Distribution and Abundance. The initial criteria used to separate endangered fish stocks was distribution during the spawning season and abundance of each species in the upper basin. Some stocks are geographically separated from others and do not appear to interact with other stocks. Geographical levels were subjectively assigned based on the knowledge of the overall movement/dispersal of a stock to/from a spawning site and habitat types within river reaches. Depending on the species, some populations have very broad geographic distributions, while others are specific to a canyon or river reach.

   Dams fragment the habitat in the upper basin and prevent free movement of the endangered fishes. Hence, some of the geographic separation among stocks is due to altered habitats. Some interchange has been documented for several razorback sucker, humpback chub, and Colorado pikeminnow stocks. In most cases, only a few fish were known to move between different spawning seasons, but a relative few fish have been observed. A small amount of interchange among stocks is natural during the evolutionary process. However, even limited interaction of different stocks during the spawning season can result in genetic homogenization. Stocks with limited interaction will be classified separately until adequate information is available to justify combining them. This conservative classification is intended to prevent or minimize the risk of losing unique genetic attributes that may be important in the recovery effort.

4. Molecular (Genetic) Identification and Characterization of Stocks. The genetic diversity of endangered fish stocks in the Upper Colorado River Basin has been characterized, in some cases, by comparing the distribution of genetic diversity through appropriate techniques such as protein electrophoresis for protein analysis and restriction endonuclease analysis for mtDNA.

   Protein electrophoresis is an indirect method of genetic analysis because it focuses on phenotypes that imply the genotypes. The method allows detection of the presence or absence of allozymes and relative frequencies and allelic differences among groups of animals. Allozymes provide a phenotypic expression of alleles. Restriction fragment length polymorphism (RFLP) analysis of mitochondrial deoxyribonucleic acid (mtDNA) allows a more direct genetic characterization of stocks or populations. A combination of the two methods provides a powerful tool for genetic identification and characterization.

   Quantification of within and among population variation is necessary to 1) define stock structure and 2) define the level of within population genetic variation within captive stocks to mimic that found in the wild population (Allendorf and Phelps 1987; Allendorf and Ryman 1987; Gauldie 1981; Hynes et al. 1981). Unlike many phenotypic traits, molecular traits are not subject to environmental induction (effects). Verification of distribution patterns is extremely important to ensure that differences have a genetic basis and are not due to other factors such as environmental effects, development stage of fish that are sampled, or treatment of samples (Kapuscinski and Jacobson 1987). In addition, early detection of inadvertent introgression from stocking will allow changes in stocking procedures that could preserve the genetic integrity of remaining wild endangered fish stocks (Hynes et al. 1981).

5. Morphometric/Meristic Identification and Characterization of Stocks. Morphological analyses are used to identify and characterize fish stocks in some cases.

IV. IDENTIFICATION OF ENDANGERED FISH STOCKS BASED ON ESTABLISHED CRITERIA

Procedures for Reviewing Stock Identification and Characterization. Members of the Program's Biology Committee will annually review presumptive stocks of endangered fishes in the Upper Colorado River Basin as new information becomes available on distribution, behavior, migrations, gene flow (i.e., interchange between stocks), phenotypic information, and genetic information. Even with the available information on criteria for stock identification and characterization, the present ability to evaluate stocks is not complete. Therefore, all stocks will be treated separately (i.e., using a conservative approach) until future information indicates otherwise because all present stocks may be important in the recovery effort. Revisions to the identified stocks based on new information and changes in this plan will be further reviewed by an ad hoc panel of conservation geneticists.

Present Stock Identification and Characterization of Endangered Fishes in the Upper Colorado River Basin. The Program Biology Committee and other interested persons reviewed available information on delineating presumptive stocks of endangered fishes in the upper basin during several meetings in 1993 (Wydoski 1994) and at subsequent Biology Committee meetings. Eleven presumptive stocks of endangered fishes were identified in the upper basin: three stocks of razorback suckers, five stocks of humpback chub, and three stocks of Colorado pikeminnow (Table 1). The identification of the stocks in Table 1 was made conservatively since all stocks may be important in the recovery effort. Individual bonytail are captured only rarely in the upper basin with long periods of time between captures. Therefore, sufficient bonytails are not available to develop a genetically sound broodstock. Therefore, restoration efforts will be made in the upper basin using bonytail progeny from Lake Mohave origin.

Table 1. Criteria used for identification and characterization of presumptive endangered fish stocks in the Upper Colorado River Basin (Y=Yes, determined; U=Unknown, little or no information; ?=Undetermined, inconclusive or unagreed upon results based on information available). See Appendix 2 for background information.

Species	Presumptive Stocks	Criteria[1]				
		Spawning Sites/ Movements	Fidelity to Spawning Sites	Geographic	Molecular Genetics	Morphometric
Razorback sucker	Middle Green River (Yampa and Middle Green River)	Y	Y	Y	?	U
	Lower Green River	U	U	Y	?	U
	Upper Colorado River	Y	U	Y	?	U
Bonytail	Upper Basin					
Humpback chub	Yampa River	Y	U	Y	?	Y
	Desolation-Gray Canyons	Y	U	Y	?	U
	Black Rocks Canyon	Y	U	?	?	U
	Westwater Canyon	Y	U	?	?	U
	Cataract Canyon	Y	U	Y	?	U
Colorado pikeminnow	Green/Yampa River	Y	Y	Y	?	U
	Desolation-Gray Canyons	Y	Y	Y	?	U
	Upper Colorado River including Gunnison River	Y	U	Y	?	U

[1] Definitions of Criteria:
Spawning sites/movements - Ripe fish collected on suspected spawning sites; larval fishes collected downstream of suspected spawning sites. Migrations to/from spawning sites; home ranges.
Fidelity to spawning sites - Fish return exclusively to the spawning sites they originated at.
Geographic - Stocks that are spatially separated from others by large distances (e.g., 100 river miles).
Molecular Genetic - Allozyme or mtDNA analyses indicating separation of stocks.
Morphometric - Systematic body measurements indicating differences among stocks/species.

V. STATUS AND TRENDS OF ENDANGERED FISH STOCKS AND CURRENT GENETIC MANAGEMENT ACTIONS

Criteria for Determining Status and Trends of Endangered Fish Stocks. Determining the status and trends of endangered fish stocks is imperative in making informed management decisions (Philipp et al. 1986). Decisions on actions regarding endangered species must be made on a case-by-case basis using standard criteria (Rohlf 1991) as developed here. The status of presumptive endangered fish stocks in the upper basin is determined by:

1. Monitoring the distribution and relative abundance of presumptive stocks by species,
2. Documenting spawning and recruitment,
3. Determining the potential risk for extinction from catastrophes, and
4. Estimating the probability for immediate extinction.

Distribution and relative abundance of Colorado pikeminnow in the upper basin and humpback chubs in Black Rocks and Westwater Canyons are estimated through the Recovery Program's Interagency Standardized Monitoring Program (McAda et al. 1993). Data on the present relative abundance as well as status and trends of the razorback sucker and nonnative fishes are obtained through the basinwide razorback sucker monitoring program. Other ongoing field studies provide additional information on status and trends of all endangered fish species as well as nonnative fishes.

Monitoring the Status and Trends of Endangered Fish Stocks. The status and trends of endangered fish stocks in the Upper Colorado River Basin will be reviewed annually by the Program's Biology Committee using new information on the stocks from the Interagency Standardized Monitoring Program and ongoing studies.

Present Status and Trends of Endangered Fishes in the Upper Colorado River Basin. The status and trends of these endangered fish stocks were reviewed by members of the Program's Biology Committee and other interested persons using the criteria described above and are summarized in Table 2.

Razorback Sucker: The interim management objective for adult razorback sucker estimated population size in the upper Colorado River basin is 5316 (± 804) per stock (Lentsch et al 1998). Current status and trends of the razorback sucker are at critically low levels throughout the Upper Basin (Bestgen 1990; Burdick 1992; Lanigan and Tyus 1989; Maddux et al. 1993; McAda and Wydoski 1980; Tyus and Karp 1990). Old individuals in current presumptive stocks are declining rapidly.

Middle Green River

The presumptive stock in the middle Green River between the confluence with the Duchesne and Yampa rivers is low, Modde et al. 1993 estimated about 500 adults; but some recruitment occurs in this reach as indicated by the presence of small fish (< 475 mm). However, this recruitment is not sufficient to maintain self-sustaining populations of this species in that river reach. The razorback sucker population was estimated to be 948 fish (95% confidence interval, 758 - 1,138) in 1988 (Lanigan and Tyus 1989). This population declined to between 250 and 550 fish in 1993 (Modde et al. 1993). Statistical analyses of this population, using the same data as Lanigan and Tyus with the addition of data from recent years, indicates that the previous population estimate was high (Modde et al. 1993).

Although spawning occurs in the Yampa River, no recruitment has been documented and the number of spawning fish appears low and may be declining. Fourteen ripe razorback suckers were captured in the Yampa spawning site in 1975, but only 32 ripe fish were captured during the of 1975, 1981, 1988, and 1989 (Tyus and Karp 1989).

An augmentation plan was implemented in 1995 (Wydoski 1996). During 1995, 929 razorback sucker averaging 170 mm in total length along with 21 ranging in 74-125 mm in total length were stocked in the Green River. In 1996, 1,068 razorback sucker ranging in size from 209-308 mm total length were stocked (Tom Pruitt, personal communication). No recaptures of fish stocked in 1995 have occurred; this stocking has been considered unsuccessful with little or no survival after two years of observations. To date, 7 of the 1996 stocking event have been recaptured.

Lower Green River

Yet to be determined, the basinwide monitoring program was unable to collect samples in this portion of the River due to Program cut backs in 1997. The expansion of the ISMP in 1998, includes quantifying the trends of razorback in the lower Green River.

Upper Colorado River

A dramatic decline in razorback suckers occurred between 1974 and 1991 for the reach of the Upper Colorado River between River Miles 152.8 and 185.1 (Burdick 1992). A high capture of 206 razorback suckers in this reach during 1974 declined and no fish were captured during 1989-1992 (Burdick 1992). During 1993, three adult razorback suckers were captured in this reach of the

Colorado River (F. Pfeifer, 1993, Personal Communication). The razorback sucker has been extirpated from the Gunnison River upstream from the Redlands Irrigation Diversion Dam and upstream from the Price-Stub Irrigation Diversion Dam (Burdick 1992). This stock declined rapidly and the razorback sucker is extremely rare in the upper Colorado River at the present time. About 600 razorback suckers are in Etter Pond along the Colorado River near Debeque, Colorado (B. Elmblad, 1994 personal communication). These fish were progeny from few parents (presumably, 1 female and 2 males) and contain a high frequency of a flannelmouth sucker allele (Buth 1993; Dowling and Minckley 1994; Philipp 1994).

Bonytail: The interim management objective for adult bonytail estimated population size in the upper Colorado River basin is 4118 (± 817) per population (Lentsch et al 1998). The bonytail is considered extirpated in the Upper Basin.

The bonytail was common in the Green River below its confluence with the Yampa River after Flaming Gorge Dam became operational in 1962 (U.S. Fish and Wildlife Service 1990a; Vanicek 1967). During a four year study of the upper basin (Holden 1973), 29 adult bonytails were captured during 1968, three in 1969, and four in 1970 in the Green River at Dinosaur National Monument. No young bonytail were collected during 1968 and 1970 by Holden (1973). During another study in the Green and Yampa rivers of Dinosaur National Monument between 1974 and 1976 (Seethaler et al. 1979), no bonytail were collected. One adult bonytail (279 mm TL) was reported from the lower Yampa River in 1979 (Holden and Crist 1981). No bonytail were captured from the Green River in Dinosaur National Monument during 1981-1983 (Miller et al. 1982). U.S. Fish and Wildlife Service personnel collected one suspected juvenile bonytail in 1987 (Tyus and Karp 1989).

The bonytail broodstock at Dexter National Fish Hatchery, New Mexico was developed from five pairs of bonytails collected from Lake Mohave between 1976 and 1981 (Minckley et al. 1989). Six additional bonytail from Lake Mohave were added as broodstock with the progeny of the original matings in 1988. Minckley et al. (1989) state that the genetic heterozygosity for these bonytail was comparable to mean values reported for other western North American cyprinids and that the broodstock was considered suitable producing captive-reared fish for reintroductions into suitable wild habitats.

