Glen Canyon Dam Technical Work Group
Agenda Item Information
June 22-23, 2009

Agenda Item

Comprehensive Plan for the Management and Conservation of Humpback Chub (*Gila cypha*) in the Lower Colorado River Basin

Action Requested

- ✓ Review the draft document and consider forwarding it to AMWG for their review.
- ✓ Proposed Motion:

  The TWG accepts the HBC Comprehensive Plan and forwards it to AMWG for review, comment, and consideration for transmission to its Implementation Plan Ad Hoc Group.

Presenter

Shane Capron, TWG Chair
Humpback Chub Comprehensive ad hoc

Documents

AIF Humpback Chub Comprehensive Plan
Draft June 16, 2009 Humpback Chub Comprehensive Plan
Science Advisor Comments on draft plan
HBC ad hoc response to Science Advisor comments

Background Information

In 2003, in response to a continuing decline in the Grand Canyon population of humpback chub (GCMRC 2003a), the AMWG began a process to identify a comprehensive approach to the management of humpback chub in Grand Canyon. The specific charge was to "consider actions to implement a comprehensive research and management program for the humpback chub" (motion passed January 28, 2003). This charge resulted in the Status and Management Strategy for Humpback Chub in Grand Canyon (Humpback Chub Ad Hoc Committee 2003). In subsequent review of the Plan, the AMWG determined that there are management needs for humpback chub that are within the scope of the adaptive management program, as well as management needs outside the scope of the program which will require alternative funding sources for implementation (i.e. actions needed for recovery). This focus is clear in the AMWG motion that directed the preparation of this document (motion passed on March 3, 2005; see minutes of February 2-3, 2005 TWG and March 3-4, 2005 AMWG meetings):

> The AMWG directs the TWG to further develop the humpback chub comprehensive plan, as follows:
> 1. Describe linkages, sequences, and feedback loops among projects.
> 2. Identify priorities and a timeline for completion of each action within the comprehensive plan.

3. Spell out specific steps and criteria for any actions that would be needed if a crisis occurs (e.g., severe population decline).
4. Continue to include active participation by GCMRC staff and any additional expertise.
5. Incorporate comments from the Science Advisors. The TWG will include a response to comments document in their final draft.

The AMWG also directs the creation of a humpback chub implementation plan Ad Hoc Group. This Ad Hoc Group will:

1. Determine which actions identified in the humpback chub comprehensive plan can be accomplished under the AMP.
2. Explore the various options for completing actions that do not fall under the authorities of the AMP.

To complete this charge, the TWG formed the Humpback Chub Comprehensive Plan Ad Hoc Group (Ad Hoc) to revise the Plan, and the AMWG formed the Humpback Chub Implementation Ad Hoc Group to determine which aspects of the Plan would be carried out by the AMP.2 The Ad Hoc interpreted these charges to mean that the Plan should include all aspects necessary to accomplish recovery of the lower basin recovery unit because the AMWG specifically asked for actions that are both within, and outside, the scope of the AMP.

The purpose and scope of the plan is to compile information on the status of the Grand Canyon population of humpback chub (i.e. lower basin recovery unit as defined by the U.S. Fish and Wildlife Service), summarize the threats to this population, and define a comprehensive strategy, which includes specific research and management actions, to improve the status of the population and minimize or eliminate threats. The Plan also responds to the AMWG charge to describe linkages, sequences, and feedback loops among projects, identify priorities and a timeline for completion of actions, and determine steps and criteria for actions needed in a crisis (e.g., severe population decline).

DRAFT

Comprehensive Plan for the Management and Conservation of Humpback Chub (*Gila cypha*) in the Lower Colorado River Basin

Prepared by
The Glen Canyon Dam Adaptive Management Program
Technical Work Group
Humpback Chub Comprehensive Plan Ad Hoc Group

June 16, 2009

ABSTRACT

Humpback chub in Grand Canyon[1] remain threatened by habitat alteration due to the presence and operation of Glen Canyon Dam, presence of nonnative competitors, predators, and parasites, and the threat of stochastic events. The Glen Canyon Dam Adaptive Management Program (AMP) created this Comprehensive Plan for the Management and Conservation of Humpback Chub in the Lower Colorado River Basin (Plan) to provide a comprehensive list of actions designed to better understand and ameliorate these threats to assist in recovery of the humpback chub. The primary actions thought to ameliorate these threats include but may not be limited to habitat improvement in the mainstem Colorado River to improve its capability for spawning and rearing of humpback chub, especially via increased water temperatures, either through modified releases from Glen Canyon Dam or modification of the dam itself via a selective withdraw structure and related infrastructure; control and removal of nonnative fish; the use of translocation to increase the range of spawning and rearing of humpback chub in Grand Canyon; the creation of offsite refuge populations of humpback chub to guard against stochastic event-driven catastrophic loss; and planning documents to guide long-term threat abatement.

PREFACE

The Glen Canyon Dam Adaptive Management Program is a unique program developed to provide an organization and process for cooperative integration of dam operations, downstream resource protection and management, and monitoring and research information, as well as to improve the values for which the Glen Canyon National Recreation Area and Grand Canyon National Park were established. Adaptive management is a dynamic process where people of many talents and disciplines come together to develop recommendations in the interest of resource improvement using a structured, iterative process of optimal decision making in the face of uncertainty, with an aim to reduce uncertainty over time via system monitoring (Holling 1978,Walters 1986). The AMP evolved from various laws and legislation, including the Law of the River (numerous laws and compacts that adjudicate the Colorado River), the Grand Canyon

[1] In this document, references to Grand Canyon include the geographic areas of both Marble and Grand canyons, unless otherwise specified.

Protection Act, the Endangered Species Act, the National Environmental Policy Act, and the National Historic Preservation Act. In 1989, the Secretary of the Interior directed an Environmental Impact Statement (EIS) be prepared regarding the operation of Glen Canyon Dam by the Bureau of Reclamation. The Final EIS was completed in March 1995. Findings from the EIS indicated that many uncertainties still exist regarding the downstream impacts of water releases from Glen Canyon Dam on significant resources, including water, sediment, fish, vegetation, wildlife and habitat, endangered and other special status species, cultural resources, air quality, recreation, hydropower, and non-use values. The endangered humpback chub was, and continues to be, a primary resource of concern.

In compliance with the Grand Canyon Protection Act, the EIS proposed utilizing the process of adaptive management whereby the effects of dam operations on downstream resources would be monitored, assessed, and managed. The EIS also recommended formation of a Federal Advisory Committee in order to comply with the consultation requirement in Section 1805 of the Grand Canyon Protection Act. In January 1997, Interior Secretary Babbitt signed a Notice of Establishment for this Federal Advisory Committee, naming it the Glen Canyon Adaptive Management Work Group (AMWG). The Charter of this group was signed on January 15, 1997.

The AMP consists of a diverse group of stakeholders, including state and federal agencies, water users, customers who purchase federal power, environmental groups, recreation interests, and American Indian tribes, that directs coordinated scientific studies conducted by the Grand Canyon Monitoring and Research Center (GCMRC) of the U.S. Geological Survey (USGS). The AMWG provides the opportunity for public involvement in the decision-making process and includes those stakeholders with interest in the operation of Glen Canyon Dam and downstream resources. The Adaptive Management Program is administered through a senior Department of the Interior official, the "Secretary's designee," who also acts as chair of the AMWG. Three other groups serve to advise the AMWG; the Technical Work Group (TWG) as a subgroup to work on technical tasks charged to them by the AMWG; the GCMRC, a USGS science center tasked specifically with administering science directed at AMP needs; and independent advisory panels, contracted groups of scientists tasked with reviewing the products of the AMP program. Together, these bodies form the AMP, advising the Secretary of the Interior, through an adaptive management framework, on management of Glen Canyon Dam. Because the AMP is made up of federal and state agencies, tribes, and private groups, many of these entities have authorities and responsibilities for AMP resources. These authorities are presented in detail in the AMP Strategic Plan (2002).

1.0 INTRODUCTION

1.1 Background

The humpback chub (*Gila cypha*) is a large cyprinid fish endemic to the Colorado River Basin (Miller 1946) that attains a maximum size of about 480 mm total length (TL) and 1.2 kg in weight (Valdez and Ryel 1997). The humpback chub is currently listed as "endangered" under the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 et. seq.). Critical habitat was published on March 21, 1994 (U.S. Fish and Wildlife Service 1994). The latest revised humpback chub recovery plan was approved on September 19, 1990 (U.S. Fish and

Wildlife Service 1990). Recovery goals for humpback chub were completed in 2002 (U.S. Fish and Wildlife Service 2002), and draft revised goals completed in 2008 (U.S. Fish and Wildlife Service 2008).

The decline of the humpback chub throughout its range and continued threats to its existence are due to habitat modification and streamflow regulation (including cold-water dam releases and habitat loss, described further in relation to Glen Canyon Dam below), competition with and predation by nonnative fish species, parasitism, hybridization, and pollutants (U.S. Fish and Wildlife Service 2002). Dams and associated streamflow regulation, in general, alters flows and temperatures that may be needed for spawning and successful recruitment (Muth et al. 2000), but also may reduce the availability of habitats created by fine sediment such as backwaters which may be important to native fish (U.S. Geological Survey 2007, 2008a). This loss of habitat is exacerbated by predation and competition from nonnative fishes (Minckley 1991, Marsh and Douglas 1997, Valdez and Ryel 1997, Chart and Lentsch 2000, Pilger et al. 2008). Parasitism, (especially by nonnative Asian tapeworm *Bothriocephalus acheilognathi*), hybridization with other native *Gila*, and pesticides and pollutants are also factors in the decline (U.S. Fish and Wildlife Service 2002).

The recovery goals define two recovery units: the upper Colorado River basin, and the lower Colorado River basin (divided at Glen Canyon Dam, Arizona; U.S. Fish and Wildlife Service 2008). Recovery criteria were developed for each of the two recovery units (i.e., the upper basin, including the Green River and upper Colorado River subbasins; and the lower basin, including the mainstem and its tributaries from Glen Canyon Dam downstream to Lake Mead National Recreation Area), to address unique threats and site-specific management actions necessary to minimize or remove those threats. The recovery units encompass three management areas under different and separate recovery or conservation programs (i.e., Upper Colorado River Recovery Program, the AMP, and Lower Colorado River Multi-Species Conservation Program; see section 1.3 for description of geographic coverage by each of the programs). The lower Colorado River basin recovery unit consists of all of the aggregations of humpback chub in Marble and Grand canyons (see Section 2.2 below). This Plan was developed for conservation of the lower Colorado River basin recovery unit.

A U.S. District Court ruling on January 18, 2006, set aside the recovery goals, essentially because they lacked time and cost estimates for recovery. The court did not fault the recovery goals as deficient in any other respect, thus the Fish and Wildlife Service and the AMP continue to utilize the underlying science in the recovery goals, including in the development of this Plan. As part of the review and revision of the goals, the U. S. Fish and Wildlife Service will analyze time and cost estimates for recovery, and will provide this information in an updated version of the recovery goals. A draft revision was completed and made available by the U.S. Fish and Wildlife Service in 2008; this version will be further revised based on comments received for a final version.

In 1995, the Fish and Wildlife Service completed a jeopardy biological opinion on the operation of Glen Canyon Dam. The biological opinion concluded that the Modified Low Fluctuating Flow Alternative, the preferred alternative in the Bureau of Reclamation's EIS on the Operation of Glen Canyon Dam (Bureau of Reclamation 1995), was likely to jeopardize the

continued existence of the humpback chub and razorback sucker (*Xyrauchen texanus*), and was likely to destroy or adversely modify designated critical habitat. The biological opinion included a Reasonable and Prudent Alternative with four elements: 1) Development of an adaptive management program that implements research and management actions to attain river conditions that support all life stages of endangered and native fish species; 2) Development of a management plan for the Little Colorado River; 3) Development of a management plan for razorback sucker in Grand Canyon; and 4) Establishment of a second spawning aggregation of humpback chub in Grand Canyon (U.S. Fish and Wildlife Service 1995).

As explained in the preface, the AMP is a conservation program that was established by the Secretary of the Interior under the Federal Advisory Committee Act in 1996 to provide oversight on the operation of Glen Canyon Dam to protect and/or enhance development of the Colorado River ecosystem through Grand Canyon. The AMP defined goals for target resources in its Strategic Plan (AMP 2001) including humpback chub. The AMP goal for humpback chub is to maintain or attain viable populations, remove jeopardy and prevent adverse modification to humpback chub critical habitat. As stated, the goals of the AMP focus on meeting the requirements of the 1995 jeopardy biological opinion, which is limited to minimizing and removing the threats from operation of Glen Canyon Dam. The AMP goals do not specifically address the need to recover the species because program members have determined that recovery of humpback chub is beyond the scope of the program.

In 2003, in response to a continuing decline in the Grand Canyon population of humpback chub (GCMRC 2003a), the AMWG began a process to identify a comprehensive approach to the management of humpback chub in Grand Canyon. The specific charge was to "consider actions to implement a comprehensive research and management program for the humpback chub" (motion passed January 28, 2003). This charge resulted in the Status and Management Strategy for Humpback Chub in Grand Canyon (Humpback Chub Ad Hoc Committee 2003). In subsequent review of the Plan, the AMWG determined that there are management needs for humpback chub that are within the scope of the adaptive management program, as well as management needs outside the scope of the program which will require alternative funding sources for implementation (i.e. actions needed for recovery). This focus is clear in the AMWG motion that directed the preparation of this document (motion passed on March 3, 2005; see minutes of February 2-3, 2005 TWG and March 3-4, 2005 AMWG meetings):

> The AMWG directs the TWG to further develop the humpback chub comprehensive plan, as follows:
>
> 1. Describe linkages, sequences, and feedback loops among projects.
> 2. Identify priorities and a timeline for completion of each action within the comprehensive plan.
> 3. Spell out specific steps and criteria for any actions that would be needed if a crisis occurs (e.g., severe population decline).
> 4. Continue to include active participation by GCMRC staff and any additional expertise.
> 5. Incorporate comments from the Science Advisors. The TWG will include a response to comments document in their final draft.

The AMWG also directs the creation of a humpback chub implementation plan Ad Hoc Group. This Ad Hoc Group will:

1. Determine which actions identified in the humpback chub comprehensive plan can be accomplished under the AMP.
2. Explore the various options for completing actions that do not fall under the authorities of the AMP.

To complete this charge, the TWG formed the Humpback Chub Comprehensive Plan Ad Hoc Group (Ad Hoc) to revise the Plan, and the AMWG formed the Humpback Chub Implementation Ad Hoc Group to determine which aspects of the Plan would be carried out by the AMP.[2] The Ad Hoc interpreted these charges to mean that the Plan should include all aspects necessary to accomplish recovery of the lower basin recovery unit because the AMWG specifically asked for actions that are both within, and outside, the scope of the AMP.

In 2007, the Secretary of the Interior responded to an AMWG recommendation to develop a Lower Colorado River Fish Recovery Implementation Program. The Secretary recognized that recovery of the humpback chub in the lower basin exceeded the limited authority and role of the AMP. The Secretary further directed that the Fish and Wildlife Service take the lead in developing a recovery implementation program for the humpback chub population in Grand Canyon (i.e. the lower basin recovery unit). The Ad Hoc anticipates that this recovery implementation program will develop separate documents to recover the lower basin recovery unit of humpback chub, and will assimilate resources to implement actions that are beyond the scope of the AMP.

In December 2007, the U.S. Fish and Wildlife Service issued a biological opinion on the proposed adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Interim Guidelines) (U.S. Fish and Wildlife Service 2007). With respect to Glen Canyon Dam, the guidelines essentially broadened the range of possible annual release volumes. The biological opinion concluded that implementation of the Interim Guidelines, including a set of conservation measures, was not likely to jeopardize the continued existence of the humpback chub, and was not likely to destroy or adversely modify designated critical habitat.

In February 2008, the U.S. Fish and Wildlife Service issued a new biological opinion on the operation of Glen Canyon Dam that replaced the 1995 jeopardy biological opinion. The biological opinion concluded that a five year program including a 2008 High Flow Test, Modified Low Fluctuating Flows with Steady Flows in September and October, and a set of conservation measures, was not likely to jeopardize the continued existence of the humpback chub, and was not likely to destroy or adversely modify designated critical habitat. The conservation measures included elements of the Plan, including: implementation of the Plan, humpback chub translocation, nonnative fish control, a humpback chub nearshore ecology study, maintenance of humpback chub refuges, and Little Colorado River watershed planning. A list of

[2] The TWG had passed a motion proposing to complete the Plan if directed by the AMWG in February 2005.

these conservation measures, as well as conservation measures from the biological opinion on the Shortage Criteria, are provided in Appendix F.

On May 26, 2009, the District Court of Arizona found in favor of the Grand Canyon Trust with respect to their complaint that the 2008 Biological Opinion was in violation of the Endangered Species Act. The court remanded that section of the biological opinion assessing the effects of the Modified Low Fluctuating Flow (MLFF), and specifically, effects of the MLFF on humpback chub, its critical habitat, and its recovery. The remanded portion of the biological opinion is ordered to be revised by October 30, 2008.

The AMP defined goal for humpback chub (AMP 2001) is to maintain or attain viable populations, remove jeopardy and prevent adverse modification to humpback chub critical habitat. As stated, the goals of the adaptive management plan focus on meeting the requirements of the 1995 jeopardy biological opinion, which is limited to minimizing and removing the threats from operation of Glen Canyon Dam. Although the AMP goals do not specifically address the need to recover the species, and program members have determined that recovery of humpback chub is beyond the scope of the program in its current form, there is no preclusion to evaluate actions to recover the species, or to implement actions that assist in recovery of the species.

1.2 Purpose and Scope

The purpose and scope of this Plan is to compile information on the status of the Grand Canyon population of humpback chub (i.e. lower basin recovery unit as defined by the U.S. Fish and Wildlife Service), summarize the threats to this population, and define a comprehensive strategy, which includes specific research and management actions, to improve the status of the population and minimize or eliminate threats. The Plan also responds to the AMWG charge to describe linkages, sequences, and feedback loops among projects, identify priorities and a timeline for completion of actions, and determine steps and criteria for actions needed in a crisis (e.g., severe population decline).

The Plan relies upon the Humpback Chub (*Gila cypha*) Recovery Goals (U.S. Fish and Wildlife Service 2002, 2008) and other available information and knowledge, and was developed by and for the Glen Canyon Dam Adaptive Management Program. The Plan should be used to identify needs that can be met by the Adaptive Management Program, as well as those that are outside the scope of the program and thus require additional resources. The Ad Hoc believes that, used in this way, the Plan will help guide the efforts of the new recovery implementation effort.

The Ad Hoc recognizes that although this Plan is specifically directed at one species, the humpback chub, other native fish species within the Colorado River ecosystem will benefit from the actions recommended here. These include the endangered razorback sucker (a rare species that is considered extirpated in Grand Canyon but is found in limited numbers downstream in areas of Lake Mead), speckled dace (*Rhinichthys osculus*), bluehead sucker (*Catostomus discobolus*), and the flannelmouth sucker (*Catostomus latipinnis*). The flannelmouth and bluehead suckers are considered special status species by all of the Colorado River basin states in which they occur, and are the subjects, in part, of both a range-wide and an Arizona state-wide

conservation agreement (Arizona Game and Fish Department 2006a). Goal 2 of the AMP, as defined in the AMP Strategic Plan, is to"[m]aintain or attain viable populations of existing native fish, remove jeopardy for humpback chub and razorback sucker, and prevent adverse modification to their critical habitat." These other native fishes should also benefit from many of the recommendations and projects in this Plan.

1.3 Recovery or Conservation Programs

The Glen Canyon Dam Adaptive Management Program (AMP). The AMP is a conservation program that was established by the Secretary of the Interior in 1996 following the Record of Decision on the Environmental Impact Statement assessing operation of Glen Canyon Dam (U.S. Department of the Interior 1995). The AMWG is a federal advisory committee that provides recommendations to the Secretary of the Interior regarding operation of Glen Canyon Dam and other measures to protect and/or enhance the Colorado River ecosystem through Grand Canyon, defined geographically as the mainstem Colorado River and its tributaries from Glen Canyon Dam downstream to Grand Wash Cliffs, River Mile (RM) 276.5. The AMP addresses elements of the EIS on the operation of Glen Canyon Dam and requirements of U.S. Fish and Wildlife biological opinions for the humpback chub and razorback sucker (U.S. Fish and Wildlife Service 2007, 2008). The AMP considers findings of the GCMRC and a group of Science Advisors during development of recommendations regarding dam operations, management actions and conservation of the endangered fishes.

Upper Colorado River Endangered Fish Recovery Program: The Upper Colorado River Endangered Fish Recovery Implementation Program (UCRIP) is a recovery program that was initiated under a Cooperative Agreement signed by the Secretary of the Interior on January 22, 1988, as a coordinated effort of State and Federal agencies, water users, customers who purchase federal power, and environmental groups, to recover four endangered fishes in the upper basin downstream to the inflow of Lake Powell, excluding the San Juan River (U.S. Fish and Wildlife Service 1987, Wydoski and Hamill 1991, Evans 1993). It functions under the general principles of adaptive management and consists of the following seven program elements: instream flow protection; habitat restoration; reduction of nonnative fish and sportfish impacts; propagation and genetics management, research, monitoring, and data management; information and education; and program management. As stated in its governing document (U.S. Fish and Wildlife Service 1987), the program goal is to recover the endangered fishes while allowing water development to proceed in compliance with state and federal laws, including the Endangered Species Act (ESA), state water laws, interstate compacts, the Law of the River and federal trust responsibilities to Native American tribes. Funding for the UCRIP will continue through 2013 (soon to be 2023) under extension of the cooperative agreement (signed December 6, 2001) pursuant to the authorizing legislation passed in October 2000 (P.L. 106-392).

Recovery Implementation Plan Scientific Workgroup: In 1999, the U.S. Fish and Wildlife Service Region 2 convened a group of biologists, formally named the Scientific Workgroup, to develop a Recovery Implementation Plan for the endangered native fishes of the Lower Colorado River Basin from Glen Canyon Dam to the Gulf of California (Mexico). Primary emphasis was to be placed on recovery of bonytail, humpback chub, Colorado pikeminnow, and razorback sucker. The workgroup met regularly initially but then less frequently in subsequent years and

completed a final management plan for the Lower Colorado River Basin (U.S. Fish and Wildlife Service 2005) as its final product. The plan identifies Grand Canyon as a geographic recovery subunit for humpback chub and provides downlisting and delisting criteria equivalent to those identified in the Recovery Goals (U.S. Fish and Wildlife Service 2002).

Lower Colorado River Multi-Species Conservation Program: The Lower Colorado River Multi-Species Conservation Program (MSCP) was established in response to environmental compliance needs of water and power entities in Arizona, California and Nevada. The program is intended to remove jeopardy and work toward recovery of listed species, including the razorback sucker, bonytail, and humpback chub, while accommodating current water diversions and power production. In return, member stakeholders are seeking incidental take authorization under the ESA from the U.S. Fish and Wildlife Service to allow for implementation of covered activities and conservation measures over the next 50 years. The MSCP planning area encompasses the Colorado River from the Lake Mead full pool elevation of 1229 feet to the Southerly International Boundary with Mexico. At this elevation, the inflow area of the Colorado River is influenced by the reservoir as far upstream as Separation Rapids (RM 239.5). These rapids are about 37 river miles upstream of Grand Wash Cliffs (RM 276.5), the western boundary of the AMP, and so a geographic overlap exists between the programs. This overlap has been recognized by the MSCP in a commitment to support the AMP for humpback chub as follows: "Provide $10,000/year for 50 years (total: $500,000) to the Glen Canyon Dam Adaptive Management Workgroup to support implementation of planned, but unfunded, species conservation measures and, as appropriate, to fund species conservation measures in the lower canyon of the Colorado River upstream of Lake Mead." In 2007, the U.S. Fish and Wildlife Service completed a biological opinion on the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (U.S. Fish and Wildlife Service 2007), which included, as a conservation measure, creation and maintenance of an off-site refuge population of humpback chub, to be funded by Reclamation by providing expedited advancement of $200,000 in funding to the U.S. Fish and Wildlife Service from the $500,000 commitment for the species by the MSCP.

Lower Colorado River Recovery Implementation Program: In 2007, the Secretary of the Interior responded to an AMWG recommendation to develop a Lower Colorado River Fish Recovery Implementation Program. The Secretary recognized that recovery of the humpback chub in the lower basin exceeded the limited authority and role of the AMP. The Secretary further directed that the U.S. Fish and Wildlife Service take the lead in developing a recovery implementation program for the humpback chub population in Grand Canyon (i.e. the lower basin recovery unit). The Ad Hoc anticipates that this recovery implementation program will develop a plan to recover the lower basin recovery unit of humpback chub, and will assimilate resources to implement actions that are beyond the scope of the AMP.

2.0 STATUS OF HUMPBACK CHUB IN THE COLORADO RIVER BASIN

2.1 Status of Humpback Chub Populations in the Upper Colorado River Basin

There are five populations of humpback chub located above Glen Canyon Dam in the Upper Colorado River Basin. These populations include three in the Colorado River, at Cataract

Canyon, Utah, Black Rocks, Colorado, and Westwater Canyon, Utah; one in the Green River in Desolation and Grey canyons in Utah, and one in the Yampa and Green Rivers in Dinosaur National Monument. Population estimates for humpback chub using mark-recapture estimators began in 1998 with the Black Rocks and Westwater Canyon populations, and were conducted during 1998-2000 and 2003-2005. These estimates show the Black Rocks population between about 1,000 and 2,000 adults (age 4+) and the Westwater Canyon population between about 1,700 and 5,100 adults (McAda 2002, 2004, 2006, Hudson and Jackson 2003a, 2003b, Jackson 2004a, 2004b). Population estimates for Desolation/Gray Canyon in 2001-2003 show the population between about 1,000 and 2,600 adults (Jackson and Hudson 2005). The Cataract Canyon and Yampa Canyon populations were recently estimated at about 100 and 400 adults, respectively (Valdez and Badame 2005, Finney 2006).

2.2 Status of Humpback Chub in the Lower Colorado River Basin

Humpback chub in the lower Colorado River basin below Glen Canyon Dam occur in the Colorado River in Marble and Grand canyons, and in the lower 18 km (11 miles) of the Little Colorado River, constituting the Grand Canyon population, which also represents the lower basin recovery unit (U.S. Fish and Wildlife Service 2002). Critical habitat in Arizona includes most of the habitat now used by the Grand Canyon population of humpback chub. Designated reaches are the lower 8 miles (12.9 km) of the Little Colorado River and from RM 34 (Nautiloid Canyon) to RM 208 (Granite Park) along the Colorado River. This represents approximately 28 percent of the historical habitat for the species, and 48 percent of critical habitat. The dominant factors affecting critical habitat in Grand Canyon are habitat alteration due to the presence and operation of Glen Canyon Dam and the presence of nonnative fish that prey on and compete with native fishes. The known constituent elements of critical habitat are present and functional throughout designated critical habitat in the action area, primarily in the Little Colorado River; the mainstem Colorado River may provide all constituent elements, but at times appears too cold or has too many nonnative fishes to fully function.

Historically, humpback chub were likely distributed throughout Grand Canyon, with local concentrations, although there is little information to gauge historical abundance. Valdez and Ryel (1995) estimate that the range of humpback chub in Grand Canyon has declined by about 61 miles or 24 percent since Glen Canyon Dam was completed, based on historical captures of humpback chub from the dam site to Separation Canyon (RM 241), and current capture locations from South Canyon (RM 30.0) to Separation Canyon (RM 239.5).

Mark-recapture methods have been used since the late 1980s to assess trend in adult abundance and recruitment of the Little Colorado River aggregation of humpback chub. These estimates indicate that adult population declined through the 1980s and early 1990s but has been increasing for the past decade (Coggins et al. 2003, Coggins 2006, 2007, Coggins and Walters 2008). Coggins (2007) summarized information on abundance and analyzed monitoring data collected since the late 1980s and found that the adult population had declined from about 8,900-9,800 in 1989 to a low of about 4,500-5,700 in 2001. Current methods for assessment of humpback chub abundance rely on the Age-Structured Mark-Recapture model (ASMR). The ASMR has limited capability to provide abundance estimates because of the uncertainty associated with assigning an age to an individual fish based on its length. Coggins and Walters

(2009) however conclude that "considering a range of assumed natural mortality-rates and magnitude of ageing error, it is unlikely that there are currently less than 6,000 adults or more than 10,000 adults" and estimate the current adult (age 4 years or more) population is approximately 7,650 fish. Coggins and Walters (2009) caution however that, because of the variance in the model, "we suggest that the most robust finding in this report is the increasing trend in adult abundance, and that there is considerably more uncertainty about the 2008 absolute adult abundance estimate."

The sampling program for the Little Colorado River aggregation of humpback chub also results in a second set of population estimates for the humpback chub in the Little Colorado River only. These efforts are designed to be directly comparable to prior studies of humpback chub abundance in the early 1990s (Douglas and Marsh 1996). Two pass mark-recapture surveys are conducted in the spring and fall each year. Abundance estimates are derived using the Chapman Petersen closed model. These estimates show a similar pattern to the ASMR. Abundance declined from the 1996 level, but has recently increased dramatically. The 2007 spring estimate for humpback chub greater than 150 mm total length in the Little Colorado River was 5,124 (CI 4,295-5,953); the closed population estimate of April 1992 was 5,555 (CI 4,416-7,067). Closed population estimates thus also indicate recent increases in adult abundance (Van Haverbeke and Stone 2008).

The improvement in the status of the Little Colorado River aggregation of humpback chub appears due to an increase in recruitment, which was particularly high in the 2003-4 period (Coggins and Walters 2009). Interestingly, recruitment began to improve in the mid-1990s, prior to warmer mainstem water temperatures (due to drought and low Lake Powell levels), efforts to mechanically remove nonnative fishes, and translocation. Although the 2000 low summer steady flow (that resulted in warmer mainstem water temperatures) could have benefitted the brood years as early as 1998, recruitment appears to have increased prior to this flow experiment (Coggins and Wlaters 2009). No explanations for this recruitment increase have been proposed to date. The increase could have been due to factors associated with the Little Colorado River, the mainchannel Colorado River (the switch to MLFF flows for example), or from changes in both rivers.

The Grand Canyon population consists primarily of adults residing in and near the Little Colorado River, with much smaller aggregations of the species scattered throughout approximately 180 river miles of the mainstem Colorado River. Valdez and Ryel (1995) identified nine mainstem aggregations of humpback chub in Grand Canyon: 30 mile (RM 29.8 to 31.3); Little Colorado River Inflow (RM 57.0-65.4); Lava to Hance (RM 65.7-76.3); Bright Angel Creek Inflow (RM 83.8-93.2); Shinumo Creek Inflow (RM 108.1-108.6); Stephen Aisle (RM 114.9-120.1); Middle Granite Gorge (RM 126.1-129.0); Havasu Creek Inflow (RM 155.8-156.7); and Pumpkin Spring (RM 212.5-213.2). Monitoring continues to confirm the persistence of these aggregations (Trammell et al. 2002), although few or no humpback chub have been caught at the Havasu Inflow and Pumpkin Spring aggregations since 2000 (Ackerman 2007). Humpback chub have been caught infrequently downstream of Pumpkin Spring. One adult was captured downstream of Maxson Canyon (RM 244) in 1994 (Valdez 1994), and four humpback chub were caught at Separation Canyon (RM 239.5) in 2006 (Arizona Game and Fish Department 2006b). The Little Colorado River Inflow is the largest aggregation, which is in the

lower 13 km of the Little Colorado River and the adjoining 15 km of the Colorado River (RM 57.0-65.4). This aggregation has been expanded upstream of Chute Falls through mechanical translocation of fish (Stone 2007). The contribution of mainstem aggregations, other than the Little Colorado River Inflow aggregation, to the overall Grand Canyon population are not known.

