RESTORATION OF HABITAT AND CONSERVATION OF GENETIC RESOURCES TO EFFECT RECOVERY OF ENDANGERED FISHES OF THE LOWER COLORADO RIVER IN THE CONTEXT OF ADAPTIVE MANAGEMENT OF ECOSYSTEMS

FIRST DRAFT

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EXECUTIVE SUMMARY

The endangered "big river fishes" of the Colorado River, the Colorado squawfish, bonytail chub, humpback chub, and razorback sucker, were abundant in the advent of the 20th century but now face extinction as the 21st century dawns. Presently, the Colorado squawfish has been extirpated from the lower basin and the bonytail chub is on the brink of extinction. A series of massive dams and diversion projects has drastically altered the natural hydrology and aquatic environments of the wild Colorado River. These man-made structures have precluded completion of life histories of the big river fishes by impounding riverine habitat behind high mainstem dams which release cold, fluctuating flows and block migration routes of spawning

fish. As a result, population losses of native fishes and habitat degradation has paralleled the rapid development of water projects throughout the southwestern United States in the 20th century.

The recognition that a species is endangered indicates that their populations have been severely reduced, usually by destruction or disruption of natural habitats. Population losses and reductions in distributional range signal the loss of genetic resources, i.e., genetic diversity and adaptive genotypes. Loss of genetic resources reduce the ability of species to evolve (adapt) in response to environmental change or may preclude successful re-establishment in some parts of the former range. Endangered species continue to lose genetic resources because of random processes in small populations, or because of selection driven by disruption/destruction of natural habitats, or through negative interactions with introduced species. Without intervention, continuing loss of genetic resources in remaining populations may seal the destiny of extinction for endangered species. Luckily, the long life spans of the big river fishes of the Colorado River have prolonged the extinction process and provide managers with opportunities to intervene to preserve genetic resources and implement conservation actions to reduce population losses.

The massive scale of habitat alterations in the lower Colorado River basin is daunting; minor mitigative conservation actions beneficial to endangered fishes may be too little and too late to prevent extinction of remnant wild populations. When whole ecosystems are significantly disrupted by human activities, specific habitat protection/restoration and species-by-species conservation actions for endangered species are not generally successful. Usually, there is a lack of sufficient funding and societal support and such approaches ignore the connections between species and their biological communities and ecosystems. Thus, species recovery is more likely in the context of ecosystem restoration and management where the linkages of physical and biological components are considered.

In recent years, the adaptive management approach has been developed and used to address ecosystem-level management and restoration. In the lower Colorado River basin, an adaptive management program has been established by the U.S. Department of the Interior to operate Glen Canyon Dam for the benefit of downstream natural resources in Grand Canyon. This new management approach addresses disruption/destruction of ecosystem functions and components as the root causes of species endangerment and extinction. Because ecosystem and habitat restoration are necessary for recovery of endangered species, recovery should be a major goal of adaptive management programs and the status of endangered species can serve as indicators of ecosystem health and function. An adaptive management program is recommended for operation of Hoover, Davis, and Parker dams in the lower Colorado River to address ecosystem restoration and endangered species recovery. This recommended adaptive management program should be linked to the Grand Canyon program to further recovery programs for endangered fishes.

While adaptive management programs hold great promise for ecosystem/habitat restoration and recovery of endangered species, the recovery process may be prolonged and extinction becomes a likely outcome. Thus, conservation actions employing innovative approaches are needed to reverse or stop population losses and improve opportunities for future recovery. Conservation actions to preserve population resources should be a corollary to habitat and ecosystem restoration programs. Genetic management programs are especially critical to maintaining genetic resources of endangered species and will improve the likelihood of future re-establishment of populations throughout their former distributional range. Other conservation actions should address control of introduced predators and diseases, management of aquatic environments for the benefit of natives fishes, establishment of experimental populations, establishment or augmentation of captive broodstocks, and supplemental stocking in remnant populations when guided by approved genetic management plans.