No bonytail stocks were identified in the upper basin because no aggregations of this species exist at the present time.

Humpback Chub: The interim management objective for adult humpback chub estimated population size in the upper Colorado River basin is 4796 (± 1317) per stock (Lentsch et al 1998).

Yampa River Stock

This humpback chub population estimate is approximately 600 adults and probably stable. The humpback chub population in the Yampa River exhibits large variation in phenotypes.

Desolation-Gray Canyon Stock

This humpback chub stock is probably stable and composed of a relatively small number of fish based on collections by Holden and Stalnaker (1970), Tyus et al. (1982), Chart (1993).

Black Rocks Stock

The humpback chub stock in Black Rocks Canyon is apparently stable and is modest in size (Archer et al. 1985, 1986; Valdez and Clemmer 1982; Kaeding et al. 1990). An estimate of the population in Black Rocks-Westwater canyons is approximately 7,000 adults.

Westwater Canyon Stock

This stock is considered to be small but stable and self-sustaining (Valdez and Clemmer 1982; Chart 1994, personal communication).

Cataract Canyon Stock

The humpback chub stock in Cataract Canyon is small but apparently stable based on the presence of juvenile fish (Valdez 1990). The trend of stability should be expected to continue in this remote location since few human activities should affect the population.

Colorado Pikeminnow: The interim management objective for adult Colorado pikeminnow estimated population size in the upper Colorado River basin is 5477 (± 966) per stock (Lentsch et al 1998).

Yampa/Green River Stock

The Yampa/Green River stock of Colorado pikeminnow is stable based on the numbers of adults (n = 145) captured in the Yampa River between 1981 and 1988 and the collection of larval and postlarval pikeminnow that demonstrates successful reproduction is occurring in the river (Tyus and Karp 1989). The estimated population is approximately 1400. The downstream drift of larval pikeminnow from the Yampa River spawning area suggests that the fish must move a long distance upstream to repopulate upstream areas on the Yampa that are used for the nonspawning period of the year (Tyus 1986). Colorado pikeminnow probably return to the Yampa River as sub-adults because only 3% of 198 fish collected in the Yampa were juveniles (Tyus and Karp 1989).

Desolation-Gray Canyon Stock

The Colorado pikeminnow in the Desolation - Gray Canyons is estimated at 1,000 adults and considered stable with successful reproduction and recruitment indicating that the stock is self-sustaining.

Upper Colorado River Stock

The Colorado pikeminnow stock in the reach of the Colorado River downstream from Grand Junction, Colorado, is approximately 600 and increasing. During standardized surveys of the Upper Colorado River between RK 212.5 and 247.9, an average of 3 adult Colorado pikeminnow were captured annually between 1979 and 1981 or 0.16 fish per kilometer of river (Osmundson and Kaeding 1989**a**). The mean catch per unit of effort for subadult and adult Colorado pikeminnow by electrofishing between 1987 and 1992 has been relatively stable (an average of about 0.2 fish per hour) with a high peak of slightly more than 1 fish per hour in 1991 (McAda et al. 1993; 1994).

The Interagency Standardized Monitoring Program provides data on Colorado pikeminnow for two reaches of the Colorado River (Reach 7: RK 159 - RK 138 and Reach 8: RK 109 - RK 79). The catch per unit of electrofishing for subadult and adult Colorado pikeminnow in Reach 7 averaged slightly over 0.3 fish per hour between 1986 and 1992 (McAda et al. 1993). The catch in 1992 was over 1 fish per hour that was about three times greater than the average. The catch per unit of electrofishing for subadult and adult Colorado pikeminnow in Reach 8 averaged 0.59 fish per hour between 1986 and 1992 (McAda et al. 1993). The catch in 1992 in Reach 8 was about 1.9 fish per hour that was nearly four times the average.

Table 2. Status and trends of endangered fish stocks in the Upper Colorado River Basin (X=Known; U=, little or no information; ?=Undetermined, inconclusive or unagreed upon results based on information available).

		Criteria[1]					
Species	Populations	Identified spawning stocks	Recruitment	Population Estimate (Citation)	Interim Management Objective	Status	Probability of immediate extinction
Razorback sucker	Middle Green River (Yampa and Middle Green rivers)	X[2]	X	500 (Modde, et al. 1993)	5316 (± 804)	Declining	High
	Lower Green River	U	U	U	5316 (± 804)	Declining	High
	Upper Colorado River	U	U	U	5316 (± 804)	Declining	High
Bonytail[3]	Upper basin	?	?	?	4118 (±817)	Nearly extirpated	High
Humpback chub	Yampa River	X	X	600 (Karp and Tyus 1990)	4796 (±1317)	Insufficient information	Unknown
	Desolation-Gray Canyons	X	X	U	4796 (±1317)	Insufficient information	Unknown
	Black Rocks Canyon	X	X	1528 (Pfeifer, et al. 1998)	4796 (±1317)	Stable	Low
	Westwater Canyon	X	X	1050 (Chart and Lentsch 1999)	4796 (±1317)	Stable	Low
	Cataract Canyon	X	X	U	4796 (±1317)	Insufficient information	
Colorado pikeminnow	Green/Yampa River	X	X	1400 (Crowl and Bouwes 1998)	5477 (±966)	Stable	Low
	Desolation-Gray Canyons	X	U	1000 (Crowl and Bouwes 1998) 969 (1998 Annual Report)	5477 (±966)	Stable	Low
	Upper Colorado River	X	X	600 (Osmundson and Burnham 1997) 735 (1998 Annual Report)	5477 (±966)	Increasing	Low

[1] Definitions of Criteria:
Identified spawning stocks - Ripe fish collected on suspected spawning sites; larval fishes collected downstream of suspected spawning sites.
Recruitment - All life stages present at the site based on length frequency of the presumptive stock.
Population Status (Citation) - Documented estimates of population sizes with citation.
Interim Management Objectives - Identification of population sizes with confidence interval in Interim Management Objectives.
Status - Refers to the status of a presumptive stock from subjective judgment: stocks were considered to be increasing, stable, or declining.
Probability of extinction - Probability that a presumptive stock could be extirpated in the immediate future. High: Prevent immediate extinction due to limited or no recruitment, augmentation may postpone or prevent immediate extinction; Medium Prevent further decline of population or range expand a population, some recruitment, augment population while taking other management actions; Low: enhance a population, adequate recruitment, augmentation after other management actions (nonnative fish control, habitat improvements) have been successful.

[2] Two spawning sites have been identified one in the Yampa River and one in the Middle Green. Several razorback suckers have been observed moving between sites among spawning years.

[3] Bonytail are extremely rare in the upper basin; only occasional individuals are captured very infrequently; therefore, the probability of obtaining sufficient adult bonytails for broodstock development is very remote. Hence, bonytails of Lake Mohave origin will be used to develop broodstocks for recovery efforts in the upper basin.

VI. PRIORITIES FOR PLACING ENDANGERED FISHES IN GENETIC REFUGES OR DEVELOPING BROODSTOCKS

Priorities for holding endangered fish in refuges or for development of broodstocks for captive propagation were discussed and established by the Biology Committee based on available knowledge of their status and trends and potential risks of extinction (Table 2). These priorities are summarized in Table 3 by species and by stocks within species. Priority 1 is the highest priority and priority 4 is the lowest. Species priorities have precedence over stock priorities for propagation of placing fish in refugia. Priorities for species were based on status and trends from the Interagency Standardized Monitoring Program (McAda et al. 1994) and catch-per-unit-of-effort from research efforts. Species priority was based on status and trends of the stocks as determined from catch-per-unit-or-effort; stock priority was subjectively determined by considering historic abundance and distribution, identified spawning sites, recruitment, and the probability of the stock being extirpated in the wild.

With species and stock priorities established, the Biology Committee made decisions ("yes/no") regarding the need to place a particular stock into a refuge and develop broodstock. Table 4 reflects the decisions made by the committee over several meetings. Recognizing that the stocks of razorback sucker are continually declining the decision was made to concentrate an effort on developing the broodstock for the Green and Colorado rivers. Restoration plans for bonytail require the development of broodstock. With an augmentation plan for Colorado pikeminnow in the upper Colorado River, refugia and broodstock may be necessary. The committee decided it was not necessary at this time to place the other stocks of Colorado pikeminnow and all the stocks of humpback chub in refugia or develop broodstock.

Razorback Sucker: As a species, razorback sucker are considered the highest priority within the Recovery Program because of recent and continued population declines combined with low recruitment and poor spawning events.

Middle Green River

This stock was assigned the highest priority of "1" because the Middle Green/Yampa River stock contains approximately 500 adult fish as of 1993 and appears to be declining with an estimated 80% survival annual rate. Lack of recruitment and few numbers of spawning adults has been indicated by a lower catch-per-unit-effort and estimated population size.

Lower Green River

This razorback sucker stock was assigned priority "1" because all stocks may be important in the recovery effort.

Upper Colorado River

This stock was designated as priority "1" because of the rapid decline and precarious status. Few wild razorback suckers have been caught in recent years. Augmentation stocking events have had limited success demonstrating poor survival.

Bonytail: The bonytail is nearly extirpated in the upper basin (Maddux et al. 1993; U.S. Fish and Wildlife Service 1990a). Only occasional individuals are captured very infrequently (i.e., years between captures). Broodstocks have been developed from Lake Mohave stock for restoration stocking in the upper basin. This species was assigned Priority "2" because it is nearly extirpated from the upper basin and broodstocks for restoration stocking will be developed from Lake Mohave stock.

Humpback Chub: This species is considered third in priority within the Recovery Program, mainly because limited information on the status and trends of the various identified stocks suggests the stocks are small but stable.

Yampa River Stock

This humpback chub stock was assigned Priority "2" because it is located in the relatively unaltered Yampa River. Concern of nonnative fish predation impacting this stock is currently under investigation

Desolation-Gray Canyon Stock

The humpback chub stock in Desolation - Gray Canyons of the Green River were assigned Priority "1" because of small numbers of fish, morphological variation, and remoteness in the upper basin.

Black Rocks Stock

A priority of "4" was assigned to this stock because the phenotypes indicate a pure humpback chub stock. Recent population estimates suggest this population is within the range of current Interim Management Objective targets.

Westwater Canyon

This stock was assigned Priority "4" because the phenotypes appear to be pure humpback chubs like the Black Rocks Canyon stock. Recent population estimates suggest this population is within the range of current Interim Management Objective targets.

Cataract Canyon Stock

This humpback chub stock was assigned priority "3" within the species because the phenotypes indicate the stock is not as variable as the Yampa River and Desolation - Gray Canyon stock and the stock is less likely to be impacted from human activities.

Colorado Pikeminnow: The Colorado pikeminnow was assigned priority "4" among the four endangered fishes in the upper basin. Recent population estimates are below the currently accepted Interim Management Objectives, yet catch-per-unit-effort data from the annual Interagency Standardized Monitoring Program has not shown any decline.

Green/Yampa River Stock

The Yampa River stock was assigned priority "3" for the species.

Desolation-Gray Canyon Stock

The Desolation - Gray Canyon stock of Colorado pikeminnow was assigned priority "2".

Upper Colorado River Stock

The Colorado pikeminnow stock in the Upper Colorado River (upstream from Westwater Canyon) as assigned priority "1". These numbers are lower than in the Green River and the species has become extirpated from a large part of the historic habitat above barriers (e.g., the reach of the Colorado River between Rifle, Colorado and the Price-Stub Irrigation Diversion Dam). Activities are underway to begin stream side spawning, intensive culture and augmentation stocking to increase the population and expand the range of this Colorado pikeminnow stock

Table 3. Hierarchical priorities among endangered fish species and among presumptive stocks within species.

Priority[1] Species	Presumptive stocks	Priority of each stock
1. Razorback sucker	Middle Green/Yampa River (Razorback-Jensen Bar)	1
	Lower Green River	1
	Upper Colorado River	1
2. Bonytail	Upper Basin	1
3. Humpback chub	Yampa River	2
	Desolation-Gray Canyons	1
	Black Rocks Canyon	4
	Westwater Canyon	4
	Cataract Canyon	3
4. Colorado pikeminnow	Gren/Yampa River	3
	Desolation-Gray Canyons	2
	Upper Colorado River	1

[1] Priority - 1, indicates the highest priority and 4 indicates the lowest priority for species or stocks.
NOTE: Species priority was based on status and trends of the stocks as determined from catch-per-unit-or-effort; stock priority was subjectively determined by considering historic abundance and distribution, identified spawning sites, recruitment, and the probability of the stock being extirpated in the wild.