New information also shows greater numbers of young humpback chub in the mainstem than in previous years. Catch-rate indices indicate increases in numbers of sub-adult humpback chub (150-199 mm TL [5.91-7.83 in]; Coggins 2007). During 2002-2006, a total of 442 humpback chub <100 mm (3.94 in) TL were captured upstream of the Little Colorado River Inflow (RM 61.3) as far upstream as RM 30.7 (Ackerman 2007). Of the 442 fish, 225 (13-66 mm [0.51-2.60 TL) were caught between RM 30 and RM 50. The 30-Mile aggregation is located 31 miles upstream of the Little Colorado River inflow and it is unlikely that the young humpback chub swam upstream that distance, especially given cool mainstem temperatures. Furthermore, the distribution of these fish, as well as average size above (mean = 38 mm [1.50 in] TL) and below the Little Colorado River (mean = 67 mm [2.64 in] TL), indicate that the natal source is upstream of RM 50 and not from the Little Colorado River. The causes for these recent increases in young humpback chub in the mainstem Colorado River are uncertain, but declines in nonnative trout over this period as well as warmer river temperatures due to low reservoir levels in Lake Powell, have been implicated.

Young-of-year and juvenile humpback chub observed outside the Little Colorado River aggregation were most abundant at RM 110-130 (Stephen Aisle and Middle Granite Gorge aggregations) during 2000 and 2004 and RM 160-200 during 2000 (Johnstone and Lauretta 2004, 2007, Trammell et al. 2002, Arizona Game and Fish Department 1996, Ackerman 2007). Seine catches of all young-of-year humpback chub outside the nine aggregations were at their highest in 21 years during 2004 (Johnstone and Lauretta 2007). Four humpback chub were also collected at Separation Canyon (RM 239.5) in 2005 (Ackerman et al. 2006). The Middle Granite Gorge aggregation (which includes adults) has been stable or increasing in size since 1993 (Trammell et al. 2002) and may be sustained via immigration from the Little Colorado River aggregation, as well as local reproduction. No humpback chub have been caught at the Havasu Inflow and Pumpkin Spring aggregations since 2000 (Ackerman 2007). Valdez and Ryel (1995) provided mark-recapture estimates for PIT-tagged humpback chub adults (≥200 mm [7.87 in] TL) in five of the remaining eight aggregations, including 30-Mile (estimate, n-hat = 52), Shinumo Inflow (n-hat = 57), Middle Granite Gorge (n-hat = 98), Havasu Inflow (n-hat = 13), and Pumpkin Spring (n-hat = 5). Population estimates have not been made for other mainstem aggregations since 1993 (Trammell et al. 2002).

Translocations may have increased the range and size of the Little Colorado River Inflow aggregation. In August 2003, nearly 300 young humpback chub were translocated above a natural barrier, Chute Falls, in the Little Colorado River approximately 16 km above the confluence. This translocation was followed by another translocation of 300 fish in July 2004, and 567 fish in July 2005 (Stone 2006). Results indicate that translocated fish had high survival and growth rates. Reproduction above Chute Falls and downstream movement below Chute Falls has also been documented (Stone 2006). An additional 299 juvenile humpback chub were translocated in July 2008.

Douglas and Douglas (2007) provided a thorough analysis of the genetic structure of humpback chub, examining all extant populations including the nine aggregations in Marble and Grand Canyon. They concluded that genetic differences among the Marble and Grand canyon aggregations of humpback chub were difficult to distinguish at the microsatellite level. Aggregations appeared to be connected by geneflow, suggesting downstream drift of larvae and juveniles as a likely mechanism. Aggregations were relatively homogeneous when compared to each other. They also found that the Grand Canyon population (the nine aggregations considered as a group), is markedly distinct from upper basin populations based on microsatellites, although there was no differentiation between the upper and lower basins in the mitochondrial DNA analysis. On the basis of these results, Douglas and Douglas (2007) recommended the aggregations in Marble and Grand canyons be treated as a single management unit. They also found that the Grand Canyon population (the nine aggregations considered as a group), is markedly distinct from upper basin populations based on microsatellite DNA analysis, although there was no differentiation between the upper and lower basins in the mitochondrial DNA analysis. On the basis of these results, Douglas and Douglas (2007) recommended the aggregations in Marble and Grand canyons be treated as a single management unit, and that both the upper and lower basins be considered as a single species.

Although Douglas and Douglas (2007) concluded that the Little Colorado River population appeared to be the primary source aggregation in the Grand Canyon population, they found that contribution from occasional local reproduction by mainstem aggregates could not be excluded. They found two individuals in the 30-mile aggregation in Marble Canyon with *G. elegans* haplotypes, and the microsatellite profile for this population was intermediate between genotypes found in Desolation Canyon (a hypothesized hybrid population) and Grand Canyon. Although reproduction has been documented for the 30-mile aggregation, it appears to have very low numbers of fish. As the only population in Grand Canyon that is upstream from the Little Colorado River, it is least likely to receive migrants from downstream locations such as the Little Colorado River aggregation. Nevertheless, although Douglas and Douglas (2007) recommended further study of the 30-mile aggregation to evaluate the potential distinctiveness of these fish, they concluded that the entire Grand Canyon population should be considered a single management unit. This is consistent with the 2002 and draft 2008 Humpback Chub Recovery Goals which consider the Grand Canyon population a single and separate recovery unit (U.S. Fish and Wildlife Service 2002).

3.0 THREATS TO HUMPBACK CHUB IN GRAND CANYON

3.1 Baseline Condition for Humpback Chub in the Lower Colorado River Basin

The decline of humpback chub in Grand Canyon has long been thought to be due primarily to emplacement of Glen Canyon Dam. The predam river was a highly variable ecosystem. Flow varied greatly between seasons, from peak flood flows in May or June with a median monthly discharge of about 50,000 cubic feet per second (cfs), to low flows in January with a median monthly discharge of about 5,000 cfs. Flood flows of over 120,000 cfs were relatively common, occurring about every six years, and low flows of 500-1,000 cfs were also common. Daily variation in discharge was relatively small, with a median of about 542 cfs

(Topping et al. 2003). A turbid and sediment-laden stream much of the year, the river was nearly clear at low flows (Blinn and Cole 1990). Temperatures varied from about 0 to 30°C (32 to 86°F)(Korn and Vernieu 1998). Minckley (1991) suggested that food base for fishes was likely meager due to the high turbidities seasonally present and the scouring nature of the river, although allochthonous inputs, much reduced post dam, may have provided a significant source of macroinvertebrates as well as nutrients for autochthonous production (Minckley and Rinne 1985, Haden et al. 1999). The fish fauna was notably already dominated by nonnative carp and catfish which may have depressed native fish populations at the time of dam construction (McDonald and Dotson 1960).

In contrast, the post-dam river is a more stable environment in all ways except for daily variation in discharge. The river now is limited by the 1996 ROD to discharges between 5,000 and 25,000 cfs (with the exception of high flow tests which may be up to 45,000 cfs), and a maximum daily fluctuation of 8,000 cfs (U.S. Bureau of Reclamation 1996). Releases from Glen Canyon Dam are varied throughout the day to meet the demand for electricity. The post-dam median daily change in discharge (8,580 cfs) is now approximately 15 times greater than pre-dam (542 cfs) and actually exceeds the pre-dam median discharge (7,980 cfs; Topping et al. 2003). Post-dam changes in discharge created dramatic changes in diurnal river stage, up to 2 meters (m, 6.6 ft) in some areas; pre-dam, diurnal stage change was seldom more than 0.3 m (1.0 ft) (GCMRC unpublished data). The river is now perennially cold, although warmer in the winter than predam (Voichick and Wright 2007). Glen Canyon Dam releases hypolimnetic water (the deeper layer of the reservoir) with a relatively constant temperature which typically ranges from 8-10 °C at high reservoir levels (46-50 °F; GCMRC unpublished data), although releases from 2004-2006 were much warmer due to low Lake Powell reservoir levels. Post-dam productivity is much higher in terms of algal and invertebrate biomass, thus food availability for fishes is likely greater than pre-dam (Blinn and Cole 1991). Turbidity is almost nil, approximately 84-94 percent of the fine sediment input is now trapped behind the dam, and the post-dam median discharge of 12,600 cfs causes remaining fine sediment to be lost continually (Topping et al. 2000, Topping et al. 2003, Wright et al. 2005).

Much of the Grand Canyon population of humpback chub, and the majority of all spawning, occurs in the lower 16 km (10 miles) of the Little Colorado River (Valdez and Ryel 1995; Paukert et al. 2006). The Little Colorado River appears to be little changed hydrologically from pre-Anglo settlement times, and is similar in some respects to the pre-dam Colorado River. Flow ranges from a median low discharge of about 200 cfs in June to a median high discharge in April of about 600 cfs. When at low or base flow, this travertine system is relatively clear and turquoise blue in color. During floods, the Little Colorado River carries large sediment loads and is extremely turbid. Water temperatures range from near freezing to about 25°C (77°F; Voichick and Wright 2007). At low flow, the Little Colorado River at Cameron is dry, with flow in the lower river supplied entirely by Blue Springs, about 20 km (12.5) miles upstream from the confluence. Blue Spring is warm spring, with a constant outflow temperature of 22.6°C (Mattes 1993). The seasonally-warm water temperatures in the Little Colorado River provide near optimal spawning and rearing habitat for humpback chub.

Many of the physical changes in the post-dam Colorado River are believed to have contributed to eliminating spawning and recruitment of humpback chub in the mainstem river.

Humpback chub require a minimum of about 16°C (60°F) for successful spawning, hatching and rearing of young fish (Hamman 1982; Marsh 1985; Clarkson and Childs 2000; Muth et al. 2000). Bulkley et al. (1982) found that young humpback chub 73-134 mm (2.9-5.28 in) TL forced to swim at a velocity of 0.51 m/sec fatigued after an average of 85 minutes at 20°C, (68°F) but fatigued after only 2 minutes at 14°C (57°F); a decrease of 6°C (11°F) reduced fatigue time by 98 percent. From the time that Lake Powell first filled in about 1980 until about 2000, cold hypolimnetic releases of 8-10°C (46-50°F; GCMRC unpublished data) were characteristic of Glen Canyon Dam operations. These cold temperatures largely prevented mainstem reproduction by humpback chub, except perhaps in localized warm springs (Valdez and Masslich 1999). Throughout this post-dam period, low survival of larval and post-larval fish led to low recruitment to the adult population. This trend was attributed to effects of cold water temperatures (thermal shock, and poor swimming performance and predator avoidance) and nonnative fish predators and competitors (Lupher and Clarkson 1994, Valdez and Ryel 1995, Marsh and Douglas 1997, Clarkson and Childs 2000 Robinson and Childs 2001, Ward et al. 2002). Because cold temperatures can also cause larvae and juvenile fish to experience thermal shock (Berry 1988), and swimming ability is greatly reduced (Berry and Pimentel 1985, Ward and Bonar 2003), juvenile humpback chub exiting the warm Little Colorado River and entering the cold mainstem may be too lethargic to effectively avoid predation or swim to suitable nearshore habitats (Valdez and Ryel 1995, Robinson et al. 1998).

Although Glen Canyon Dam releases have been relatively constant at 8-10 °C (46-50 °F; GCMRC unpublished data) since Lake Powell filled, they are influenced by lake elevation, inflow hydrology, release volumes and meteorological conditions. Release temperatures have varied from 7 to 16 °C (45-60 °F) from 2000 through 2006. Between 1999 and 2005, Lake Powell elevations dropped more than 140 feet as a result of a basin-wide drought. Glen Canyon Dam release temperatures increased to 16 °C (60 °F) in the fall of 2005. The drop in Lake Powell elevation (e.g. level) resulted in warmer releases because the epilimnion was closer to the penstock withdrawal zone. Release temperatures from Glen Canyon Dam during 2004 and 2005 were the highest since August 1971 when the reservoir was filling. Since 2005, reservoir levels have increased resulting in cooler release temperatures. Releases are predicted to remain cool to cold for the next 5-10 years (i.e. there is a 75 percent chance that reservoir levels will remain above 3,600 ft and corresponding release temperatures will be <11 °C (51.8 °F) from 2009-2013)(U.S. Bureau of Reclamation 2007).

The ongoing drought and corresponding low reservoir levels and warm-water releases in 2004-2006 illustrate the potential for climate change to impact humpback chub. Some authors have indicated that this drought is the beginning of a shift to a more arid climate in the American Southwest (Seager et al. 2007, USCCSP 2008). The Fourth Assessment Report (Summary for Policymakers) of the Intergovernmental Panel on Climate Change (IPCC 2007) presented a selection of key findings regarding projected changes in precipitation and other climate variables as a result of a range of unmitigated climate changes projected over the next century. Although annual average river runoff and water availability are projected to decrease by 10-30 percent over some dry regions at mid-latitudes, information with regard to potential impacts on specific river basins was not included. Recently published projections of potential reductions in natural flow on the Colorado River Basin by the mid-21st century range from approximately 45 percent by Hoerling and Eischeid (2006) to approximately 6 percent by Christensen and Lettenmaier

(2006). If predicted effects of climate change result in persistent drought conditions in the Colorado River basin similar to those seen in recent years, warm-water conditions below Glen Canyon Dam may become the norm rather than the exception.

Fluctuations also influence water temperatures in the mainstem river. Temperature differences between mainchannel and nearshore habitats can be especially pronounced in backwaters and other low velocity areas. But the amount of warming that occurs in backwaters is affected by daily fluctuations, which cause mixing with cold mainchannel waters (Arizona Game and Fish Department 1996). Hoffnagle (1996) found that mean, minimum, and maximum temperatures of backwaters were higher under steady versus daily fluctuating flows, with mean daily temperatures (14.5 °C [58.1 °F]) under steady flows about 2.5 °C (4.5 °F) greater than those under fluctuating flows. Differences in the mainchannel temperatures during steady and fluctuating flows were also statistically significant, but mean temperatures differed by only 0.5 °C (0.9 °F). Similar results were documented by Trammell et al. (2002), who found backwater temperatures during the 2000 low steady summer flow experiment to be 2-4 °C (3.6-7.2 °F) above those during 1991-1994 under fluctuating flows. Korman et al. (2006) also found warmer backwater temperatures under steady flow conditions, concluding that backwaters were cooler during fluctuations because of the daily influx of cold main channel water. Vegetation, talus, and debris fan shorelines appear to be important nearshore habitats for juvenile humpback chub (Converse et al. 1998). The relative importance is poorly understood and subject of current study (the nearshore ecology study, Project 8 of this plan).

Korman et al. (2006) also noted that nearshore areas affected by fluctuating flows (i.e., in the varial zone) warmed substantially for brief periods each day, which posits an ecological trade-off for fish utilizing these areas. On the one hand, fish may choose to exploit the warmer temperatures of the fluctuating zone on a daily basis and simply sustain any bioenergetic disadvantages of acclimating to rapidly changing discharge; or they may choose to remain in the permanently wetted zone which is always wetted, but colder than the immediate nearshore margin. In addition to increasing energy demands to fish that must move out of backwaters due to fluctuating flows, there is also an increased vulnerability to predation (Korman et al. 2004).

As discussed above, Glen Canyon Dam caused reductions in sediment supply, because Glen Canyon Dam and Lake Powell trap most of the sediment transported by the Colorado River. This has likely altered the number and quality of nearshore habitats that may be important for small bodied fishes such as juvenile humpback chub. Tributaries downstream of the dam are now the only renewable sediment source to Glen, Marble, and Grand canyons. The dam and reservoir have also reduced annual flood peaks and increased moderate flows. The altered flow releases from the dam have less capacity to transport sand and coarser sized sediments than under pre-dam conditions with frequent floods (U.S Geological Survey 2007). How these changes have effected rearing of juvenile humpback chub is not well understood. An ongoing study (Project 8, the nearshore ecology study) to investigate the ecology of nearshore aquatic habitats will help to better understand how sediment influences nearshore habitat and how fish utilize these habitats.

The high flow tests of 1996 and 2004 were found effective at building or rebuilding sandbars, although persistence of the sandbars is variable. Preliminary results appear similar for

the 2008 high flow test. The 1996 beach/habitat-building flow deposited more sandbars and at a faster rate than predicted (Webb et al. 1999). Repeat topographic and hydrographic mapping of 33 sandbar-eddy complexes showed that the 1996 beach/habitat-building flow rebuilt previously eroded high-elevation sandbars, regardless of location, bar type, or canyon width (Hazel et al. 1999). More than half of the sand deposited at higher elevations was taken from the lower portions of the sandbars (Schmidt 1999) rather than being derived from tributary sand supplies accumulated on the channel bed, as originally hypothesized in the 1995 EIS (Wright et al. 2005). Over time, however, this resulted in a net decrease in total eddy-sandbar area and volume (Topping et al. 2004); many sandbars built during the 1996 high flow test eroded in as little as several days following the experiment.

In contrast to the 1996 high flow test, the 2004 high flow test was strategically timed to take advantage of highly sediment-enriched conditions (U.S. Geological Survey 2007a). Suspended sediment concentrations during the 2004 experiment were 60 to 240 percent of those measured during the 1996 experiment, although there was less sand in suspension below RM 42 (Topping et al. 2004). This resulted in creation of larger sandbars than those observed during the 1996 experiment in Marble Canyon, but area and volume of sandbars downstream of RM 42 actually decreased due to comparatively less sand in that area in 2004 than in 1996. Thus, it was clear from results of the 2004 high flow test that high flows conducted under sediment-depleted conditions (such as 1996) cannot be used to sustain sandbar area and volume (Topping et al. 2004); additionally, it became evident that more sand would be needed during future high flow tests to restore sandbars throughout Marble and upper Grand canyons.

In 2007, sand inputs from the Paria River were at least 2.5 million metric tons, or about 2.5 times the historical average (U.S. Geological Survey 2007). Together with inputs from the Little Colorado River in 2006 and unexpected retention of sediment from both tributaries during 2006, sand inputs were at least 3 times the amount that triggered the 2004 high flow test, and greater than since at least 1998 (U.S. Geological Survey 2007). This presented a unique opportunity to evaluate effects of a high flow test under sand-enriched conditions greater than ever tested before. The 2008 high flow test initially resulted in beach and bar building similar to results seen in the 2004 test, although positive results were spread throughout the canyon, as opposed to the 2004 test which resulted in bar building primarily in upper Marble Canyon (GCMRC, unpublished data).

Backwaters are thought to be important rearing habitat for fish due to low water velocity, warm water and high levels of biological productivity (Hoffnagle 1996, Goeking et al. 2003). They are created as water velocity in eddy return channels decline to near zero with falling river discharge, leaving an area of stagnant water surrounded on three sides by sand deposits and open to the mainchannel environment on the fourth side (Rubin et al. 1990). Reattachment sandbars are the primary geomorphic features that function to isolate nearshore habitats from the cold, high velocity mainchannel environment.

Backwater numbers vary spatially among geomorphic reaches in Grand Canyon and tend to occur in greatest number in river reaches with the greatest active channel width, including the reach immediately downstream from the Little Colorado River (RM 61.5-77)(McGuinn-Robbins 1995). Numbers and size also vary temporally as a function of sediment availability and

hydrology, and their size can vary within a year at a given site. Backwaters declined in number from 1990 to 1992 under experimental high fluctuating flows and MLFF, but a rapid but short lived increase in backwater numbers resulted from high inputs and flows from the Little Colorado River in 1993 as a result of high flood flows (Beus et al. 1994, McGuinn-Robbins 1995). Backwaters created in 1993 declined in 1994 under more average sediment and flow conditions (McGuinn-Robbins 1995). Backwater number can also vary tremendously depending on flow elevation during sampling and tends to be greatest at low flow elevations. Stevens and Hoffnagle (1999) noted that backwater numbers and area were reduced at flows greater than 10,000 cfs at any given point in time. McGuinn-Robbins found more backwaters during 1990 at the 5,000 cfs level than at the 8,000 cfs level, although backwater area was greatest at the 8,000 cfs level.

Persistence of backwaters created during the 1996 high flow test appeared to be strongly influenced by post-high flow dam operations. Whereas the 1996 test resulted in creation of 26 percent more backwaters, potentially available as rearing areas for Grand Canyon fishes, most of these newly created habitats disappeared within two weeks due to reattachment bar erosion (Brouder et al. 1999, Hazel et al. 1999, Parnell et al. 1997, Schmidt et al. 2004). Nearly half of the total sediment aggradation in recirculation zones had eroded away during the 10 months following the experiment and was associated in part with relatively high fluctuating flows of 15,000-20,000 cfs (Hazel et al. 1999).

Goeking et al. (2003) found no relationship between backwater number and flood frequency, although backwater size tends to be greatest following high flows and less in the absence of high flows due to infilling. Considering both area and number, however, no net positive or negative trend in backwater availability was noted during 1935 through 2000. At the decadal scale, several factors confound interpretation of high flow effects on backwaters bathymetry, including site-specific relationships between flow and backwater size, temporal variation within individual sites, and high spatial variation in reattachment bar topography (Goeking et al. 2003). Efficacy of high flow tests at creating or enlarging backwaters also depends on antecedent sediment load and distribution, hydrology of previous years (Rakowski and Schmidt 1999) and post-high flow river hydrology, which can shorten the longevity of backwaters to a few weeks depending on return channel deposition rates or erosion of reattachment bars (Brouder et al. 1999).

The 1996 high flow caused an immediate reduction in benthic invertebrate numbers and fine particulate organic matter (FPOM) through scouring (Brouder et al. 1999, Parnell et al. 1999). Invertebrates had rebounded to pre-test levels by September 1996, but it is thought that the rate of recolonization was hindered by a lack of FPOM. Still, recovery of key benthic taxa such as chironomids and other Diptera was relatively rapid (3 months), certainly rapid enough for use as food by the following summer's cohort of young-of-year native fish (Brouder et al. 1999). Also during the 1996 high flow test, Parnell et al. (1999) documented burial of autochthonous vegetation during reattachment bar aggradation, which resulted in increased levels of dissolved organic carbon, nitrogen and phosphorus in sandbar ground water and in adjacent backwaters. These nutrients are thus available for uptake by aquatic or emergent vegetation in the backwater.

Dam operations may influence the food base and hence food availability for humpback chub. Humpback chub are usually considered an omnivore with a diet consisting of insects, crustaceans, plants, seeds, and occasionally small fish and reptiles. They appear to be opportunistic feeders, capable of switching diet according to available food sources, and ingesting food items from the water's surface, mid-water, and river bottom. Arizona Game and Fish Department (1996) reported that juvenile humpback chub in Grand Canyon consumed 19 different prey items, eight more than any other species examined, which included chironomid larvae, terrestrial insects, simuliid larvae, and copepods. The green alga Cladophora has often been recorded as a large component of humpback chub diet, mixed with a variety of invertebrates and detritus (Minckley et al. 1980, Carothers and Minckley 1981, Kubly 1990, Valdez and Ryel 1995). Valez and Ryel (1995) found that humpback chub in the mainstem river consumed 14 invertebrate taxa and nine terrestrial taxa (Valdez and Ryel 1995), including simuliids (blackflies, in 77.8% of fish), chironomids (midges, 57.6%), Gammarus (freshwater shrimp, 50.6%), Cladophora (23.4%), Hymenoptera (wasps, 20.9%), and cladocerans (water fleas, 19.6%). Seeds and human food remains were found in eight (5.1%) and seven (4.4%) fish respectively. Diet composition was related to food availability, illustrating the opportunistic feeding habit of humpback chub; for example, simuliids were available and consumed throughout the canyon, but terrestrial invertebrates replaced Gammarus in lower reaches where the latter were absent. Adult humpback chub in the Little Colorado River have also been reported to be cannibalistic on their young during periods of high reproductive success (Gorman 1994).

Drift, organic matter drifting with the current in the water column, is an important aspect of the food base because particulate organic matter becomes available to downstream organisms to feed on via drift. Researchers in Grand Canyon have not had consistent results when examining the link between seasonality and drift, with the greatest quantities found in either the spring (McKinney et al. 1999) or summer (Shannon et al. 1996). There does appear to be a direct relationship between the amount of organic matter in the drift and flow volume (Angradi and Kubly 1994, Benenati et al. 2001). Fluctuations in flow can also influence drift directly because periodic desiccation can weaken algae and invertebrates causing fragmentation and subsequent entrainment by the river (Kennedy and Gloss 2005) or indirectly through the concomitant daily increases in flow volume (Shannon et al. 1996). McKinney et al. (1999) found that the density of Gammarus in the drift increased on the descending limb of the fluctuating hydrograph in Glen Canyon. Kennedy and Gloss (2005) summarized that the reduction in fluctuations from MLFF likely increased food base overall, especially the standing crops of important food items like *Gammarus* and *Cladophora*, due to a net increase in the amount of river bottom that is permanently submerged, but they also noted that large changes in monthly volume present under MLFF may periodically destroy significant quantities of food available for fish (Kennedy and Gloss 2005).

In a study conducted in the upper Colorado River basin (middle Green River, Utah) Grand et al. (2006) found that the most important biological effect of fluctuating flows in backwaters is reduced availability of invertebrate prey caused by dewatered substrates (see also Blinn et al. 1995), exchange of water (and invertebrates) between the mainchannel and backwaters, and (to a lesser extent) reduced temperature. As the magnitude of within-day fluctuations increases, so does the proportion of backwater water volume influx, which results in a net reduction in as much as 30 percent of daily invertebrate production (Grand et al. 2006).

Potential geomorphic differences between the Grand Canyon and the Upper Colorado River basin underline the need for additional research investigation.

An outstanding information need for management of Grand Canyon backwaters is the relationship between backwater bathymetry and suitability as fish habitat, specifically the relationship between depth, area, volume and thermal characteristics. Goeking et al. (2003) point out large backwaters may not incur as many benefits to young native fish as smaller backwaters because the latter will warm faster and thus remain warmer over time than larger backwaters; however, due to their depth, they may be more frequently available as fish habitat over a greater range of flows. In the Upper Colorado River basin, Colorado pikeminnow were found to utilize backwaters with average depths greater than 0.3 m (1.0 ft)(Trammell and Chart 1999) and average areas of 992 m2 (0.245 acre)(Day et al. 1999). The issue of backwater depth is a research need from the standpoint that while greater depths afford more availability over a wide range of flows (Muth et al. 2000), the concurrent increase in volume with depth may slow warming rates.

Water temperatures in the mainstem Colorado River downstream of Glen Canyon Dam were relatively constant during the period from 1980 to 2000. In 2000, the AMP conducted a low summer steady flow experiment during which Glen Canyon Dam releases were dominated by a steady flow of 8,000 cfs. The experiment resulted in significant warming of the mainstem, likely due to the reduced volume and somewhat secondarily to a lack of a fluctuating flow regime. Subsequent efforts to develop a mainstem temperature model for the Colorado River below Glen Canyon Dam corroborate that release volume has a strong effect on downstream temperature (Anderson and Wright 2007), although reservoir elevation appears to have a stronger effect (Wright et al. 2008). Drought conditions in the Colorado River basin since 2000 have resulted in low Lake Powell reservoir levels such that dam release water temperature was significantly increased. Increased water temperature of releases has continued through 2008 as a result of inflow and/or reservoir elevations, with the warmest years occurring from 2004-2006 (GCMRC unpublished data). These warmer temperatures have provided a test of the hypothesis of how native fish would respond to dam modifications (i.e. a selective withdrawal structure) or changes in operations to warm release water temperatures. The positive change in the status of native fishes during this period would seem to support this approach. However other actions during this period, such as the removal of nonnative fishes (discussed below) may have contributed to this response. Additionally, in a workshop conducted by GCMRC in April of 2007 to support the Bureau of Reclamation's Long Term Experimental Plan development (U.S. Geological Survey 2008a), a panel of scientists concluded that although the single most important condition that would benefit the humpback chub in the near term is warming mainstem nearshore habitats, control of nonnative species is also key. The panel further noted that the most readily available tool to stabilize the presence and persistence of warm nearshore habitats is steady flows from Glen Canyon Dam and that a selective withdrawal structure should be built only if it is designed to release the warmest water possible and also have the ability to release cool water under all conditions, including when reservoir conditions are relatively low and release water would normally be warm. Warmer water, either that provided through a selective withdrawal structure or due to drought or climate change could result in invasion of nonnative warm-water piscivorous fish (Johnstone and Lauretta 2007, Rahel et al. 2008). The ability to also release cool water was thought to be necessary to control any future expansions or invasions

of warmwater nonnative aquatic species, especially nonnative fish. The Bureau of Reclamation prepared a draft risk assessment model to evaluate risks and benefits from a two-unit selective withdrawal structure on Glen Canyon Dam. The assessment showed benefits to all native fish species, but also benefits to most nonnative fish species, especially rainbow trout, brown trout, and smallmouth bass. Interestingly, the abundance and distribution of channel catfish was relatively unaffected by the selective withdrawal structure (Valdez and Speas 2007).

Nonnative fish species have been present in the lower Colorado River, and likely in Grand Canyon, for over a century (Mueller and Marsh 2002). Programs to introduce non-native species for sport and food into Grand Canyon began at the turn of the century. Most releases were trout species, although warm-water fish, including carp, were also stocked. Trout were introduced for sport purposes by the National Park Service (NPS), Arizona Game and Fish Department, and the US Fish and Wildlife Service in the 1920s. NPS ceased stocking in 1964, the Arizona Game and Fish Department continued to plant rainbow trout near Lees Ferry until the 1990's. Since 1956, 24 nonnative fish species have been reported from Grand Canyon; 17 of which were present before the closure of Glen Canyon Dam (Valdez and Ryel 1995, Wieringa and Morton 1996). In Grand Canyon, brown trout, channel catfish, black bullhead, and rainbow trout have been identified as principal predators of young humpback chub (Marsh and Douglas 1997, Valdez and Ryel 1997). Valdez and Ryel (1997) also theorized that common carp (*Cyprinus carpio*) could be a significant predator of incubating humpback chub eggs in the Little Colorado River. Minckley (1991) suggested that nonnative fish predation is the single most important threat to the persistence of native fishes in Marble and Grand Canyons. The potential for invasion of black bass species under warmer water conditions in Grand Canyon may pose a serious threat; smallmouth bass (*Micropterus dolomieu*) have become a significant predator in the Yampa River (U.S. Fish and Wildlife Service 2008), and largemouth bass (*Micropterus salmoides*) appear to be a significant predator on native fishes in the San Juan River (Pilgera et al. 2008).