BACKGROUND

During the 20th Century, the installation of a system of massive dams and diversions in the lower Colorado River basin has transformed the once wild and muddy river into a chain of large oligotrophic reservoirs connected by highly regulated river reaches of clear, cold water. Prior to this Federal program to harness the water resources of the Colorado River, four indigenous "big river" fishes were abundant in mainstem habitats: Colorado squawfish, bonytail chub, humpback chub, and razorback sucker. Declines and extirpation of these unique fishes have paralleled the progress of the construction of water development projects along the Colorado River, which has lead to their listing as endangered species in the last quarter of the 20th century.

The massive scale of habitat alterations in the lower Colorado River basin is daunting; there is essentially no natural riverine habitat remaining below the inflow of Lake Powell to protect for native fishes. Here the Colorado River ecosystem is permanently altered from its natural state and is actively or passively managed by operation of mainstem dams. The principal effect of dams on native fishes of the Colorado River has been their reduction or elimination in mainstem habitats. Construction and operation of dams have altered or destroyed natural riverine habitat and drastically altered conditions necessary for completion of native fish life histories. Alterations include shift from lotic to lentic habitat in impounded reaches, radical changes in river hydrology in flowing portions, prevention of seasonal flooding, loss of sediment and nutrient inputs, imposition of perennially cold, daily fluctuating clear water releases downstream of dams, blockage of upstream migration routes to adults, and impairment of downstream drift and survival of young. Full restoration of pre-dam hydrographic regimes, warm water conditions, and large inputs of sediment are impractical or impossible short of removal of the dams.

Ecosystem/habitat restoration is usually viewed as necessary to effect recovery of endangered species. Species recovery is achieved when ecosystems are sufficiently restored to allow populations of listed species to be self-sustaining, viable components of biological communities.

A critical component of recovery is protection and/or restoration of habitat needed to complete a species' life history. Without the appropriate habitat (type, quantity, stability, etc.) in suitable locations (within historic distributional range) and with suitable conditions (climate, hydrology, control of exotic predators, competitors, diseases, etc.), recovery is impossible. The ideal of ecosystem/habitat restoration may need to be tempered in cases of highly altered and managed systems that have great economic value to society, such as the system of massive dams and diversion projects on the lower Colorado River. Political and economic realities preclude restoration of this system to pre-settlement "pristine" or "wilderness" conditions for the sake of listed fishes. However, it may be possible to restore some components of ecosystem function and natural habitat by changing the operation of mainstem dams.

A new concept in ecosystem restoration is *adaptive management,* an iterative learning approach in which research, monitoring, and management actions are tied in feedback loops to allow refinement of management actions so as to better achieve restoration goals. This new approach to ecosystem management is being implemented in the Grand Canyon with the passage of the Grand Canyon Protection Act of 1992 and signing of the Record of Decision (ROD) for the Glen Canyon Dam Environmental Impact Statement (EIS) in 1996. Changes in dam operations in the context of adaptive management are aimed at restoring ecosystem functions to improve the status of downstream natural resources. *Achievement of recovery of listed species needs to be a primary goal of adaptive management programs because recovery signals significant restoration of ecosystem health and function.*

One of the greatest obstacles to effective habitat restoration is the lack of riverine life history information for most native fishes; almost all the anthropogenic alterations in the river system occurred before detailed ecological studies were conducted. Without accurate life history information, it is difficult to know how to effectively modify dam operations. Without knowledged-based recommendations, costly modifications of dam operations would be difficult to justify. However, the long life spans of larger river fishes (20-50 years) has provided extra time to resolve problems in acquiring life history knowledge and formulating recommendations for management actions. However, time is rapidly running out for endangered fishes of the lower Colorado River; populations of some species have long since disappeared (e.g., Colorado squawfish; bonytail chub), others are expected to disappear in the near future (e.g., razorback sucker), or current status is jeopardized (e.g., humpback chub).