Table 4. Assessment of needs for inclusion of presumptive stocks in refugia and broodstock development in the Upper Colorado River Basin.

Species	Presumptive stocks	Refugia	Broodstock Development
Razorback sucker	Middle Green/Yampa River (Razorback-Jensen Bar)	Yes	Yes
	Lower Green River	Yes	Yes
	Upper Colorado River	Yes	Yes
Bonytail	Upper Basin[2]	Yes	Yes
Humpback chub	Yampa River	No	No
	Desolation-Gray Canyons	No	No
	Black Rocks Canyon	No	No
	Westwater Canyon	No	No
	Cataract Canyon	No	No
Colorado pikeminnow	Green/Yampa River	No	No
	Desolation-Gray Canyons	No	No
	Upper Colorado River	Yes	Yes

VII. SPECIFIC RECOMMENDED GENETIC MANAGEMENT ACTIONS FOR ENDANGERED FISH STOCKS IN THE UPPER COLORADO RIVER BASIN

Razorback Sucker

Middle Green River

1. Continue development of a broodstock of the Middle Green/ Yampa River (Razorback-Jensen Bar) stock at Ouray National Fish Hatchery. This stock contains sufficient fish to apply the recommended breeding strategy of 25 paired matings (i.e., 50 fish). In 1998 two more family lots were developed to give a total of 10 family lots. Over the past two years, post-spawned adults collected in the river, held a year and then induced to spawn, have failed to produce useful broodstock lots. An urgency has developed on two fronts in developing the broodstock: one, recognition by fishery biologists that the population is readily declining; and two, with the developed broodstock annual augmentation stocking numbers has not been met. A concerted effort should be made in spring 1999 to collect, hold and spawn as many razorback suckers stream side as possible to complete the 25x25 paired matings (i.e., 15 males x 15 females for 15 family lots). The progeny will be developed at Ouray NFH and Wahweap, Utah State Hatchery. In addition, 5x5 diallele crosses should be made to allow for the production of stocking plans. Consideration should be given to introducing razorback suckers from the Lake Mohave stock to enhance the genetic diversity of the Green River population.
2. Develop a broader stocking plan for the Green River. Modify stocking plan of 1000 razorback sucker to a greater number in the fall of the year using equal family lot scenarios, but also determine the success and appropriate sizes to stock. In 1995 an augmentation plan was implemented; 931 razorback sucker 100-127 mm (4-5 inches) in total length were stocked. No fish from this stocking has been collected to date and its assumed that the size of the fish was too small to escape predation and survival appears to be extremely low. In 1996, 1068 larger razorback sucker 209-308 mm (8-12 inches) in total length were stocked at Split Mountain, at least 7 of these fish were collected in ISMP monitoring efforts during the spring and summer 1997 (Tom Chart, per. comm.). Continue to implement the basinwide razorback monitoring program in the middle Green River to determine the population status and trends and evaluate stocking efforts.

Lower Green River

1. This stock has gained recognition based on the recent collections of larvae and adults in the lower Green River. Little information is available regarding movements. A question remains as to how they are related to razorback suckers from above in the middle Green River and previously collected fish in the Colorado Arm of Lake Powell. Allozyme and/or mtDNA testing should be done to determine the relatedness to razorback suckers from upstream and downstream of this river reach.
2. Continue to monitor and observe the population through basinwide razorback monitoring. Determine movements among river reach populations and Lake Powell.
3. Determine population size estimate and its relation to interim management objectives for razorback sucker.

Upper Colorado River

1. A refuge broodstock of this razorback sucker stock is being developed and augmentation stocking has been implemented in the Gunnison River from the Redlands Irrigation Diversion upstream to Delta, Colorado as well as future restoration stocking in the reach of historic habitat between Palisades and Rifle, Colorado (US Fish and Wildlife Service 1995).
2. Implement refugia and broodstock development.
3. Continue stocking in the Gunnison River, as production is increased and appropriate numbers become available, expand the stocking effort to include the Colorado River reach from Palisade to Rifle, CO when production goals have been met for the Gunnison River. A total 318 [83-110 mm (3-4 inches) total length] in 1995 and 282 [280-406 mm (11-16 inches) total length] in 1996 razorback sucker

were stocked in the Gunnison River near Delta. In 1997, approximately 3,732 were stocked. In 1998, 608 were stocked.

4. All wild adult razorback suckers that are collected in the Upper Colorado River will be maintained in refuge ponds at the Horsethief State Wildlife Area for broodstock development. During a meeting in September, 1994, the Genetic Panel recommended that the broodstock for the Upper Colorado River be developed from a mixed stock using wild adults from the nearest neighbor population (i.e., Lake Powell). Although 10 adults have been collected in 1995 and 1996 from the Colorado River and San Juan arms of Lake Powell, attempts in 1997 failed and the effort has been discontinued. The current breeding matrix at the Grand Valley endangered Fish Facility is using the 5x5 diallele cross. This should be expanded to utilize the 25x25 matings and 25 family lots strategy to reduce the risk of inbreeding. The 25x25 paired matings should be developed as soon as possible to meet upcoming production needs in restoration stocking. In the summer of 1997, 11 (6:5 male:female sex ratio) adult razorback suckers were transferred from Ouray National Fish Hatchery to the Grand Valley Endangered Fish Facility/Horsetheif Ponds. The Ouray facility had limited success in 1997 in spawning these fish. In the spring of 1998, attempts were made to spawn these fish at Grand Valley. Spawning was not very successful at Grand Valley, one lot was returned to Ouray to add to broodstock and family lot development needs in the middle Green River. Lake Mohave razorback suckers larvae should be raised to adults and used to complete the 25x25 paired matings in the event upper basin fish are unavailable by 2002.

Bonytail

1. Continue implementation of bonytail reintroduction plan. Utah Division of Wildlife Resources has developed a Bonytail Reintroduction Plan and the Program has begun implementing it in the Professor Valley reach of the Colorado River, Utah. Approximately 2000 yoy bonytail were stocked in 1996. Several weeks after stocking, 18 of the fish were collected in an evaluation of the stocking effort. In the fall of 1997, about 2200 yoy and 350 Age-I (1996 year class) bonytail were stocked again at Professor Valley.
2. Begin development of a bonytail broodstock from 25 paired matings (i.e., 50 adults) to be used in restoration stocking of this species in the upper basin until 1996. The Biology Committee unanimously agreed that development of a bonytail broodstock would have to be from Lake Mohave stock, being maintained at the Dexter National Fish Hatchery, New Mexico. Continue to allow Dexter National Fish Hatchery and Technical Center to maintain and develop bonytail broodstock, yet supply the upper basin needs for production of early life stages for grow out and stocking. Dexter is currently developing a new broodstock of bonytail principally using the 1981 year class consisting of 354 fish (sex ratio @ 50:50) (Roger Hamman, Holt Williamson, per. comm.) . The priorities at Dexter are to develop the new broodstock, and produce fish for stocking into Lake Mohave as mitigation, upper basin fish needs become the third priority. Personnel at Dexter think they can meet all these needs. If Dexter begins to fail in meeting production needs in the upper basin, because of Region 2 priorities, the Program should institute a broodstock for the upper basin. If the upper basin decides to develop a broodstock in the upper basin, the use of survivors of earlier stockings should strongly be considered, i.e., Professor Valley survivors.
3. Conduct *Gila* genetics workshop in 1999 to determine the risk of hybridization. Have acceptance by the Service for potential hybridization and determine how hybrids count toward endangered species status, management objectives and recovery goals.
4. Implement the current plan for the production 460,800 in 5 years for Colorado State waters (Nesler 1998).

Humpback Chub

Yampa River Stock

1. The morphometric and genetic information should be available in March, 1999. Humpback chubs collected from the Yampa River exhibit great variation in the nuchal hump and may be hybridizing with roundtail chubs. Conduct *Gila* genetics workshop in 1999 to determine the risk of hybridization. The Service needs to accept potential hybridization and determine how hybrids count toward endangered species status, interim management objectives and recovery goals.
2. Determine population size estimate and its relation to interim management objectives for this stock.

Desolation-Gray Canyon Stock

1. The morphometric and genetic information should be carefully reviewed when available in March, 1999. Humpback chubs collected from the Desolation-Gray Canyon reach of the Green River exhibit great variation in the nuchal hump and may be hybridizing with roundtail chubs. Conduct *Gila* genetics workshop 1999 to determine the risk of hybridization. The Service needs to accept potential hybridization and determine how hybrids count toward endangered species status, interim management objectives and recovery goals.
2. Determine population size estimate and its relation to interim management objectives for this stock.

Black Rocks Stock

1. In September 1996, 15 humpback chub were collected from Black Rocks Canyon and held in Horsethief ponds. During the summer of 1997, these fish were all lost, at least some due to coyote predation. Prior to the demise of the adult humpback chubs in Horsethief ponds, a spawn occurred resulting in 90 young of year in captivity. These fish should grown in captivity for another year and released back to Black Rocks Canyon in the fall of 1999.
2. Continue to monitor this humpback chub stock using standardized sampling methods (McAda et al. 1994) to follow the status and trend of the stock. Determine population size estimate and its relation to interim management objectives for this stock.
3. Conduct *Gila* genetics workshop in 1999 to determine the risk of hybridization. The Service needs to accept potential hybridization and determine how hybrids count toward endangered species status, management objectives and recovery goals.

Westwater Canyon

1. Continue to monitor this humpback chub stock using standardized sampling methods (McAda et al. 1994) to follow the status and trend of this stock. Determine population size estimate and its relation to interim management objectives for this stock.
2. Determine if upstream movement of humpback chubs from Westwater Canyon to Black Rocks Canyon is occurring from the large number of tagged fish in Westwater.
3. Conduct *Gila* genetics workshop in 1999 to determine the risk of hybridization. The Service needs to accept potential hybridization and determine how hybrids count toward endangered species status, management objectives and recovery goals.

Cataract Canyon Stock

1. Conduct *Gila* genetics workshop in 1999 to determine the risk of hybridization. The Service needs to accept potential hybridization and determine how hybrids count toward endangered species status, management objectives and recovery goals.
2. Determine if bonytail stocked in the Professor Valley reach are moving into the Cataract Canyon reach and possibly hybridizing with the humpback chub stock.
3. Determine population size estimate and its relation to interim management objectives for this stock.

Colorado Pikeminnow

Green/Yampa River Stock

1. Monitor the stock periodically (3-5 years) using standard sampling methods to determine the status of the stock and follow any changes in the trend of this stock.
2. Determine population size estimate and its relation to interim management objectives for Colorado pikeminnow.

Desolation-Gray Canyon Stock

1. Monitor the stock periodically (3-5 years) using standard sampling methods to determine the status of the stock and follow any changes in the trend of this stock.
2. Determine population size estimate and its relation to interim management objectives for Colorado pikeminnow.

Upper Colorado River Stock

1. Continue to monitor the Colorado pikeminnow using the Interagency Standardized Monitoring Program (McAda et al. 1994). Determine another population size estimate and its relation to the interim management objective for Colorado pikeminnow.
2. Continue development of a broodstock of the Upper Colorado River stock of Colorado pikeminnow in 1999. Seventeen family lots were developed in 1991 using the breeding strategy of a 5 X 5 di-allele cross (Williamson and Wydoski 1994). To reduce the risks of inbreeding, the 5x5 diallele crosses should be discontinued and a 25x25 paired matings resulting in 25 family lots for broodstock development implemented. The 25x25 paired matings strategy should incorporate what ever possible from the earlier 5x5 diallele crosses. Wild fish should be stream spawned in paired matings during 1999. Coordination with Dexter National Fish Hatchery and Technical Center needs to be coordinated with since they hold some of the original 5x5 diallele crosses. The broodstock will be essential in developing fish to restore the reach from Palisade to Rifle, CO.
3. Continue to monitor the movement of Colorado pikeminnow through the Redlands fish ladder. Before stocking Colorado pikeminnow from hatchery production the effects of fish moving from the Colorado River up the Gunnison should be thoroughly investigated, i.e., extent of use in the Gunnison River and length of time residing above the dam.
4. Implement a stocking plan for the reach of river between Palisade and Rifle, CO. Two plans currently exist: Burdick's (1995) plan being implemented in the Gunnison River calls for similar number for the Palisade to Rifle reach but production shortages in fish have not allowed stocking to occur; and CDOW's plan for the stocking of native fishes (Nesler 1998).