Generally, the upper reaches of the mainstem river are dominated by coldwater nonnative species, such as rainbow trout, and the lower reaches by warmwater species such as channel catfish and common carp. Brown trout are captured in greatest numbers in and near Bright Angel Creek (Rogers and Makinster 2006, Johnstone and Lauretta 2007). Catfish appear to be the dominant species in the mainstem below Diamond Creek and above the Lake Mead delta area (Ackerman 2007). Other nonnative species such as bullhead (*Ameiurus* spp.), fathead minnow (*Pimephales promelas*), red shiner (*Cyprinella lutrensis*), and plains killifish (*Fundulus zebrinus*) are primarily tributary species, mostly in the Little Colorado River (Van Haverbeke 2006) but can occur in the mainstem, especially in backwaters immediately downstream of the confluence of the Little Colorado River (Johnstone and Lauretta 2007). These small-bodied species may be important predators and competitors of young humpback chub, especially in backwaters and other sheltered near-shore habitats, and given their occurrence in areas and habitats of high importance.

The Lee's Ferry Reach (dam to Paria River) supports a self-sustaining fishery of rainbow trout, whose population and food base are influenced by dam operations (McKinney et al. 1999, McKinney and Persons 1999, McKinney et al. 2001, Speas 2004, Speas et al. 2004, Korman et al. 2005). Brown trout occasionally move into the reach between the dam and the Paria River

from downstream populations, but is not managed as part of the sport fishery and is not a desired species in this reach. Although their abundance has declined significantly over the last seven years, rainbow trout are still the dominant nonnative species between the Paria River and the Little Colorado River (Ackerman 2007, Johnstone and Lauretta 2007). Other nonnative species sporadically found in that reach include brown trout, common carp, channel catfish and fathead minnow. Invasion of nonnative fish from the upper Little Colorado River has recently been documented (Stone et al. 2007).

Floods have, for some time, been identified in small streams as a potential means to disadvantage nonnative fishes and thereby advantage native fishes (Meffe 1984, Minckley and Meffe 1987) although that potential in a large river system remains unproven. Dam operations have been speculated as a means of disadvantaging nonnative fishes via artificial floods or other flows from displacement due to flooding, stranding, or altering spawning and rearing habitats. The 1996 Glen Canyon Dam beach habitat building flow appeared to have only short-term effects on the densities of some nonnative fishes (primarily small-bodied forms like plains killifish and fathead minnow; Hoffnagle et al. 1999, Valdez et al. 1999), perhaps because at 45,000 cfs, the flow was still less than the pre-dam one-year return interval flood of 50,000 cfs (Hoffnagle et al. 1999, Topping et al. 2003). From 2003-2005, releases from Glen Canyon Dam included "experimental fluctuating flows", high fluctuating releases of 5,000-20,000 cfs per day from January-March, to test their capability to reduce the survival rate of young rainbow trout to reduce the size of the Lees Ferry trout population. These flows had little effect on incubation mortality and consequently adult population size (Korman et al. 2005). Additionally, reductions in early life stages appeared to be offset by compensatory survival at larger life stages (Korman et al. 2005). Korman et al. 2005 did note however that because young-of-year rainbow trout generally remain at the daily minimum flow elevation in Lees Ferry, and because September flow reductions during the study resulted in density reductions documented in Glen Canyon, as well as substantial literature on stranding impacts to young trout, a 'stranding' flow operation from Glen Canyon Dam targeted at reducing young-of-year rainbow trout recruitment could be very effective.

The Grand Canyon fish community has apparently shifted over the past five years from one dominated by nonnative salmonids to one dominated by native species (Trammell et al. 2002, Johnstone et al. 2003, Arizona Game and Fish Department 2006b, Lauretta and Serrato 2006, Ackerman 2007). Electrofishing catch rates of flannelmouth and bluehead suckers have increased four to six-fold in the past seven years, whereas trout catch rates have correspondingly declined (Arizona Game and Fish Department 2006b, Arizona Game and Fish Department 2008); a similar trend is evident from trammel net data (Johnstone et al. 2003, Lauretta and Serrato 2006). Riverwide, young flannelmouth suckers were more abundant in 2004 than the previous 16 years (Johnstone and Lauretta 2007) and speckled dace were abundant in hoop net and seining samples, particularly in downstream reaches (Ackerman 2007). It is hypothesized that the recent shift from nonnative to native fish is due in part to warmer water temperatures, although the decline of coldwater salmonid competitors (due to mechanical removal, temperature increases, or other causes) is also a potential cause (USGS 2006, Ackerman 2007). Rainbow trout currently appear to be increasing in abundance system-wide (AGFD unpublished data).

Recent declines in trout abundance in the Lees Ferry tailwater may be due to a variety of factors, including, but probably not limited to, increased daily fluctuations during the 2003-2005 period, increased water temperatures with commensurate increased trout metabolic demands, excessive population for available food supply, periodic oxygen deficiencies and nuisance aquatic invertebrates (e.g., New Zealand mudsnails *Potamopyrgus antipodarum*). The individual or collective contribution of these factors, if any, to the decline is uncertain at this time. Whirling disease, a fish disease that can decimate trout populations, was detected in Lees Ferry in June of 2007, but at a very low level, and has not been detected since, and is not likely a cause of the decline in trout abundance. Highly invasive quagga mussels (*Dreissena* sp.) were discovered in Lake Mead during the summer of 2007. Because of their high filtration and reproductive rates, quagga mussels frequently alter aquatic food webs and damage water supply infrastructure. A risk assessment on the establishment potential of quagga mussels in the Colorado River below Glen Canyon Dam concluded that there is low risk of these mussels becoming established in high densities in the Colorado River or its tributaries below Lees Ferry (Kennedy 2007), although conditions in the clear tailwater reach immediately below the dam appear more suitable for establishment of this species.

The nonnative fish fauna of the Lees Ferry reach historically included less frequent taxa including common carp, largemouth bass (*Micropterus salmoides*), golden shiner (*Notemigonus crysoleucas*), redside shiner (*Richardsonius balteatus*), striped bass (*Morone saxatilis*), and threadfin shad (*Dorosoma petenense*) (GCMRC unpublished data). In more recent years, however, young-of-year green sunfish (*Lepomis cyanellus*), smallmouth bass, brown trout, and channel catfish have been collected in this reach; mature smallmouth bass and walleye (*Stizostedion vitreum*) have also been collected (GCMRC unpublished data). Sources of these fish are unknown, but the closest source containing green sunfish, catfish and smallmouth bass would be Lake Powell; means of introduction is unknown, but Reclamation is currently assessing risk potential for entrainment of Lake Powell fish through the dam penstocks.

Recently, a few smallmouth bass and striped bass were collected in the vicinity of the Little Colorado River (GCMRC unpublished data), but no population-level establishment has been documented to date. There are also recent records of green sunfish, black bullhead, yellow bullhead (*Ameiurus natalis*), red shiner, plains killifish and largemouth bass downstream of the Little Colorado River, usually associated with warm springs, tributaries, and backwaters (Johnstone and Lauretta 2007, GCMRC unpublished data). Striped bass are found in relatively low numbers below Lava Falls (Ackerman 2007).

Stone et al. (2007) reported common carp, fathead minnow and red shiner below Grand Falls (an ephemeral reach of the Little Colorado River), which indicates that the Little Colorado River is a viable conduit for introduction of nonnative fish from areas higher in the watershed. Other nonnative fish documented in the upstream reaches of the Little Colorado River basin include golden shiner, black bullhead, yellow bullhead, channel catfish, rock bass (*Ambloplites rupestris*), bluegill, green sunfish, smallmouth bass, and largemouth bass (Stone et al. 2007); thus these species could eventually occur in Grand Canyon.

Fish samples collected below Diamond Creek in 2005 (Ackerman et al. 2006) were comprised primarily of red shiner (28 percent), channel catfish (18 percent), common carp (12

percent), and striped bass (9 percent); smallmouth bass, mosquitofish (*Gambusia affinis*), and fathead minnow were also present in low numbers. Bridge Canyon Rapid impedes upstream movement of most fish species, except for the striped bass, walleye, and channel catfish (Valdez 1994, Valdez et al. 1995). Nonnative fish species increased from 11 above to 18 below the rapid (Valdez 1994, Valdez et al. 1995). Above Bridge Canyon Rapid, the red shiner was absent, but below the rapid it comprised 50 percent and 72 percent of all fish captured in tributaries and the mainstem, respectively (Valdez 1994, Valdez et al. 1995). Other common fish species found below Bridge Canyon Rapid include common carp, fathead minnow, and channel catfish; however, very little fish habitat exists in this reach due to declining elevations of Lake Mead and subsequent downcutting of accumulated deltaic sediments in inflow areas. Flannelmouth suckers comprised about 15 percent of the total catch from this reach during 2005 (Ackerman et al. 2006), several times greater than the 1.3 percent observed during 1992-1995 (Valdez et al. 1995). Percentage of speckled dace in the reach has not changed appreciably over the last decade, and no bluehead suckers were collected during 2005 (Valdez et al. 1995, Ackerman et al. 2006).

In an attempt to benefit native species, mechanical removal targeted at nonnative salmonid species in the mainchannel Colorado River and tributaries in Grand Canyon took place during 2003-2006 (Coggins and Yard 2003). Removal of salmonids and other nonnative fish (black bullhead, fathead minnow, common carp, brown trout) in the vicinity of the Little Colorado River by electrofishing contributed to a 90 percent reduction in rainbow trout over a four year period, although trout also declined significantly throughout this period in Glen, Marble, and Grand canyons, perhaps due to warmer water or other factors as discussed above. Main channel water temperatures during the removal period were as high as 6 °C (11 °F) above the 1990-2002 average. At the same time, electrofishing catch rates of young-of-year and age-1 flannelmouth sucker, bluehead sucker, and humpback increased by as much as a factor of ten; catch rates of speckled dace also increased. Recent monitoring indicates rainbow trout are increasing in this reach, although data not yet analyzed (AGFD unpublished data).

Mechanical removal of spawning brown trout through weir operations in Bright Angel Creek yielded inconclusive results. During operations in 2002 (November-January), over 400 brown trout were removed from Bright Angel Creek and euthanized (Leibfried et al. 2005). When a similar removal effort was conducted in November-January of 2006, only 54 brown trout were removed, and rainbow trout catches were decreased by a similar proportion (Sponholtz and VanHaverbeke 2007). The decline cannot be attributed to weir operations alone, however, because of the considerable system-wide decline in abundance of these species during this time (Arizona Game and Fish Department 2008).

Multi-pass backpack electrofishing was evaluated as a mechanical control technique in Bright Angel and Shinumo creeks. In a 3.35 km reach of Bright Angel Creek, approximately 55 percent and 57 percent of the brown and rainbow trout populations, respectively, were removed through as many as 4 electrofishing passes. At Shinumo Creek, 35 to 85 percent of rainbow trout were removed through similar methods (Leibfried et al. 2006). In both creeks, however, recolonization rates from upstream and downstream have not been evaluated. Recently, GCMRC has proposed to implement a strategy to reduce warmwater nonnative fish (including crayfish) abundance and negative impacts to native fish found in the Colorado River in Grand Canyon (Hilwig et al., in review). This strategy would very likely be needed to offset potential

undesirable positive responses of nonnative fish to artificial or natural increases in river temperatures. The draft plan consists of short-term period to collect baseline information needs followed by implementation of longer-term nonnative fish control and management programs.

Another aspect of the changes in sediment supply in Grand Canyon that may affect humpback chub is turbidity. Predam, turbidity was very high much of the year except during base flows. As discussed above, the dam largely eliminated turbid mainstem conditions. The mainstem is turbid now only at times of tributary flooding. With increases in nonnative fishes over the last century in Grand Canyon, especially sight-feeding predators like rainbow trout, this loss of turbidity may exacerbate the losses of humpback chub to piscivory of nonnative fishes. Turbidity has been shown to decrease the reactive distance of rainbow trout (Barrett et al. 1992). Johnson and Hines (1999) found that decreased turbidity resulted in significantly greater rates of predation of razorback sucker from both native Colorado pikeminnow and green sunfish. Interestingly, data collected on diet of rainbow and brown trout in the Colorado River in Grand Canyon during mechanical removal of these species indicated that turbidity had little effect on incidence of predation of native fish (GCMRC, unpublished data).

Asian fish tapeworm (*Bothriocephalus acheilognathi)*, and anchor worm (*Lernaea cyprinacea*), may pose threats to native fish below Glen Canyon Dam. Asian tapeworm, first reported from Grand Canyon in 1990, is currently the most abundant fish parasite in the Little Colorado River, infecting 23-51 percent of all humpback chub (Clarkson et al. 1997, Choudhury et al. 2004) and also a variety of cyprinids. Main channel infestation rates are much lower and may be temperature-limited (4-22 percent) (Valdez and Ryel 1995). Optimal *B. acheilognathi* development occurs at 20-30 °C (68-86 °F) (Granath and Esch 1983). Choudhury et al. (2004) hypothesized that infection rates were positively related to both fish host and copepod density in the Little Colorado River and parasitic fauna found there have diversified through invasion of nonnative host fish species. *Lernaea cyprinacea* infects humpback chub at a higher rate than other species of fish in Grand Canyon (Hoffnagle 2000) and favors temperatures greater than 18 °C (64 °F) (Grabda 1963), with 23-30 °C (73-86 °F) being optimum (Bulow et al. 1979). Post-dam mainstem temperatures have prevented *L. cyprinacea* from completing its life cycle and limited its distribution to warmer waters. Infestation apparently does not increase fish mortality in the Upper Colorado Basin (Valdez and Ryel 1995).

3.2 Summary of Current Threats to Humpback Chub in the Lower Colorado River Basin by Recovery Factor

As described in the preceding baseline discussion, past habitat alteration and invasion of nonnative fishes have contributed to the current status of the humpback chub in Grand Canyon and are continuing threats. These threats are summarized here from threats identified in the Humpback Chub Recovery Goals and draft Humpback Chub Recovery Goals 2008 Revisions (U.S. Fish and Wildlife Service 2002, 2008) and other documents including three AMP reports (Gloss and Coggins 2005, Melis et al. 2006b, U.S. Geological Survey 2008a). The Ad Hoc refers the reader to these documents and sections for a more complete picture of our status of knowledge of these threats. The Ad Hoc found that there is uncertainty associated with many of these threats with regard to their respective severity and interaction. Threats to the humpback chub in Grand Canyon, listed by recovery factor, are summarized as follows.

Recovery Factor A.─ Adequate Habitat and Range for Recovered Populations Provided

1. Inadequate flows to support all life stages

As described in the preceding seection, flows have changed dramatically in Grand Canyon since closure of Glen Canyon Dam in 1962. Spring peak flows are much reduced and base flows in summer through winter have increased. Daily fluctuations in flow, unknown in the ecosystem historically, are now the norm. These changes may no longer provide the necessary requirements for all life stages of humpback chub in the mainstem river. Little is known about the overall and continuing effect of these changes, but some aspects, such as effects on mainstem temperature and sediment transport are available and are discussed below.

2. Inadequate habitat due to streamflow regulation

As described above in the baseline discussion, streamflow regulation by Glen Canyon Dam has resulted in drastic changes in the riverine ecosystem in Marble and Grand canyons, changes that have contributed to the decline in status of the humpback chub. Daily flow fluctuations may alter habitat suitability, structure, and availability, especially for young fish. Fluctuations cause destabilization of nearshore habitats (Hoffnagle 2000), which has been implicated in increased energy demand and increased predation of humpback chub (Korman et al. 2004, 2006), and also causes colder water temperatures in backwaters, which may be important habitats for native fish (Arizona Game and Fish Department 1996, Trammel et al. 2002, Korman et al. 1996). In the Upper Colorado River basin (in the Green River in Utah), Grand et al. (2006) found that fluctuating flows significantly reduced the availability of invertebrate prey, an important food source for young fish, due to dewatered substrates, exchange of water (and invertebrates) between the main channel and backwaters, and reduced temperature. Robinson et al. (1998) and Stone and Gorman (2005) hypothesized that fluctuations reduced the growth and survival of young humpback chub Fluctuations are also directly proportional to export of sediment; thus dam operations may contribute to the loss of important nearshore habitats, especially those that depend on sand bar formation, such as backwaters (Melis et al. 2006b).

Cold hypolimnetic releases from Glen Canyon Dam have long been acknowledged as a major threat to humpback chub (Maddux et al. 1987). Generally water temperature in the mainstem Colorado River is primarily a function of: 1) Lake Powell reservoir level; 2) release volume; 3) inflow volume and temperature; and 4) ambient air temperature. This function typically results in release temperatures 8-10 °C (46-50 °F; GCMRC unpublished data). Release volume and Lake Powell reservoir level have been shown to have a significant effect on mainstem water temperature (Anderson and Wright 2007, Wright et al. 2008). Effects of cold temperatures are further discussed below.

3. Inadequate water temperatures to support all life stages

The humpback chub is an obligate warm-water species that requires relatively warm water temperatures of about 16-22 °C (61-72 °F) for spawning, egg incubation, and survival of young (Hamman 1982, Marsh 1985). Typical mainstem temperatures range from about 10-12 °C (50-54 °F; Gloss and Coggins 2005), although have recently been as warm as 17 °C (64°F) in 2005

(GCMRC unpublished data) due to drought. Because cold temperatures can also cause larvae and juvenile fish to experience thermal shock (Berry 1988), and swimming ability is greatly reduced (Berry and Pimentel 1985, Ward and Bonar 2003), juvenile humpback chub exiting the warm Little Colorado River and entering the cold mainstem may be too stunned to effectively avoid predation or swim to suitable nearshore habitats (Lupher and Clarkson 1994, Valdez and Ryel 1995, Marsh and Douglas 1997, Robinson et al. 1998, Clarkson and Childs 2000, Robinson and Childs 2001, Ward et al. 2002, U.S. Geological Survey 2008a).

An important aspect of mainstem water temperature is the effect on nonnative fishes. Cold mainstem water temperatures that have been the norm since Lake Powell filled 30 years ago have advantaged nonnative salmonids and apparently disadvantaged warm-water species such as green sunfish, smallmouth bass, and to some extent carp and channel catfish (Valdez and Ryel 1995, Johnstone and Lauretta 2007). Temperature must continually be examined for its effect on management of both native and nonnative fish species in Grand Canyon. Efforts to modify the dam or operations to warm mainstem temperatures, or "natural" warming due to drought and effects of climate change, could enhance conditions for invasion of warm-water nonnative fishes.

4. Inadequate food base to support all life stages

Many variables, including flow, turbidity, and temperature may affect humpback chub food base. Our understanding of how dam operations affect food base, the degree to which food base is limiting, and what threat exists in this, regard is limited. Understanding the food web and how it is affected by both dam operations and nonnative species is an important information need (U.S. Geological Survey 2008b).

5. Inadequate water quality to support all life stages

As discussed previously, turbidity may have some effect on nonnative fish predation on native fishes in Grand Canyon (Barrett et al. 1992, Johnson and Hines 1999). Since closure of Glen Canyon Dam, flow in the mainstem Colorado River is much less turbid. Also, selenium or other contaminants could affect reproduction or other aspects of humpback chub life history. Many potential contaminants (e.g., petroleum products, radionuclides, selenium, pesticides, and heavy metals such as mercury) could affect water quality in the form of nonpoint source pollution. Understanding how contaminants act to suppress populations is not well understood (Hinck et al. 2007). Another identified concern is the potential for a hazardous materials spill on the Highway 89 Bridge at Cameron, Arizona, which is approximately 60 km (37 miles) upstream of occupied habitat in the Little Colorado River. Although much of this reach of the river is dry during most of the year, floods create flow in this reach almost annually, and a spill could have disastrous affects on water quality downstream in the prime humpback chub spawning habitat of the Little Colorado River.

Recovery Factor B.—Protection from Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

6. Over-handling for scientific studies

Despite the essential need to monitor humpback chub status, netting and electrofishing as well as marking fish, such as with PIT tags, can cause mortality. Trammel netting likely causes the most mortality of the gears employed in Grand Canyon to survey humpback chub, but electrofishing and hoop netting also likely cause some level of mortality (Ruppert and Muth 1997, Paukert et al. 2005, Ward et al. 2008). Although unlikely to cause population-level affects singularly, cumulatively, with effects from other threats, this threat could be significant.

7. Adverse effects from recreational use

Very little data exist on the effects of recreation on humpback chub. Recreational use of the Little Colorado River may affect reproductive habitat or interfere with reproduction. Although the potential for adverse effects has been recognized, and some regulations have been implemented to address this threat, more research is needed in this area (National Park Service 2007).

Recovery Factor C.—Adequate Protection from Disease or Predation

8. Asian tapeworm, *Lernaea* sp., other parasites and diseases

Asian tapeworm, and anchor worm (*Lernaea cyprinacea*), may pose threats to native fish below Glen Canyon Dam. Asian tapeworm, first reported from Grand Canyon in 1990, is currently the most abundant fish parasite in the Little Colorado River, infecting 23-51 percent of all humpback chub (Clarkson et al. 1997, Choudhury et al. 2004) and also a variety of cyprinids. Main channel infestation rates are much lower (4-22 percent) and may be temperature-limited (Valdez and Ryel 1995). Optimal *B. acheilognathi* development occurs at 20-30 °C (68-86 °F) (Granath and Esch 1983). Choudhury et al. (2004) hypothesized that infection rates were positively related to both fish host and copepod density in the Little Colorado River and parasitic fauna found there have diversified through invasion of nonnative host fish species. *Lernaea cyprinacea* infests humpback chub at a higher rate than other species of fish in Grand Canyon (Hoffnagle 2000) and favors temperatures greater than 18°C (64 °F)(Grabda 1963), with 23-30 °C (73-86 °F) being optimum (Bulow et al. 1979). Postdam mainstem temperatures have prevented *L. cyprinacea* from completing its life cycle and limited its distribution to warmer backwaters. Infestation apparently does not increase fish mortality in the Upper Colorado Basin (Valdez and Ryel 1995). Intestinal nematodes and trematodes (*Ornithodiplostomum* sp. and *Rhabdochona* sp.) have been documented from humpback chub in the Little Colorado River (Hoffnagle et al. 2000).

9. New intentional and unintentional introductions of nonnative aquatic species in the Colorado River and its tributaries in Grand Canyon

Invasions of nonnative species can have devastating impacts on native species, even to the extent of causing extinction. Numerous potential predators and competitors of humpback chub occupy the mainstem Colorado River and its tributaries in proximity to Marble and Grand Canyons, and could invade given suitable habitat conditions. Many of these species are contacted in Marble and Grand canyons at low levels, such as green sunfish, smallmouth bass and walleye.

Stone et al. (2007) found that non-native fish are transported to the lower reaches of the Little Colorado River during floods from presently unknown sources in higher reaches of the watershed. GCMRC conducted a nonnative species workshop in December 2008; workshop participants determined that identifying and eliminating sources of nonnative species is a high priority for conservation of humpback chub.

The nonnative invasive quagga mussel, a close relative of the zebra mussel (*Dreissena polymorpha*), has recently invaded the lower Colorado River as far upstream as Lake Mead, and could invade Grand Canyon. GCMRC conducted a risk assessment on the potential for quagga mussel to invade the Colorado River Ecosystem (defined as the segment of the Colorado River from just below Glen Canyon Dam to Diamond Creek; Kennedy 2007). The assessment concluded that there is low risk of these mussels becoming established in high densities in the Colorado River or its tributaries below Lees Ferry due to poor habitat conditions, although conditions in the clear tailwater reach immediately below the dam appear more suitable for establishment.

10. Nonnative fish species present in Grand Canyon

Minckley (1991) considered nonnative fish predation to be the single most important threat to the persistence of native fishes in Marble and Grand Canyons. Brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), channel catfish (*Ictalurus punctatus*) and black bullhead (*Ameiurus melas*) are all locally common in the Colorado River in Grand Canyon and have been identified as principal predators of young humpback chub, with consumption estimates that suggest loss of complete year classes to predation (Marsh and Douglas 1997, Valdez and Ryel 1997). Data collected during nonnative removal efforts by the AMP from 2003-2006 indicate that predation rate by rainbow trout on humpback chub is substantial when trout densities are high. Common carp, also common in Grand Canyon, could be a significant predator of incubating humpback chub eggs in the Little Colorado River (Valdez and Ryel 1997). Small-bodied fishes such as red shiner and fathead minnow can be common in the Little Colorado River and the Colorado River in Grand Canyon and may compete with and prey upon young native fish in nursery habitats. As discussed above, efforts to target removal of these nonnative species have met with some success, particularly for rainbow trout (GCMRC unpublished data).

Recovery Factor D.—Adequate Existing Regulatory Mechanisms

11. Lack of legal protection of habitat and flow

Long-term legal protection of habitat and flow in the Little Colorado River and mainstem is necessary for long-term conservation of humpback chub. The draft Recovery Goals (U.S. Fish and Wildlife Service 2008) identify the need to determine and implement mechanisms for legal protection of adequate habitat in the mainstem Colorado River through Grand Canyon and the Little Colorado River through instream-flow rights, contracts, agreements, or other means necessary to provide adequate habitat and sufficient range for all life stages of humpback chub to support a recovered Grand Canyon population.

12. Need for conservation plans

The draft Recovery Goals (U.S. Fish and Wildlife Service 2008) require that conservation plans be developed for use after delisting to provide for the long-term management and protection of humpback chub populations. Example elements of such plans include provision of flows for maintenance of adequate habitat conditions for all life stages of humpback chub, regulation and/or control of nonnative fishes, minimization of the risk of hazardous-materials spills, minimization of risks of parasites, and monitoring of populations and habitats. Development of conservation plans is not an identified project of this plan because their development is more appropriate, and conservation needs for the species post-delisting will be better understood when humpback chub are considered for down-listing.

Recovery Factor E.─ Other Natural or Manmade Factors

13. Non-point source pollutants in the Little Colorado River watershed

A number of potential sources of pollution exist in the Little Colorado River watershed. Collectively, these may affect water quality in occupied and critical habitat in the Little Colorado River and could affect reproduction and survival of all life stages of humpback chub. Many potential contaminants (e.g., petroleum products, radionuclides, selenium, pesticides, and heavy metals such as mercury) could affect water quality in the form of nonpoint source pollution. Understanding how contaminants act to suppress populations is not well understood (Hinck et al. 2007).

14. Hazardous materials spills at bridges over the Little Colorado River

As discussed above, minimizing the risk of hazardous-materials spills into critical habitat is a priority. A spill at one of the Little Colorado River bridges such as the Highway 89 bridge at Cameron, Arizona, could be transported downstream to occupied and critical habitat, resulting in possible losses of all ages of humpback chub at the primary spawning location for the species in Grand Canyon.

15. The interaction of threats

Many of the threats listed here are known to interact, but the relationships are poorly understood. Cold water temperatures can cause thermal shock of juvenile humpback chub, for example, which could cause juvenile humpback chub to be more susceptible to predation by nonnative fishes. Management actions which could benefit humpback chub may have unintended consequences. While increased turbidity resulting from high flow tests may reduce predation pressure from nonnative fishes on humpback chub, it could also reduce primary production and ultimately food base available for humpback chub and other native fishes. Also, providing warmer water temperatures using steady flows or a selective withdrawal structure could benefit nonnative warm-water fishes more than native fishes, negating any beneficial effects to native species from increased predation losses.

Another way to look at the interaction of threats is from a cumulative perspective. Examining native fish species records in the American Southwest (including humpback chub), Fagan et al.

(2002) illustrated that as populations grow smaller and more isolated their risk of extinction increases. This is likely because the population is less robust and able to withstand some loss without long-term harm to the population structure and there is a lower likelihood that local losses will be offset by immigration from nearby populations. Another example is the "predator pit" hypothesis (Messier 1994). This hypothesis proposes that as a population of a species shrinks, especially when this happens rapidly, the predators of the species will have a greater and greater impact on its survival due to the relatively constant consumption amount, and thus increased consumption rate. In situations where predator populations also increase, the effect can be substantial. Mechanical removal of nonnative fish in the Colorado River in Marble and Grand Canyons from 2003-2006 indicated that while predation rate by rainbow trout on humpback chub was low, rainbow trout can reach densities where predation losses are significant (GCMRC unpublished data). Development of a comprehensive Colorado River ecosystem model would likely help to understand these interactions.

3.3 An Overview of the Use of Management Actions to Address Threats

Threats to the species and corresponding recommended management actions are provided in the strategy section 4.0. Of the 15 threats previously identified, some require more immediate attention to either ameliorate the threat or better understand its severity. Complex interactions among these threats may challenge future management, and our understanding of this is limited. Several threats to humpback chub in Grand Canyon require immediate attention; however, we lack sufficient information to prioritize these threats. These threats and current or potential management actions to address them include the following:

- Water temperature: Cold water releases are known to inhibit mainstem reproduction, swimming ability, and growth of humpback chub. The AMP science advisors completed a risk assessment recommending a selective withdrawal structure on Glen Canyon Dam be built and tested (Baron et al. 2003); a recent panel of scientists concluded a selective withdrawal structure presents a serious risk because of the potential to advantage nonnative species, and recommended that it only be built if it could provide both warm and cool water at a wide range of reservoir elevations (U.S. Geological Survey 2008a). Also, temperatures of Glen Canyon Dam releases in recent years were much warmer due to the 2000 Low Summer Steady Flow and drought during the period 2000-2008; warmer releases could continue given the predicted effects of global climate change (USCCP 2008). More evaluation of the effects of these temperatures is needed to determine the overall effect to native and nonnative fishes.

- Predators: Control of nonnative species that prey on and compete with humpback chub in the Colorado River above and below the confluence of the Little Colorado River was implemented as an adaptive management experiment from 2003-2006 for rainbow trout, brown trout, and other fish species susceptible to electrofishing (Coggins 2008). A corollary effort, using a weir, was implemented by the National Park Service (NPS) in 2005-2007 to remove trout from Bright Angel Creek (Leibfried et al. 2005). The NPS is also conducting feasibility studies for

removing non-native fish from other tributaries within Grand Canyon National Park. These efforts should be continued to better evaluate their benefit to humpback chub (U.S. Geological Survey 2008a). Mechanical removal of nonnative fishes in the mainstem was restarted in 2009 as a conservation measure or the 2008 biological opinion. Efforts are underway to address control of non-salmonid predators, including in the mainstem, the Little Colorado River, and other tributaries, and development of nonnative control plans to address this threat.

- Hazardous materials spills: The risk of hazardous materials spills continues to loom over the Little Colorado River. Immediate actions are needed to develop and implement a plan to minimize this risk (U.S. Fish and Wildlife Service 2008).

- Parasites: Asian tapeworm and *Lernaea* copepod are the two parasites of most concern for humpback chub. Investigations should continue to assess extent of infestation, the risks of increased infection in the mainstem under warmer water conditions, and the potential for treatment to reduce infestation levels in the humpback chub population.

- Flow regimes from dam releases: The effects of dam releases are not fully understood relative to humpback chub, but experimental flows continue to provide information under adaptive management. The U.S. Fish and Wildlife Service's 2008 biological opinion included a conservation measure to conduct a nearshore ecology study to further develop information on the effect of flows on mainstem habitats for humpback chub. The Nearshore ecology study is planned to begin in FY 2009-2010 as a joint project between GCMRC and an external cooperator (U.S. Geological Survey 2008b).

- Threat interactions: Although many possible interactions have been identified, these interactions are poorly understood, and require more study. The Ad Hoc recommends that an overall Colorado River ecosystem model be developed to better understand these interactions.