Implementation of ad hoc mitigative conservation plans for the sole benefit of endangered species are usually not successful in preventing ultimate extinction of remnant wild populations, especially when ecosystems are significantly disrupted by human activities. Such programs usually seek specific habitat protection/restoration on a species-by-species basis. Usually, there is a lack of sufficient funding and societal support and such approaches ignore the connections between species and their biological communities and ecosystems. Furthermore, such countermeasures do not address the root cause of species endangerment and insult, i.e., grossly disturbed ecosystems. Species recovery is more likely in the context of ecosystem restoration and management where the linkages of physical and biological components are considered. The primary strategy for achieving recovery is protection and/or restoration of habitat critical to completion of a species' life history. However, by focusing exclusively on this objective, actions to restore habitat assume that populations of the listed species remains sufficiently stable so that future successful re-establishment is possible. In many cases this assumption is false. Habitat restoration may be a protracted process and the remaining populations of listed species may dwindle toward extinction.

In order to increase opportunities for future recovery, population resources, particularly genetic variation, must be conserved. Lessons from evolutionary biology tell us that populations require sufficient genetic diversity to achieve local adaptation or to adapt to future changing conditions. Populations with low genetic diversity or lacking key adaptive genotypes, are less likely to persist for long periods. Unfortunately, many species have become threatened or endangered because of drastic reductions in population size as a consequence of habitat destruction. A consequence of those reductions is loss of genetic diversity and key genotypes (=genetic resources) which will greatly compromise the success of future recovery efforts. Once an endangered species is recognized, protection of remaining populations is critical for preserving opportunities for future recovery. Protection usually involves securing appropriate habitat, reducing or eliminating take, and exercising management actions that promote reproduction. A corollary to this protection of habitat is implementing a genetic management plan conserve the remaining genetic resources. Usually, recovery is in the distant future and populations of endangered species may undergo continual population reductions with concomitant loss of genotypes brought about by strong selection in altered environments.

A lack of attention to implementing peer-reviewed genetic management plans has caused further losses of genetic resources in endangered species. Captive broodstocks with inherently low genetic variation have been massively overstocked in remaining populations, and the resulting genetic swamping has resulted in further losses of genetic resources. Probability of long-term persistence of these populations is low. In other cases, managers have inadvertently selected for certain genotypes for propagation and stocking programs by use of selective capture gear or other sampling biases. Greater attention to sampling designs and inventory of genetic resources is required to improve opportunities for recovery. There is an urgent need to rethink our approach to protecting and recovering endangered species; too little consideration has been given to taking steps to preserve the genetic resources of remaining populations or to assessing impacts of well-intentioned but ultimately harmful stocking programs.

STATUS OF NATIVE BIG RIVER FISHES IN THE LOWER COLORADO RIVER BASIN (LCRB)

Early in this century, the razorback sucker (*Xyrauchen texanus*), Colorado squawfish (*Ptychocheilus lucius*), and bonytail chub (*Gila elegans*) were abundant and distributed throughout the upper and lower Colorado River and its larger tributaries, the Green, San Juan, and Gila rivers. Razorback sucker and bonytail chub were especially abundant in the lower

Colorado River downstream of its confluence with the Gila River and in the lower Gila River drainage. Declines of these species followed the construction of dams and water diversions during the first half of the 20th century.