VIII. GENERAL RECOMMENDED GENETIC MANAGEMENT ACTIONS FOR ENDANGERED FISH STOCKS IN THE UPPER COLORADO RIVER

Four stocks of endangered fishes have been mated or will be mated to develop broodstocks from pedigree family lots following the Genetic Management Guidelines (Williamson and Wydoski 1994). Established schedules of upper basin biologists, logistics to obtain fish from other stocks, and lack of space limit the number of broodstocks that can be developed at the present time. Therefore, priority species and stocks were identified by the Biology Committee for development of broodstocks as described below.

Maximizing the Effective Population Size (N_e): The broodstock N_e is based on the 25x25 mated pairs, except for bonytail (5x5) in order to have the highest genetic diversity within the propagation program. The stocking of equal family lots has been the general process used to maximize N_e in the wild as stocked fish are incorporated into the population. Other ways to maximize N_e in the wild need to be pursued.

Pedigree Analyses: Methods of pedigree analysis in order to keep track of matings, progeny and crosses in following generations is needed to maximize the genetic diversity. This will aid in determining crosses among F_1 broodstock to develop production numbers in the future.

A. Razorback sucker. The razorback sucker was considered to be priority "1" among the four endangered fish species because all stocks are declining rapidly and little or no recruitment has been documented. All stocks were assigned a "Priority 1" designation since all stocks may be important in the recovery effort. In addition, some wild stocks in the upper basin (e.g., middle Green River) contain sufficient adult fish so that this species has a high potential for recovery. The development of two broodstocks of razorback suckers was begun in 1993 as an "insurance policy" to prevent immediate extinction of this species from the wild in the upper basin.

1. Middle Green/Yampa River (Razorback-Jensen Bar) Stock. In 1995, the Program switched from the 5x5 diallele cross to the 25x25 paired matings strategy to develop 25 F_1 future broodstock. Currently the Ouray National Fish Hatchery is holding 20 F_1's family lots; 7 of these are appropriate for the 25 single paired matings, the others are now excess and need to be distributed according to the disposition policy. A total of 18 males and 18 females are needed to complete the 25x25 paired matings, 7 of each sex (14 total) are being held at Grand Valley Endangered Fish Facility. In the spring of 1998, a concerted effort is being organized to collect the other 11 of each sex, spawn them stream side and maintain the family lots at Wahweap State and Ouray National hatcheries.

2. Lower Green River Stock. In 1997, one adult and two larval razorback sucker were collected near the San Rafael River and several larvae in the area of Lake Powell inflow. In 1998, two possible adult razorback sucker and flannelmouth sucker hybrids were collected by electrofishing and 35 larvae in light traps (80% of samples processed) near the confluence of the San Rafael River. Razorback sucker in the lower Green River should be genetically compared to those throughout the Upper Basin. Fish should be secured in refugia and broodstock development should be initiated.

2. Upper Colorado River Stock. Seventeen wild caught razorback sucker have been used in a 5x5 diallele cross to produce 32 family lots. The current breeding matrix at the Grand Valley endangered Fish Facility is using the 5x5 diallele cross. This should be expanded to utilize the 25x25 matings and 25 family lots strategy to reduce the risk of inbreeding. The 25x25 paired matings should be developed as soon as possible to meet upcoming production needs in restoration stocking. In the summer of 1997, 11 (6 male:5 female sex ratio) adult razorback suckers were transferred from Ouray National Fish Hatchery to the Grand Valley Endangered Fish Facility/Horsethief Ponds. The Ouray facility had limited success in 1997 in spawning these fish. In the spring of 1998, attempts will again be made to spawn these fish at Grand Valley. If spawning is successful at Grand Valley, the majority of these progeny should be returned to Ouray to meet broodstock and family lot development needs in the middle Green River. These progeny should be transported at the earliest life stage possible, but with minimum risk in mortality. A minimum number should be kept at Grand Valley for broodstock development needs in the Colorado River. To further meet the broodstock development need, adult Lake Mohave razorback suckers and/or their sperm should be used to complete the 25x25 paired matings.

B. Bonytail. The bonytail was assigned "Priority 2" among the four endangered fishes because this species is nearly extirpated from the upper basin and the possibility of using upper basin bonytails for broodstock development is very remote. The Biology Committee participants agree that broodstock development of the bonytail for future restoration stocking will be done using the Lake Mohave stock that is maintained at Dexter National Fish Hatchery in New Mexico.

1. Lake Mohave Stock. New broodstock development is continuing with 25 paired matings of bonytail at Dexter. The Program should maintain a working relationship where Dexter National Fish Hatchery maintains and develops broodstock and early life stages for grow out in the upper basin facilities.

C. Humpback chub. The humpback chub was assigned "Priority 3" among the four endangered species because the stocks are considered stable but small and localized in deep canyon river reaches.

Phenotypes of the humpback chub in the Yampa River and Desolation-Gray Canyons in the Green River vary considerably and indicates possible hybridization with roundtail chubs at these two locations. The Yampa River stock was assigned a Priority 2 designation among stocks within the species. Priority 3 within the species was assigned to the Cataract Canyon stock and Priority 4 was assigned to the Desolation-Gray Canyon stock, primarily because of the remoteness of these stocks and low potential for catastrophic risk.

1. Black Rocks Canyon Stock. Fifteen adult humpback chubs should be collected from two locations: Black Rocks Canyon and Westwater Canyon. These fish will be maintained at Horsethief State Wildlife Area, Colorado, as a safeguard against extinction from a catastrophe.

D. Colorado pikeminnow. The Colorado pikeminnow was assigned "Priority 4" among the four endangered fishes because the stocks are considered to be stable. However, the Upper Colorado River stock (upstream from Westwater Canyon) is low in number and was assigned Priority 1 among Colorado pikeminnow stocks. The other stocks were assigned Priorities 2 or 3. The stock in the Gunnison River is small and declining. A fishway has been constructed and operated at the Redlands Irrigation Diversion Dam since in 1996 which provide**s** access to Colorado pikeminnow from the Colorado River. Through October 1998, the operation of the fish ladder has allowed 23 Colorado pikeminnow to pass.

1. Upper Colorado River Stock (downstream to Lake Powell). The Colorado pikeminnow has been extirpated from its historic habitat between the Price-Stub Irrigation Diversion Dam and Rifle, Colorado. Restoration stocking of this reach has been proposed by the Colorado Division of Wildlife. Wild fish should be stream spawned in paired matings during 1999. Details of the augmentation plan to stock using the stream spawned progeny have yet to be worked out. The general concept is to raise the progeny intensively in for a period of 1 to 3 years to attain a size where survival is greatly enhanced. The majority of these fish will be used to establish themselves in the river above the Price-Stubb Irrigation Diversion Dam. In addition, translocation of adults to above the Price-Stubb Irrigation Diversion Dam will potentially allow the determination of adult movements from this section of river prior to passage being constructed.

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APPENDIX 1.

GLOSSARY

Adaptive management - Making decisions based on available information and allowing flexibility for refinements (i.e., adaptation) to such decisions as new information becomes available.

Allele - One of two or more alternate forms of the same gene; alleles for the same gene occur at the same locus; each individual diploid organism has a maximum of two alleles for a specific gene.

Allee effect - The effect that results when a critical number of mature animals may be is not available for successful natural reproduction.

Allozyme - An enzyme produced by an allele at a structural gene locus; different allozymes are produced by different alleles at the same locus.

Artificial selection - The process of choosing parents on the basis of a trait in order to obtain a phenotypic and genetic change in the next generation.

Broodstock - Progeny from pedigreed matings of endangered fish that will be used for the production of offspring for stocking.

Di-Allele cross - The mating of all different combinations of animals to produce family lots as broodstocks. For example, a 5 X 5 di-allele cross would produce 25 family lots.

DNA - Abbreviation for deoxyribonucleic acid.

Dominance - The property of an allele that suppresses expression of other alleles at the same locus; a dominant allele is the only allele expressed phenotypically in a heterozygote.

Effective population size - The size of an ideal population that would experience genetic drift and inbreeding at the same rate as the real population under consideration.

Electrophoresis - A laboratory procedure for the separation of proteins (enzymes) that can be used as genetic markers.

Enzyme - A protein produced in living cells that speeds up a specific chemical reaction.

Evolutionary Significant Unit - A natural biological grouping of animals that exhibit patterns of diversity associated with evolutionary history, breeding isolation, unique adaptation, and production.

Factorial mating - The mating of different numbers of males and females to produce broodstocks. In general, the least numerous sex is mated with mature animals of the more abundant sex. For example, if a single female was available, it would be mated with several mature males to produce a number of family lots corresponding to the number of males that were available.

Full-sibs - Individuals having both parents in common.

Gene - A segment of DNA that occupies a specific position (locus) on a chromosome, is heritable, and has one or more specific effects upon the phenotype of an organism.

Genetic diversity - The genetic variation in within and among individuals, populations, or species.

Genetic drift - random or chance changes in the allelic frequencies due to natural or human sampling errors that occur each generation; the rate of genetic drift may increase as the effective population size decreases.

Genotype - The set of alleles at one or more loci in a organism; the entire set of genes carried by an individual.

Half-sibs - Individuals having one parent in common.

Haploid - a cell (i.e., gamete) or organism with a single set of homologous chromosomes.

Hardy-Weinburg equilibrium - the relationship between allelic and genotypic frequencies in a stable population after a single generation of random mating.

Heterozygote - A cell or organism with two different alleles at a particular locus.

Homozygote - A cell or organism with two identical alleles at a particular locus.

Hybridization - Interbreeding of different species and the union of gamete that results in a new organism.

Inbreeding - Mating of closely related individuals (e.g., brothers and sisters).

Inbreeding depression - The loss in fitness of offspring due to the unmasking of deleterious recessive alleles that results from mating closely related individuals.

Isozymes - Multiple molecular forms of enzymes that promote the same chemical reaction but may be the products of alleles at different loci.

Locus - the position of a particular gene on a chromosome.

Mitochondrial DNA (mtDNA) - Deoxyribonucleic acid (DNA) found in the mitochondria of a cell; mtDNA is inherited from the maternal parent.

Natural selection - The selection of successful genotypes in natural environments on the basis of phenotypic traits related to fitness.

Naturalized stocks or populations - Fish that have become established in river reaches after augmentation or restoration stocking and are completing their entire life cycle in natural environments.

Outbreeding Depression - The loss in fitness of offspring due to the breakdown of coadapted gene complexes from mating individuals that are too distantly related.

Phenotype - The physical characteristics of an individual organism that can be detected visually; phenotypes are influenced by the genotype and environment.

Polymorphic - A gene or qualitative trait that exists in two or more forms in a population.

Population - A group of organisms that freely interbreed.

Presumptive Stock - A group of individuals that are presumed to be a breeding aggregation that has spatial, temporal, or behavior integrity.

Recessive - A trait or allele that is expressed only in homozygotes.

Stock - A randomly breeding group of individuals that has spatial, temporal, or behavioral integrity from other randomly breeding groups of that same species.

Supplementation - Stocking of captive-reared fish with the goal of augmenting or restoring self-sustaining populations; the genetic diversity of broodstocks is maintained through proper breeding strategies.

Wild stocks or populations - Endangered fish that are naturally reproducing and have the potential for natural recruitment if limiting factors are eliminated.