4.0 STRATEGY FOR IMPROVING CONDITIONS FOR HUMPBACK CHUB IN THE LOWER COLORADO RIVER BASIN

The AMP goals for humpback chub are to maintain or attain viable populations, remove jeopardy and prevent adverse modification to humpback chub critical habitat. This plan expands that goal to include assisting in achieving recovery goals for humpback chub in Grand Canyon by expanding the population size, improving recruitment and reducing threats to the population. This will be accomplished by (1) expanding the range of spawning and rearing in Grand Canyon for humpback chub, (2) increasing survival and recruitment of humpback chub, and (3) reducing the threat of catastrophic events or unintended consequences that may negatively affect the wild population of humpback chub. The Ad Hoc acknowledges that implementation of some elements of the strategy will be outside the scope of the AMP and will require additional and different funding sources and processes.

4.1 Expanding the Range of Spawning and Rearing and Increasing Survival and Recruitment for Humpback Chub

One mechanism for expanding range is to increase the suitability of the mainstem Colorado River for reproduction and recruitment of humpback chub. This may be accomplished by warming dam releases with a selective withdrawal structure and/or modifying dam releases to provide flows necessary for spawning and rearing, and mechanical removal of predators and competitors of humpback chub from both the mainstem and selected tributaries. A panel of scientists convened by GCMRC in 2007 concluded that utilizing stable flows is the only readily available means to achieve flow related habitat changes currently, and recommended providing stable releases from July 15 through mid-October. However, much uncertainty surrounds this action, necessitating scientific planning and assessment. Transloctaion to tributary streams in Grand Canyon also may serve to expand the reange of humpback chub in Grand Canyon, may provide habitat relatively free from threats, and have watersheds largely contained on Tribal or Federal land. Actions that are believed to help expand the range of humpback chub in the Lower Colorado River include:

(1) Further explore the need to modify operations of Glen Canyon Dam either through construction and testing a selective withdrawal structure, by testing stable flow releases, or both, to improve habitat in the mainstem for humpback chub. Improving temperature conditions in the mainstem may improve humpback chub reproduction and survivorship. However, warmer temperatures in the mainstem may increase other threats such as predation by nonnative fishes and diseases and parasites, and thus should be thoroughly scientifically evaluated. Warmer water temperatures have been the norm rather the exception since 2003 and could continue to be released given the effects of increased demands of human populations on the Colorado River and the effects on runoff in the Colorado Basin from global climate change. A selective withdrawal structure should be able to supply cold water as well as the warmest water possible over a range of reservoir elevations to be effective and have the capability to minimize the spread of warm-water nonnative species.

(2) Control existing non-native predators and competitors and prevent new introductions of nonnative species to reduce impacts to humpback chub and other native species. This would also help ensure that any negative impacts from temperature modification would not be exacerbated by an already high predator/competitor load. Additional research is needed to determine which non-natives have the greatest impact on humpback chub mortality, and which might be controlled by mechanical or other removal methods. Mainstem and tributary control actions should target non-native species using the most appropriate and effective methods. Monitoring of native and non-native fish species must be able to detect changes in these populations that may result from management actions. Development of a stocking plan for nonnative fish similar to the agreement between the U. S. Fish and Wildlife Service and the states of Utah and Colorado would help to prevent further incursions of predators and competitors into Grand Canyon. Completion and implementation of an invasive species management plan for the Little Colorado River Basin

that defines provisions for controlling escapement of non-native fishes may help to protect humpback chub in the reach of critical habitat in the lower Little Colorado River.

(3) Use dam releases to improve habitat. Dam releases should continue to be evaluated as a means to: potentially displace or disadvantage non-native fish; maintain levels of turbidity that reduce predation by sight-feeding non-natives in the mainstem; improve spawning and rearing habitat for native fish in the mainstem, such as through creation of sediment-formed habitats such as backwaters); and controlling the spread of non-native species. All of these actions are poorly understood at the present time and will require additional monitoring and research.

(4) Research the potential to control parasites and diseases. Additional monitoring and research is needed to determine the level of infestation and to examine the need to develop control methods. Warmer dam releases may increase the spread or impact of disease and parasites on humpback chub in the mainstem.

(5) Translocation of humpback chub to other tributaries. Humpback chub have already been successfully translocated within the Little Colorado River above a natural barrier, Chute Falls. These translocated fish have become established, exhibited fast growth rates, and spawned, essentially increasing the range of the species by several kilometers within the Little Colorado River, and likely increasing the population size by several hundred fish or more (Stone 2006, 2007). Translocating humpback chub to other tributary streams within Grand Canyon, such as Havasu, Shinumo, Bright Angel creeks or the Paria River, could also result in new, successful populations, and should be investigated (Valdez et al. 2000, Stevens et al. 2006). A number of factors will have to be considered in translocation of humpback chub. For example, care must be taken to ensure that genetics of translocated populations are representative of the Grand Canyon population, and that translocation efforts do not result in overharvest of wild fish from the Little Colorado River aggregation. Genetic concerns regarding translocation should be addressed by development of a genetics management plan.

(6) Consider the use of other management actions such as sediment/turbidity augmentation to disadvantage non-native fish and provide cover for native species. An experimental test of increased turbidity is could determine the ecological impacts of such augmentation, with particular regard to effects on sight-feeding predators of humpback chub and effects on fish food resources. Such tests could also be conducted *ex situ* in a laboratory setting.

(7) Explore methods to reduce impacts from scientific and recreational uses. The recently completed Protocol Evaluation Panel on the AMP's fish monitoring programs identify the need to continually modify sampling efforts to reduce the effect of handling stress on humpback chub.

4.2 Reducing the Threat of Catastrophic Events

There is a risk of extirpation resulting from catastrophic events in the Little Colorado River, such as hazardous materials spills or dewatering of the regional aquifer supporting Blue Springs, because it is currently the primary spawning location for humpback chub in Grand Canyon, and is occupied by much of the population at any given time. Also, increasing water temperatures in the mainstem Colorado River and other management actions intended to benefit the humpback chub carry the risk of unintended consequences that may negatively affect the humpback chub population.

The top priorities to protect against such risks are (1) expand the range of the population both above and below the Little Colorado River confluence (both mainstem and tributaries) so that a catastrophic event is less likely to negatively affect the entire population, (2) develop and implement an action plan to alleviate threats that may originate in the Little Colorado River watershed, including plans for early response to toxic spills, pollution control, and invasive species and (3) establish one or more refuge populations and/or captive breeding populations, consistent with a genetics management plan, for protection against the loss of the Grand Canyon population.

4.3 Monitoring and Assessment

Monitoring is a key component of adaptive management (Nyberg 1998, Walters 1986, Taylor et al. 1997) and monitoring of the Grand Canyon humpback chub population and its habitat and assessment of the trend in their status is essential to this plan. The AMP has already established a sufficient program of monitoring for fishes and the aquatic ecosystem. This program should continue, and continue to be evaluated in light of new information. Longstanding efforts to monitor the primary humpback chub aggregation in the Little Colorado River, and newer efforts to monitor fishes throughout Grand Canyon, including the reach between Diamond Creek and Lake Mead, should likewise continue. The AMP should also continue to monitor fish diseases and parasites, the aquatic food base, and Little Colorado River hydrology and water quality, to provide an extensive, integrated monitoring framework for humpback chub. The AMP should continue to maintain this level of monitoring effort, and continue to periodically evaluate monitoring protocols to improve their accuracy, precision, and consistency. Humpback chub demographic modeling should be consistent with U.S. Fish and Wildlife Service requirements. Comprehensive ecosystem models are necessary to test the tradeoffs inherent in different management alternatives and should be an important component of monitoring and assessment.

5.0 STRATEGY IMPLEMENTATION - PROPOSED PROJECTS

The first draft of this document, completed in 2003, utilized an approach that relied on a set of projects targeted at specific research needs or conservation actions identified by committee to implement the conservation strategy. We continue that approach here, and link them conceptually. This current iteration consists of 14 projects, listed in Table 1, that the Ad Hoc believes are necessary to conserve humpback chub in the Lower Colorado River Basin. Some projects are identified only at a feasibility level; that is, they are studies that will lead the way to evaluation and testing, likely as pilot projects, through the AMP adaptive management process to determine their utility in contributing to the recovery goals. Some projects are already funded

and are being implemented through the AMP by GCMRC either internally or through contracts. We provide project descriptions in Appendix B, including the project's current status and expected completion timeframe. More detail on these projects can be found in work plans produced by GCMRC for fiscal year (FY) 2002-2009. Other projects outside the purview of the AMP would likely require funding as part of a recovery program for humpback chub in Lower Colorado River Basin. The Humpback Chub Implementation Ad Hoc will evaluate all of the projects for their potential inclusion in the AMP in a separate report.

Table 1. Projects to facilitate conservation of the humpback chub in the Lower Colorado River Basin.

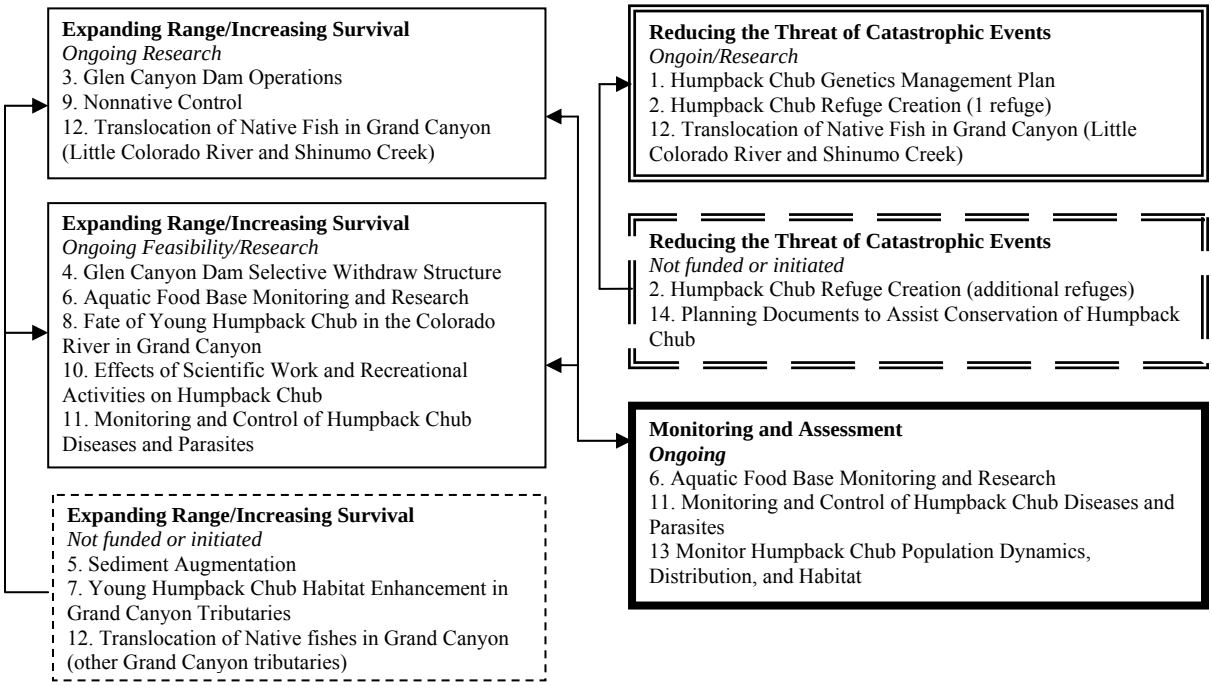
1 Humpback Chub Genetics Management Plan
2 Humpback Chub Refuge Creation
3 Glen Canyon Dam Operations
4 Glen Canyon Dam Selective Withdraw Structure
5 Sediment Augmentation
6 Aquatic Food Base Monitoring and Research
7 Young Humpback Chub Habitat Enhancement in the Little Colorado River and other Grand Canyon Tributaries
8 Fate of Young Humpback Chub in the Colorado River in Grand Canyon (Nearshore Ecology Study)
9 Nonnative Control
  a. Nonnative Control in Tributaries of the Colorado River in Grand Canyon
  b. Nonnative Control Near the Mouth, and/or in the Lower 15 km, of the Little Colorado River
  c. Develop Nonnative and Invasive Species Control Plan for the Grand Canyon Region
  d. Develop Nonnative Stocking Procedures for Grand Canyon Region
10 Effects of Scientific Work and Recreational Activities on Humpback Chub
11 Monitoring and Control of Humpback Chub Diseases and Parasites
12 Translocation of Native fishes in Grand Canyon
  a. Translocation of Humpback Chub above Chute Falls in the Little Colorado River
  b. Translocation of Native fish to Grand Canyon Tributaries other than the Little Colorado River
13 Monitor Humpback Chub Population Dynamics, Distribution, and Habitat
  a. Monitor Hydrology and Water Quality in the Little Colorado River
  b. Maintain a Core Monitoring Effort for Humpback Chub in Grand Canyon
  c. Monitor the Status and Trends of the Downstream Fish Community in Grand Canyon
  d. Monitor the Status and Trends of Fishes below Diamond Creek
14 Planning Documents to Assist Conservation of Humpback Chub
  a. Develop Watershed Management Plan for the Little Colorado River
  b. Develop Emergency Response/Contingency Plan for the Little Colorado River
  c. Develop Pollution Control Plan for Little Colorado River

5.1 Project Linkages, Sequences and Feedback Loops

Defining the interaction of the projects is difficult because there is uncertainty associated with the threats to humpback chub with regard to their respective severity and interaction. Thus, the possible interaction of various projects is likewise difficult to determine. In addition, many of the projects are general in nature and may represent several separate projects when funded and implemented. However, we have attempted to provide this in Figure 1, which illustrates that projects fit into three categories that correspond to the overall conservation strategy: 1, those that serve to expand the range and/or survivorship of humpback chub; 2, those that reduce the threat of catastrophic events; and 3, those that provide monitoring and assessment of conservation

efforts. Within these categories, projects are in various stages of development, unfunded and/or not implemented, in a feasibility/research phase, or ongoing (see Figure 1). Project timing is also illustrated in this way, and is also provided in the status section of individual project synopses in Appendix B.

Figure 1. Diagram illustrating linked elements of the conservation strategy for humpback chub in Grand Canyon, including associated projects and their status.



5.2 Project Prioritization

Numerous examples of how to prioritize and rank threats are provided in the National Marine Fisheries Service Interim Recovery Planning Handbook (2007a). Rarely is enough information available to rank threats based on numerical values. In almost all cases in recovery planning, agencies have resorted to using qualitative criteria based on expert opinion. Usually there is some data to weight the available evidence, but not to conduct an entire ranking analysis.

A "weight of evidence" approach was used by NMFS to assess the relative impact of each threat (factor) in the most recent Steller Sea Lion Recovery Plan (NMFS 2008). This qualitative assessment approach was selected rather than a quantitative approach because of the substantial uncertainty in the understanding of each threat's influence on sea lion population dynamics. Using the extensive expertise of the recovery team, they were able to identify three relative threat levels, Low, Medium, and High.

The assessment allowed the development of a recovery strategy and prioritization of recovery actions. It is expected that in future plans that these threats will be more finely assessed. Although the rankings were developed to be relative to each other, a conceptual definition of each level is provided below:

High: a threat with substantial impacts to recovery requiring mitigation and/or further research to identify impacts
Medium: a threat with moderate impacts which if mitigated could increase the likelihood of recovery, but in and of itself has limited impact on population trajectories
Low: a source of mortality that likely has little impact on population trajectory

NMFS used the following parameters to describe each threat: (1) the mechanism by which each threat operates (bottom-up, or top-down, or both); (2) the age-class most vulnerable to the threat; (3) the relative frequency that the threat occurs; (4) the uncertainty in the evidence used to determine the relative impact; and (5) the feasibility of mitigation.

The Ad Hoc conducted a similar exercise to help prioritize the projects. The 14 humpback chub projects were ranked using 5 criteria (on a scale of 1-5, 5 being best): benefit, cost, feasibility, learning, and timeframe. The results for the project rankings were summarized both unweighted and utilizing a weighted value for the "benefit" criteria, which provides a ranking that emphasizes the potential benefit of a project to humpback chub over the other criteria. The benefit-weighted ranking was the preferred ranking of the Ad Hoc. The rankings are presented in Appendix D, and are provided as guidance to assist in planning and budget development. However all 14 of the projects included in this report are considered to be important by the Ad Hoc, and are strongly recommended for consideration to support conservation of humpback chub.

5.3 Reducing the Threat of Catastrophic Events

The current humpback chub population in the lower Colorado River is primarily concentrated in the Little Colorado River (Paukert et al. 2006). For some time this has caused concern for managers because of the potential for an event that results in a severe population decline in humpback chub, such as a contaminant spill at one of the bridges that cross the Little Colorado River upstream of the population. Reducing this threat is a key component of the strategy of this plan. As discussed above, the plan includes mechanisms to protect against such risks by: expanding the range of the population in Grand Canyon; developing and implementing action plans to alleviate threats that may originate in the Little Colorado River watershed, including plans for early response to toxic spills, pollution control, and invasive species; and establishing one or more refuge populations and/or captive breeding populations, consistent with a genetics management plan, for protecting against the loss of the Grand Canyon population. There are four projects proposed in this plan that are key to achieving these strategy elements: Project 1, the Humpback Chub Genetics Management Plan; Project 2, Humpback Chub Refuge Creation; Project 9, Nonnative Control; and Project 14, Planning Documents to Assist Conservation of Humpback Chub.

The Humpback Chub Genetics Management Plan will guide development of one or more refuge populations and/or captive breeding populations, as well as translocation of humpback chub to other areas, and ensure that these actions follow the U. S. Fish and Wildlife Service policy on controlled propagation (U.S. Fish and Wildlife Service 2000). A number of precautions must be employed when utilizing captive populations in conservation of a species.

Development of broodstock should not compromise the viability of any extant aggregations (i.e., it may be appropriate only to collect gametes or young-of-year from the mainstem aggregations). Guidelines should be developed for creation and maintenance of refuge populations, and for translocation. Criteria must be developed to determine when stocking of captive bred individuals will be employed as a conservation action. The genetics management plan will be the guidance document for these actions.

A refuge is defined as a place that provides shelter or protection, in the case of this plan, for humpback chub. The term refugium (pl., refugia) is often mistakenly used in this context (a refugium is a relict area of relatively unaltered climate that is inhabited by plants and animals during a period of continental-scale climatic change). The Ad Hoc recommends maintaining several refuge populations as a tool in conservation of Grand Canyon humpback chub to ensure species persistence and to protect against potentially catastrophic events until threats can be alleviated, habitat improved, and the range of humpback chub expanded to the point that low population levels and catastrophic events are no longer considered a threat. The Ad Hoc does not recommend stocking captive reared humpback chub into Grand Canyon at this time.

Control of nonnative species, including a plan to control invasion of new nonnative species, will reduce the threat that nonnative species will lead to a catastrophic loss of humpback chub from Grand Canyon. There are also several planning documents proposed collectively as Project 14 that also serve to reduce the threat of catastrophic events. In particular, development of an emergency response plan for the Little Colorado River will provide a contingency plan to help address the threat of a contaminant spill. A Little Colorado River watershed management plan and pollution control plan, also recommended by the Ad Hoc, will also aid in reducing threats to critical habitat in the Little Colorado River.

5.4 Implications of Implementation

Implementation of management actions to benefit the humpback chub may impact other resources in Grand Canyon. These impacts may occur as a result of redirected efforts and funding for humpback chub research, monitoring, and management actions. Implementation of these actions must be consistent with the mission and management objectives of the AMP. Management actions recommended in this report are intended to complement and support the mission of AMP, but it is also recognized that implementing a part or all of these actions will likely require additional or different funding sources.

6.0 Discussion

The recent improvement in the status of the humpback chub in Grand Canyon provides an opportunity to learn about the causal factors that may be important in its recovery. Numerous factors, including cold water temperatures, have been identified as potential factors in the decline of the species and may be critical in its recovery. A number of management actions were tested during this period of recovery, including high flow and low steady flow testing, nonnative removal, and translocations. These activities may have contributed to the improvement in status and should continue to be evaluated for efficacy. Translocation in particular may be an important tool in expanding the range of humpback chub in Grand Canyon, particularly translocation into

tributaries. Tributary translocations should be considered in suitable streams to expand the range of spawning and rearing of humpback chub and to reduce the risk of extirpation in Grand Canyon due to a catastrophic event in the Little Colorado River.

An important consideration for managers is that actions that may have positive benefits for some resources can also have negative consequences. For example, the low summer steady flow in 2000 created relatively warm water temperatures in the mainstem river (Andersen 2009), but low flows can adversely affect food base by limiting primary production (Kennedy and Gloss 2005). Likewise, augmenting sediment to create turbidity could provide cover for native fishes and reduce predation from nonnative fish (Valdez and Ryel 1995), but increases in turbidity could also decrease food base by decreasing primary production (Blinn et al. 1992). The recent increase in humpback chub abundance (Andersen 2009) was likely driven in part by warmer water temperatures, which may have improved growth and survivorship of juvenile humpback chub in the mainstem river. However, warmer water temperatures may also benefit nonnative fishes (Valdez and Speas 2007), and any benefits to humpback chub could be negatively offset by losses to predation, especially if new nonnative species were to invade and become established. Nonnative removal has proven effective in removing trout, but the benefits of removing trout to humpback chub is uncertain (Coggins 2008), and other nonnative species are less susceptible to current capture methods and may pose a more significant predation risk to humpback chub (Arizona Game and Fish Department 2008). The efficacy of removing nonnative fishes to benefit humpback chub is still an open question, as is the most effective means of nonnative removal. Research should be implemented to provide insight into these questions and tradeoffs. This may entail rethinking the AMWG priority questions for humpback chub to focus attention on determining the causal factors of the recent positive population trajectory.

Although many uncertainties remain with regard to the most efficient and cost-effective means to recover the humpback chub in Grand Canyon, ongoing research and management actions taken by the Adaptive Management Program may provide many important answers over the next 5-10 years. Clearly it will be a challenge to manage these tradeoffs within the Adaptive Management Program. Development of comprehensive models to further evaluate the effect of these treatments on humpback chub recruitment in an ecosystem context will be essential in this process. The goal of adaptive management is improved decision making through learning by doing (Williams et al. 2007). If implemented correctly, adaptive management will vastly improve the power of managers to make decisions that are not just effective, but are also lower risk and cost-effective (Williams et al. 2007). The Adaptive Management Program has made great strides in improving our understanding of how best to conserve humpback chub in the Grand Canyon. Important questions remain, but if recovery of humpback chub in Grand Canyon is to be successful, its best hope lies in the continued application of adaptive management.

7.0 Conclusions

The purpose of this plan is to compile information on the status of the Grand Canyon population of humpback chub (i.e. the lower basin recovery unit as defined by the U.S. Fish and Wildlife Service, 2008), summarize the threats to this population, and define a comprehensive strategy, which includes specific research and management actions, to improve the status of the

population and minimize or eliminate threats. The AMP was created by the Department of the Interior to ensure, as defined in Section 1802 of the Grand Canyon Protection Act, that Glen Canyon Dam is operated "... in such a manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established, including, but not limited to natural and cultural resources and visitor use." The AMWG directed that this report be updated to guide efforts to accomplish this for the humpback chub, although much of what is recommended in this report will also benefit other native species that occur in Marble and Grand canyons. Not all actions described here are necessarily the requirement of the AMP. A separate process will be used by the AMWG to determine what elements of this plan should be recommended to the Secretary for implementation by the AMP.

The status of the Grand Canyon population of humpback chub appears to be improving following a significant decline. Adult population estimates for an age-structured Jolly–Seber model ranged from about 14,500 in 1989 to about 2,400 in 2001; a similar model, the ASMR, estimated population size from 10,000-11,000 adults in 1989 to 3,100-4,400 in 2001 (Coggins et al. 2006). The main cause for the decline appears to be a decline in recruitment such that adult mortality exceeds recruitment. Recent ASMR analyses indicate that the Grand Canyon population appears to have increased to 7,650 (CI 6,000-10,000), and that the decline in recruitment began to stabilize or reverse in the mid-1990s (Coggins and Walters 2009). New information also indicates that there are greater numbers of humpback chub in the mainstem Colorado River than in previous years (Johnstone and Lauretta 2004, 2007, Trammell et al. 2002, Arizona Game and Fish Department 1996, Ackerman et al. 2006, Ackerman 2007). The range and size of the Little Colorado River Inflow aggregation has also increased as a direct result of translocating humpback chub from the Little Colorado River above Chute Falls (a natural barrier waterfall) in the Little Colorado River approximately 16 km above the confluence. Results indicate that translocated fish had high survival and growth rates, and reproduction and downstream movement has been documented (Stone 2006), as well as recruitment into the adult population (Stone 2007).

The AMP has undertaken a number of actions to benefit humpback chub. In 2000, a low summer steady flow was conducted which significantly warmed mainstem Colorado River water temperatures (GCMRC unpublished data). From 2003 to 2006, nonnative fishes were removed using electrofishing from the Little Colorado River inflow reach. In 1996, 2004, and 2008 high flow tests were conducted to rebuild sand-formed habitats. Humpback chub were translocated within the Little Colorado River to improve growth and survival from 2003-2005 and in 2008. All of these actions met with some degree of success and likely provided a conservation benefit to the species. Additionally, Reclamation has undertaken a number of conservation measures as part of two biological opinions to conserve humpback chub (see Appendix F) many of which are recommended projects in this plan.

While the recent increase in population size and stability of the Grand Canyon population of humpback chub has previously been attributed to increased recruitment resulting from warmer water temperatures, mechanical removal of nonnative piscivorous fish and/or experimental flows (high flow tests, steady flows in 2000), recent modeling suggests that initiation of increased recruitment predates each of these factors by at least four years (Coggins 2007, Coggins and

Walters 2009). No explanations for this recruitment increase have been proposed to date. The increase could have been due to factors associated with the Little Colorado River, the mainchannel Colorado River, or both parts of the system.

The Ad Hoc recommends working to further improve status of the humpback chub with a 3 tiered strategy: (1) expanding the range of spawning and rearing in Grand Canyon, (2) increasing survival and recruitment, and (3) reducing the threat of catastrophic events or unintended consequences. Expanding the range of humpback chub and improving survival and recruitment can be achieved in numerous ways, but mainstem habitat conditions, and in particular, the water temperature of the mainstem and suitability of nearshore habitats for rearing young are likely most important, but nonnative species could offset these actions via predation and competition. Improving mainstem habitats for humpback chub will likely require modifications to the infrastructure or operations of Glen Canyon Dam, and prior actions by the AMP such as the 2000 Low Summer Steady Flow have contributed to our learning in this regard. The Ad Hoc agrees with previous assessments (U.S. Geological Survey 2008a) that any efforts to modify Glen Canyon Dam address the capability to release both warm and cold water as needed to better address the threat of inadvertently benefitting warm water nonnative species. We note that global climate change may also warm the Colorado River (USCCP 2008). New initiatives to reduce the threat of catastrophic events recommended in this report are currently underway, such as creation of a humpback chub refuge, but additional efforts are needed, such as the long-standing need to develop an emergency response/contingency plan for protection of the downstream ecosystem from contaminant spills into the Little Colorado River at Cameron Bridge or other potential sites. Controlling nonnative species continues to be identified as the most critical need for this species. Preventing the invasion and expansion of nonnative species is likely the most important and difficult action required for the continued conservation of humpback chub.

LITERATURE CITED

Ackerman, M.W. 2007. 2006 Native fish monitoring activities in the Colorado River, Grand Canyon. Cooperative Agreement (04WRAG0030) Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. 79 p.

Ackerman, M.W., D. Ward, T. Hunt, R.S. Rogers, D.R. VanHaverbeke, A. Morgan, and C. Cannon. 2006. 2006 Grand Canyon long-term fish monitoring in the Colorado River, Diamond Creek to Lake Mead. Annual report to the U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Andersen, M.A. 2009. Status and trends of the Grand Canyon population of humpback chub. US Geological Survey Fact Sheet 2009-3035.

Anderson, C.R., and S.A. Wright. 2007. Development and application of a water temperature model for the Colorado River ecosystem below Glen Canyon Dam, Arizona. Hydrological Science and Technology , vol. 23 (1-4): Proceedings of the American Institute of Hydrology 2007 Annual Meeting and International Conference, pp. 13-26.

Angradi, T.R., and D.M. Kubly. 1994. Concentration and transport of particulate organic matter below Glen Canyon Dam on the Colorado River, Arizona. Journal of the Arizona-Nevada Academy of Science 28: 12-22.

Arizona Game and Fish Department. 1996. The ecology of Grand Canyon backwaters. Cooperative Agreement Report (9-FC-40-07940) to Glen Canyon Environmental Studies, Flagstaff, Arizona. 165 p.

Arizona Game and Fish Department. 2006a. Arizona Statewide Conservation Agreement for roundtail chub (*Gila robusta*), headwater chub (*Gila nigra*), flannelmouth sucker (*Catostomus latipinnis*), Little Colorado River sucker (*Catostomus spp*.), bluehead sucker (*Catostomus discobolus*), and Zuni bluehead sucker (*Catostomus discobolus yarrowi*). Arizona Game and Fish Department, Wildlife Management Division, Nongame Branch Native Fish Program, Version 1.0, December 2006.

Arizona Game and Fish Department. 2006b. Development of fish monitoring (electrofishing) and recent trends in the Grand Canyon fish community. Presentation to the GCDAMP Technical Work Group, November 2006.

Arizona Game and Fish Department. 2008. Non-native Fish in the Colorado River (GCD Lake Mead). GCMRC Non-native Fish Workshop Handout, December 16-17, 2008.

Baron, J., V. Dale, L. Gunderson, A. Howard, D. Hulse, J. Kitchell, J. Loomis, M. Palmer, R. Parker, D. Robertson, D. Schwartz, J. Watkins, and D. Garrett. 2003. Evaluating a Glen Canyon Dam temperature control device to enhance native fish habitat in the Colorado River: a risk assessment by Adaptive Management Program Science Advisors. Submitted to Adaptive Management Work Group, Glen Canyon Dam Adaptive Management Program. July 2003. 46 pp.

Barrett, J.C., G.D. Grossman, and J.Rosenfeld. 1992. Turbidity-induced changes in reactive distances of rainbow trout. Transactions of the American Fisheries Society (121) 437-443.

Benenati, E.P., J.P. Shannon, J.S. Hagan, and D.W. Blinn. 2001. Drifting fine particulate organic matter below Glen Canyon Dam in the Colorado River, Arizona. Journal of Freshwater Ecology 16: 235–248.

Berry, C.R. 1988. Effects of cold shock on Colorado River Squawfish larvae. Southwestern Naturalist 33(2): 193-197.

Berry, C.R., and R. Pimentel. 1985. Swimming performances of three rare Colorado River fishes. Transactions of the American Fisheries Society 114:397-402.

Beus, S.S., M.A. Kaplinksi, J.E. Hazel, and L. Kearsley. 1994. Monitoring the effects of interim flows from Glen Canyon Dam on sand bar dynamics and campsite size in the Colorado River corridor, Grand Canyon National Park, Arizona. Draft final report submitted to Glen Canyon Environmental Studies, U.S. Bureau of Reclamation.