Bonytail chub have been extirpated throughout most of their historical range; only a small population persists in L. Mohave, a mainstem reservoir in the lower basin. Colorado squawfish has been extirpated in the lower basin and its numbers greatly reduced in the upper basin; stocking programs in the upper basin are beginning to show some modest success. A small population of razorback sucker persists in the Green River between and Yampa and White rivers in Utah while the largest remaining population is found in Lake Mohave. The L. Mohave population was trapped in the reservoir by the final closure of Davis Dam in 1954. It has been noticed that razorback sucker populations trapped in newly formed reservoirs have persisted for ~40-45 years without measurable reproduction before disappearing; examples include Roosevelt, Havasu, and Mead (and now Mohave) (Minckley et al. 1991). If the same pattern is followed as with other reservoirs, this L. Mohave population will disappear in 40-45 years, that is, around the turn of the 21st century. Signs of the decline are already evident: population estimates have declined from 60,000 in the late 1980s to less than 25,000 in recent years (Paul Marsh, pers. comm.). As this population continues to decline, there is a irreplaceable loss of genetic resources that will diminish opportunities for future recovery and persistence of the species. In recent years, the Native Fish Work Group, acting as an ad hoc multi-agency recovery team for the L. Mohave razorback sucker population, has reared larval razorback suckers collected from the lake and released as young adults. This effort is intended to address the lack of successful recruitment of razorback suckers in L. Mohave. However, a shortage of suitable rearing facilities limits the production of young razorback suckers for stocking into the lake. While efforts are underway to alleviate this shortage, time may be running out. Hopefully, sufficient numbers of razorback suckers will be stocked into the lake to offset the impending population decline.

Like the other big river fishes of the Colorado, humpback chub (*Gila cypha*) has undergone large reductions in range and numbers of populations after erection of numerous mainstem dams and flooding of white water canyon habitats. The humpback chub is restricted to swift, canyon-bound reaches of the Colorado River. In the upper basin, relatively small populations persist in 5 restricted reaches (Black Rocks, Westwater Canyon, Cataract Canyon, Desolation/Gray canyons, and Yampa Canyon). The largest remaining population is found in the lower basin in Grand Canyon in the vicinity of the Little Colorado River. Because of the difficulty of sampling in rugged remote canyon reaches, the status of the upper basin populations is difficult to assess. The Grand Canyon population has been intensively studied over the period 1991-1995 and data from monitoring efforts go back to 1978. Recent preliminary population analyses suggest this population has undergone significant reductions over the past 20 years and is vulnerable to loss or extirpation.

LOCAL ADAPTATION, LONG-TERM RECOVERY, AND CONSERVATION OF RIVERINE GENOTYPES

The long life span of the big river fishes has prolonged population declines and extirpation. Over the past 30-40 years ecologists have become aware of the critical status of these species which has lead to their listing as endangered and the designation of critical habitat in the Colorado River basin. Clearly, if these species had 10-year life spans, they would have become extinct long before we recognized their populations were imperiled by anthropogenic alterations of the Colorado River. A well accepted principle of population and evolutionary biology is the need for genetic variation in populations to allow evolutionary adaptation to different environmental conditions over time and space. Local adaptations may be reflected in the preponderance of specific genotypes in some localities because these genotypes manifest life history traits that are most adaptive to the local environment. Long-term persistence of species in changing environments is dependent on sufficient genetic variation upon which natural selection can act. Without sufficient genetic variation or where some specific genotypes are lost, the probability of extinction increases.

As already discussed, endangered species have already undergone significant reduction in numbers and in populations, which indicates the loss of genetic diversity and perhaps genotypically determined life history traits. The altered conditions in the Colorado River preclude many genotypes from successful reproduction, however, the long life span of these fishes provides a unique opportunity to preserve some genotypes that have not successfully reproduced for 30-50 years. Genotypes that spawn in mainstem riverine habitats under warm flowing conditions during summer months during or immediately after seasonal flooding have not spawned successfully after installation of mainstem dams. Genotypes that can spawn at constant low temperatures in reservoirs or in smaller tributaries with altered spawning phenologies are preferentially selected. Long-term recovery and persistence of the big river fishes of the Colorado River depend on conservation of genotypes that provide life history traits adapted to natural riverine conditions. Presently, there is a small window of opportunity (<5-10 years) to preserve some of these riverine genotypes before the last old wild fish die out. This can be accomplished through peer-reviewed, vigorous genetic management plans which include augmentation of broodstocks and collection and preservation of genetic resources through sperm banks. Remnant populations of old fish that have not successfully reproduced should be targeted for banking of genetic resources (e.g, razorback sucker population in L. Mohave tailwater, mainstem humpback chub population at river mile 30 of Marble Canyon, remaining large bonytail chub in L.Mohave).