APPENDIX 2.
CRITERIA USED FOR THE IDENTIFICATION OF STOCKS

A. Razorback sucker. Razorback suckers historically occurred in the Colorado, Green, and San Juan rivers of the Upper Colorado River Basin; and was found in the Colorado River, as far upstream as Rifle, Colorado (Bestgen 1990). Historic distribution of the razorback sucker in the Green River extended from its confluence with the Colorado River, upstream to Green River, Wyoming (Baxter and Simon 1970). Razorbacks also occurred in the lower Yampa River, from its confluence with the Green River upstream to the confluence of the Little Snake River (Lanigan and Tyus 1989; McAda and Wydoski 1980) and in the Gunnison River upstream to Delta, Colorado (Holden 1980; Hubbs and Miller 1953; Wiltzius 1978). Razorback suckers are now extirpated from the Gunnison River. This species was never recorded in the Dolores River (Holden and Stalnaker 1975). Sigler and Miller (1963) reported them as uncommon in the lower White River near Ouray, Utah.

The razorback sucker occurs presently in the Colorado River upstream to Palisade, Colorado (Bestgen 1990), in the Green River from its confluence with the Colorado River upstream to its confluence with the Yampa River, and generally in the lower 2.1 km of the Yampa River (Tyus 1990; Tyus and Karp 1990; Tyus and Karp 1991). Individual razorbacks may occur farther upstream. For example, two adult razorback suckers (one in 1979 and one in 1980) were collected in the Lily Park area of the Yampa River at about RK 80.5 (Wick et al. 1982).

Three presumptive stocks of razorback suckers were identified in the upper basin: Middle Green/Yampa River (Razorback-Jensen Bar), Lower Green River, and Upper Colorado River (Tyus 1997). Two concentration areas for razorback sucker in the upper basin were identified as (1) the Green River from the mouth of the Duchesne River to the Yampa River and (2) the Upper Colorado River from Grand Junction to Clifton, Colorado (U.S. Fish and Wildlife Service 1987).

1. Middle Green (Yampa and middle Green rivers)

(1) Spawning Sites and Movements. Modde and Wick (1997) described the seasonal and spawning movements of 7 male razorback suckers in the middle Green River. Tagged razorback suckers moved throughout the system sometimes establishing themselves at various tributary mouths and dispersing both upstream and downstream after spawning occurred. Two of these fish moved to different spawning areas in separate years**.**

The largest concentration of spawning razorback suckers in the Upper Colorado River Basin occurs in the middle Green River between RK 486.4 and RK 504.0 at a site known as "Razorback Bar" (RK 311.5) when the water temperature averaged 14.1 C with a range of 9 to 17 C (Tyus and Karp 1990). Most ripe razorback suckers (98%, n = 191) were collected in flowing water in riffles but, during the high flows of 1986, 30% of ripe or tuberculated fish were captured in flooded river bottoms of Old Charley Wash and Stewart Lake Drain (Tyus and Karp 1991). Twelve ripe razorback suckers were captured in Old Charlie Wash (an off-channel lake with an inlet and an outlet) in late May and June (Tyus and Karp 1990). These fish may have entered this site after spawning to forage on abundant zooplankton since the fish were robust and in excellent condition.

Thirty-two ripe razorback suckers were captured in the lower Yampa River during the spring of 1975, 1981, 1988, and 1989 (Tyus and Karp 1989). The average depth at capture was 0.61 m and the average water velocity was 0.64 m/s. The average water temperature was 13.8 C with a range of 10.5 to 16 C (Tyus and Karp 1990). McAda and Wydoski (1980) reported capturing 14 ripe razorback suckers (12 males and 2 females) on a cobble bar composed of cobble from 20 to 50 mm in diameter that was located about 400 meters upstream from the mouth of the Yampa River during May of 1975. Other females that were captured nearby in the Green River and Yampa River were not ripe, indicating that females do not occupy spawning areas until they are ready to spawn. A female razorback sucker was captured in the Island Park area of the Green River in April of 1975 that was recaptured 2 weeks later at the mouth of the Yampa River (McAda and Wydoski 1980). This fish was ripe when recaptured, indicating that the 21 km movement was for spawning.

R. Muth (per. comm.) confirmed about 270 razorback sucker larvae collected from the Green and Colorado rivers from Razorback/Jensen Bar in the middle Green River to the Sheep Canyon area in the inflow of the Colorado River into Lake Powell. Although razorback sucker larvae have been collected in the upper basin, few juveniles have been collected.

The razorback sucker exhibits movements of moderate distance, up to 138 kilometers (86 river miles) (McAda and Wydoski 1980). Spawning migrations between 31 kilometers (19 miles) and 106 kilometers (66 miles) in the Green River were reported by Tyus and Karp (1991). Razorback movements between 7 and 12 miles were reported by Osmundson and Kaeding (1989a). Although some razorback suckers exhibited a fidelity to a specific spawning riffle in different years, the adults dispersed to different areas of the Green River for the remainder of the year (Tyus and Karp 1990).

Three adult razorback suckers were documented to move between spawning sites on the Green River and Yampa River that are approximately 70 km apart:

1. A ripe male razorback sucker (Tag Number 5015) was captured on April 28, 1989 at RK 0.8 on the Yampa River and recaptured at RK 500 in the Green River on May 18, 1989. This was the only instance where a ripe razorback sucker was captured from the two rivers in the spawning season during the same year (T. Modde, per. comm.).

2. A ripe adult male (Tag Number 6148) was captured in the Green River at RK 500.7 on May 25, 1988 and again on April 24, 1990 that corresponds to the spawning season for razorback suckers. This fish was recaptured on May 13, 1994 at the mouth of the Yampa River, RK 0 (T. Modde, per. comm.).

3. A razorback sucker with a radio transmitter (Frequency 40.140) collected on the Yampa River spawning bar in 1993 but moved to Escalante spawning area in 1994; another male collected at Island Park in 1993 also moved to the Escalante spawning area in 1994 (Modde and Wick 1997).

Although three adult razorback suckers were captured at two known spawning sites, they may have been moving to a primary spawning site. Therefore it is uncertain whether these fish actually spawned at both sites.

(2) <u>Fidelity to Spawning Sites.</u> There is documentation that some razorback suckers exhibit a spawning fidelity to a specific riffle (Tyus and Karp 1990). Limited results from imprinting studies indicated only approximately half the fish moved into a test chamber. However, those that did move significantly chose the chamber with the substance they were imprinted on (B. Haines, per. comm.). In addition, two of six radio tagged males moved to different spawning sites in separate years (Modde and Wick 1997). Twenty-six razorback suckers (22 males and 4 females) in breeding condition were recaptured in the same spawning reach in different years, indicating a fidelity to that site (Tyus and Karp 1990). Tyus and Karp reported that six fish were captured at that site in three different years. Also, Tyus and Karp

reported a capture of a ripe male in the lower Yampa River in 1988 that had been tagged at the same site in 1981 indicating a fidelity to this spawning site.

Although initial studies indicated fidelity to spawning sites, more recent information from radio telemetered adult male razorback suckers, suggests a fair amount of movement by individuals among spawning sites. Modde and Iriving (1998) found 3 of 6 adult males monitored through three consequtive spawning years were located at multiple spawning sites. In addition, two fish visited two sites during the same spawning year. Adult fish occurring at multiple spawning areas suggests a single spawning population; perhaps with most individuals of the population spawning in a single area, while others move among other spawning sites.

(3) Geographic Distribution. The largest group of reproducing razorback suckers in a lotic environment occurs in low gradient reaches of the Green River Basin, with the center of distribution between the mouth of the Duchesne River to the mouth of the Yampa River (Tyus and Karp 1990; 1991).

Holden and Stalnaker (1975) found scattered razorback suckers throughout most of the upper basin and discovered concentrations of 10 to 15 fish in the mouth of Yampa River in March and November 1970. During 1974-1976, twenty-seven razorback suckers were collected from Echo Park area of Dinosaur National Monument (McAda and Wydoski 1980). Razorback suckers occupied the mouth of the Yampa River from late fall and apparently remained there until the following spring when they migrated about 400 meters upstream to spawn. Razorback sucker are rarely found upstream as far as the Little Snake River (McAda and Wydoski 1980; Lanigan and Tyus 1989; Hawkins et al. 1997). Razorback suckers utilize pools and shoreline runs with a depth of < 2 m and an average velocity of < 0.5 m/s the lower 21 km of the Yampa River (Tyus 1987; Tyus and Karp 1989).

(4) Molecular Genetic Characterization. Undetermined.

Buth et al. (1987) stated that "Introgressive hybridization has important management and evolutionary consequences in regard to maintenance of the integrity of gene pools and the acquisition of new alleles by means other than mutation." Buth et al. (1987) reported that some introgression has occurred involving the razorback sucker and flannelmouth sucker. They estimated that introgression for two loci was low and in the range of 0-5% toward flannelmouth sucker and 0-3% toward razorback sucker.

The variation in mtDNA in razorback suckers from the Upper Colorado River Basin (the most northern part of the species range) is less than in the lower basin (Dowling and Minckley 1994). Razorback suckers from Lake Powell contained 7 haplotypes (n=20), the Green River contained 4 haplotypes (n=28), and the Upper Colorado River contained 1 haplotype (n=27). In the lower basin (Lake Mohave), razorback suckers contained 32 haplotypes (n=48). In determining mitochondrial DNA diversity among razorback populations, Dowling et al. (1996) have determined that substantial geneflow occurred between populations historically. They recommended for genetic conservation purposes treating the razorback sucker throughout the basin as one breeding population. Although debate still persists on this topic, the general guideline followed for developing broodstock was outlined in Wydowski (1994), that being to use local populations first, then go to nearest neighboring populations then to the Lake Mohave population.

(5) Morphological Characterization. Unknown.

2. Lower Green River Stock

(1) Spawning Sites and Movements. Muth et al. 1997 recently collected one tuberculated adult and 2 larvae in the San Rafael River area indicating spawning and production is occurring in the lower Green River. Fifteen larvae that have been confirmed through DNA analysis as razorback sucker larvae were collected in the Lake Powell inflow during June 21-22, 1993 (Valdez and Cowdell 1994). These larvae were captured in light traps in Sheep Canyon at RK 285 by National Park Service personnel. Based on their size and adults collected near Green River, Utah, they could not have originated much further upstream.

The paucity of adult razorback suckers in the inflow of the Colorado River into Lake Powell casts doubt that spawning is occurring in this area. It is most likely that the razorback sucker larvae drifted into the inflow from upstream spawning sites.

(2) Fidelity to Spawning Sites. Unknown.

(3) Geographic Distribution. Muth et al. (1997) recently collected one tuberculated adult and 2 larvae in the San Rafael River area indicating spawning and production is occurring in the lower Green River; additionally some adults have been collected in fyke nets by the Utah Department of Natural Resources during routine monitoring in areas around Green River, Utah (T. Chart, per. comm.). The draft Razorback sucker recovery plan has used this information to require 2000 adult fish in this river reach to meet downlisting requirements. These fish most likely contributed to a larger geographical area which included the Colorado River Arm of Lake Powell.

(4) Molecular Genetic Characterization. In determining mitochondrial DNA diversity among razorback populations, Dowling et al. (1996) have determined that substantial geneflow occurred between populations historically. They recommended for genetic conservation purposes treating the razorback sucker throughout the basin as one breeding population. Although debate still persists on this topic, the general guideline followed for developing broodstock was outlined in Wydowski (1994), that being use local populations first, then go to nearest neighboring populations then to the Lake Mohave population.

(5) Morphological Characterization. Unknown.

3. Upper Colorado River Stock

(1) Spawning Sites and Movements. McAda and Wydoski (1980) collected ripe razorback suckers of both sexes from the Walter Walker State Wildlife Area (an embayment connected to the Colorado River by a canal near Grand Junction, Colorado) during 1974-1976. Ripe male razorback suckers were also collected from this site in May and early June 1979-1980 (Wick et al. 1982). Aggregations of razorback suckers were also collected from gravel pits along the Colorado River near Clifton, Colorado (Wick et al. 1982). These fish gained access to the gravel pits through drainage ditches and culverts. Ripe razorback suckers of both sexes were collected from these pits, artificially spawned, hatched in greenhouses at the Colorado State University campus (E. Wick, per. comm.).

Razorback suckers apparently do not move very far in the Upper Colorado River. Osmundson and Kaeding (1989a) reported short movements of up to 19 km in the Upper Colorado River for razorback suckers. Eight fish, tagged with Floy Anchor Tags, were recaptured near the original point of capture in successive years at the Walter Walker State Wildlife Area (McAda and Wydoski 1980). A single razorback sucker that was tagged in the "15-mile reach" of the Colorado River (RK 275 - RK 298) in 1986 moved to a side channel near the Walter Walker State Wildlife Area and remained there until the following spring. This fish moved to a deep pool at RK 270 where it remained until April 1988 when it moved to the location where it had been originally tagged in 1986 (Osmundson and Kaeding 1989a).