Blinn, D.W., and G.A. Cole. 1991. Algal and Invertebrate Biota in the Colorado River: Comparison of Pre-and Post-Dam Conditions. Pp. 102-123 in Colorado River Ecology and Dam Management, Proceedings of a symposium, May 24-25, 1990. National Academy Press, Washington, DC.

Blinn, D.W., Stevens, L.E., and Shannon. J.P. 1992. The effects of Glen Canyon Dam on the aquatic food base in the Colorado River corridor in Grand Canyon, Arizona: Flagstaff, Ariz., Bureau of Reclamation, Glen Canyon Environmental Studies Report 11-02.

Blinn, W.J. P. Shannon, L.E. Stevens and J.P. Carder. 1995. Consequences of fluctuating discharge for lotic communities. Journal of the North American Benthological Society 14(2): 233-248.

Brouder, M. J. and T. L. Hoffnagle. 1997. Distribution and prevalence of the Asian fish tapeworm, *Bothriocephalus acheilognathi*, in the Colorado River and tributaries, Grand Canyon, Arizona, including two new host records. Journal of the Helminthological Society of Washington 64:219-226.

Brouder, M.J., D.W. Speas and T.L. Hoffnagle. 1999. Changes in number, sediment composition and benthic invertebrates of backwaters. Pp. 241-248 in Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The Controlled Flood in Grand Canyon. American Geophysical Union monograph 110.

Bulkley, R.V., C.R. Berry, R. Pimental, T. Black. 1982. Tolerance and preferences of Colorado River endangered fishes to selected habitat parameters. Colorado River Fishery Project Final Report Part 3. Bureau of Reclamation, Salt Lake City, Utah.

Bulow, F. J., J. R. Winningham, and R. C. Hooper. 1979. Occurrence of copepod parasite Lernaea cyprinacea in a stream fish population. Transactions of the American Fisheries Society 108: 100–102.

Carothers, S.W., and C.O. Minckley. 1981. A survey of the fishes, aquatic invertebrates and aquatic plants of the Colorado River and selected tributaries from Lees Ferry to Separation Rapids. Final Report to U.S. Bureau of Reclamation, Museum of Northern Arizona, Flagstaff.

Chart, T.E., and L. Lentsch. 2000. Reproduction and recruitment of Gila spp. and Coloradopikeminnow (Ptychocheilus lucius) in the middle Green River; 1992–1996. Utah Division of Wildlife Resources, publication number 00-18. Final Report to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

Christensen, N. and D.P. Lettenmaier. 2006. A multimodel ensemble approach to assessment of climate change impacts on the hydrology and water resources of the Colorado River basin. Hydrology and Earth System Sciences Discussion 3: 1-44.

Childs, M. 2005. Humpback chub hatchery evaluation: prospective refuge facilities. Arizona Game and Fish Department. 58 pp.

Choudhury, A., T.L. Hoffnagle, and R.A. Cole. 2004. Parasites of Native and Nonnative Fishes of the Little Colorado River, Grand Canyon, Arizona. Journal of Parasitology 90: 1042- 53.

Clarkson, R.W., and M.R. Childs. 2000. Temperature effects of hypolimnial-release dams on early life stages of Colorado River Basin big-river fishes. Copeia 2000:4 02–412.

Clarkson, R.W., A.T. Robinson, and T.L. Hoffnagle. 1997. Asian tapeworm (*Bothriocephalus acheilognathi*), in native fishes from the Little Colorado River, Grand Canyon, Arizona.Great Basin Naturalist 57: 66–69.

Coggins, L.G. 2007. Abundance trends and status of the Little Colorado River population of humpback chub: an update considering 1989-2006 data. United States Geological Survey open file report 2007-1402.

Coggins, L.G., Jr. 2008. Active adaptive management for native fish conservation in the Grand Canyon: implementation and evaluation. Ph.D. Dissertation, University of Florida, Gainseville, FL. 173 pp.

Coggins, L.G., Jr., W.E. Pine, III, C.J. Walters, D.R. Van Haverbeke, D. Ward, and H.D. Johnstone. 2006. Abundance trends and status of the Little Colorado River population of humpback chub. North American Journal of Fisheries Management 26: 233-245.

Coggins, L.G., Jr., and C.J. Walters. 2009. Abundance trends and status of the Little Colorado River population of humpback chub; an update considering data from 1989-2008: U.S. Geological Survey Open-File Report 2009-1075, 18 p.

Coggins, L. and M. Yard. 2003. Nonnative fish removal efforts in Grand Canyon: A proposed modification to ongoing activities. U.S. Geological Survey, Grand Canyon Monitoring And Research Center, Flagstaff, Arizona.

Cole, R.A. 2002. Proposal to investigate life cycle and impact of *Truttaedacnitis truttae* on Lees Ferry rainbow trout and conduct preliminary parasite inventory on flannelmouth sucker from the Lees Ferry reach. Proposal submitted to USGS State Partnership Grant and Grand Canyon Monitoring and Research Center, 2002.

Czapla, T.E. 1999. Genetics management plan (revised). Upper Colorado Endangered Fish Recovery Program, U.S. Fish and Wildlife Service, Denver, Colorado.

Czapla, T.E. 2002. Facilities plan for the production of endangered fishes to meet state stocking plans as part of the Upper Colorado River Endangered Fish Recovery Program. U.S. Fish and Wildlife Service, Denver, Colorado.

Czapla, T.E. Genetics Management Plan for Humpback Chub, Draft 1. U.S. Fish and Wildlife Service, Denver, Colorado. 8 pp.

Douglas, M.R., and M.E. Douglas. 2007. Genetic structure of humpback chub Gila cypha and roundtail chub G. robusta in the Colorado River ecosystem. Final Report to Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Douglas, M.E. and P.C. Marsh. 1996. Population estimates/population movements of *Gila cypha*, an endangered cyprinid fish in the Grand Canyon region of Arizona. Copeia 1996: 15-28.

Day, K.S., K.D. Christopherson, and C. Crosby. 1999. An assessment of young-of-year Colorado pikeminnow Ptychocheilus lucius use of backwater habitats in the Green River, Utah. Report B in Flaming Gorge Studies: Assessment of Colorado pikeminnow nursery habitat in the Green River. Final Report to Upper Colorado River Endangered Fish Recovery Program. Utah Division of Wildlife Resources, Salt Lake City, Utah.

Evans, P. 1993. A "recovery" partnership for the upper Colorado River to meet ESA Section 7 needs. Natural Resources and Environment 71: 24-25.

Fagan, W.F., P.J. Unmack, C. Burgess, and W.L. Minckley. 2002. Rarity, fragmentation, and extinction risk in desert fishes. Ecology 83(12): 3250-3256.

Finney, S. 2006. Adult and juvenile humpback chub monitoring for the Yampa River population, 2003-2004. Final Report of U.S. Fish and Wildlife Service to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

Finney, S, T. Modde, B. Haines, and K. Christopherson. 2004. Yampa Canyon Population of Humpback Chub: Past, Present, and Future. U.S. Fish and Wildlife Service. Presentation at Population Estimates Workshop II, August 24-25, 2004, Grand Junction, Colorado.

Glen Canyon Dam Adaptive Management Program. 2002. Strategic Plan, Approved January 17, 2002.

Gloss, S.P. and L.G. Coggins. 2005. Fishes of Grand Canyon. Pp. 33–49 in Gloss, S.P., J.E. Lovich, and T.E. Melis, eds., The State of the Colorado River ecosystem in Grand Canyon: U.S. Geological Survey Circular 1282. 220 pp.

Gloss, S.P., J.E. Lovich, and T.E. Melis, eds. 2005. The State of the Colorado River ecosystem in Grand Canyon: U.S. Geological Survey Circular 1282, 220 pp.

Goeking, S.A., J.C. Schmidt, and M.K. Webb. 2003. Spatial and temporal trends in the size and number of backwaters between 1935 and 2000, Marble and Grand Canyons, Arizona. Department of Aquatic, Watershed, and Earth Resources. Utah State University. Report prepared for U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Gorman, O.T. 1994. Habitat use by the humpback chub, Gila cypha, in the Little Colorado River and other tributaries of the Colorado River. Final report. U.S. Fish and Wildlife Service, Flagstaff, Arizona.

Grabda, J. 1963. Life cycle and morphogenesis of Lernaea cyprinacea L. Acta Parasitologica Polonica XI: 169–199.

Granath, W.O., Jr., and G.W. Esch. 1983. Seasonal dynamics of Bothriocephalus acheilognathi in ambient and thermally altered areas of a North Carolina cooling reservoir. Proceedings of the Helminthological Society Washington 50:205–218.

Grand, T., C.S.F. Railsback, J.W. Hayse and K.E. LaGory. 2006. A physical habitat model for predicting the effects of flow fluctuations in nursery habitats of the endangered Colorado pikeminnow Ptychocheilus lucius. River Research and Applications 22: 1125-1142.

Grand Canyon Monitoring and Research Center (GCMRC). 2003a. An overview of status and trend information for the Grand Canyon population of humpback chub, *Gila cypha*. Prepared by the Grand Canyon Monitoring and Research Center, Flagstaff, AZ for the Glen Canyon Dam Adaptive Management Work Group. April 22, 2003.

Grand Canyon Monitoring and Research Center (GCMRC). 2003b. Proposed Two-Year Science Plan for Experimental Flow Treatments and Mechanical Removal Activities in WY's 2002-2004. Submitted to Adaptive Management Work Group, Glen Canyon Dam Adaptive Management Program.

Haden, G.A., D.W. Blinn, J.P. Shannon, and K.P. Wilson. 1999. Driftwood: an alternative habitat for macroinvertebrates in a large desert river. Hydrobiologia 397: 179–186.

Hamman, R.L. 1982. Spawning and culture of humpback chub. Progressive Fish-Culturist 44: 213–216.

Haines, B. and T. Modde. 2002. Humpback chub monitoring in Yampa Canyon, 1998-2000. Final Report of U.S. Fish and Wildlife Service to Upper Colorado River Endangered Fish Recovery Program, Denver, CO.

Hawkins, J.A.. 2002. X-ray assessment of electrofishing injury of Colorado pikeminnow. Colorado State University, Fort Collins, CO. 29 p.

Hawkins, J.A. 2003. Recapture and growth rates of three Colorado River endangered fish species: a comparison between electrofishing and nonelectrofishing. Colorado State University, Fort Collins, CO. 23 p.

Hazel, J.E., M. Kaplinksi, R. Parnell, M. Manone and A. Dale. 1999. Topographic and bathymetric changes at thirty-three long-term study sites. Pp. 161-183 in Webb, .H., J.C.

Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The Controlled Flood in Grand Canyon. American Geophysical Union monograph 110.

Hinck, J.E., V.S. Blazer, N.D. Denslow, K.R. Echols, T.S. Gross, T.W. May, PJ.Anderson, 1.J. Coyle, and D.E. Tillit. 2007. Chemical contaminants, health indicators, and reproductive biomarker responses in fish from the Colorado River and its tributaries. Science of the Total Environment 378: 376-402.

Hoerling, M. and J. Eischeid. 2006. Past peak water in the Southwest. Southwest Hydrology 6(1).

Hoffman, G. L. and G. Schubert. 1984. Some parasites of exotic fishes. Pp. 233-261 *in* W. R. Courtney, Jr. and J. R. Stauffer, Jr., editors. Distribution, biology, and management of exotic fishes. Johns Hopkins University Press, Baltimore.

Hoffnagle, T.L. 1996. Changes in water quality parameters and fish usage of backwaters during fluctuating vs. short-term steady flows in the Colorado River, Grand Canyon. Arizona Game and Fish Dept. Prepared for Glen Canyon Environmental Studies, U.S. Bureau of Reclamation.

Hoffnagle, T.L. 2000. Humpback chub Gila cypha health and parasites, 1998–1999. Arizona Game and Fish Department. Final Report to U.S. Fish and Wildlife Service, Grand Canyon Fishery Resource Office, Flagstaff, Arizona.

Hoffnagle, T. L., A. Choudhury and R. A. Cole. 2000. Parasites of native and non-native fishes of the lower Little Colorado River, Arizona. 2000 Annual Report. Arizona Game and Fish Department, Phoenix.

Hoffnagle, T. L., A. Choudhury and R. A. Cole. 2000. Parasitism and body condition in humpback chub from the Colorado and Little Colorado rivers, Grand Canyon, Arizona. Journal of Aquatic Animal Health 18: 184–193.

Hoffnagle, T. L. and R. A. Cole. 1999. Distribution and prevalence of *Lernaea cyprinacea* in fishes of the Colorado River and tributaries in Grand Canyon, Arizona. Proceedings of the Desert Fishes Council 29:4 5-46.

Hoffnagle, T.L., R.A. Valdez, and D.W. Speas. 1999. Fish abundance, distribution, and habitat use. Pp. 273-287 in Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The Controlled Flood in Grand Canyon. American Geophysical Union monograph 110.

Holling, C. S. (ed.) (1978). Adaptive Environmental Assessment and Management. Wiley, Chichester, England.

Hudson, M.J. and J.A. Jackson. 2003a. Population estimates for humpback chub (*Gila cypha*) and roundtail chub (*Gila robusta*) in Desolation/Gray Canyons, Green River, Utah, 2001-

2002. Draft Report of Utah Division of Wildlife Resources to Upper Colorado River Endangered Fish Recovery Program, Denver, CO.

Hudson, M.J. and J.A. Jackson. 2003b. Population estimates for humpback chub (*Gila cypha*) and roundtail chub (*Gila robusta*) in Westwater Canyon, Colorado River, Utah, 1998-2000. Final Report of Utah Division of Wildlife Resources to Upper Colorado River Endangered Fish Recovery Program, Denver, CO.

Intergovernmental Panel on Climate Change. 2007. Summary for Policymakers, in Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller, eds., Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, New York.

Jackson, J. 2004a. Westwater Canyon Humpback Chub Population Estimates. Utah Division of Wildlife Resources. Presentation at Population Estimates Workshop II, August 24-25, 2004, Grand Junction, Colorado.

Jackson, J. 2004b. Desolation and Gray Canyon Humpback Chub Population Estimate 2001-2003. Utah Division of Wildlife Resources. Presentation at Population Estimates Workshop II, August 24-25, 2004, Grand Junction, Colorado.

Jackson, J.A., and J.M. Hudson. 2005. Population estimate for humpback chub (*Gila cypha*) in Desolation and Gray Canyons, Green River, Utah 2001-2003. Final Report of Utah Division of Wildlife Resources to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

Johnson, J.E., R.T. Hines. 1999. Effect of suspended sediment on vulnerability of young razorback suckers to predation. Transactions of the American Fisheries Society 128 648-655.

Johnstone, H.C., and M. Lauretta. 2004. Native Fish Monitoring Activities in the Colorado River within Grand Canyon during 2003. SWCA, Inc., Final Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Johnstone, H.C., and M. Lauretta. 2007. Native Fish Monitoring Activities in the Colorado River within Grand Canyon during 2004. SWCA, Inc., Final Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Johnstone, H.C., M. Lauretta, and M. Trammell. 2003. Native Fish Monitoring Activities in the Colorado River within Grand Canyon during 2002. SWCA, Inc., Final Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Kennedy, T.A. 2007. A Dreissena Risk Assessment for the Colorado River Ecosystem. U.S. Geological Survey open file report 2007-1085.

Kennedy, T.A. and S.P. Gloss. 2005. Aquatic ecology: the role of organic matter and invertebrates. In, S.P. Gloss, J.E. Lovich, and T.S. Melis, eds., The State of the Colorado River Ecosystem in Grand Canyon. USGS Circular 1282, U.S. Geological Survey, Reston, VA.

Korman, J., M. Kaplinski and J. Buszowski. 2006. Effects of air and mainstem water temperatures, hydraulic isolation, and fluctuating flows from Glen Canyon Dam on water temperatures in shoreline environments of the Colorado River in Grand Canyon. Final Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Korman, J., M. Kaplinski, J.E. Hazel III, and T.S. Melis. 2005. Effects of the experimental fluctuating flows from Glen Canyon Dam in 2003 and 2004 on the early life history stages of rainbow trout in the Colorado River. Final Report to Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Korman, J, S.M. Wiele, and M. Torizzo. 2004. Modeling effects of discharge on habitat quality and dispersal of juvenile humpback chub (Gila cypha) in the Colorado River, Grand Canyon. Regulated Rivers 20: 379-400.

Korn, J. and B. Vernieu. 1998. Mainstem and tributary temperature modeling in Grand Canyon Arizona. U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Kubly, D.M. 1990. The endangered humpback chub (Gila cypha) in Arizona: a review of past studies and suggestions for future research. Arizona Game and Fish Department, Phoenix, Arizona.

Lauretta, M. V. and K. M. Serrato. 2006. Native fish monitoring activities in the Colorado River within Grand Canyon during 2005, draft annual report. SWCA, Inc., Final Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Liebfried, B., K. Hilwig, K. Serrato, and M. Lauretta. 2006. Restoring native fish habitat in selected tributaries of Grand Canyon National Park. SWCA, Inc., Draft Report to the National Park Service, Grand Canyon National Park, Arizona.

Leibfried, W.C., H. Johnstone, S. Rhodes, and M. Lauretta. 2005. Feasibility study to determine the efficacy of using a weir in Bright Angel Creek to capture brown trout. Final Report to Grand Canyon Monitoring and Research Center from SWCA Environmental Consultants, Flagstaff, Arizona.

Lupher, M.L., and R.W. Clarkson. 1994. Temperature tolerance of humpback chub (Gila cypha) and Colorado squawfish (Ptychocheilus lucius), with a description of culture methods for humpback chub. Glen Canyon Environmental Studies phase II 1993 annual report. Arizona Game and Fish Department, Phoenix.

Marsh, P.C. 1985. Effect of incubation temperature on survival of embryos of native Colorado River fishes. Southwestern Naturalist 30: 129–140.

Marsh, P.C., and M.E. Douglas. 1997. Predation by introduced fishes on endangered humpbackchub and other native species in the Little Colorado River, Arizona. Transactions of the American Fisheries Society 126: 343–346.

Mattes, W.P. 1993. An evaluation of habitat conditions and species composition above, in, and below the Atomizer Falls complex of the Little Colorado River. Master's thesis, University of Arizona, Tucson.

McAda, C.W. 2002. Population size and structure of humpback chub in Black Rocks, 1998-2000. Final Report of U.S. Fish and Wildlife Service to Upper Colorado River Endangered Fish Recovery Program, Denver, CO.

McAda, C.W. 2004. Black Rocks Humpback Chub Population Estimate 2003. U.S. Fish and Wildlife Service. Presentation at Population Estimates Workshop II, August 24-25, 2004, Grand Junction, Colorado.

McAda, C.W. 2006. Population estimate of humpback chub in Black Rocks. Annual report to the Upper Colorado River Endangered Fish Recovery Program, Project Number 131. U.S. Fish and Wildlife Service, Grand Junction, Colorado.

McDonald, D.B., and P.A. Dotson. 1960. Fishery investigations of the Glen Canyon and Flaming Gorge impoundment areas. Utah State Dept. of Fish and Game, information bulletin, no. 60-3, Ogden, Utah, 1960, 70 p.

McKinney, T., and W.R. Persons. 1999. Rainbow Trout and Lower Trophic Levels in the Lee's Ferry Tailwater Below Glen Canyon Dam, Arizona: A Review. Arizona Game and Fish Department Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

McKinney, T., R.S. Rogers, A.D. Ayers, and W.R. Persons. 1999a. Lotic community responses in the Less Ferry reach. In Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The controlled flood in Grand Canyon. American Geophysical Union, Geophysical Monograph Series, v. 110, Washington D.C. pp 249-258.

McKinney, T., D.W. Speas, R.S. Rogers and W.R. Persons. 1999b. Rainbow trout in the Lees Ferry recreational fishery below Glen Canyon Dam, Arizona, following establishment of minimum flow requirements. Arizona Game and Fish Department, Final Report submitted to Grand Canyon Monitoring and Research Center, Phoenix, Arizona.

McKinney, T., D.W. Speas, R.S. Rogers and W.R. Persons. 2001. Rainbow trout in a regulated river below Glen Canyon Dam, Arizona, following increased minimum flows and reduced discharge variability. North American Journal of Fisheries Management 21:216-222.

McGuinn-Robbins, D.K. 1995. Comparisons in the number and area of backwaters associated with the Colorado River in Glen, Marble and Grand Canyons, Arizona. Draft report to Glen Canyon Environmental Studies, U.S. Bureau of Reclamation. Arizona Game and Fish Department, Phoenix, Arizona.

Meffe, G.K. 1984. Effects of abiotic disturbance on predator-prey fish species. Ecology 65:1525-1534.

Melis, T.S., S.J.D. Martell, L.G. Coggins, Jr., W.E. Pine, III, and M.E. Andersen. 2006a. Adaptive management of the Colorado River ecosystem below Glen Canyon Dam, Arizona: Using science and modeling to resolve uncertainty in river management. American Water Resources Association Specialty Conference: Adaptive Management of Water Resources. June 26-28, 2006, Missoula, Montana.

Melis, T.S., Wright, S.A., Ralston, B.E, Fairley, H.C., Kennedy, T.A., Coggins, L.G., and Andersen, M.E. 2006b. Knowledge Assessment of the Effects of Glen Canyon Dam on the Colorado River Ecosystem. Grand Canyon Monitoring and Research Center, final draft report. 77 pp.

Messier, F. 1994. Ungulate population models with predation: a case study with the North American moose. Ecology 75:478-488.

Miller, R.R. 1946. Gila cypha, a remarkable new species of cyprinid fish from the Colorado River in Grand Canyon, Arizona. Journal of the Washington Academy of Sciences 36: 409-415.

Minckley, W.L. 1991. Native fishes of the Grand Canyon region: An obituary? Pp. 124-177 in Colorado River Ecology and Dam Management. Proceedings of a symposium, May 24- 25, 1990. National Academy Press, Washington, DC.

Minckley, W.L., and G.K. Meffe. 1987. Differential selection by flooding in stream fish communities of the arid American Southwest. Pp. 93-104 in Matthews, W.J., and D.C. Heins, eds., Community and Evolutionary Ecology of North American Stream Fishes. Univ. Oklahoma press, Norman.

Minckley, C.O., S.W. Carothers, J.W. Jordan, and H.D. Usher. 1980. Observations on the humpback chub, Gila cypha, within the Colorado and Little Colorado rivers, Grand Canyon National Park, Arizona. National Park Service Transactions and Proceedings Series 8: 176–183.

Minckley, W.L., and J.N. Rinne. 1985. Large woody debris in hot-desert streams: an historical review. Desert Plants 7(3):142-153.

Mueller, G.A. and P.C. Marsh. 2002. Lost, a desert river and its native fishes: A historical perspective of the Lower Colorado River. U.S. Geological Survey Information and Technology Report 2002-0010, Denver, Colorado. 69 pp.

Muth, R.T., L.W. Crist, K.E. LaGory, J.W. Hayse, K.R. Bestgen, T.P. Ryan, J.K. Lyons, and R.A. Valdez. 2000. Flow and temperature recommendations for endangered fishes in the Green River downstream of Flaming Gorge Dam. Final Report to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

Muth, R.T. and J.B. Rupert. 1996. Effects of two electrofishing currents on captive ripe razorback suckers and subsequent egg-hatching success. North American Journal of Fisheries Management 16: 473-476.

National Marine Fisheries Service. 2008. Recovery Plan for the Steller Sea Lion (*Eumetopias jubatus*). Revision. National Marine Fisheries Service, Silver Spring, MD. 325 pp.

Nyberg, B. 1998. Statistics and the Practice of Adaptive Management. In Statistical Methods for Adaptive Management Studies, edited by Vera Sit and Brenda Taylor. Pp. 1-7. Victoria, BC: Research Branch of the British Columbia Ministry of Forests, Land Management Handbook No. 42.

Parnell, R., A. Springer and L. Stevens. 1997. Flood-induced backwater rejuvenation along theColorado River in Grand Canyon, Arizona: 1996 final report. Northern Arizona University, Flagstaff. 67 p.

Paukert, C.P., L.G. Coggins, Jr., and C.E. Flaccus. 2006. Distribution and movement of humpback chub in the Colorado River, Grand Canyon, based on recaptures. Transactions of the American Fisheries Society 135: 539-544.

Paukert, C.P., D.L, Ward, P.J. Sponholtz, K.D. Hilwig. 2005. Effects of repeated hoopnetting and handling on bonytail chub. Journal of Freshwater Ecology 20(4): 649-653.

Pilgera, T.J., N.R. Franssenb, and K.B. Gidob. 2008. Consumption of native and nonnative fishes by introduced largemouth bass (*Micropterus salmoides*) in the San Juan River, New Mexico. The Southwestern Naturalist 53(1): 105-108.

Rahel F. J., B. Bierwagen, and Y. Taniguchi. 2008. Managing aquatic species of concern in the face of climate change and invasive species. Conservation Biology 22(3):551-561.

Rakowski, C. L., and J. C. Schmidt. 1999. The geomorphic basis of Colorado pikeminnow nursery habitat in the Green River near Ouray, Utah. Report A in Flaming Gorge Studies: Assessment of Colorado pikeminnow nursery habitat in the Green River. Final Report to Upper Colorado River Endangered Fish Recovery Program. Utah Division of Wildlife Resources, Salt Lake City.

Robinson, A.T. and M.R. Childs. 2001. Juvenile growth of native fishes in the Little ColoradoRiver and in a thermally modified portion of the Colorado River. North American Journalof Fisheries Management 21: 809-815.

Robinson, A.T., R.W. Clarkson, and R.E. Forrest. 1998. Dispersal of larval fishes in a regulated river tributary. Transactions of the American Fisheries Society 127: 722–786.

Robinson, A.T., D.M. Kubly, R.W. Clarkson, and E.D. Creef. 1996. Factors limiting the distributions of native fishes in the Little Colorado River, Grand Canyon, Arizona. Southwestern Naturalist 41: 378-387.

Rogers, R.S. and , A.S. Makinster. 2006. Grand Canyon Long-term Nonnative Fish Monitoring, 2003 Annual Report. Report submitted to Grand Canyon Monitoring and Research Center Cooperative Agreement 02WRAG0030, February 2005.

Rubin, D.M., J.C. Schmidt, and J.N. Moore. 1990. Origin, structure, and evolution of a reattachment bar, Colorado River, Grand Canyon, Arizona. Journal of Sedimentary Petrology 60(6): 982-991.

Ruppert, J. B., and R. T. Muth. 1997. Effects of electrofishing fields on captive early juveniles of two endangered cyprinids. North American Journal of Fisheries Management 17: 314-320.

Schäpperclaus , W. 1986. Fish diseases, volume 2. Akademie-Verlag, Berlin.

Schmidt, J.C. 1999. Summary and synthesis of geomorphic studies conducted during the 1996 controlled flood in Grand Canyon. Pp. 329-342 in Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The Controlled Flood in Grand Canyon. American Geophysical Union monograph 110.

Schmidt, J.C., D.J. Topping, P.E. Grams, and J.E. Hazel. 2004. System wide changes in the distribution of fine sediment in the Colorado River corridor between Glen Canyon Dam and Bright Angel Creek, Arizona. Final Report of the Fluvial Geomorphology Laboratory, Utah State University, Logan, Utah. 99 p.

Seager, R., M. Ting, I. Held, Y. Kushnir, J. Lu, G. Vecchi, H. Huang, N. Harnik, A. Leetmaa, N.Lau, C. Li, J. Velez, and N. Naik. 2007. Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America. Science.10: 1126.

Shannon, J.P., D.W. Blinn, P.L Benenati, and K.P. Wilson. 1996. Organic drift in a regulated desert river: Canadian Journal of Fisheries and Aquatic Sciences 53: 1360–1369.

Speas, D. W. 2004. Effects of Low Steady Summer Flows on Rainbow Trout in the Lee's Ferry Tailwater, 2000. Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Speas, D. W., W.R. Persons, R.S. Rogers, D.L. Ward, A.S. Makinster, and J.E. Slaughter, IV. 2004. 2001 Fish Investigations in the Lee's Ferry Tailwater. Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Sponholtz, P.J. and D.R. VanHaverbeke. 2007. Bright Angel Creek trout reduction project: summary report of fall 2006 weir and electrofishing efforts. U.S. Fish and Wildlife Service report (Interagency Agreement R8219070736) to the National Park Service, Grand Canyon National Park. 19p.

Stevens, L.E. and T.L. Hoffnagle. 1999. Spatio-temporal changes in Colorado River backwaters downstream from Glen Canyon Dam, Arizona 1965-1997. Unpublished report available from U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Stone, D.M. 2006. Monitoring in 2006 of humpback chub (*Gila cypha*) and other fishes above lower Atomizer Falls in the Little Colorado River, Arizona. May 23–29 and June 28–July 3, 2006, Trip Report (USFWS-AZFRO-FL-07-002) to U.S. Geological Survey, Grand Canyon Monitoring and Research Center Flagstaff, Arizona.

Stone, D.M. 2007. Monitoring in 2007 of humpback chub (*Gila cypha*) and other Fishes above lower Atomizer Falls in the Little Colorado River, Arizona. June 1–7 and June 26–July 2, 2007 Trip Report (USFWS-AZFRO-FL-07-010) to U.S. Geological Survey, Grand Canyon Monitoring and Research Center Flagstaff, Arizona.

Stone, D.M. and O.T. Gorman. 2006. Ontogenesis of endangered humpback chub (*Gila cypha*) in the Little Colorado River, Arizona. American Midland Naturalist 155: 123-135.

Stone, D.M., D.R. VanHaverbeke, D.L. Ward, and T.A. Hunt. 2007. Dispersal of nonnative fishes and parasites in the intermittent Little Colorado River, Arizona. Southwestern Naturalist 52(1): 130-137.

Taylor, B.L. Kremsater, and R. Ellis. 1997. Adaptive Management of Forests in British Columbia. Victoria, BC: Research Branch of the British Columbia Ministry of Forests.

Topping, D.J., J.C. Schmidt, and L.E. Vierra, Jr. 2003. Computation and analysis of the instantaneous-discharge record for the Colorado River at Lees Ferry, Arizona-May 8, 1921, through September 30, 2000. U.S. Geological Survey Professional Paper 1677, Reston, Virginia.

Topping, D.J., D.M. Rubin, and L.E. Vierra, Jr. 2000. Colorado River sediment transport 1. Natural sediment supply limitation and the influence of Glen Canyon Dam. Water Resources Research 36: 515-542.

Topping, D.J., T.S. Melis, D.M. Rubin, and S.A. Wright. 2004. High-Resolution Monitoring of Suspended-Sediment Concentration and Grain Size in the Colorado River in Grand Canyon Using a Laser-Acoustic System. Pp. 2507-2514 in C. Hu and Y. Tan, eds., Proceedings of the Ninth International Symposium on River Sedimentation. Tsinghua University Press, Yichang, People's Republic of China.

Trammell, M. A. and T. E. Chart. 1999. Colorado pikeminnow young-of-year habitat use, Green River, Utah, 1992-1996. Report C in Flaming Gorge Studies: Assessment of Colorado

pikeminnow nursery habitat in the Green River. Utah Division of Wildlife Resources, Final Report to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

Trammell, M., R. Valdez, S. Carothers, and R. Ryel. 2002. Effects of a low steady summer flow experiment on native fishes of the Colorado River in Grand Canyon, Arizona. SWCA Environmental Consultants. Final Report (Contract Number 99-FC-40-2260). Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

U.S. Climate Change Science Program (CCSP). 2008: Abrupt Climate Change. A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Clark, P.U., A.J. Weaver (coordinating lead authors), E. Brook, E.R. Cook, T.L. Delworth, and K. Steffen (chapter lead authors)]. U.S. Geological Survey, Reston, VA, 459 pp.