RECOVERY OF ENDANGERED LCRB FISHES IN THE CONTEXT OF ADAPTIVE MANAGEMENT OF ECOSYSTEMS

As stated in Section 2 of the Endangered Species Act (ESA), the purpose of the Act is to "*provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved and to provide a program for the conservation of such endangered and threatened species*". Clearly, the authors of the ESA recognized the importance of addressing protection and recovery of endangered species within an ecosystem context. Success of these efforts is less likely if problems are addressed on a species-by-species basis without consideration of the biological communities and ecosystems that support endangered and threatened species. Because entire ecosystems are involved, recovery and protection can never be the responsibility of a single agency or interested party, and the Act states that such programs are intended to be a cooperative efforts among Federal and State agencies and interested parties: "*It is further declared to be the policy of Congress that all Federal departments and agencies shall seek to conserve endangered species and threatened species and shall utilize their authorities in furtherance of the purposes of this Act*", and, "*It is further declared to be the policy of Congress that Federal agencies shall cooperate with State and local agencies to resolve water resource issues in concert with conservation of endangered species*". The Act states that the Federal Government will promote protection and recovery of endangered species and their ecosystems by "*encouraging the States and other interested parties, through Federal financial assistance and a system of incentives, to develop and maintain conservation programs*".

A Prime example of application of the ecosystem approach intended by the ESA can be found in recently adopted adaptive management programs. Adaptive management is an iterative learning approach to ecosystem management inwhich research, monitoring, and management actions are tied in feedback loops to allow refinement of management actions so as to better achieve restoration goals. This approach promises assessment and achievement of goals in a timely fashion. Ideally, these programs are implemented by a host of stakeholders, including Federal, State, and other interested parties. Although the goal of ecosystem management is to broadly restore and maintain ecosystem components and functions, endangered species recovery should be a primary focus of management plans. The status of endangered species can be used as an indicator of ecosystem health and function and can be used to assess the progress or success of ecosystem restoration.

With the passage of the Grand Canyon Protection Act of 1992 and the signing of the Record of

Decision for the Glen Canyon Dam EIS in October 1996, the Department of the Interior has launched an Adaptive Management Program to improve and enhance the natural resources for the Grand Canyon. The intent of the program is to establish a new adaptive management approach to operation of Glen Canyon Dam for the benefit of the downstream environment, including endangered species. This program is a clear example of the Federal government providing financial assistance and incentives to *"develop and maintain conservation programs"* to *"resolve water resource issues in concert with conservation of endangered species"*.

DEVELOPMENT OF LIFE HISTORY MODELS AND MANAGEMENT PLANS FOR ENDANGERED LCRB FISHES

The first stage in the adaptive management process is to develop ecosystem models to better understand the factors that effect ecosystem functions (considering natural and altered states). Modeling allows identification of linkages among ecosystem components and principle factors that affect overall ecosystem health and function. Life history models for endangered species need to be developed and integrated into ecosystem models to identify linkages and principle factors that affect the status of populations. From these models, efficient management plans can be devised to modify the current ecosystem state toward a more natural ecosystem state. Ecosystem management plans should be directed at improving the status of endangered species but should have recovery of endangered species as the one of the major management goals. Achievement of a more natural ecosystem state may be monitored by measurement of specific ecosystem functions or performance indicators. The status of endangered species can be used to evaluate achievement of a more natural ecosystem state. Below is an outline of suggested stages for the development of a life history model and management sub-plan for the recovery of endangered fishes in the lower Colorado River basin (LCRB).

STAGE I. Ecology and Conservation Biology of Endangered and Native Fishes of the LCRB

A. Integration/synthesis.

Integration and synthesis of the existing information base is a necessary first step to understanding the status of native and endangered fish populations in the LCRB. More credible and successful management actions can be developed and executed when based on a sound knowledge base.