Although no recruitment of the razorback sucker has been documented in the Upper Colorado River, Osmundson and Kaeding (1989b) suggested that flooded bottomlands may have been historically the primary spawning areas in the Grand Valley. Levees constructed to contain the river in the channel prevent the razorback sucker from using flooded bottomland sites in this river reach at the present time. A major Recovery Program action is to reconnect flooded bottomlands with the rivers in the upper basin to serve as nursery areas for the razorback sucker. However, this enhancement and restoration will also provide suitable habitats for nonnative, warmwater fishes that are considered to be predators or competitors with the endangered fishes. It is imperative that measures to control nonnative fishes be incorporated into the planning to reconnect the flooded bottomlands with the rivers to ensure some survival of razorback sucker larvae.

(2) Fidelity to Spawning Sites. Unknown.

(3) Geographic Distribution. Razorback suckers were caught in the Colorado River at the roller dam, upstream of Palisade, Colorado (Quartarone 1993). Quartarone reported that older residents along the Upper Colorado River told him of large numbers of fish, including razorback suckers, that were deposited in peach orchards from irrigation ditches near Palisade and many suckers [hundreds] including razorback suckers were found dead in irrigation ditches that were drained to control aquatic vegetation along the Gunnison River near Delta, Colorado.

The largest numbers of razorback suckers in the Upper Colorado River occurred in the Grand Valley of Colorado (Valdez et al. 1982; Osmundson and Kaeding 1989a). Long-time residents reported "several thousand" razorback suckers using flooded areas adjacent to the Colorado River in the Grand Valley in the 1930's and 1940's (Osmundson and Kaeding 1989b). Wick et al. (1982) reported capturing 8 razorback suckers from gravel pits along the Colorado River near the old bridge near Clifton, Colorado in 1980. Several of these fish were ripe and were spawned on site.

During a survey of gravel pits along the Upper Colorado River, upstream of irrigation dams, razorback suckers were found in a pond (Etter Pond) near Debeque, Colorado (B. Emblad, 1994, personal communication). Emblad estimated a population of 609 razorback suckers in the pond using the mark-recapture method. It is believed that these fish were trapped in the pond when high streamflows of 1983 and 1984 receded. Age analyses of scales supported this belief. Forty razorback suckers from this population were radio-tagged and stocked in two locations in the upper basin: 20 were stocked in the Colorado River near Debeque and another 20 were stocked in the Gunnison River near Delta, Colorado following a stocking plan prepared by Burdick (1992).

(4) Molecular Genetic Characterization. In determining mitochondrial DNA diversity among razorback populations, Dowling et al. (1996) have determined that substantial geneflow occurred between populations historically. They recommended for genetic conservation purposes treating the razorback sucker throughout the basin as one breeding population. Although debate still persists on this topic, the general guideline followed for developing broodstock was outlined in Wydowski (1994), that being use local populations first, then go to nearest neighboring populations then to the Lake Mohave population.

(5) Morphological Characterization. Unknown.

B. Bonytail.

1. Upper Colorado River Basin Stock

(1) Spawning Sites and Movements. None are known at the present time. The most recent report of natural reproduction of the bonytail in the upper basin was in Dinosaur National Monument in the Green River during 1959, 1960, and 1961 (Vanicek and Kramer 1969). Spawning of bonytail has not been observed in a river but collection of ripe fish in the Green River at Dinosaur National Monument during late June and early July when water temperatures were about 18 C provides some information related to spawning (Vanicek and Kramer 1969).
Spawning bonytail were observed over a gravel bar in Lake Mohave in water about 9 m deep shortly after its impoundment (Jonez and Sumner 1954). A female was generally escorted by 3 to 5 males and apparently broadcasted her eggs. This behavior is typical for many minnows. Wagner (1955) concluded that spawning by bonytail occurs in late spring or early summer in Lake Mohave.

Nothing is known about the movements of bonytail in riverine environments. Bonytail collected by Vanicek (1967), Vanicek and Kramer (1969), and Holden and Stalnaker (1975) were never tagged. Few bonytail have been captured in the upper basin since 1975.

(2) Fidelity to Spawning Sites. Unknown.

(3) Geographic Distribution. The historic distribution of the bonytail included the mainstem of the Colorado, Gunnison, and Green rivers in the upper basin (U.S. Fish and Wildlife Service 1990a). The distribution of the bonytail occurred upstream in the Green River to southern Wyoming in the vicinity of the present Flaming Gorge Reservoir (Smith et al. 1979), in Dinosaur National Monument of Colorado and Utah (Vanicek and Kramer 1969), and Desolation and Gray Canyons (Holden and Stalnaker 1975). Bonytail occurred in the Colorado River from Lake Powell (E. Wick, per. comm.), Cataract Canyon (Valdez 1990), upstream to the vicinity of Grand Junction, Colorado (Smith et al. 1979). Smith et al. (1979) also reported that the bonytail occurred in the Gunnison River.

Several of the last confirmed captures of bonytails included a single specimen from the Colorado River in Black Rocks Canyon in 1984 (Kaeding et al. 1986), two adults and three juveniles from Cataract Canyon during 1985-1987 (U.S. Fish and Wildlife Service 1990a), and one bonytail adult from the Colorado River about four miles upstream from its confluence with the Green River in 1993 (F. Pfeifer, per. comm.).

(4) Molecular Genetic Characterization. Dowling and DeMarais (1993) reported that introgressive hybridization played an important role in creating a high morphological diversity among *Gila* minnows in western North America. Dowling and DeMarais (1993) stated that the Colorado River *Gila* represent a complex of self sustaining, genetically distinctive species that are capable of exchanging genetic material. Although the phylogenetic linkages are distinct, local introgression has clearly occurred among the three Colorado River *Gila* in the past.

(5) Morphological Characterization. Unknown.

C. Humpback chub. The historic distribution of the humpback chub in the upper basin included the Colorado, Green, White, and Yampa rivers (U.S. Fish and Wildlife Service 1990b).
The present stocks of humpback chub are small to moderate in size and restricted to isolated deep canyon areas of the upper basin. Viable stocks of humpback chub occur in Black Rocks and Westwater Canyons of the Colorado River (Valdez and Clemmer 1982). A small population of humpback chub occurs in Cataract Canyon of the Colorado River (Valdez and Williams 1986). Humpback chubs were collected from Desolation-Gray Canyons on the Colorado River in the early 1970's (Holden and Stalnaker 1975), during the late 1970's into the mid-1980's (Tyus et al. 1987), and during 1989-1992

(Chart 1993). The final stock of humpback chub was identified in the Yampa River (Tyus and Karp 1989).

Some *Gila* that have been tentatively identified as humpback chubs have been collected at other sites in the upper basin. *Gila* with humpback chub characteristics were collected from Debeque Canyon area of the Upper Colorado River (RK 314) in 1979-80 (Valdez 1980). In the spring of 1988, seven suspected humpback chub adults and two suspected roundtail chub - humpback chub hybrids were collected from the Little Snake River (Wick et al. 1991). Wick et al. (1991) believed that the chubs used the Little Snake River in the spring when high stream flows occurred in the Yampa River.

Five presumptive stocks of humpback chub have been identified in the upper basin: Yampa River, Desolation-Gray Canyons of the Green River, and Black Rocks, Westwater, and Cataract Canyons of the Colorado River (Wydoski 1994).

1. <u>Yampa River Stock</u>

   Although Tyus and Karp (1989) reported that the humpback chub can be distinguished from roundtail chubs (*Gila robusta*) based on qualitative and quantitative criteria of Douglas et al. (1989), field identification of this species has been reported by other investigators to be difficult (Holden and Stalnaker 1970; Valdez and Clemmer 1982). Although there is a great deal of variation in the phenotypes of humpback chub, the species is considered to be very "plastic" in morphology (M. Douglas, per. comm.). Humpback chubs in the Yampa River and Desolation-Gray Canyons of the Green River exhibit large variation in phenotypes (Chart 1993; Tyus and Karp 1989, 1990).

   (1) <u>Spawning Sites and Movements</u>. Spawning of humpback chubs was first documented in Yampa Canyon in 1986 with the capture of 2 spent females and 2 ripe males (Tyus et al. 1987). Spawning was documented again in 1987 with the capture of 2 ripe females and 7 ripe males and in 1988 with the capture of 1 ripe female and 5 ripe males (Tyus and Karp 1989). Tyus and Karp reported a total of 32 humpback chubs (counting fish that were tuberculated) in spawning condition in Yampa Canyon. Thirteen juvenile humpback chubs (168-227 mm TL) were collected from Yampa Canyon between RK 0.16 and RK 64 (Tyus and Karp 1989).

   Three recaptures of 32 tagged mature humpback chubs occurred in Yampa Canyon (Tyus and Karp 1989). Only local movement has been documented for this species in the Colorado River (Kaeding et al. 1990). It is assumed that little movement of adult humpback chubs occurs out of the Yampa River.

   (2) <u>Fidelity to Spawning Sites</u>. Unknown.

   (3) <u>Geographic Distribution</u>. Humpback chub were first reported from the lower Yampa River by Holden and Stalnaker (1975). Tyus and Karp (1991) reported 95 captures of humpback chub from the Yampa River between 1981-1988. Humpback chubs were most often captured in shoreline eddies off rapids with large boulders as substrate and an average depth of 2 m. Juvenile humpback chubs inhabit shoreline eddies and runs (Tyus and Karp 1991).

   (4) <u>Molecular Genetic Characterization</u>. Undetermined.

   (5) <u>Morphological Characterization</u>. In comparison of qualitative characters *between Gila cypha* (humpback chub) and *G. robusta* (roundtail chub), Douglas et al. (1989) could discriminate from several meristic characters the two species and indicated apparently no hybridization has occurred.

2. <u>Desolation - Gray Canyon Stock</u>

Chart (1993) stated that some humpback chubs were readily identified by morphologic characters but that many of the *Gila* from Desolation - Gray Canyons were less distinct, resulting in inconclusive identification similar to the observations of Holden and Stalnaker (1970).

(1) Spawning Sites and Movements. Young *Gila* have been collected from Desolation and Gray Canyons of the Green River in the range of 0 -25 mm TL during 1992 and larger fish of 76 - 200 + mm in 1989, 1990, 1991, and 1992 (Chart 1993) indicating that spawning occurs in this reach of the Green River. However, actual spawning has not been documented for the humpback chub in this reach of the Green River.

Seven humpback chubs were recaptured at the original capture site in Gray Canyon between 1 and 11 months after release (Tyus et al. 1982). The humpback chubs in Desolation - Gray Canyons of the Green River are expected to exhibit only localized movements based on movement information on the species from other locations (Archer et al. 1985, 1986; Kaeding et al. 1990).

(2) Fidelity to Spawning Sites. Unknown.

(3) Geographic Distribution. Humpback chub were collected from Desolation Canyon of the Green River in 1967 (Holden and Stalnaker 1970). This species was also collected from Desolation - Gray Canyons during 1979 - 1981 (Tyus et al. 1982). Humpback chubs were also collected in both canyons during 1985 - 1992 (Chart 1993).

Desolation Canyon (RK 342 to RK 249) continues with Gray Canyon (RK 249 - RK 211) beginning with the Three Fords Rapid. Both canyons are adjacent to each other and are therefore considered to be one geographic area in the Green River (Chart 1993).

(4) Molecular Genetic Characterization. Undetermined.

(5) Morphological Characterization. Unknown.

3. Black Rocks Stock

Humpback chubs from Black Rocks and Westwater Canyons can be identified rather well from morphologic and meristic characteristics (Valdez and Clemmer 1982; Kaeding et al. 1990). Kaeding et al. (1990) reported difficulty with identification of about 9.5% of the 597 *Gila* that were examined during 1983-1985.