U.S. Bureau of Reclamation. 1995. Operation of Glen Canyon Dam, final environmental impact statement. Upper Colorado Region, Salt Lake City, Utah.

U.S. Bureau of Reclamation. 2007. Biological assessment on the operation of Glen Canyon Dam and proposed experimental flows for the Colorado River below Glen Canyon Dam during the years 2008-2012. U.S. Bureau of Reclamation, Upper Colorado River Region, Salt Lake City, Utah.

U.S. Climate Change Science Program. 2008. Abrupt Climate Change. A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Clark, P.U., A.J. Weaver (coordinating lead authors), E. Brook, E.R. Cook, T.L. Delworth, and K. Steffen (chapter lead authors)]. U.S. Geological Survey, Reston, VA, 459 pp.

U.S. Fish and Wildlife Service. 1987. Recovery implementation program for endangered fish species in the Upper Colorado River Basin., U.S. Fish and Wildlife Service, Region 6, Denver, Colorado.

U.S. Fish and Wildlife Service. 1990. Humpback chub recovery plan. U.S. Fish and Wildlife Service, Denver, Colorado. 43 p.

U.S. Fish and Wildlife Service. 1994. Final rule, determination of critical habitat for the Colorado River endangered fishes: razorback sucker, Colorado squawfish, humpback chub, and bonytail chub. Federal Register 59: 13374-13400.

U.S. Fish and Wildlife Service. 1995. Final biological opinion operation of Glen Canyon Dam as the modified low fluctuating flow alternative of the final environmental impact statement operation of Glen Canyon Dam. Reference 2-21-93-F-167. Prepared by Ecological Services, Arizona State Office, December 1994.

U.S. Fish and Wildlife Service. 1996. Procedures for stocking nonnative fish species in the Upper Colorado River Basin. Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

U.S. Fish and Wildlife Service. 2000. Policy regarding controlled propagation of species listed under the Endangered Species Act. Federal Register 65(183):56916-56922.

U.S. Fish and Wildlife Service. 2002. Humpback chub (*Gila cypha*) Recovery Goals: amendment and supplement to the Humpback Chub Recovery Plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

U.S. Fish and Wildlife Service. 2005. Final Management Plan for the Big River Fishes of the Lower Colorado River Basin. U.S. Fish and Wildlife Service, Southwest Region (2), Albuquerque, New Mexico.

U.S. Fish and Wildlife Service. 2007. Final biological opinion for the proposed adoption of Colorado River interim guidelines for lower basin shortages and coordinated operations for Lake Powell and Lake Mead. Consultation number 22410-2006-F-0224. U.S. Fish and Wildlife Service, Phoenix, Arizona.

U.S. Fish and Wildlife Service. 2008a. Humpback chub (*Gila cypha*) Recovery Goals (2008 Revisions). U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

U.S. Fish and Wildlife Service. 2008b. Final Biological Opinion for the Operation of Glen Canyon Dam. Consultation number 22410-1993-F-167R1. U.S. Fish and Wildlife Service, Phoenix, Arizona.

U.S. Geological Survey. 2006. Grand Canyon humpback chub population stabilizing. U.S. Geological Survey Fact Sheet 2006–3109, July 2006.

U.S. Geological Survey. 2007. Science Plan for Potential 2008 Experimental High Flow at Glen Canyon Dam, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. 104 p.

U.S. Geological Survey. 2008a. USGS Workshop on Scientific Aspects of a Long-Term Experimental Plan for Glen Canyon Dam, April 10–11, 2007, Flagstaff, Arizona. Open-File Report 2008–1153.

U.S. Geological Survey. 2008b. Glen Canyon Dam Adaptive Management Program Budget and Work Plan-Fiscal Year 2009. Prepared by Bureau of Reclamation, Salt Lake City, and U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Utah Division of Wildlife Resources. 2004. Humpback chub population estimate in Cataract Canyon, Colorado River, Utah. Report to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

Valdez, R.A. 1994. Effects of interim flows from Glen Canyon Dam on the aquatic resources of the lower Colorado River from Diamond Creek to Lake Mead: Phase I. Bio/West, Inc., Final Report to Glen Canyon Environmental Studies.

Valdez, R.A., and P. Badame. 2005. Humpback chub population estimate in Cataract Canyon, Colorado River, Utah. Annual report to Upper Colorado River Recovery Program, Project 130. Utah Division of Wildlife Resources, Moab, Utah.

Valdez, R.A., S. W. Carothers, M. E. Douglas, M. Douglas, R.J. Ryel, K.R. Bestgen, and D.L. Wegner. 2000. Research and implementation plan for establishing a second population of humpback chub in Grand Canyon. Report to Grand Canyon Monitoring and Research Center, Flagstaff, AZ. SWCA, Inc., Flagstaff, AZ. December 2000.

Valdez, R. A., B. R. Cowdell, and E. Pratts. 1995. Effects of interim flows from Glen Canyon Dam on the aquatic resources of the lower Colorado River from Diamond Creek to Lake Mead: Phase II, final report to Glen Canyon Environmental Studies from Bio/West, Inc., Logan, UT.

Valdez, R.A., and W.J. Masslich. 1999. Evidence of reproduction by humpback chub in a warm spring of the Colorado River in Grand Canyon, Arizona. Southwestern Naturalist 44(3):384-387.

Valdez, R.A. and R.J. Ryel. 1995. Life history and ecology of the humpback chub (*Gila cypha)* in the Colorado River, Grand Canyon, Arizona. Final report to the Bureau of Reclamation, Salt Lake City, Utah, Contract No. 0-CS-40-09110. BIO/WEST Report No. TR-250-8. BIO/WEST, Inc., Logan Utah.

Valdez, R.A., and R.J. Ryel. 1997. Life history and ecology of the humpback chub in the Colorado River in Grand Canyon, Arizona. Pp. 3–31 *in* C. van Riper, III and E.T. Deshler, eds., Proceedings of the Third Biennial Conference of Research on the Colorado Plateau. National Park Service Transactions and Proceedings Series 97/12.

Valdez, R.A., J.P. Shannon, and D.W. Blinn. 1999. Biological implications of the 1996 controlled flood. Pp. 343-350 in Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The Controlled Flood in Grand Canyon. American Geophysical Union monograph 110.

VanHaverbeke, D.R. 2006. Stock assessment and fisheries monitoring activities in the Little Colorado River within Grand Canyon during 2005: report to Grand Canyon Monitoring and Research Center, Flagstaff, Arizona, July 2006.

VanHaverbeke, D.R., and R.L. Simmonds. 2003. The feasibility of developing a program to augment the population of humpback chub (*Gila cypha*) in Grand Canyon. DCN # USFWS-AZFRO-FL-03-007. Draft report to Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. 108 pp.

Van Haverbeke, D.R. and D.M. Stone. 2008. Stock assessment and fisheries monitoring activities in the Little Colorado River within Grand Canyon during 2007. Annual Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. Interagency Acquisition No. 01-3022-R1009. U.S. Fish and Wildlife Service Document No. USFWS-AZNFWCO-FL-08-002. 109 pp.

Voichick, N., and S.A. Wright. 2007. Water-temperature data for the Colorado River and tributaries between Glen Canyon Dam and Spencer Canyon, northern Arizona, 1988-2005. U.S. Geological Survey Data Series 251. 24 pp.

Walters, C.J. 1986. Adaptive Management of Renewable Resources. McGraw-Hill, New York.

Ward, D.L. 2007. Removal and quantification of asian tapeworm from bonytail chub using praziquantel. North American Journal of Aquaculture 69: 207-210.

Ward, D.L., M.R. Childs, and W.R. Persons. 2008. PIT tag retention and tag induced mortality in juvenile bonytail and Gila chub. Fisheries Management and Ecology 15: 159–161.

Ward. D.L., O.E. Maughan, S.A. Bonar, and W.J. Matter. 2002. Effects of temperature, fish length, and exercise on swimming performance of age-0 flannelmouth sucker. Transaction of the American Fisheries Society 131: 492-497.

Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez. 1999. The Controlled Flood in Grand Canyon. American Geophysical Union monograph 110. 367 p.

Wieringa, M.J. and A.G. Morton. 1996. Hydropower, adaptive management, and biodiversity: Environmental Management 20(6): 831-840.

Williams, B.K., R.C. Szaro, and C.D. Shapiro. 2007. Adaptive Management: The U.S. Department of the Interior Technical Guide. US Department of the Interior.

Wright, S.A., T.S. Melis, D.J. Topping, and D.M. Rubin. 2005. Influence of Glen Canyon Dam operations on downstream sand resources of the Colorado River in Grand Canyon. Pp. 17-31 in Gloss, S.P., J.E. Lovich, and T.S. Melis, eds., The state of the Colorado River ecosystem in Grand Canyon. A report of the Grand Canyon Monitoring and Research Center 1991-2004. USGS Circular 1282. U.S. Geological Survey, Flagstaff, Arizona.

Wright, S.A., C.R. Anderson, and N. Voicheck. 2008. A Simplified Water Temperature Model for the Colorado River Below Glen Canyon Dam. River Research and Applications.

Wydoski, R.S. and J. Hamill. 1991. Evolution of a cooperative recovery program for endangered fishes in the Upper Colorado River Basin. Pp. 123-139 *in* W. L. Minckley and J. E. Deacon, eds., Battle against extinction: native fish management in the American West. University of Arizona Press, Tucson.

APPENDIX A: **Members of the Humpback Chub Comprehensive Plan Ad Hoc Group**

Name	**Affiliation**	**E-mail Address**
Dennis Kubly	Bureau of Reclamation	dkubly@uc.usbr.gov
Larry Stevens	Grand Canyon Wildlands Council	farvana@commspeed.com
Bill Persons	Arizona Game and Fish Department	bpersons@azgfd.gov
Gary Burton	Western Area Power Admin.	burton@wapa.gov
Shane Capron	Western Area Power Admin.	capron@wapa.gov
Mark Steffen	Federation of Fly Fishers	steffenflyrod@lycos.com
Pam Sponholtz	U.S. Fish and Wildlife Service	pam_sponholtz@fws.gov
Kerry Christensen	Hualapai Tribe	cuszhmann@yahoo.com
Norm Henderson	National Park Service	Norm Henderson@nps.gov
Steve Mietz	National Park Service	Ken McMullen@nps.gov
Bill Davis	Ecoplan, Colorado River Energy Distributors Aassociation	wdavis@ecoplanaz.com
Matthew Andersen	U.S. Geological Survey	mandersen@usgs.gov

APPENDIX B: Project Synopses

Projects to Facilitate Conservation of the Federally Endangered Humpback Chub (*Gila cypha*) in the Lower Colorado River Basin

The Adaptive Management Workgroup of the Glen Canyon Dam Adaptive Management Program (AMP) commissioned a Humpback Chub Ad Hoc Committee in early 2003 to develop a comprehensive suite of proposed projects or management actions believed necessary to ensure conservation of the humpback chub in the lower Colorado River basin (i.e. the lower Colorado River basin recovery unit in the U.S. Fish and Wildlife Service draft Humpback Chub Recovery Goals 2008 Revisions).

This document represents the latest edition of the report to the AMP, and, like previous versions, lists and describes projects deemed necessary to ensure recovery of the humpback chub in the lower Colorado River basin. The projects have been updated by the Ad Hoc. This document contains synopses of the projects organized in a manner that groups related projects, provides an update on their implementation status, and suggests an appropriate sequence for their implementation. Although these projects are designed with humpback chub specifically in mind, other native fishes should also benefit. Some of these proposed projects have already been accepted and are underway or completed. Some projects are outside the scope of the AMP and may need to be addressed by other processes.

Project Synopses

Genetic, Augmentation and Hatchery Considerations. Developing an effective recovery strategy for a species requires a thorough understanding of its genetic characteristics and relationships among populations. Genetic information will be assimilated and utilized in developing a genetics management plan. The genetic management plan will be used to guide recovery efforts and management actions, such as projects that enhance species recovery or safeguard against catastrophic loss of a single population.

01. Develop and implement a genetics management plan for humpback chub in Grand Canyon.

Propagation and genetics management is one of the seven elements of the Upper Colorado Endangered Fish Recovery Program. Guidance for controlled propagation of federally listed species has been promulgated by the U. S. Fish and Wildlife Service (2000). A genetics management plan is a necessary precursor to several elements of genetic management for humpback chub: translocation, refuge creation, captive grow-out of wild caught fish, or stocking from captive breeding stocks. Such a plan has been developed for populations of humpback chub and the other three big river endangered fish for use in the Upper Colorado Endangered Fish Recovery Program (Czapla 1999), but no corollary plan has been finalized for humpback chub in Grand Canyon. The Upper Colorado plan: (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. The genetics management plan for humpback chub in Grand Canyon should be in place and be used for planning: (1) removal of humpback chub for creation of refuge populations; (2) translocation of humpback chub to other tributaries in Grand Canyon; (3) or for captive propagation of individuals as a source for restocking.

Several projects recently completed by the AMP will aid development of the genetics management plan. Douglas and Douglas (2007) recently completed a study evaluating the interrelationships among populations of the endangered *Gila cypha* within Grand Canyon. This report helps identify genetic distinctiveness of aggregations in the mainstem Colorado River, their interrelationships, and how they can be adaptively managed in a dam-perturbed environment. Dexter National Fish Hatchery has also recently completed a study analyzing the genetic makeup of approximately 75 humpback chub housed at Willow Beach National Fish hatchery. This assessment will be useful in determining the genetic value of these fish to recovery of humpback chub. The Pinetop Fishery Resources Center has completed a report entitled "The Feasibility of Developing a Program to Augment the Population of Humpback Chub (*Gila cypha*) in Grand Canyon" (Van Haverbeke and Simmonds 2003). This document provides a valuable assessment of the benefits and risks associated with three potential methods of augmenting humpback chub populations: (1) captive propagation of wild caught individuals removed from the Little Colorado River to a hatchery facility to produce progeny for restocking; (2) removing wild caught young-of-year humpback chub from the Little Colorado River to a grow-out facility and rearing them to a large size in captivity and then restocking them; and, (3) translocation of wild caught humpback chub upstream to unoccupied habitat in the Little Colorado River and from the Little Colorado River to other tributaries. The Arizona Game and Fish Department has recently completed an evaluation of hatcheries, aquaria, and established refuge facilities within the United States as potential refuge locations for humpback chub from Grand Canyon (Childs 2005). This suite of projects, all contributed by the AMP or by AMP stakeholders, will be important in development of the genetics management plan.

***Relationship to Programs*:**

Adaptive Management Program

Strategic Plan, Management Objective 2.1 – Maintain or attain humpback chub abundance in the Little Colorado River and other aggregations at appropriate levels for viable populations and to remove jeopardy.
Strategic Plan, Management Objective 2.4 – Establish humpback chub spawning aggregations outside the Little Colorado River in the Colorado River ecosystem below Glen Canyon Dam to remove jeopardy.

Humpback Chub Recovery Goals

Downlisting and delisting of humpback chub require demographically and genetically viable populations. A genetics management plan is a necessary precursor to developing refuge populations and stocking from captive breeding stocks to augment declining wild populations

of humpback chub and is a component of the propagation and genetics management segment of the Upper Basin Endangered Fish Recovery Program.

Status: Dexter National Fish Hatchery is expected to complete the Genetics Management Plan in 2009.

02. Create one or more refuge populations of humpback chub.

The Ad Hoc recommends that off-river refuges that replicate the diversity of the wild population be created for the Grand Canyon population of humpback chub to protect the genetic integrity of this population. Young humpback chub have been abundant recently in the lower reach of the Little Colorado River. These fish are subject to high mortality. Collection of young humpback chub for use in a refuge population at such times when they are abundant will provide a safeguard against future catastrophic loss with very low risk to the overall population from collection and removal. This project will: 1) refine the methods for translocation of wild caught humpback chub to a refuge facility; 2) refine the methods for holding humpback chub in captivity; 3) establish one or more refuges to protect the genetic integrity of wild humpback chub from the Grand Canyon population; 4) potentially provide a source of humpback chub for use in ex-situ experiments (either from progeny or replacement of senescent individuals).

The humpback chub genetics management plan will provide specific information on how to best create and maintain refuge populations with regard to numbers of humpback chub necessary to maintain genetic integrity in a refuge population that is representative of the wild population. However, the genetics management plan is not necessary as a precursor to begin this project. Efforts could begin prior to completion of the genetics management plan as multiple collections of humpback chub are anticipated. Preliminary research suggests that collections of young humpback chub at the mouth of the Little Colorado River are representative at least of the Little Colorado River aggregation, the primary aggregation in need of protection.

***Relationship to Programs*:**

Adaptive Management Program

Strategic Plan, Management Objective 2.1 – Maintain or attain humpback chub abundance in the Little Colorado River and other aggregations at appropriate levels for viable populations and to remove jeopardy.
Strategic Plan, Management Objective 2.4 – Establish humpback chub spawning aggregations outside the Little Colorado River in the Colorado River ecosystem below Glen Canyon Dam to remove jeopardy.

2008 Biological Opinion on the Operation of Glen Canyon Dam Conservation Measures

Humpback Chub Refuge – Once appropriate planning documents are in place, and refuge populations of humpback chub are created (as a conservation measure of the Shortage

Guidelines biological opinion), Reclamation will assist FWS in maintenance of a humpback chub refuge population at a Federal hatchery or other appropriate facility by providing funding to assist in annual maintenance. In case of a catastrophic loss of the Grand Canyon population of humpback chub, a humpback chub refuge will provide a permanent source of sufficient numbers of genetically representative stock for repatriating the species. This action would also be an important step toward attaining recovery.

2007 Biological Opinion for the Bureau of Reclamation's Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead Conservation Measures

Humpback Chub Refuge – Reclamation will assist FWS in development and funding of a broodstock management plan and creation and maintenance of a humpback chub refuge population at a Federal hatchery or other appropriate facility by providing expedited advancement of $200,000 in funding to the FWS during CY 2008; this amount shall be funded from, and within, the amount identified in the MSCP BO (FWS 2005a; page 26). Creation of a humpback chub refuge will reduce or eliminate the potential for a catastrophic loss of the Grand Canyon population of humpback chub by providing a permanent source of genetically representative stock for repatriating the species.

Humpback Chub Recovery Goals

Downlisting and delisting of humpback chub require demographically and genetically viable populations. Refuge populations of humpback chub are needed to ensure that a source of fish is available should captive propagation and repatriation of captive breed individuals becomes necessary due to some unforeseen catastrophic loss of the Grand Canyon population.

Status: The Fish and Wildlife Service, Arizona Game and Fish Department, and the Hualapai Nation have initiated a project to create a refuge population of humpback chub on Hualapai tribal lands. Juvenile humpback chub were removed from the Little Colorado River in 2008 and are currently being maintained at Dexter National Fishery. Future collections will be needed to augment and maintain this new refuge.

In Situ Conservation The placement and operation of Glen Canyon Dam and the introduction, invasion, and establishment of nonnative organisms are strongly implicated as causes of the decline of humpback chub in Grand Canyon. These projects explore the extent to which these factors may be mitigated to improve habitats in Grand Canyon in support a self-sustaining population of humpback chub.

03. Use dam operations, or mitigate the effects of dam operations, to benefit humpback chub.

The operation of Glen Canyon Dam is thought to directly and indirectly affect the endangered humpback chub (U.S. Fish and Wildlife Service 2008a, 2008b; U.S. Geological Survey 2008b). There are linkages between such variables as flow, temperature, sediment, flow, food base, native/nonnative species interactions, and water quality. Since 1996, the

AMP has conducted a number of ecosystem experiments designed to test specific physical and biological hypotheses (e.g. 1996 Beach/Habitat Building Flow, 1997 and 1999 Habitat Maintenance Flows, 2000 Low Steady Summer Flow, the 2003-2006 experimental removal of nonnative fishes from the mouth of the Little Colorado River, the 2004 and 2008 High Flow Tests). These experiments not only investigated the ecosystem reaction to flow perturbations, but also attempted to determine what habitat conditions are necessary to sustain a recovered population of humpback chub. The AMP should continue to propose and support dam operation experiments to benefit humpback chub through adaptive management. The current experiment is to test the Modified Low Fluctuating Flow in concert with the 2008 high flow test and steady flows in September and October from 2008-2012.

Relationship to Programs:

Adaptive Management Program

Strategic Plan, Management Objective 2.1 – Maintain or attain humpback chub abundance in the Little Colorado River and other aggregations at appropriate levels for viable populations and to remove jeopardy.
Strategic Plan, Management Objective 2.2 – Maintain or attain year class strength of juvenile humpback chub in the Little Colorado River and other aggregations for viable populations and removal of jeopardy.
Strategic Plan, Management Objective 2.3 – Maintain or attain humpback chub recruitment in the Little Colorado River and other aggregations for viable populations and removal of jeopardy.

Humpback Chub Recovery Goals

5.2.2.1 Factor A. – Adequate habitat and range for recovered populations provided
Management Action A-1 – Investigate the role of the mainstem Colorado River in maintaining the Grand Canyon humpback chub population and provide appropriate habitats in the mainstem as necessary for recovery.

Task A-1.1 – Identify life stages and habitats of humpback chub in the mainstem Colorado River and determine the relationship between individuals in the mainstem Colorado River and Little Colorado River.

Task A-1.2 - Provide appropriate habitats for humpback chub in the mainstem Colorado River (as determined necessary under Task A-1.1).

Management Action A-2 – Provide flows necessary for all life stages of humpback chub to support a recovered Grand Canyon population, based on demographic criteria.

Task A-2.1 – As determined necessary and feasible, continue to operate Glen Canyon Dam water releases under adaptive management to benefit humpback chub in the mainstem Colorado River through Grand Canyon.

Task A-2.3 – Provide flow regimes (as determined under Tasks A-2.1 and A-2.2 that are necessary for all life stages of humpback chub to support a recovered Grand Canyon population.

Status: Reclamation has committed to implement a program of experimentation to benefit the humpback chub through the AMP. The current experiment is to test the Modified Low Fluctuating Flow in concert with the 2008 high flow test and steady flows in September and October from 2008-2012.

04. Complete feasibility study of the selective withdrawal structure on Glen Canyon Dam.

Cold-water releases from Glen Canyon Dam are below optimal for the existing trout fishery and far below those temperatures needed to allow the humpback chub to thrive in the mainstem of the Colorado River. Cold-water releases may improve the efficiency of trout preying on young, native, warm-water fish. Thermal shock from cold mainstem temperatures has been recognized as a likely cause of mortality for young endangered fish leaving seasonally warmed tributaries, and growth of humpback chub is markedly decreased in cold mainstem waters (Valdez and Carothers 1999). Increasing the temperature of dam releases could be an effective tool to reduce thermal shock and improve growth, survival, and recruitment of humpback chub that descend the Little Colorado River to the mainstem.

The 2000 Low Summer Steady Flow resulted in significant warming in the mainstem Colorado River downstream of Glen Canyon Dam. Since 2000, drought has resulted in the decline of Lake Powell elevation to a level where increased temperatures of dam releases are being documented. Recent positive changes in the status of humpback chub have coincided with this warming. Catch-rate data from near the confluence of the Colorado and Little Colorado rivers, and from in middle and lower Marble Canyon, indicate an increased abundance of juvenile humpback chub since 2003 and an overall increase in recruitment, possibly since the late 1990s (Coggins and Walters 2009), suggesting more favorable conditions for spawning and incubation in these reaches. Continued monitoring of these warmer temperatures may provide important insights into the effects of these physical parameters on humpback chub.

Warming the Colorado River could have unintended negative consequences by improving conditions for warm-water nonnative fish, increasing diseases and parasites, and affecting the artificially cold-adapted food base of algae and aquatic invertebrates. However, the Science Advisors to the AMP evaluated these risks and concluded that there is adequate potential benefit to justify modifying Glen Canyon Dam and testing a selective withdrawal structure, particularly if actions are developed to mitigate subsequent negative consequences (Baron et al. 2003), stating: “The Advisors think sufficient knowledge exists to make an informed policy decision about proceeding or not proceeding with this adaptive management option. That decision would be for the AMWG to move forward as rapidly as possible with an Adaptive Management Program that incorporates construction and operation of a TCD [temperature control device] at Glen Canyon Dam.” A GCMRC- led knowledge assessment workshop in 2005 also concluded that warmer water might benefit all life stages of humpback chub (Melis et al. 2006b). However, in a workshop conducted by GCMRC in April of 2007, a panel of scientists concluded that a selective withdrawal structure should be only be built if it hast the capability to release both cool water and warm water to address the potential threat of expansion of warm-water nonnative aquatic species (U.S. Geological Survey 2008a). The capability to design and build a selective withdrawal structure that can

release both cool and warm water at a wide range of Lake Powell reservoir elevations has not been assessed by the Bureau of Reclamation.

The Humpback Chub Comprehensive Plan Ad Hoc recommends that the AMP continue intensive study of the effects of warmer water on the Colorado River ecosystem and humpback chub below Glen Canyon Dam, utilizing laboratory study and in situ study of warmer water due to drought and low reservoir levels in Lake Powell, and that the AMP recommend to the Secretary's designee that the Bureau of Reclamation proceed with compliance, building, and testing of a selective withdrawal structure on Glen Canyon Dam if the capability exists to deliver both cold and warm water at as wide a range of Lake Powell elevations as possible.

Relationship to Programs:

Adaptive Management Program

Strategic Plan, Management Objective 7.1 – Attain water temperature ranges and seasonal variability in the mainstem necessary to maintain or attain desired levels of desirable biological resources (e.g., native fish, foodbase and trout).
Strategic Plan, Management Objective 7.2 – Maintain water quality in the mainstem of the Colorado River ecosystem.

Humpback Chub Recovery Goals

5.2.2.1 Factor A. - Adequate habitat and range for recovered populations provided
Management Action A-3. - Investigate the anticipated effects of and options for providing warmer water temperatures in the mainstem Colorado River through Grand Canyon that would allow for range expansion of the Grand Canyon humpback chub population and provide appropriate water temperatures if determined feasible and necessary for recovery.

> *Task A-3.1* - Determine the effects and feasibility of a temperature control device for Glen Canyon Dam under the Glen Canyon Dam Adaptive Management Program (U.S. Bureau of Reclamation 1999) to increase water temperatures in the mainstem Colorado River through Grand Canyon that would allow for range expansion of humpback chub.
> *Task A-3.1.2.* - Implement a temperature control device for Glen Canyon Dam if determined feasible and necessary for recovery of humpback chub.

Status: There are no current efforts to plan or test a selective withdrawal structure at Glen Canyon Dam.

05. Sediment augmentation to benefit native fish (e.g. sediment pipeline from Lake Powell), both long-term feasibility and short term experiment.

This project has two components: (1) evaluate the effects of increased turbidity or an extension of the period of turbidity on interactions between native and nonnative fish experimentally, either in a laboratory setting or *in situ* in the Colorado River, potentially at

the mouth of the Paria River or the mouth of the Little Colorado River; and, (2) evaluate the potential for delivering sufficient amounts of fine sediment to reverse the present decline of these sediments in Marble Canyon and thus increase mainstem turbidity. An experimental test of increased turbidity is proposed to determine the ecological impacts of such augmentation, with particular regard to effects on sight-feeding predators of humpback chub and effects on fish food resources. Turbidity will either be tested in a laboratory setting or by increasing turbidity in situ, for example through additions of fine sediments in the reach below the Paria River. Turbidity could be tested in situ either via small or large-scale experiments. The latter would require a significant compliance effort.

Relationship to Programs:

Humpback Chub Recovery Goals

5.2.2.1 Factor A. - Adequate habitat and range for recovered populations provided.
Management Action A-1 - Investigate the role of the mainstem Colorado River in maintaining the Grand Canyon humpback chub population and provide appropriate habitats in the mainstem as necessary for recovery.

Task A-1.2 - Provide appropriate habitats for humpback chub in the mainstem Colorado River (as determined necessary under Task A-1.1 [of the Recovery Goals]).

Status: The Bureau of Reclamation completed a feasibility assessment for large-scale sediment augmentation in 2002 that concluded such a project is feasible, though costs were estimated at $140 million for construction and $3.6 million annually for operation. Other aspects of this project have not been funded or implemented.

06. Examine the effects of flows, temperature, and sediment on food base, and protect and improve food base for humpback chub.

The importance of the linked aquatic-terrestrial food base on the distribution, condition, and abundance of native fish, including humpback chub, is poorly understood. Are Grand Canyon fish food-limited, and if so, what foods are important and can dam operations be used to improve food availability? Past and present efforts have focused on the reach-varying structure and seasonal variation in lower trophic level biomass and production in relation to dam operations and turbidity. Some research has suggested relationships between aquatic food base and nonnative trout growth in upper reaches of the study area; however, little critical linkage has been established between the aquatic food base and native fish population dynamics downstream from Lees Ferry.

Several topics require direct measurement before comprehensive food base-fisheries modeling can be achieved. First, it is important to understand seasonal and interannual distribution, population dynamics, and variation in the diets of larval, young, subadult, and adult age classes of all important native and nonnative fish species. Next, additional taxonomic information and physical habitat requirements are needed of the primary producers and consumers. Third, thorough quantification of the structure, density, and production/delivery of aquatic algae and invertebrates, terrestrial leaf litter, and invertebrates

is needed. With the above information in hand, it will then be possible to frame experiments to test the role of dam flows and temperature on food base limitations on native and nonnative fish populations. Appropriate laboratory and small scale in situ experiments should be undertaken to construct and test interacting life history models for the important fish species in relation to their food base. Enhanced plankton delivery rates are anticipated from the selective withdrawal structure, and the consequences of increased food availability on interactions among native and nonnative fish species also deserves experimental exploration and monitoring. Such investigations will greatly improve predictive modeling of flows and temperature on fish population dynamics.

The resulting trophically-based, multi-species fish population model can be used to run various scenarios of dam and natural flow and temperature variation on the food base and fisheries responses. Such modeling will establish the degree to which fish are limited by food resources, by either low production at the base of the food web or via shunting of energy to nonnative animals such as New Zealand mudsnails or rainbow trout. This information will provide guidance to managers considering various management options, and will establish baselines for use in comparing the effects of experimental treatments of varying flows, temperatures, and turbidities, and their interactions on native and nonnative fisheries.

Relationship to Programs:

Adaptive Management Program

Strategic Plan, Management Objective 1.3 – Maintain or attain biomass and composition of primary producers (algae, diatoms, and macrophytes) on cobble bars in the mainstem Colorado River below the Paria River.
Strategic Plan, Management Objective 1.4 – Maintain or attain biomass and composition of benthic invertebrates on cobble bars in the mainstem Colorado River below the Paria River.
Strategic Plan, Management Objective 1.5 – Maintain or attain abundance of food base drift on cobble bars in the mainstem Colorado River below the Paria River.

Humpback Chub Recovery Goals

5.2.2.1 Factor A. - Adequate habitat and range for recovered populations provided.
Management Action A-1 - Investigate the role of the mainstem Colorado River in maintaining the Grand Canyon humpback chub population and provide appropriate habitats in the mainstem as necessary for recovery.