B. Population analyses: status and trends.

Population analyses of endangered and other native fishes are the first needed product of the integration/synthesis stage. The coupling of existing databases with ongoing monitoring will allow retrospective/prospective analyses of population status and trends.

Information needs from analyses:

Population analysis: age and size structure, seasonal and long-term trends in population size/age/composition/condition factor.

Survivorship and life table characteristics (if possible).

Relationship between population trends and environmental trends.

Movement of endangered other native fishes in mainstem habitats and reservoirs and tributaries.

Develop predictive population models for endangered and other native fishes in the LCRB that can account for environmental trends and management actions.

Determine the interactions and impacts of non-native fishes on endangered and other native fishes. Consider management activities that increase the abundance of non-native fishes.

C. Physiological and ecological requirements for spawning and rearing endangered and native fishes in the LCRB.

Physiological and ecological requirements for spawning and rearing of endangered and other native fishes in the LCRB need to be determined. This information is needed in advance of studies to determine the ability of dam/river system to deliver required conditions (D., below).

Information needs:

Physiological requirements for spawning: minimum temperature regimes for maturation of oocytes, fertilization, embryogenesis, hatching.

Ecological conditions associated with spawning: habitat, food, population characteristics, hydrological ques, physical factors.

Physiological conditions for rearing of larval and young-of-year: temperature regimes for optimal growth to assure recruitment of young.

Ecological conditions for rearing of larval and young-of-year: habitat, food, biological factors (competition, predation), physical factors.

D. Determine possible (feasible) environmental conditions in LCRB habitats for reproduction of endangered fishes.

Feasible physical and ecological conditions in LCRB that will allow successful spawning and recruitment of endangered and other native fishes in mainstem riverine and reservoir habitats need to be determined. Can flow and temperature conditions in riverine habitats be sufficiently modified by dam operations to allow establishment of reproducing populations of endangered fishes?

Information needs:

Spawning and rearing of endangered and other native fishes in riverine LCRB habitats: abundance, distribution relative to spawning habitat, stability, temperature regime.

Experimental flows and temperature modification from dams: what flow characteristics and temperatures provide conditions for suitable spawning habitat and rearing of young?

E. Monitoring of native and endangered fishes.

Populations of endangered and other native fishes and their environments need to be monitored to detect short- and long-term population and environmental trends. Monitoring also provides critical feedback for assessing the success of the Adaptive Management Program and effects of anthropogenic influences on natural resources.

F. Implement conservation actions to guard against losses for endangered fishes of the LCRB.

Because full implementation of Adaptive Management Programs and expected benefits for endangered fishes in the LCRB may take considerable time to appear, conservation actions should be implemented early to minimize or prevent further population losses and broaden opportunities for the success of recovery efforts.

Establishment of captive broodstocks and experimental populations and implementing genetic management programs are needed to protect against losses of genetic resources and maintain or increase opportunities for future recovery. As a component of genetic management programs, stored gametes can be used to analyze genetic diversity of LCRB endangered fish populations and can be used to produce genetically appropriate fish for re-establishing extirpated populations or augmenting critically endangered populations.

STAGE II. Synthesis: Develop Life History Models for Endangered Fishes of the LCRB.

The second cycle of synthesis of information from research and monitoring efforts (Stage I) will identify the physiological and ecological requirements for spawning and recruitment of endangered and other native fishes and reveal the potential for the present LCRB environment to provide suitable conditions for re-establishing spawning populations. From this synthesis, initial life history models for endangered and native fishes of the LCRB can be formulated and from which management recommendations can be developed (Stage III, below). Ideally, life history models should be integrated into a larger conceptual models of the LCRB ecosystem(s) in order to identify links with other biological and physical components and common elements for ecosystem management. Additional areas for research and refinements in monitoring and conservation actions can be identified at this stage.

STAGE III. Development, Implementation and Refinement of LCRB Management Plans.