(1) Spawning Sites and Movements. Ripe humpback chubs were collected in 1980-1981 from Black Rocks Canyon from intermittent sand beaches between protruding rock pillars (Valdez and Clemmer 1982). Valdez and Clemmer suggested that spawning may have occurred on nearby gravel bars based on observations made at Willow Beach National Fish Hatchery, Arizona, where captive humpback chubs spawned on 4 - 10 cm cobble in a raceway. Humpback chubs in Black Rocks Canyon spawned from about mid-June to the end of July when the river discharge was at its peak or on the descending limb of the hydrograph and the water temperature was 14-24 C (Kaeding et al. 1990).
The humpback chub and roundtail chub spawn at the same time (i.e., temporal overlap) but remain spatially separated from the closely related roundtail chub in Black Rocks Canyon of the Colorado River where the deep, swift riverine habitat of the canyon reach have not been altered by humans (Kaeding et al. 1990).

Thirty-three humpback chub and 17 roundtail chub had radio transmitters implanted in them to determine their movements in Black Rocks Canyon (Kaeding et al. 1990). The humpback chubs remained in Black Rocks Canyon and exhibited localized movements with a maximum displacement of 1.4 km from their release site whereas roundtail chubs had a mean displacement of 33.9 km. Kaeding et al. also recaptured 63 Carlin-tagged humpback chubs. Most (55) were tagged during the 1983-1985 period and the remaining 12 fish were tagged during earlier investigations in 1979, 1980, and 1981. Humpback chubs that were at large for up to 56 months were recovered an average distance of 1.1 km from their release sites (range 0 - 21.7 km).`

One humpback chub that was recaptured in 1983 and another that was recaptured in 1984 were tagged at Westwater Canyon in 1980 that is about 22 km downstream from Black Rocks Canyon in the Colorado River (Kaeding et al. 1990). Sixteen of 218 humpback chubs that were tagged with Carlin tags in Black Rocks and Westwater Canyons during 1979-1981 moved an average of 1.6 km (range 0 to 23 km) from the release sites between 1 and 434 days after release (Valdez and Clemmer 1982). One humpback chub that was tagged in Westwater Canyon was recaptured 232 days later in Black Rocks Canyon about 23 km upstream from the release site (Valdez and Clemmer 1982). Four unidentified PIT-tagged humpback chubs were captured by Tom Chart, Utah Division of Wildlife Resources, in Westwater Canyon in 1994. Two of these fish were PIT-tagged in Black Rocks Canyon (B. Emblad, per. comm.). One fish traveled 24 kilometers downstream in two days after being tagged and the second fish traveled 27 kilometers in 3 days after tagging. Hence, some interchange of humpback chubs occurs between the two sites.

The humpback chub stocks (e.g., the stocks in Black Rocks and Westwater Canyons in the Colorado River) do not migrate for spawning (Kaeding et al. 1990) but a lower basin humpback chub stock spawns in the Little Colorado River and some of the fish remain in the Little Colorado River year-round (R. Valdez, per. comm.). However, most fish move into the mainstem Colorado River in the Grand Canyon for the remainder of the year (Kaeding and Zimmerman 1983; R. Valdez, per. comm.).

(2) Fidelity to Spawning Sites. Unknown.

(3) Geographic Distribution. Concentrations of humpback chub were reported from Black Rocks Canyon of the Colorado River in 1980 and 1981 (Wick et al. 1980; Valdez and Clemmer 1982). Adults occur as a localized population that inhabit runs and eddies with bedrock, boulder, and sand substrates in this deep canyon reach of the Colorado River. The mean depth occupied by adult humpback chubs in this reach was 4.3 m (range 0.7 - 12.2 m) with a mean water velocity of 0.18 m (range 0.03 - 1.16 m/s) . Juvenile humpback chubs inhabited a similar habitat and most juveniles were found in small eddies, pools, or angular pockets along rock walls (Valdez and Clemmer 1982). Forty-five percent of 597 mature *Gila* collected from Black Rocks Canyon were positively identified as humpback chubs based on morphologic and meristic characteristics (Kaeding et al. 1990). About 9.5% of the *Gila* from this reach could not be classified with certainty. Equal numbers of adult roundtail chubs were collected from the site during 1983-1985 (Kaeding et al. 1990).

(4) Molecular Genetic Characterization. Undetermined.

(5) Morphological Characterization. Unknown.

4. Westwater Canyon

(1) Spawning Sites and Movements. Natural reproduction of humpback chubs has been documented in Westwater Canyon from the collection of all life stages including young, juveniles, subadults, and adults (Valdez and Clemmer 1982). The humpback chub probably spawns at or shortly after peak flows similar to the conditions at Black Rocks Canyon 22 km upstream in the Colorado River. Juvenile humpback chub in Westwater Canyon occupy low velocity areas along the shoreline during low flow years and backwaters during high flow

years (T. Chart, per. comm.). An apparent relationship in young Gila appears to be related to streamflow in Westwater Canyon. More juvenile humpback chub were collected during moderate to high streamflow years. During low streamflow years, more juvenile roundtail chubs appear to be present in this river reach (T. Chart, per. comm.).

Humpback chubs exhibit localized movements within their, deep canyon reach (Valdez and Clemmer 1982; Kaeding et al. 1990). Three adult humpback chubs of 43 tagged in Westwater Canyon moved upstream to Black Rocks Canyon (Valdez et al. 1982). Four unidentified PIT-tagged humpback chubs were captured by Tom Chart, Utah Division of Wildlife Resources, in Westwater Canyon in 1994. Two of these fish were PIT-tagged in Black Rocks Canyon (B. Emblad, per. comm.). One fish traveled 24 kilometers downstream in two days after being tagged and the second fish traveled 27 kilometers in 3 days after tagging. Hence, some interchange of humpback chubs occurs between the two sites.

About 1,200 humpback chubs were PIT-tagged by the Utah Division of Wildlife Resources through 1994 and most recaptures of these fish were close to the point of release (T. Chart, per. comm.).

Some interchange occurs between the humpback chub populations in Black Rocks and Westwater Canyons.

(2) Fidelity to Spawning Sites. Unknown.

(3) Geographic Distribution. The humpback chub stock in Westwater Canyon is considered to be a small but stable, self-sustaining population (Valdez and Clemmer 1982). These fish occupied similar habitats to those described for the Black Rocks Canyon stock.

(4) Molecular Genetic Characterization. Undetermined.

(5) Morphological Characterization. Unknown.

5. Cataract Canyon

The long geographic distance between other humpback chub stocks in the Upper Colorado River Basin from Cataract Canyon (206 RK upstream to Westwater Canyon on the Colorado River and 257 RK upstream to Gray Canyon on the Green River) and localized movements that have been reported for this species (Valdez and Clemmer 1982; Kaeding et al. 1990) suggests that little exchange should be expected among these stocks.

(1) Spawning Sites and Movements. Actual spawning of bonytail chub has not been documented in Cataract Canyon or the upper basin. However, the presence of juvenile fish that have been identified from morphologic characters as well as suspected larval fish and young-of-the-year fish that are suspected to be humpback chubs provides evidence that successful recruitment is occurring in the 26 km reach of Cataract Canyon (Valdez 1990).

The humpback chub stock in Cataract Canyon has not been studied as intensively as the stocks in Black Rocks, Westwater, and Yampa canyons. However, short, localized movements in Cataract Canyon may be assumed to be similar to that documented for Black Rocks and Westwater canyons (Valdez et al. 1982; Valdez and Clemmer 1982; Kaeding et al. 1990).

(2) Fidelity to Spawning Sites. Unknown.

(3) Geographic Distribution. Twenty-two adult humpback chubs, 56 juveniles, 19 young-of-the-year, and 11 larvae were collected from Cataract Canyon on the Colorado River during 1985-1988 (Valdez 1990).

(4) Molecular Genetic Characterization. Undetermined.

(5) Morphological Characterization. Unknown.

D. Colorado pikeminnow. The historic distribution of the Colorado pikeminnow in the Upper Colorado River Basin included the Colorado, Dolores, Gunnison, Little Snake, White, Uncompahgre, and Yampa rivers (U.S. Fish and Wildlife Service 1991).

The present distribution of the Colorado pikeminnow includes the Colorado River from Palisade, Colorado downstream to Lake Powell; the Green River from the confluence of the Yampa River downstream to its confluence with the Colorado River; the Yampa River from Hayden, Colorado downstream to its confluence with the Green River; the White River from Taylor Draw Dam near Rangely, Colorado, downstream to its confluence with the Green River; and the Gunnison River (Maddux et al. 1993; Miller et al. 1982; U.S. Fish and Wildlife Service 1991). Some adult Colorado pikeminnow occupy the upper Yampa River but migrate to the lower Yampa to spawn (Tyus and McAda 1984; Tyus and Karp 1989). Colorado pikeminnow also inhabit other upper basin reaches such as the White and Green Rivers during nonspawning periods and migrate to other sites for spawning. For example, no larval or young-of-the-year pikeminnow were collected from the White River during 1983-1985 but 41 adults were captured (Matinez 1986). Martinez (1986) reported that most captures or sightings (69%) occurred about 16 km below Taylor Draw Dam.

One adult pikeminnow was collected in the White River 33.8 km above Rangely, Colorado (Wick et al. 1980). Seventeen adult pikeminnow were collected in the White River during 1992 and 15 during 1993 (Irving and Modde 1994). Adult Colorado pikeminnow congregate below Taylor Draw Dam (Lanigan and Berry 1981; Martinez 1986; Chart et al. 1987; Trammel et al. 1993). However, an attempt to establish Colorado pikeminnow in Kenney Reservoir by stocking 96,597 fingerlings (65-114 mm TL) was unsuccessful (Trammel et al. 1993). Trammel et al. (1993) also reported that four captive-reared adult pikeminnow and three wild adults with radio tags were released in Kenney Reservoir. Only one of the wild pikeminnow moved into the White River upstream of the reservoir and remained there until its signal was lost. The other adult fish either died or moved downstream.

During the spring of 1988, contact was made with two radio-tagged Colorado pikeminnow in the Little Snake River (Wick et al. 1991). These fish were radio-tagged in September 1987 and released in the Yampa River about 3 km above its confluence with the Little Snake River. Contact was made with one of these fish in a known spawning site later in 1988 (Wick et al. 1991). Wick et al. suggested that some adult Colorado pikeminnow may move into the Little Snake River to feed or to escape the high spring streamflows in the Yampa River similar to their use of backwaters and flooded mouths of smaller tributaries elsewhere in the upper basin.

Four presumptive spawning stocks of Colorado pikeminnow were identified in the upper basin: Yampa River, Desolation-Gray Canyons of the Green River, Gunnison River, Upper Colorado River.

Gilpin (1993) conducted a population variability analysis of the Colorado pikeminnow in the Upper Colorado River Basin and concluded that this species is not threatened by any stochastic force that may threaten the species with extinction by any reasonable standard (e.g., a 1% threat in 100 years). Gilpin pointed out that this analysis was based on the assumption that present environmental conditions in the upper basin will not change significantly.

1. Green/Yampa River Stock

(1) Spawning Sites and Movements. Adult Colorado pikeminnow migrate downstream in the Yampa and White rivers and upstream in the Green River to spawn in a common area of the lower 51.2 km of the Yampa Canyon (Tyus and Karp 1989). The single Yampa River stock disperses after spawning to other river reaches. Forty-three radio-tagged Colorado

pikeminnow were tracked to the Yampa Canyon spawning area between 1981 and 1988. Most (65%) of these fish were from the upper Yampa River, 30% from the Green River, and 5% from the White River.

Successful reproduction of Colorado pikeminnow has been demonstrated in the drift from the Yampa River from collections of larval (sac-fry) Colorado pikeminnow (Tyus et al. 1982; Haynes et al. 1984). Larval pikeminnow (9-13 mm) were collected in the lower Yampa River by Tyus and McAda (1984). These larval pikeminnow concentrate in shallow backwaters in the Green River (Tyus et al. 1982; 1987). The estimated time for larval pikeminnow to drift from the midpoint of the spawning area in the Yampa River (RK 26.4 - RK 29.1) to its mouth is 16 days (Tyus and Karp 1989).

(2) Fidelity to Spawning Sites. Fidelity of Colorado pikeminnow to spawning sites has been documented by Tyus (1985) and Wick et al. (1983). Tyus (1985) documented the migration of 8 radio-tagged Colorado pikeminnow to the Yampa River spawning areas in 1981 and 8 radio-tagged Colorado pikeminnow in 1983. Two ripe fish caught in 1983 were captured at this site in 1981 and one fish tagged in 1982 returned to the same location for spawning. Baseline flow spikes are apparently used as spawning cues, for Colorado pikeminnow in the Yampa River (Nesler et al. 1988).