Task A-1.2 - Provide appropriate habitats for humpback chub in the mainstem Colorado River (as determined necessary under Task A-1.1 [of the Recovery Goals]).

Status: Portions of this project are currently underway and should be completed in 2009.

07. Examine the use of young humpback chub habitat enhancement in the Little Colorado River or other tributaries in Grand Canyon.

This project proposes to conduct an investigation into the feasibility of temporarily modifying tributary shorelines to improve in-tributary rearing of native fish, particularly native cyprinids and humpback chub. The Little Colorado River and other tributaries have relatively little shoreline slackwater or backwater habitat. This project will test the utility of shoreline modification using rock and/or inflatable shoreline dams to construct slackwater habitats, and determine whether such efforts can be used to: 1) increase the retention of young native fish in the tributary; 2) increase in-tributary growth of native fish; and 3) reduce population losses due to drift into the mainstem and consequent thermal shock. In addition, the role of water depth, shading, and other microsite conditions will be tested. Surrogate species may be considered prior to testing on humpback chub. Such efforts may be used to replicate or restore, to a limited extent, the ponding of the Little Colorado River that occurred during mainstem floods, and to determine whether such microsite restoration efforts can improve growth and survival of young native fish, particularly humpback chub.

Relationship to Programs:

Adaptive Management Program

Strategic Plan, Management Objective 2.2 – Maintain or attain year class strength of juvenile humpback chub in the Little Colorado River and other aggregations for viable populations and removal of jeopardy.
Strategic Plan, Management Objective 2.3 – Maintain or attain humpback chub recruitment in the Little Colorado River and other aggregations for viable populations and removal of jeopardy.

Humpback Chub Recovery Goals

5.2.2.1 Factor A. - Adequate habitat and range for recovered populations provided.
Management Action A-1 - Investigate the role of the mainstem Colorado River in maintaining the Grand Canyon humpback chub population and provide appropriate habitats in the mainstem as necessary for recovery.

Task A-1.2 - Provide appropriate habitats for humpback chub in the mainstem Colorado River (as determined necessary under Task A-1.1 [of the Recovery Goals]).

Status: This project has not been funded or implemented.

08. Study the fate of young humpback chub in the Colorado River in Grand Canyon (Nearshore Ecology Study).

Losses of young humpback chub produced in the Little Colorado River are widely regarded as limiting to growth and expansion of the Grand Canyon humpback chub population. Humpback chub are believed to enter the mainstem Colorado River between 1 and 12 months after hatching, where survival is very low. Suboptimal summertime river temperatures, lack of suitable habitat, and predation by and competition from nonnative fishes are all thought to play a role in the poor survival of humpback chub in the mainstem, but the most important limiting factor or factors are not definitively known. Critical science questions presented in

GCMRC planning documents (i.e. Strategic Science Plan, and the Monitoring and Research Plan; examples below) address these information needs. Increasing the understanding of the causes for loss of young humpback chub in the mainstem would be of great value to managers and scientists seeking to protect and expand this population.

This project recommends that GCMRC, in coordination with appropriate Technical Work Group members, develop a work plan that addresses critical science questions to serve as the basis for a request for proposals (RFP) to study the fate of young humpback chub in the Colorado River in Grand Canyon. The primary objective of the project will be to determine where and why young humpback chub are usually lost after being produced in the Little Colorado River.

Critical Science Questions:

Strategic Science Question 1-1: To what extent are adult populations of native fish controlled by production of young fish from tributaries, spawning and incubation in the mainstem, survival of young-of-year and juvenile stages in the mainstem, or by changes in growth and maturation in the adult population as influenced by mainstem conditions?

Science Advisors humpback chub 1: What are the most limiting factors to successful humpback chub adult recruitment in the mainstem: spawning success, predation on YOY and juveniles, habitat (water, temperature), pathogens, adult maturation, food availability, competition?

SSQ 5-6: Do the potential benefits of improved rearing habitat (warmer, more stable, more backwater and vegetated shorelines, more food) outweigh negative impacts due to increases in nonnative fish abundance?

Relationship to Programs:

Adaptive Management Program

Strategic Plan, Management Objective 2.2 – Maintain or attain year class strength of juvenile humpback chub in the Little Colorado River and other aggregations for viable populations and removal of jeopardy.

Humpback Chub Recovery Goals

5.2.2.1 Factor A. - Adequate habitat and range for recovered populations provided.
Management Action A-1 - Investigate the role of the mainstem Colorado River in maintaining the Grand Canyon humpback chub population and provide appropriate habitats in the mainstem as necessary for recovery.

Task A-1.2 - Provide appropriate habitats for humpback chub in the mainstem Colorado River (as determined necessary under Task A-1.1 [of the Recovery Goals]).

2008 Biological Opinion on the Operation of Glen Canyon Dam Conservation Measures

Humpback Chub Nearshore Ecology Study – In coordination with other DOI AMP participants and through the AMP, Reclamation will implement a nearshore ecology study that will relate river flow variables to ecological attributes of nearshore habitats (velocity, depth, temperature, productivity, etc.) and the relative importance of such habitat conditions to important life stages of native and nonnative fishes. This study will incorporate planned science activities for evaluating the high flow test on nearshore habitats as well as the 5-year period of steady flow releases in September and October. A research plan will be developed with FWS via the AMP for this study by August 1, 2008, and a 5-year review report will be completed by 2013. The plan will include monitoring of sufficient intensity to ensure significant relationships can be established, as acceptable to the FWS. This conservation measure is consistent with the Sediment Research conservation measure in the Shortage Guidelines biological opinion. This study will help clarify the relationship between flows and mainstem habitat characteristics and availability for young-of-year and juvenile humpback chub, other native fish, and competitive or predaceous nonnative fish, and support continued management to sustain mainstem aggregations. The feasibility and effectiveness of marking small humpback chub (<150 and <100 mm TL [5.91 and 3.93 in]) will also be evaluated as part of the study, and if effective, marking young fish will be utilized in the study. Marking young humpback chub, if feasible and effective, could greatly aid in developing information on the early life history, growth and survival of young humpback chub.

Status: This project is funded in the GCMRC work plan for fiscal years 2009.

09. Control nonnative fish to reduce their predation on/competition with humpback chub.

a. Evaluate and, if feasible, control nonnative fish in selected tributaries of the Colorado River in Grand Canyon National Park and tribal lands.

This project is designed to explore the feasibility of removing nonnative fishes from tributaries of the Colorado River in Grand Canyon that may include the Little Colorado River, Bright Angel Creek, Tapeats Creek, Havasu Creek, Shinumo Creek and Kanab Creek. Reduction of nonnatives is a necessary precursor for translocation of humpback chub and for supporting other native fishes in these streams. Nonnatives that will be targeted include salmonids, carp, channel catfish, and yellow and black bullhead, but may include other nonnatives as well. The level of control necessary to reduce nonnatives, including most efficient removal methods, including reduction of by-catch and how long suppression lasts, will be investigated. Removal equipment will include trammel nets, fyke nets, hoop nets, hook-and-line, and weirs at the mouths of tributaries. Feasibility of electroshocking using canoes, rafts and backpack units will also be explored as it relates to species-specific capture frequencies and minimization of incidental by-catch. Feasibility of using chemical fish toxicants, such as rotenone or antimycin, will also be evaluated. Sample size will be related to initial capture densities and be modified based on success or failure of a particular method.

Relationship to Programs:

Adaptive Management Program

Strategic Plan, Management Objective 2.1 – Maintain or attain humpback chub abundance in the Little Colorado River and other aggregations at appropriate levels for viable populations and to remove jeopardy.
Strategic Plan, Management Objective 2.2 – Maintain or attain year class strength of juvenile humpback chub in the Little Colorado River and other aggregations for viable populations and removal of jeopardy.
Strategic Plan, Management Objective 2.3 – Maintain or attain humpback chub recruitment in the Little Colorado River and other aggregations for viable populations and removal of jeopardy.
Strategic Plan, Management Objective 2.4 – Establish humpback chub spawning aggregations outside the Little Colorado River in the Colorado River ecosystem below Glen Canyon Dam to remove jeopardy.
Strategic Plan, Management Objective 2.6 – Reduce native fish mortality due to nonnative fish predation so that it does not impinge on viability.

Humpback Chub Recovery Goals

5.2.2.3 Factor C: – Adequate protection from diseases and predation.
Management Action C-3 – Control problematic nonnative fishes as needed.

Task C-3.1 – Develop rainbow trout, channel catfish, black bullhead, and common carp control programs in the Little Colorado River to identify levels of control that will minimize predation on humpback chub (see section 4.3.2 and A.8 for discussion of effects of nonnative fishes).

Task C-3.2 – Implement identified levels (as determined under Task C-3.1) of rainbow trout, channel catfish, black bullhead, and common carp control in the Little Colorado River.

Task C-3.3: – Brown trout and rainbow trout control programs developed and implemented to identify levels of control that will minimize predation on humpback chub in the Colorado River through Grand Canyon.

2008 Biological Opinion on the Operation of Glen Canyon Dam Conservation Measures

Nonnative Fish Control – As first presented in the biological opinion on the Shortage Guidelines, Reclamation will, in coordination with other DOI AMP participants and through the AMP, continue efforts to assist NPS and the AMP in control of both cold- and warm-water nonnative fish species in both the mainstem of Marble and Grand canyons and in their tributaries, including determining and implementing levels of nonnative fish control as necessary. Because Reclamation predicts that dam releases will be cool to cold during the period of the proposed action, control of nonnative trout may be particularly important. Control of these species will utilize mechanical removal, similar to recent efforts by the AMP, and may utilize other methods, to help to reduce this threat. GCMRC is preparing a nonnative fish control plan through the AMP process that addresses both cold and warm-water species that will further guide implementation of this conservation measure.

Status: The project is currently being funded and implemented by the National Park Service in Shinumo creek with assistance from the Bureau of Reclamation and AMP.

b. Mechanical removal of nonnative fishes from the Colorado River and Little Colorado River.

A hypothesized factor in the decline in humpback chub recruitment in recent years is negative interactions (predation and competition) with nonnative fish. Interaction with nonnative fish is implicated in the decline and extinction of native fishes throughout the Colorado River Basin. Increased recruitment of rainbow and brown trout occurred during operation of Glen Canyon Dam under Modified Low Fluctuating Flows, the preferred alternative of the Glen Canyon Dam EIS, and populations in the Colorado River increased dramatically. This project is the continuation of a multi-objective study to evaluate the potential effect of rainbow and brown trout predation on humpback chub recruitment and the efficacy of mechanical removal of rainbow and brown trout from the Little Colorado River inflow reach (GCMRC 2003b). Non-native fishes were removed from a 17-mile stretch of the mainstem Colorado River using boat-mounted electrofishing units. Reduction efforts took place in 2003 – 2006 as part of a long-term experimental design to test the benefit to humpback chub. Efforts are also being directed at evaluating control methods for other non-native fishes such as common carp, channel catfish, black bullhead, and small-bodied nonnative species such as red shiner. Efforts will also consider bioenergetic community interactions of fish species to better select those species that pose the greatest risk to native fishes and to humpback chub, as well as the geospatial proximity and vagility of potential predators and competitors.

Relationship to Programs:

Adaptive Management Program

Strategic Plan, Management Objective 2.2 – Maintain or attain year class strength of juvenile humpback chub in the Little Colorado River and other aggregations for viable populations and removal of jeopardy.
Strategic Plan, Management Objective 2.3 – Maintain or attain humpback chub recruitment in the Little Colorado River and other aggregations for viable populations and removal of jeopardy.
Strategic Plan, Management Objective 2.6 – Reduce native fish mortality due to nonnative fish predation so that it does not impinge on viability.

Humpback Chub Recovery Goals

5.2.2.3 Factor C: – Adequate protection from diseases and predation.
*Management Action C-*3 – Control problematic nonnative fishes as needed.
Task C-3.1 – Develop rainbow trout, channel catfish, black bullhead, and common carp control programs in the Little Colorado River to identify levels of control that will minimize predation on humpback chub (see section 4.3.2 and A.8 for discussion of effects of nonnative fishes).

Task C-3.2 – Implement identified levels (as determined under Task C-3.1) of rainbow trout, channel catfish, black bullhead, and common carp control in the Little Colorado River.
Task C-3.3: - Brown trout and rainbow trout control programs developed and implemented to identify levels of control that will minimize predation on humpback chub in the Colorado River through Grand Canyon.

2008 Biological Opinion on the Operation of Glen Canyon Dam Conservation Measures

Nonnative Fish Control – As first presented in the biological opinion on the Shortage Guidelines, Reclamation will, in coordination with other DOI AMP participants and through the AMP, continue efforts to assist NPS and the AMP in control of both cold- and warm-water nonnative fish species in both the mainstem of Marble and Grand canyons and in their tributaries, including determining and implementing levels of nonnative fish control as necessary. Because Reclamation predicts that dam releases will be cool to cold during the period of the proposed action, control of nonnative trout may be particularly important. Control of these species will utilize mechanical removal, similar to recent efforts by the AMP, and may utilize other methods, to help to reduce this threat. GCMRC is preparing a nonnative fish control plan through the AMP process that addresses both cold and warm-water species that will further guide implementation of this conservation measure.

2007 Biological Opinion for the Bureau of Reclamation's Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead Conservation Measures

Nonnative Fish Control – In coordination with other DOI AMP participants and through the AMP, Reclamation will continue efforts to control both cold- and warm-water nonnative fish species in the mainstem of Marble and Grand canyons, including determining and implementing levels of nonnative fish control as necessary. Control of these species using mechanical removal and other methods will help to reduce this threat.

Status: This project is funded for implementation through the AMP in 2009 following a two year hiatus. Preliminary survey data indicate an increase in trout numbers in the Little Colorado River inflow reach. Results from 2003-2006 removal efforts indicate that the program was highly effective at removing rainbow trout, and increases in humpback chub may be due in part to this removal. GCMRC continues to test efforts to better remove other nonnative species.

c. Develop a nonnative and invasive species control plan for the Colorado River ecosystem, Grand Canyon region.

The continued introduction of aquatic invasive species in the Colorado River poses a serious threat to aquatic resources and an already imperiled fauna. These non-native plants and animals are transported into and throughout the Colorado River via recreational boating, fisherman, researchers, through the release of unwanted aquarium contents, or a variety of other transport vectors related to human activities. Because they have few natural controls in

their new environments, these species have great potential for rapid colonization and are already having significant impacts on the biodiversity and integrity of aquatic habitats in the Lower Colorado River, e.g. Giant salvinia and quagga mussel. Many of the tributaries to the Colorado River in Grand Canyon originate in Grand Canyon National Park, and therefore are under less threat to invasive species introductions. Other tributaries, including the Little Colorado River, traverse large distances before reaching the mainstem and pass through numerous jurisdictions where there is limited coordination in addressing invasive species.

This project would develop a response plan to detect and quickly act should additional nonnative species become established in the Colorado River ecosystem as well as develop of additional measures as part of the Little Colorado River Watershed Management Plan to prevent further introductions. The focus should be to prevent further introductions, yet with potential temperature modification, a coordinated response that acts quickly to contain the nonnative introduction and prevent further spread is necessary. It should include an evaluation of effective ways to detect new species within the Colorado River ecosystem, designate an interagency response team to respond to new introductions, and develop a response plan that would go into effect if new introductions were detected, including necessary NEPA compliance. It should include standard protocols to be used by researchers to prevent unintentional introductions.

Relationship to Programs:

Adaptive Management Program

Strategic Plan, Management Objective 2.1 – Maintain or attain humpback chub abundance in the Little Colorado River and other aggregations at appropriate levels for viable populations and to remove jeopardy.
Goal 7 – Establish water temperature, quality and flow dynamics to achieve AMP ecosystem goals.
Strategic Plan, Management Objective 7.2 – Maintain water quality in the mainstem of the Colorado River ecosystem.

2008 Biological Opinion on the Operation of Glen Canyon Dam Conservation Measures

Nonnative Fish Control – As first presented in the biological opinion on the Shortage Guidelines, Reclamation will, in coordination with other DOI AMP participants and through the AMP, continue efforts to assist NPS and the AMP in control of both cold- and warm-water nonnative fish species in both the mainstem of Marble and Grand canyons and in their tributaries, including determining and implementing levels of nonnative fish control as necessary. Because Reclamation predicts that dam releases will be cool to cold during the period of the proposed action, control of nonnative trout may be particularly important. Control of these species will utilize mechanical removal, similar to recent efforts by the AMP, and may utilize other methods, to help to reduce this threat. GCMRC is preparing a nonnative fish control plan through the AMP process that addresses both cold and warm-water species that will further guide implementation of this conservation measure.

2007 Biological Opinion for the Bureau of Reclamation's Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead Conservation Measures

Nonnative Fish Control – In coordination with other DOI AMP participants and through the AMP, Reclamation will continue efforts to control both cold- and warm-water nonnative fish species in the mainstem of Marble and Grand canyons, including determining and implementing levels of nonnative fish control as necessary. Control of these species using mechanical removal and other methods will help to reduce this threat.

Humpback Chub Recovery Goals

5.2.2.3 Factor C – Adequate protection from diseases and predation
5.2.2.4 Factor D – Adequate existing regulatory mechanisms
Management Action D-2 – Provide for the long-term management and protection of humpback chub populations and their habitats.

Task D-2.1 – Identify elements needed for the development of conservation plans that are necessary to provide for the long-term management and protection of humpback chub populations.

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

Executive Order 13112 - "By the authority vested in me as President by the Constitution and the laws of the United States of America, including the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321 et seq.), Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, as amended (16 U.S.C. 4701 et seq.), Lacey Act, as amended (18 U.S.C. 42), Federal Plant Pest Act (7 U.S.C. 150aa et seq.), Federal Noxious Weed Act of 1974, as amended (7 U.S.C. 2801 et seq.), Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.), and other pertinent statutes, to prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause…..

2008 Biological Opinion on the Operation of Glen Canyon Dam Conservation Measures

Nonnative Fish Control – As first presented in the biological opinion on the Shortage Guidelines, Reclamation will, in coordination with other DOI AMP participants and through the AMP, continue efforts to assist NPS and the AMP in control of both cold- and warm-water nonnative fish species in both the mainstem of Marble and Grand canyons and in their tributaries, including determining and implementing levels of nonnative fish control as necessary. Because Reclamation predicts that dam releases will be cool to cold during the period of the proposed action, control of nonnative trout may be particularly important. Control of these species will utilize mechanical removal, similar to recent efforts by the AMP, and may utilize other methods, to help to reduce this threat. GCMRC is preparing a

nonnative fish control plan through the AMP process that addresses both cold and warm-water species that will further guide implementation of this conservation measure.

Status: The AMP is currently funding development of a nonnative species control plan by GCMRC.

d. Develop nonnative stocking procedures for the Lower Colorado River and tributaries from Glen Canyon Dam to Lake Mead.

The threat of predation and competition by nonnative fishes on humpback chub has been recognized in Grand Canyon; brown trout (*Salmo trutta*), channel catfish (*Ictalurus punctatus*), black bullhead (*Ameiurus melas*), and rainbow trout (*Oncorhynchus mykiss*) have been identified as principal predators of juvenile humpback chub, with consumption estimates that suggest loss of complete year classes to predation (Marsh and Douglas 1997, Valdez and Ryel 1997). Marsh and Douglas (1997) documented predation on humpback chub in the Little Colorado River by rainbow trout, channel catfish, and black bullhead. Valdez and Ryel (1997) identified brown trout, rainbow trout, and channel catfish as known predators of humpback chub in the mainstem Colorado River in Grand Canyon, and suggested that common carp (*Cyprinus carpio*) could be a significant predator of incubating humpback chub eggs in the Little Colorado River.

The Colorado River in Grand Canyon is now occupied by at least 12 nonnative fish species. In addition to the ones already mentioned, fathead minnow (*Pimephales promelas*), green sunfish (*Lepomis cyanellus*), largemouth bass (*Micropterus salmoides*), plains killifish (*Fundulus zebrinus*), red shiner (*Cyprinella lutrensis*), striped bass (*Morone saxatailis*), and yellow bullhead (*Ameiurus natalis*) are also known from the region. Recently, walleye (*Sander vitreus*) was collected from below Glen Canyon Dam, and green sunfish and smallmouth bass (*Micropterus dolomieu)* were collected from near the mouth of the Little Colorado River.

Control of the release and escapement of nonnative fishes into the Colorado River in Grand Canyon and its tributaries is a necessary management action to limit the impact of currently present nonnative species, stop the introduction of new fish species into occupied habitats and to thwart periodic escapement of highly predaceous or competitive nonnatives from connected waters throughout the basin. Procedures for the stocking of nonnatives have been developed and associated implementing agreements have been signed among the U. S. Fish and Wildlife Service and the States of Colorado, Utah, and Wyoming to review and regulate all stockings within the Upper Colorado River Basin (U.S. Fish and Wildlife Service 1996) in order to reduce the introduction and expansion of nonnative fishes. Similar procedures need to be developed and implemented to protect the Grand Canyon population of humpback chub, including all portions of the Lower Colorado River Basin between Glen Canyon Dam and Hoover Dam, including the two mainstem reservoirs (U.S. Fish and Wildlife Service 2002).

Relationship to Programs:

Adaptive Management Program

Strategic Plan, Management Objective 2.6 - Reduce native fish mortality due to non-native fish predation/competition as a percent of overall mortality in the Little Colorado River and mainstem to increase native fish recruitment."

Humpback Chub Recovery Goals

5.2.2.3 Factor C - Adequate protection from diseases and predation
Management Action C-2 - Regulate nonnative fish releases and escapement into the main river, floodplain, and tributaries.

Task C-2.1 - Develop, implement, evaluate, and revise (as necessary through adaptive management) procedures for stocking and to minimize escapement of nonnative fish species into the Colorado River and its tributaries through Grand Canyon to minimize negative interactions between nonnative fishes and humpback chub (see sections 4.3.2 and A.8 for discussion of effects of nonnative fishes).

Task C-2.2 - Finalize and implement procedures (as determined under Task C-2.1) for stocking and to minimize escapement of nonnative fish species into the Colorado River and its tributaries through Grand Canyon to minimize negative interactions between nonnative fishes and humpback chub.

Status: This project has not been funded or implemented.

10. Understand the impacts and identify the threats of scientific work and recreational activities on humpback chub populations in the Grand Canyon region.

This project will assess the impacts of repetitive habitat disturbance, capture, and handling on Grand Canyon humpback chub populations and develop modified protocols and management policies to maximize recreation opportunity and scientific information collection while minimizing the impacts of these activities on humpback chub individuals and populations. Humpback chub in Grand Canyon, particularly the Little Colorado River aggregation, have endured significant environmental manipulation and individual physical handling for the last 20 years. PIT tagging efforts alone have resulted in the majority of adult humpback chub being recognized individually from multiple recaptures over time. Sediment, flow, and temperature studies, among others, affect mainstem populations to some degree through habitat disruption and invasion by investigative crews and equipment. Targeted studies affect humpback chub directly; studies targeting other species affect humpback chub indirectly, as an unintended consequence. Repetitive disturbance, capture, and handling are continual sources of stress, health risk, and potential injury for individuals and the population as a whole.

Upper Basin managers and investigators have similar concerns, but have not initiated specific studies to directly quantify the effects, if any. They have, however, produced several studies investigating the impacts of electrofishing on native fish and developed modified protocols to

minimize the risks (Muth 1996, Hawkins 2002, 2003). They also have limited population estimate efforts to three initial estimate years followed by alternating two years off and two years on to reduce the stress of population monitoring on humpback chub populations (Tom Chart and Tom Czapla personal communication, Valdez and Ryel 2000).

Scientific investigation and monitoring must continue in support of the AMP. However, the threat exists that research activities may in fact have a detrimental effect on humpback chub. This effect is ongoing for the foreseeable future and may have immediate consequences for humpback chub as long as intensive scientific effort is focused on this species and its habitat. The physical risk of injury and death associated with repeated handling and disturbance should be evaluated. Research and monitoring protocols modified to reduce frequency and severity of handling and disturbance could allow continued data collection with minimal impact to humpback chub. However, the cost of implementing such modified protocols must be weighed against the sacrifice of statistical precision required to make appropriate adaptive management decisions. Several laboratory studies have been completed. Paukert et al. (2005) for example, found that repeated hoop netting and handling of bonytail (*Gila elegans*) affected growth of that species. Additional research is needed to better understand this threat to humpback chub.

Disturbance associated with recreational activities (boating, swimming, fishing, etc.) in the Grand Canyon and especially in the lower portions of the Little Colorado River also may cause adverse affects to humpback chub. Repetitive disturbance may be a continual source of stress, health risk, and potential injury for individuals and the population as a whole. There are no assessments of the potential impact of such activities on humpback chub. Additional research is needed to better understand this threat to humpback chub.

Relationship to Programs:

Adaptive Management Program

Strategic Plan, Management Objective 2.1 – Maintain or attain humpback chub abundance in the Little Colorado River and other aggregations at appropriate levels for viable populations and to remove jeopardy.

2007 Biological Opinion for the Bureau of Reclamation's Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead Conservation Measures

Humpback Chub Recovery Goals

5.2.2.2 Factor B – Protection from overutilization for commercial, recreational, scientific, or educational purposes.
Management Action B-1 – Protect humpback chub populations from overutilization for commercial, recreational, scientific, or educational purposes.

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

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

Status: This project received funding from the AMP in FY 2004/2005. A study examining the effects of hoop netting and PIT tagging, using bonytail (*Gila elegans*) as a surrogate, has been completed and published (Paukert et al. 2005). Studies evaluating other aspects of this project have not been funded or undertaken.

11. Monitor and investigate control of fish diseases and parasites affecting humpback chub in the Colorado River, Grand Canyon region.

This project includes two elements: (1) development and implementation of a monitoring plan for fish diseases and parasites in the Colorado River and its tributaries, with emphasis on those infecting humpback chub; and, (2) investigation of mechanisms for control and suppression of important diseases and parasites.

At least four exotic parasites are known to infect fishes of the Little Colorado River. Two of these parasites, Asian fish tapeworm *Bothriocephalus acheilognathi* (Cestoda) and anchor worm *Lernaea cyprinacea* (Copepoda) infect humpback chub at a higher rate than any other species in the system (Brouder and Hoffnagle 1997; Hoffnagle and Cole 1999; Hoffnagle et al 2000). Both *B. acheilognathi* and *L. cyprinacea* have been reported as pathogenic and potentially fatal (directly or indirectly) to fish of various age classes (Schäpperclaus 1986). *Bothriocephalus acheilognathi* has caused high mortality in native fishes that it has infected outside of its native range (Hoffman and Schubert 1984). These parasites cannot complete their life cycles in the mainstem Colorado River under present, cold water conditions. However they may be transported by infected individuals to other warmer tributaries.

Information on disease and parasite distribution, and the impact of water temperature regimes on diseases and parasites is needed for decisions regarding the future operation of Glen Canyon Dam and the proposed selective withdrawal structure. Previous studies (Brouder and Hoffnagle 1997, Hoffnagle and Cole 1999, Hoffnagle et al 2000, Cole et al 2002, Hoffnagle et al. 2006) have identified parasites of native and non-native fishes of the lower Little Colorado River. Recent research by Dr. Rebecca Cole, (see FY2005 GCMRC Work Plan) has helped define the distribution of fish diseases and parasites of the colder Colorado River and other tributaries in Grand Canyon. This project will survey the river and tributaries for a complete inventory of diseases and parasites present, and will recommend a monitoring plan for fish parasites and diseases in the Colorado River ecosystem and selected tributaries. Recent research by Ward (2007) has evaluated the use of praziquantel to remove Asian tapeworm from *Gila* species in the laboratory, and 30 humpback chub were evaluated for tapeworms in the Little Colorado River in both 2005 and 2006 – thus the beginnings of a monitoring data set are in place. There is also a need to assess the status of other parasite and

disease organisms in other parts of the watershed that could invade the Colorado River ecosystem in Grand Canyon.

The second phase of this project will investigate effects of diseases and parasites on humpback chub, or a surrogate species, in laboratory settings and the feasibility of control and suppression in the wild of diseases and parasites important to the health and survival of humpback chub. For example, praziquantel has been used since 1985 to remove parasites in many different fish species in hatcheries and ornamental fish ponds. Initial investigations of Asian tapeworm have found that praziquantel can effectively remove tapeworm from humpback chub in both the laboratory and field settings, although dosages commonly reported in the literature were insufficient (Ward in press). Additional study is needed to ensure that praziquantel is safe for use on fish prior to further use and refine non-lethal methods for removing tapeworms from endangered cyprinid fishes. It will also refine efficacy in field situations where reinfestation rates may be high. Management recommendations will include a standardized protocol for the use of praziquantel to treat Asian fish tapeworm as well as recommendations for reducing the impacts of Asian fish tapeworm in humpack chub.

Relationship to Programs:

Adaptive Management Program

Strategic Plan, Management Objective 2.1 – Maintain or attain humpback chub abundance in the Little Colorado River and other aggregations at appropriate levels for viable populations and to remove jeopardy.
Strategic Plan, Management Objective 2.5 – Attain humpback chub condition in the Little Colorado River and other aggregations for viable populations and to remove jeopardy.

Humpback Chub Recovery Goals

5.2.2.3 Factor C – Adequate protection from diseases and predation
Management Action C-1 – Control Asian tapeworm as needed
Task C-1.1 – Develop an Asian tapeworm control program in the Little Colorado River to identify the levels of control that will minimize the negative effects of parasitism on the humpback chub population (see section 4.3.1 and Appendix A for discussion of diseases and parasites).
*Task C-1.*2 – Implement identified levels (as determined under Task C-1.1) of Asian tapeworm control in the Little Colorado River.

2007 Biological Opinion for the Bureau of Reclamation's Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead Conservation Measures

Parasite Monitoring – In coordination with other DOI AMP participants and through the AMP, Reclamation will continue to support research on the effects of Asian tapeworm (Bothriocephalus acheilognathi) on humpback chub and potential methods to control this

parasite. Continuing research will help better understand the degree of this threat and the potential for management actions to minimize it.

Status: The project has been partially funded and implemented by the AMP. Additional work, as explained above, is needed and has yet to be funded or implemented.

12. Translocation of native fishes including humpback chub in the Grand Canyon region.

a. Translocations of humpback chub in the Little Colorado River above Chute Falls.

The majority of young humpback chub that disburse or are displaced into the Colorado River from the Little Colorado River are presumed to perish due to cold water temperatures, diel discharge fluctuations, and predation by nonnative fishes. Most humpback chub that recruit to adulthood are believed to be individuals that remain in the warmer Little Colorado River for longer periods of time to grow and become less susceptible to the inhospitable conditions in the mainstem. Endemic speckled dace and a few, primarily small-bodied, nonnative fishes have consistently been the only species detected above a barrier waterfall, Chute Falls, during ichthyofauna surveys over the last two decades. Translocation of juvenile humpback chub from near the confluence of the Colorado and Little Colorado rivers to the reach of the Little Colorado River above Chute Falls increases the numbers of younger humpback chub that recruit to adulthood via improved survivorship due to greater food abundance, warmer water temperatures, and reduced competition and predation (because there are fewer large-bodied fishes in this area, and the thermal shock issue is eliminated) and expands suitable humpback chub rearing habitats within the Little Colorado River.