Management recommendations for flow and temperature conditions necessary for re-establishing spawning populations of endangered LCRB fishes will be derived from life history and ecosystem models (Stage II). These recommendations will be used to develop an initial management sub-plan for recovery of endangered LCRB fishes and will be integrated into a master mangement plan for LCRB ecosystems. The management sub-plan will undergo continual refinement based on new information (iteration of Stages I-III) and the response of endangered fishes to management and conservation actions.

RECOMMENDED CONSERVATION ACTIONS TO PROTECT FUTURE RECOVERY OF ENDANGERED LCRB FISHES

Implement adaptive management program for operation of Hoover, Davis, and Parker dams.

An adaptive management program has already been established by the U.S. Department of the Interior to operate Glen Canyon Dam for the benefit of downstream natural resources in Grand Canyon. An adaptive management program is recommended for operation of Hoover, Davis, and Parker dams in the lower Colorado River to address ecosystem restoration and endangered species recovery. Because these programs are executed by stakeholders from federal, state, tribal, regional and private entities, they are more likely to be successful in addressing and effecting changes and restoration of ecosystem level processes. This adaptive management program should be linked to the Grand Canyon program to further recovery programs for endangered fishes in the lower Colorado River basin.

Adaptive management plans should include endangered species recovery as a management goal.

The adaptive management approach addresses disruption/destruction of ecosystem functions and components as the root causes of species endangerment and extinction. Because ecosystem and habitat restoration are necessary for recovery of endangered species, recovery should be a major goal of adaptive management programs and the status of endangered species can serve as indicators of ecosystem health and function.

Implement a genetic management program for endangered and native LCRB fishes.

The purpose of a genetic management program for endangered LCRB fishes is to assess the genetic resources among discrete populations, cryopreserve germplasm as a hedge against loss of genetic diversity through population declines or extirpation, and to use the germplasm to produce genetically appropriate hatchery stocks should the need arise in recovery and management efforts. A genetic management plan prescribes the most efficient ways of using genetic resources of captive broodstocks and sperm banks to maintain or enhance the genetic diversity of endangered fish populations. For the endangered LCRB fishes, banking of sperm samples is the only effective way to protect population genetic resources against loss arising from continuing population declines and near-future extirpation. Adopted genetic management plans need to receive peer review and approval before implementation.

The Service has started a genetic management program for endangered fishes in the upper Colorado River basin through the Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin. Principal species of management efforts include Colorado squawfish and razorback sucker. These efforts would be greatly enhanced by an integrated Service-wide program of basin-wide genetic management for bonytail chub, humpback chub, Colorado squawfish, and razorback sucker.

Establish or augment captive broodstocks of endangered LCRB fishes.

The Service should re-establish a captive breeding stock of Grand Canyon humpback chub as a protective measure against future loss of wild populations and to provide stocks for research or for establishing experimental populations. Existing stocks of razorback sucker, bonytail chub and Colorado squawfish should be augmented to increase levels of genetic diversity in fish produced for stocking programs.

Implement conservation actions to reduce population losses in endangered LCRB fishes.

Specific conservation actions should be implemented to stem losses of endangered fishes throughout the lower Colorado River basin. Suggested actions include: predator control measures; monitoring and control of exotic diseases, where feasible and prudent, provide supplemental stocking using offspring from wild fish (as is done by the L. Mohave Native Fish

Work Group for razorback sucker); protection of critical spawning habitat; establishing experimental populations. Some of these recommendations are addressed in the Multi-Species Conservation Program (MSCP) for the Lower Colorado River (LCR) below Hoover Dam.

Manage lower Colorado River basin water resources for the benefit of endangered and other native fishes.

Reservoir and riverine habitat in the lower Colorado River basin should be managed primarily for endangered and other native fishes. Thus, stocking and management programs for introduced sport fishes need to consider the effects of management actions on native fishes. More equitable effort and funds need to be expended in improving the status of endangered and native fishes. Sport fishery programs are compatible with native fish conservation where sport fishery management does not negatively affect the status of native and endangered fishes.