The average one-way distance of migration by Colorado pikeminnow to the spawning site in the Yampa Canyon was 124.8 km (Tyus and Karp 1989). The longest migration was documented as 372.8 km for a Colorado pikeminnow from the White River that migrated to the Yampa River spawning site. This fish was tagged at RK 164.8 of the White River in 1983, tracked to RK 49.6 of the Yampa in the spring of 1984, and recaptured at RK 156.8 of the White River in 1985.

(3) Geographic Distribution. Adult Colorado pikeminnow occupy the Yampa River from its confluence with the Green River upstream to Craig, Colorado (Tyus and Karp 1989). The upper Yampa River is a concentration area for overwintering adults based on contacts with radio-tagged fish (Tyus et al. 1987) and information on abundance (Miller et al. 1982). During winter, adult Colorado pikeminnow inhabit backwaters, embayments, runs, and eddies in the Yampa River and exhibit local movements (Wick and Hawkins 1989). In spring and early summer, adult Colorado pikeminnow use backwaters or flooded bottomland habitats in the Yampa River (Tyus and Karp 1989).

(4) Molecular Genetic Characterization. The movements of Colorado pikeminnow to the common spawning area in the Yampa from different rivers (Green, White, and Yampa) during the spawning season demonstrates that this stock disperses widely after spawning (Tyus and Karp 1989).

A draft report on the comparison of genetic diversity through allozyme techniques indicates little difference among the populations in the upper Colorado River basin (Williamson et al. 1998). However, the authors continue to stress the need of local adaptability of several populations should be maintained in any broodstock program that is developed if possible.

(5) Morphological Characterization. Unknown.

2. Desolation - Gray Canyon Stock

(1) Spawning Sites and Movements. Colorado pikeminnow spawn in Gray Canyon of the Green River (Tyus 1990). The Gray Canyon is one of two major spawning areas for the Colorado pikeminnow in the Green River subbasin. The other site is the lower 51.2 km of the Yampa Canyon (Tyus 1990). Spawning occurs during a 4-5 week period when water temperatures are 22-25 C, usually in July and August (Holden and Wick 1982; Tyus 1990). Flow spikes

from rainstorms during the spring runoff was concluded to be a physical event, in conjunction with environmental factors, that provided adult Colorado pikeminnow with the cue to initiate spawning (Nesler et al. 1988). If the flow spike is absent during a low flow year, water temperature of 20 C may trigger the spawning of Colorado pikeminnow (Hamman 1986).

Larval Colorado pikeminnow drift downstream from the spawning areas and concentrate in shallow backwaters that serve as the principal nursery areas for this species (Haynes et al. 1984; Tyus and Haines 1991; Tyus 1991). The catch per effort of juvenile Colorado pikeminnow in the spring ranged from 6.5 to 28.9 per 100 square meters of backwaters that were seined in the Green River during 1986, 1988, and 1989 (Tyus and Haines 1991). Survival was considered to be best when late summer and autumn flows were low (Tyus et al. 1987). During the high flows of 1983 and 1984, survival of young Colorado pikeminnow was low and was assumed to be due to the lack of suitable backwaters that are used as nursery areas (Tyus and Haines 1991).

(2) Fidelity to Spawning Sites. Migrations of Colorado pikeminnow averaged 140.7 km (n = 63; range 32 - 372.8 km) in the Green River subbasin (Tyus 1990). Most Colorado pikeminnow (63%) tracked during 1980-1988 (n = 153) in the Green River were highly mobile with 41% migrating to known spawning sites and 11% migrating to suspected spawning sites (Tyus 1990). Tyus concluded that the fidelity of Colorado pikeminnow to specific spawning sites could be used for stock differentiation since most fish were repeat spawners at these sites.

The downstream drifting of larval Colorado pikeminnow from spawning sites (Haynes et al. 1984; Haines and Tyus 1991) and there sequential return upstream as subadults suggests that pikeminnow may become imprinted to a specific spawning site (Tyus 1985) but establish a home range during nonspawning periods in another river reach (Wick et al. 1983). Subadult and adult Colorado pikeminnow from different river systems (e.g., Green, White, and Yampa rivers) spawn in the same area (Tyus and Karp 1989, 1991) and home back to a specific river reach during the nonspawning period (Wick et al. 1983). A single spawning stock probably occurs by innate behavior of imprinting and homing behavior is probably learned by subadult fish as they move upstream and establish a home range (Tyus 1991).

(3) Geographic Distribution. Adult Colorado pikeminnow are most abundant in the middle Green River near Ouray, Utah, and lower Green River near Labyrinth Canyon downstream from the town of Green River, Utah (Tyus et al. 1987). This species is widely distributed in the Green and Yampa rivers where it is considered more abundant than any other location in the upper basin (Tyus et al. 1982).

(4) Molecular Genetic Characterization. A heterozygosity of 3.1% was determined for Colorado pikeminnow collected from 5 sites in the Green River at RK 109, 125, 149, 170, and 184 (Ammerman and Morizot 1989). Although these five sites are downstream of the Desolation-Gray Canyon reach of the Green River, this is the only information available on the genetics of Colorado pikeminnow from the Green River. This heterozygosity is very comparable to the average value of 3.78% for nine other cyprinid genera (Ammerman and Morizot 1989). A draft report on the comparison of genetic diversity through allozyme techniques indicates little difference among the populations in the upper Colorado River basin (Williamson et al. 1998). However, the authors continue to stress the need of local adaptibility of several populations should be maintained in any broodstock program that is developed if possible.

(5) Morphological Characterization. Unknown.

3. Upper Colorado River - (downstream to Lake Powell)

(1) Spawning Sites and Movements. Several spawning sites and suspected spawning sites have been documented for the Colorado River between Clifton, Colorado downstream to Cataract Canyon.

The reach of the Colorado River between Clifton and Grand Junction, Colorado (RK 257 - RK 290) has been a suspected spawning site for Colorado pikeminnow (Archer et al. 1985). During 1982-1985, fifteen of 34 Colorado pikeminnow (44%) that were radio-tagged in the 15-mile reach remained there during May and October (Osmundson and Kaeding 1989a). Based on the movements of radio-tagged Colorado pikeminnow, some pikeminnow use the 15-mile reach all year and other pikeminnow occupied the reach most of the year except during the spawning season (Osmundson and Kaeding 1989a). Suitable flows, water temperatures, and habitat for spawning by Colorado pikeminnow occurred in the 15-mile reach (Osmundson and Kaeding 1989a). Since larval pikeminnow drift downstream from the spawning areas and concentrate in shallow backwaters that serve as the principal nursery areas (Haynes et al. 1984; Tyus and Haines 1991; Tyus 1991), it is very likely that pikeminnow spawned in the 15-mile reach. Both larvae and young-of-the-year pikeminnow have been collected in the 18-mile reach immediately downstream (Osmundson and Kaeding 1989a).

The reach of the Colorado River between Loma, Colorado and Black Rocks Canyon, RK 233 - RK 217 is also a suspected spawning area for Colorado pikeminnow (Archer et al. 1985).

Colorado pikeminnow may spawn in or near Cataract Canyon approximately 22-29 km below the confluence of the Colorado River with the Green River (Valdez 1990; U.S. Fish and Wildlife Service 1991). Other locations where suspected spawning areas for the Colorado pikeminnow may occur is Professor Valley above the confluence with the Green River at RK 121-RK 137 and upstream from the confluence of the Dolores River between RK 160 and RK 185 (Archer et al. 1985; U.S. Fish and Wildlife Service 1991). All of these reaches contained aggregations of Colorado pikeminnow larvae and suitable spawning habitat (U.S. Fish and Wildlife Service 1991).

Spawning of Colorado pikeminnow has been suspected in the Gunnison River because the species has persisted even though a barrier (Redlands Irrigation Diversion Dam) was operational since 1917 (B. Burdick, per. comm.). During 1993, 5 wild adults were captured above the diversion and 5 wild adults were captured below the diversion. Seven of these fish were radio-tagged, 5 that were captured from below the diversion and 2 captured from above the diversion (F. Pfeifer, per. comm.). These fish aggregated in a specific area of the Gunnison River (RK 48 to RK 46) in early August when the water temperatures were suitable for spawning in 1993 and 1994 (B.Burdick, per. comm.). Larval Colorado pikeminnow were collected at two stations above the Redlands dam in both 1995 and 1996 (R. Anderson, per. comm.). The capture of these pikeminnow larvae documents that spawning occurs in the Gunnison River.

Two Colorado pikeminnow larvae were collected in the Gunnison River below the Redlands in 1992 (R. Anderson, per. comm.). The spawning site where these originated is unknown. A drift net station was established in the Gunnison River above Redlands in 1993 but no larval Colorado pikeminnow were collected. A new drift net station (at Bridgeport) was established in 1994 below RK 46 where radio-tagged Colorado pikeminnow aggregated in 1993 (B.Burdick per. comm.).

Colorado pikeminnow movements in the Grand Valley area of the Colorado River are small (within 80 km of the release site) in comparison with movements of pikeminnow in the

Green River subbasin that averaged 140.7 km with a maximum movement documented of 372 km (Tyus 1990).

However, it should be recognized that this disparity in movement is influenced by irrigation diversion dams that serve as barriers to upstream pikeminnow movement in the Colorado River.

There are no documented exchanges between the Colorado and Green rivers although numerous fish have been tagged in both rivers have been sampled.

Little is known about the movements of adult Colorado pikeminnow in the Gunnison River. The persistence of large pikeminnow in the Gunnison River suggests that some spawning may have occurred there. Larval pikeminnow drift downstream (Haynes et al. 1984; Nesler et al. 1988; Tyus and Haines 1991) to rear in backwater nursery areas. Subadults move upstream to areas used for feeding and resting during the nonspawning period but migrate either upstream or downstream to specific spawning areas (Tyus and Karp 1989; Tyus and Karp 1991). If spawning by Colorado pikeminnow occurs in the Gunnison River, the larvae probably drift downstream over the Redlands Irrigation Diversion Dam or are lost in the diversion. Subadults returning can now gain access as of June, 1996, via a fish ladder which was constructed around the dam. Some survival of larval pikeminnow may occur in the Gunnison River above the diversion dam because some adults are still found there 87 years after the diversion was constructed. Another possibility is that pikeminnow may have had access to the Gunnison River when the diversion dam was being repaired.

(2) Fidelity to Spawning Sites. Unknown.

(3) Geographic Distribution. The Colorado pikeminnow presently occupies the Colorado River from Palisade and Delta (Gunnison River), Colorado, downstream to Lake Powell.

The Colorado pikeminnow utilizes three adjacent reaches of the Colorado River in the Grand Valley: the 15-mile reach (RK 298 - RK 275) that extends to the confluence with the Gunnison River, the 18-mile reach immediately downstream and the lower 3.5 km of the Gunnison River between Redlands Irrigation Diversion Dam and the confluence with the Colorado River (Osmundson and Kaeding 1989a).

Between 1985 and 1988, 4,348 Colorado pikeminnow (4,161 young-of-the-year, 175 juveniles, and 12 adults) were collected in Cataract Canyon upstream from Lake Powell (Valdez 1990).
While conducting studies to define spawning of striped bass (*Morone saxatilis*) in Lake Powell during the spring of 1981, Persons and Bulkley (1982) collected 51 adult Colorado pikeminnow from the Colorado River Arm of Lake Powell.

(4) Molecular Genetic Characterization. A mean heterozygosity of 5.3% was found for Colorado pikeminnow that were collected from three sites at RK 81, 94, and 160 (Ammerman and Morizot 1989). This heterozygosity is much greater than the mean heterozygosity value of 3.78% for nine other cyprinid genera (Ammerman and Morizot 1989). Genotypes deviated from Hardy-Weinberg proportions at two loci (EST-1*, GPI-2*) in the Colorado River samples and at one locus (EST-1) from the Green River (Ammerman and Morizot 1989). Such deviations suggests reduced gene flow (Ammerman and Morizot 1989).

(5) Morphological Characterization. Unknown.

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