Relationship to Programs:

Adaptive Management Program

Strategic Plan, Management Objective 2.1 – Maintain or attain humpback chub abundance in the Little Colorado River and other aggregations at appropriate levels for viable populations and to remove jeopardy.
Strategic Plan, Management Objective 2.2 – Maintain or attain year class strength of juvenile humpback chub in the Little Colorado River and other aggregations for viable populations and removal of jeopardy.
Strategic Plan, Management Objective 2.3 – Maintain or attain humpback chub recruitment in the Little Colorado River and other aggregations for viable populations and removal of jeopardy.

2008 Biological Opinion on the Operation of Glen Canyon Dam Conservation Measures

Humpback Chub Translocation – In coordination with other Department of the Interior (DOI) AMP participants and through the AMP, Reclamation will assist NPS and the AMP in funding and implementation of translocation of humpback chub into tributaries of the Colorado River in Marble and Grand canyons. Nonnative control in these tributaries will be an essential precursor to translocation, so Reclamation will help fund control of both cold

and warm-water nonnative fish in tributaries, as well as efforts to translocate humpback chub into these tributaries. Havasu, Shinumo and Bright Angel creeks will initially be targeted for translocation, although other tributaries may be considered. Reclamation will work with FWS, NPS and other cooperators to develop translocation plans for each of these streams, utilizing existing information available such as SWCA and Grand Canyon Wildlands (2007) and Valdez et al. (2000a). These plans will consider and utilize genetic assessments (Douglas and Douglas 2007, Keeler-Foster in prep.), identify legal requirements and jurisdictional issues, methods, and assess needs for nonnative control, monitoring and other logistics, as well as an implementation schedule, funding sources, and permitting. Reclamation and the AMP will also fund and implement translocation of up to 500 young humpback chub from the lower Little Colorado River to above Chute Falls in 2008 if FWS determines that a translocation is warranted. Reclamation and the AMP will continue to monitor humpback chub in the reach of the Little Colorado River above Chute Falls for the 5-year period of the proposed action, and will undertake additional translocations above Chute Falls as deemed necessary by FWS.

Status: Translocation began as a conservation measure of the December 6, 2002, Biological Opinion. Small humpback chub (50-100 mm TL) from the lower Little Colorado River have been moved to above Chute Falls in an attempt to improve survival of young of year humpback chub in 2003, 2004, 2005, and 2008. To date, approximately 1,500 humpback chub have been moved. Monitoring has indicated translocated humpback chub have persisted above Chute Falls, shown impressive growth rates, and appear to have spawned in 2005. Translocation is currently funded by the AMP and is planned for 2009-2012.

b. Translocation of native fishes to tributaries of the Colorado River in Grand Canyon National Park and on tribal lands.

This project is linked to project 9a, which involves removal of nonnative fish from tributaries selected for translocation. Nonnative suppression likely is a necessary prerequisite for translocation of humpback chub into tributaries having suitable physical habitat for this purpose. The goal of this project is to expand the demographic range of humpback chub and reduce the risk of catastrophic events in the Little Colorado River by using other tributaries as grow out areas for small humpback chub. The objective is to transplant young-of-year Little Colorado River humpback chub that likely would be transported to the Colorado River and otherwise not survive to potentially suitable tributaries within Grand Canyon National Park and adjoining tribal lands to improve their survival. Based on evaluations conducted by Valdez and others (2000), the probability of establishing sustained reproducing and recruiting humpback chub populations in these tributaries is small. Young humpback chub translocated to tributaries with suitable juvenile habitat and reduced predator numbers that grow to a size large enough to survive in the mainstem have an opportunity to join existing mainstem aggregations. There they may serve to augment founder populations if mainstem conditions improve sufficiently to allow reproduction and recruitment, e.g. if water temperatures increase following implementation of a selective withdrawal structure.

Relationship to Programs:

<u>Adaptive Management Program</u>

Strategic Plan, Management Objective 2.1 – Maintain or attain humpback chub abundance in the Little Colorado River and other aggregations at appropriate levels for viable populations and to remove jeopardy.
Strategic Plan, Management Objective 2.2 – Maintain or attain year class strength of juvenile humpback chub in the Little Colorado River and other aggregations for viable populations and removal of jeopardy.
Strategic Plan, Management Objective 2.3 – Maintain or attain humpback chub recruitment in the Little Colorado River and other aggregations for viable populations and removal of jeopardy.
Strategic Plan, Management Objective 2.4 – Establish humpback chub spawning aggregations outside the Little Colorado River in the Colorado River ecosystem below Glen Canyon Dam to remove jeopardy.

2008 Biological Opinion on the Operation of Glen Canyon Dam Conservation Measures

Humpback Chub Translocation – In coordination with other Department of the Interior (DOI) AMP participants and through the AMP, Reclamation will assist NPS and the AMP in funding and implementation of translocation of humpback chub into tributaries of the Colorado River in Marble and Grand canyons. Nonnative control in these tributaries will be an essential precursor to translocation, so Reclamation will help fund control of both cold and warm-water nonnative fish in tributaries, as well as efforts to translocate humpback chub into these tributaries. Havasu, Shinumo and Bright Angel creeks will initially be targeted for translocation, although other tributaries may be considered. Reclamation will work with FWS, NPS and other cooperators to develop translocation plans for each of these streams, utilizing existing information available such as SWCA and Grand Canyon Wildlands (2007) and Valdez et al. (2000a). These plans will consider and utilize genetic assessments (Douglas and Douglas 2007, Keeler-Foster in prep.), identify legal requirements and jurisdictional issues, methods, and assess needs for nonnative control, monitoring and other logistics, as well as an implementation schedule, funding sources, and permitting. Reclamation and the AMP will also fund and implement translocation of up to 500 young humpback chub from the lower Little Colorado River to above Chute Falls in 2008 if FWS determines that a translocation is warranted. Reclamation and the AMP will continue to monitor humpback chub in the reach of the Little Colorado River above Chute Falls for the 5-year period of the proposed action, and will undertake additional translocations above Chute Falls as deemed necessary by FWS.

Status: Grand Canyon National Park has acquired the necessary funding for, and is working to complete the necessary compliance on, translocation of humpback chub into Shinumo Creek in 2009. Juvenile humpback chub were removed from the lower Little Colorado River and are currently being housed at Dexter National Fish Hatcher for translocation into Shinumo in 2009. Additional collections of juvenile humpback chub for translocation into Shinumo are planned. Translocations to other tributaries have not been funded or implement, but have been evaluated (Valdez et al. 2000).

Monitoring humpback chub Population Dynamics, Distribution, and Habitat Paramount to evaluating the status of humpback chub in the Grand Canyon are scientifically defensible estimates of its population size, dynamics with respect to recruitment, and distribution. Several areas of uncertainty or lack of consensus remain regarding how and where this information is obtained. Equally important is an understanding of habitat changes over time.

13. Monitor humpback chub population dynamics, distribution and habitat in the Grand Canyon region.

a. Monitoring hydrology and water quality in the Little Colorado River.

While anthropogenic changes in the mainstem Colorado River are often cited as contributing to the decline of humpback chub, little is known about historical or recent changes in physical and chemical characteristics of the Little Colorado River in Grand Canyon, and how these may have affected the humpback chub. The Little Colorado River stream gage was reestablished in 2003, using newer and more effective (acoustic) technologies for measuring river stage. Operation of the gage record by the GCMRC Integrated Downstream Quality of Water Program (DIQWP) is aimed at establishing a continuous stage and discharge record to support ongoing fisheries monitoring and research in the lower 15 km of the Little Colorado River. The gage will also support future monitoring efforts for targeted water quality parameters associated with flows in the Little Colorado River related to Blue Spring and other sources upstream. Also needed is a monitoring program for basic water quality parameters, contaminants, and a review of existing historical hydrological and water quality data. This project will allow for continued operation of the gage and development of a monitoring program for other water quality data in the Lower Little Colorado River.

Relationship to Programs:

Adaptive Management Program

Strategic Plan, Management Objective 2.1 – Maintain or attain humpback chub abundance in the Little Colorado River and other aggregations at appropriate levels for viable populations and to remove jeopardy.

Humpback Chub Recovery Goals

5.2.2.1 Factor A. - Adequate habitat and range for recovered populations provided.
Management Action A-1 - Investigate the role of the mainstem Colorado River in maintaining the Grand Canyon humpback chub population and provide appropriate habitats in the mainstem as necessary for recovery.

Task A-1.2 - Provide appropriate habitats for humpback chub in the mainstem Colorado River (as determined necessary under Task A-1.1 [of the Recovery Goals]).

Status: This project is not currently funded or implemented.

b. Maintain a core monitoring and research effort for the humpback chub in the Grand Canyon region.

Effective monitoring of humpback chub is an essential element to this plan. Since 2000, GCMRC has implemented a rigorous stock assessment program for the Little Colorado River aggregation of humpback chub as a priority component, as well as long-term fish monitoring in Grand Canyon. This effort has consisted of several separate monitoring projects relying on mark-recapture efforts in both the Little Colorado River and mainstem.

Criticisms of the GCMRC method have largely been associated with the degree to which the mainstem Colorado River and Little Colorado River need to be monitored to obtain an accurate and precise abundance estimate for the entire Grand Canyon population of humpback chub (recognizing that this population is centered predominantly around the Little Colorado River, and migrates into the Little Colorado River during spawning). Currently, population estimates for humpback chub are conducted in the Little Colorado River in the fall of each year to estimate abundance of smaller chub and to make an early estimate of the survival and potential recruitment of a given year class. Sampling is also conducted in the spring primarily aimed at marking as many humpback chub as feasible to provide information through capture and subsequent recapture for stock assessment models. Depending on the quality of data with respect to meeting assumptions of mark-recapture population estimation models, these spring data may also be used to generate a point estimate of the population size. There has and continues to be uncertainty regarding how well point estimates derived solely from Little Colorado River sampling represent the status and trends of the 'Little Colorado River population', which contains individuals that are known to move back and forth between the Little Colorado River and mainstem, particularly during the spawning period. There is also concern about adopting consistent population estimation procedures for populations of humpback chub in the Upper and Lower Basin to satisfy criteria identified in the Recovery Goals.

Seasonal movement and distribution of humpback chub complicate finding the ideal sampling schedule for this effort. It is assumed that the largest proportion of the population goes into the Little Colorado River for spawning and may or may not remain there during part or all of the mark-recapture sampling there (i.e., the timing of movement in and out varies from year to year and good predictors of when migration will occur is lacking). Sampling in the spring would add information about the distribution of fish and their movement but could violate model assumptions for simple mark-recapture population estimation.

Recent modeling research by Dr. David Otis at the University of Iowa, utilizing data developed from the GCMRC monitoring program, indicated that adjusting current levels of effort and employing additional statistical estimators may improve GCMRC's estimation technique. Another important consideration in refining this project is the need to include translocated humpback chub in the population estimate. For example, a total of approximately 1,500 humpback chub have been moved above a natural barrier (Chute Falls) in the Little Colorado River. Subsequent monitoring of these translocated humpback chub revealed that many of the translocated individuals were found to have persisted, grown to adult size, and spawned. Given this, there may also be a need to conduct a stock assessment of the Chute Falls segment of the population and incorporate it into ongoing stock

assessments occurring below Chute Falls to provide an accurate overall stock assessment of the entire Grand Canyon population as required by the recovery goals. GCMRC is currently conducting a Protocol Evaluation Panel, which may result in changes to the fish monitoring program.

Adaptive Management Program

Strategic Plan, Management Objective 2.1 – Maintain or attain humpback chub abundance in the Little Colorado River and other aggregations at appropriate levels for viable populations and to remove jeopardy.
Strategic Plan, Management Objective 2.2 – Maintain or attain year class strength of juvenile humpback chub in the Little Colorado River and other aggregations for viable populations and removal of jeopardy.
Strategic Plan, Management Objective 2.3 – Maintain or attain humpback chub recruitment in the Little Colorado River and other aggregations for viable populations and removal of jeopardy.
Strategic Plan, Management Objective 2.4 – Establish humpback chub spawning aggregations outside the Little Colorado River in the Colorado River ecosystem below Glen Canyon Dam to remove jeopardy.
Strategic Plan, Management Objective 7.1 – Attain water temperature ranges and seasonal variability in the mainstem necessary to maintain or attain desired levels of desirable biological resources (e.g., native fish, foodbase and trout).
Strategic Plan, Management Objective 7.2 – Maintain water quality in the mainstem of the Colorado River ecosystem.

Humpback Chub Recovery Goals

5.3.1.1 Demographic criteria for downlisting (population demographics in both recovery units must be met in order to achieve downlisting)

Status: This project is ongoing, and does not currently have an expected completion date. A 2009 PEP will guide future implementation.

c. Monitoring the Status and Trends of the Downstream Fish Community in Grand Canyon.

The downstream fish community is an assemblage of native and non-native fish that occur in the Colorado River ecosystem. This assemblage is exclusive of the trout fishery that is managed in Glen Canyon by the Arizona Game and Fish Department. The constituents include four native fish and introduced competitors/predators including rainbow trout, brown trout, channel catfish, carp, and other nonnative species. The status and trends of the fishery are regulated by biotic and abiotic mechanisms that may in turn be affected by the operations of Glen Canyon Dam. Monitoring basic population statistics including recruitment, abundance, and distribution of native and nonnative fishes provide the fundamental information necessary to assess the status of these resources and the attainment of AMP goals and objectives.

Since 2000, GCMRC and cooperators have been developing a long-term monitoring program for fishes in the Colorado River ecosystem. To date, significant progress has been made toward this end such that it is now appropriate for GCMRC to formalize a longterm monitoring program for key nonnative fishes (i.e. rainbow trout, brown trout, and common carp). A key aspect of this program will be the development of a conceptual ecosystem model.

Relationship to Programs:

Adaptive Management Program

Strategic Plan, Management Objective 2.6 – Reduce native fish mortality due to nonnative fish predation so that it does not impinge on viability.
Strategic Plan, Management Objective 2.8 – Maintain or attain abundance of flannelmouth sucker, bluehead sucker, and speckled dace at levels to be determined.

2008 Biological Opinion on the Operation of Glen Canyon Dam Conservation Measures

Nonnative Fish Control – As first presented in the biological opinion on the Shortage Guidelines, Reclamation will, in coordination with other DOI AMP participants and through the AMP, continue efforts to assist NPS and the AMP in control of both cold- and warm-water nonnative fish species in both the mainstem of Marble and Grand canyons and in their tributaries, including determining and implementing levels of nonnative fish control as necessary. Because Reclamation predicts that dam releases will be cool to cold during the period of the proposed action, control of nonnative trout may be particularly important. Control of these species will utilize mechanical removal, similar to recent efforts by the AMP, and may utilize other methods, to help to reduce this threat. GCMRC is preparing a nonnative fish control plan through the AMP process that addresses both cold and warm-water species that will further guide implementation of this conservation measure.

2007 Biological Opinion for the Bureau of Reclamation's Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead Conservation Measures

Nonnative Fish Control – In coordination with other DOI AMP participants and through the AMP, Reclamation will continue efforts to control both cold- and warm-water nonnative fish species in the mainstem of Marble and Grand canyons, including determining and implementing levels of nonnative fish control as necessary. Control of these species using mechanical removal and other methods will help to reduce this threat.

Humpback Chub Recovery Goals

5.2.2.3 Factor C: – Adequate protection from diseases and predation.
*Management Action C-*3 – Control problematic nonnative fishes as needed.
Task C-3.1 – Develop rainbow trout, channel catfish, black bullhead, and common carp control programs in the Little Colorado River to identify levels of control that will

minimize predation on humpback chub (see section 4.3.2 and A.8 for discussion of effects of nonnative fishes).
Task C-3.2 – Implement identified levels (as determined under Task C-3.1) of rainbow trout, channel catfish, black bullhead, and common carp control in the Little Colorado River.
Task C-3.3: - Brown trout and rainbow trout control programs developed and implemented to identify levels of control that will minimize predation on humpback chub in the Colorado River through Grand Canyon.

5.3.1.1 Demographic criteria for downlisting (population demographics in both recovery units must be met in order to achieve downlisting)

Status: This project is ongoing, and does not currently have an expected completion date. A 2009 PEP will guide future implementation.

d. Develop a monitoring program for the Colorado River downstream of Diamond Creek to detect changes in habitat and aquatic communities and complement the monitoring program upstream of Diamond Creek.

Lake Mead's full pool elevation is at 1229 feet. At this elevation, the inflow area of Colorado River is influenced by the reservoir as far upstream as Separation Rapids (RM 239.5). This location is about 37 miles upstream of Grand Wash Cliffs (RM 276.5), the western boundary of Grand Canyon National Park and the eastern boundary of Lake Mead National Recreation Area. The 1992 Grand Canyon Protection Act (GCPA) uses Grand Wash Cliffs in Grand Canyon National Park as the western boundary of the AMP. In past years, there was no monitoring of fishes or fish habitat below the confluence of Diamond Creek with the mainstem Colorado River (RM 226). The area between Separation Rapid and Grand Wash Cliffs overlaps with the area for the Lower Colorado River Multi-Species Conservation Program (MSCP), so this reach is of interest to both programs. This project would develop a monitoring program for the river downstream of Diamond Creek to detect changes in habitat and fish communities resulting from dam operations or other causes. Monitoring of nonnative and native fish in this reach may become increasingly important to both the AMP and MSCP, particularly if there is upstream movement of nonnative fish out of Lake Mead into Grand Canyon.

Relationship to Programs:

Adaptive Management Program

Strategic Plan, Management Objective 2.6 – Reduce native fish mortality due to nonnative fish predation so that it does not impinge on viability.
Strategic Plan, Management Objective 2.8 – Maintain or attain abundance of flannelmouth sucker, bluehead sucker, and speckled dace at levels to be determined.

2008 Biological Opinion on the Operation of Glen Canyon Dam Conservation Measures

Nonnative Fish Control – As first presented in the biological opinion on the Shortage Guidelines, Reclamation will, in coordination with other DOI AMP participants and through the AMP, continue efforts to assist NPS and the AMP in control of both cold- and warm-water nonnative fish species in both the mainstem of Marble and Grand canyons and in their tributaries, including determining and implementing levels of nonnative fish control as necessary. Because Reclamation predicts that dam releases will be cool to cold during the period of the proposed action, control of nonnative trout may be particularly important. Control of these species will utilize mechanical removal, similar to recent efforts by the AMP, and may utilize other methods, to help to reduce this threat. GCMRC is preparing a nonnative fish control plan through the AMP process that addresses both cold and warm-water species that will further guide implementation of this conservation measure.

2007 Biological Opinion for the Bureau of Reclamation's Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead Conservation Measures

Nonnative Fish Control – In coordination with other DOI AMP participants and through the AMP, Reclamation will continue efforts to control both cold- and warm-water nonnative fish species in the mainstem of Marble and Grand canyons, including determining and implementing levels of nonnative fish control as necessary. Control of these species using mechanical removal and other methods will help to reduce this threat.

Humpback Chub Recovery Goals

5.2.2.3 Factor C: – Adequate protection from diseases and predation.
*Management Action C-*3 – Control problematic nonnative fishes as needed.

Task C-3.1 – Develop rainbow trout, channel catfish, black bullhead, and common carp control programs in the Little Colorado River to identify levels of control that will minimize predation on humpback chub (see section 4.3.2 and A.8 for discussion of effects of nonnative fishes).

Task C-3.2 – Implement identified levels (as determined under Task C-3.1) of rainbow trout, channel catfish, black bullhead, and common carp control in the Little Colorado River.

Task C-3.3: - Brown trout and rainbow trout control programs developed and implemented to identify levels of control that will minimize predation on humpback chub in the Colorado River through Grand Canyon.

Lower Colorado River Multi-Species Conservation Program

The Little Colorado River-MSCP has established basic performance standards to meet to be in compliance with terms and conditions of an incidental take permit for covered projects. The Little Colorado River-MSCP identified the need to provide a level of support to the AMP for humpback chub.

Status: Monitoring of fish and crayfish below Diamond Creek using various gear types has occurred annually since 2004. This project is ongoing, and does not currently have an expected completion date. A 2009 PEP will guide future implementation.

14. Develop planning documents to assist with conservation of humpback chub in the Grand Canyon region.

a. Develop a watershed management plan for the Little Colorado River.

This project focuses on the improvement and protection of the Little Colorado River watershed to ensure appropriate habitat conditions downstream on the Little Colorado River in the area occupied by the humpback chub. Potential issues to be addressed include surface and groundwater quantity and quality, pesticides and other hazardous substances, and nonnative fish stocking. Several of these issues are addressed in separate projects listed below which should become components in a Little Colorado River watershed management plan that includes the hydrologic boundaries of the watershed.

The Little Colorado River watershed is a large area with many political jurisdictions and authorities. For this effort to be successful, these parties must work cooperatively together as they consider their various ideas and responsibilities. The Little Colorado River Watershed Coordinating Council (Little Colorado RiverWCC) has been organized to facilitate discussions among these various interests. The Bureau of Reclamation, Arizona Game and Fish Department, and the U.S. Fish and Wildlife Service are involved in this council. This project will review the status of this effort and its development of a watershed management plan, and then assist in the development and implementation of such a plan. The plan should identify ways to protect instream flows from Blue Spring for humpback chub recovery. This project will assist in meeting the recovery goal of assuring continued protection of conditions needed for humpback chub recovery by assisting the development of a watershed management plan for the Little Colorado River. Specifically this effort would cooperatively develop a watershed-based management plan to provide a strategy for protecting the endangered humpback chub and other federally listed species while at the same time continuing with necessary water and resource development, prioritize necessary actions to achieve these goals, identify funding sources, construct management objectives and targets for measuring success, develop the framework for cooperative agreements, and identify a timeline for completion of tasks and measurement of success.

Relationship to Programs:

Adaptive Management Program

Strategic Plan, Management Objective 2.1 – Maintain or attain humpback chub abundance in the Little Colorado River and other aggregations at appropriate levels for viable populations and to remove jeopardy.

Strategic Plan, Management Objective 7.2 – Maintain water quality in the mainstem of the Colorado River ecosystem.

Humpback Chub Recovery Goals

Humpback Chub 5.2.2.4 Factor D – Adequate existing regulatory mechanisms
Management Action A-2 – Provide flows necessary for all life stages of humpback chub to support a recovered Grand Canyon population, based on demographic criteria.
Task A-2.2 – Identify, implement, evaluate, and revise (as necessary through adaptive managment) a flow regime in the Little Colorado River to benefit humpback chub.
Management Action D-2 – Provide for the long-term management and protection of humpback chub populations and their habitat.
Task D-2.2 - Develop and implement conservation plans and execute agreements among State agencies, Federal agencies, American Indian tribes, and other interested parties to provide reasonable assurances that conditions needed for recovered humpback chub populations will be maintained.

2008 Biological Opinion on the Operation of Glen Canyon Dam Conservation Measures

Little Colorado River Watershed Planning – Reclamation will continue its efforts to help other stakeholders in the Little Colorado River watershed develop watershed planning efforts, with consideration for watershed level effects to the humpback chub in Grand Canyon.

Status: The project described here has not been funded or implemented. The Bureau of Reclamation is working to finish a Little Colorado River watershed report. Continued coordination with the Little Colorado River WCC and the AMP is needed.

b. Develop an emergency response/contingency plan for protection of downstream species from spills into the Little Colorado River at Cameron or other potential sites.

The humpback chub recovery goals discuss the need to "Review and modify, if necessary, state and federal hazardous spills emergency response plans to insure adequate protection from spills, including prevention and quick response to spills; develop and implement a hazardous spills protocol for the Cameron Bridge." This project would develop a well-designed contingency plan providing details about each step involved in preparing for, and responding to, spills of materials into the Little Colorado River channel at Cameron Bridge on Highway 89 or other potential sites for the express purpose of protecting native fish species in the Little Colorado River.

Adaptive Management Program

Strategic Plan, Management Objective 2.1 – Maintain or attain humpback chub abundance in the Little Colorado River and other aggregations at appropriate levels for viable populations and to remove jeopardy.
Strategic Plan, Management Objective 7.2 – Maintain water quality in the mainstem of the Colorado River ecosystem.

Humpback Chub Recovery Goals

5.2.2.4 Factor D – Adequate existing regulatory mechanisms
Management Action D-2 – Provide for the long-term management and protection of humpback chub populations and their habitats.
Task D-2.1 – Identify elements needed for the development of conservation plans that are necessary to provide for the long-term management and protection of humpback chub populations.
Task D-2.2 – Develop and implement conservation plans and execute agreements among State agencies, Federal agencies, Native American tribes, and other interested parties to provide reasonable assurances that conditions needed for recovered humpback chub populations will be maintained.
5.225 Factor E – Other natural or manmade factors for which protection has been provided.
Management Action E-1 – Minimize the risk of hazardous-materials spills in critical habitat.
Task E-1.1 – Review and recommend modifications to State and Federal hazardous-materials spills emergency-response plans to ensure adequate protection for humpback chub populations from hazardous–materials spills, including prevention and quick response to hazardous-materials spills.
Task E-1.2 – Implement State and Federal emergency-response plans that contain the necessary preventive measures for hazardous-materials spills.
Task E-1.3 – Identify measures to minimize the risk of hazardous-materials spills from transport of materials along U.S. Highway 89 at and near the two Cameron bridges spanning the Little Colorado River.
Task E-1.4 – Implement measures to minimize risk of hazardous-materials spills from transport of materials along U.S. Highway 89 at and near the two Cameron bridges spanning the Little Colorado River.

Status: This project has not been funded or implemented.

c. Develop a pollution control plan for Little Colorado River Basin.

The plan would provide a comprehensive evaluation of threats to the humpback chub and its critical habitat that may arise from pollution generating activities in the Little Colorado River Basin and suggest potential actions to ameliorate these threats. This would first entail a comprehensive review of existing plans and projects of federal, state, tribal, local and private entities as well as adopted and planned water quality standards and objectives for the watershed related specifically to aquatic life. Next, the project would identify various pollution scenarios related to both point and nonpoint sources of pollutants. Subsequently, the project would identify appropriate response actions that could be employed to address the identified pollution scenarios. The project would be implemented in such a manner as to complement and be consistent with other Little Colorado River watershed plans. It should provide appropriate background information on watershed activities representing potential pollution threats with particular emphasis on humpback chub, identify all relevant institutional responsibilities and contact information, and available response capabilities including equipment. The project should also identify existing best management practices,

treatment and control practices, likely sources of unintended pollution scenarios, and recommendations regarding response scenarios and responsibilities.

Adaptive Management Program

Strategic Plan, Management Objective 2.1 – Maintain or attain humpback chub abundance in the Little Colorado River and other aggregations at appropriate levels for viable populations and to remove jeopardy.
Strategic Plan, Management Objective 7.2 – Maintain water quality in the mainstem of the Colorado River ecosystem.

Humpback Chub Recovery Goals

5.2.2.4 Factor D – Adequate existing regulatory mechanisms
Management Action D-2 – Provide for the long-term management and protection of humpback chub populations and their habitats.

Task D-2.1 – Identify elements needed for the development of conservation plans that are necessary to provide for the long-term management and protection of humpback chub populations.

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

Status: This project has not been funded or implemented.

APPENDIX C. Project Cross Reference

Table B-1. List of Humpback Chub Comprehensive Plan projects cross-referenced with the Draft 2008 Recovery Goals for Humpback Chub (U.S. Fish and Wildlife Service 2008) and conservation measures from the Biological Opinion for the Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages (SBO, U.S. Fish and Wildlife Service 2007) and the Final Biological Opinion for the Operation of Glen Canyon Dam (GBO, U.S. Fish and Wildlife Service 2008). Threats addressed are as defined in the Draft 2008 Recovery Goals for Humpback Chub (U.S. Fish and Wildlife Service 2008): Factor A-Adequate habitat and range for recovered populations provided, Factor B-Protection from overutilization fro commercial, recreational, scientific, or educational purposes, Factor C-Adequate protection from diseases or predation, Factor D-Adequate existing regulatory mechanisms, Factor E-Other natural or manmade factors for which protection has been provided. Monitoring is essential to the assessment of all threats and thus is considered to address all threats.

	Project Title	Recovery Goals	Conservation Measures	Threats Addressed
1	Humpback Chub Genetics Management Plan	Action 5.3.1.1		E
2	Humpback Chub Refuge Creation	Action 5.3.1.1	SBO, GBO	E
3	Glen Canyon Dam Operations	Task A-1.1.-A-1.2, Task A-2.1-A-2.2		A
4	Glen Canyon Dam Selective Withdraw Structure	Task A-1.1-A1.2, Task A-3.1-3.2		A
5	Sediment Augmentation	Task A-1.1.-A-1.2		A
6	Aquatic Food Base Monitoring and Research	Task A-1.1.-A-1.2		A
7	Young Humpback Chub Habitat Enhancement in the Little Colorado River and other Grand Canyon Tributaries	Action 5.3.1.1		A
8	Fate of Young Humpback Chub in the Colorado River in Grand Canyon	Task A-1.1	SBO, GBO	A
9	Nonnative Control	Task C-3.1.-C-3.6	SBO, GBO	C
	a. Nonnative Control in Tributaries of the Colorado River in Grand Canyon	Task C-3.1.-C-3.6	SBO, GBO	C
	b. Nonnative Control Near the Mouth, and/or in the Lower 15 km, of the Little Colorado River	Task C-3.1.-C-3.6	SBO, GBO	C
	c. Develop Nonnative and Invasive Species Control Plan for the Grand Canyon Region	Task C-3.1.-C-3.6	SBO, GBO	C
	d. Develop Nonnative Stocking Procedures for Grand Canyon Watershed	Task C-2.1.-C-2.2		C
10	Effects of Scientific Work and Recreational Activities on Humpback Chub	Task B-1.1-B-1.2		B
11	Monitoring and Control of Humpback Chub Diseases and Parasites	Task C-1.1-C-1.2	SBO	C
12	Translocation of Native fishes in Grand Canyon	Action 5.3.1.1	GBO	A
	a. Translocation of Humpback Chub above Chute Falls in the Little Colorado River	Action 5.3.1.1	GBO	A
	b. Translocation of Native fish to Grand Canyon Tributaries other than the Little Colorado River	Action 5.3.1.1	GBO	A
13	Monitor Humpback Chub Population Dynamics, Distribution, and Habitat	Action 5.3.1.1	GBO	ALL
	a. Monitor Hydrology and Water Quality in the Little Colorado River	Task A-2.2		ALL

	b. Maintain a Core Monitoring Effort for Humpback Chub in Grand Canyon	Action 5.3.1.1	GBO	ALL
	c. Monitor the Status and Trends of the Downstream Fish Community in Grand Canyon	Action 5.3.1.1	GBO	ALL
	d. Monitor the Status and Trends of Fishes, Crayfish, and Quagga Mussel below Diamond Creek	Action 5.3.1.1	GBO	ALL
14	Planning Documents to Assist Conservation of Humpback Chub			E
	a. Develop Watershed Management Plan for the Little Colorado River	Task A-2.2, Task D-2.2	GBO	E
	b. Develop Emergency Response/Contingency Plan for the Little Colorado River	Task D-2.1-2.2, Task E-1.1-1.4		E
	c. Develop Pollution Control Plan for Little Colorado River	Task D-2.1-2.2		E

APPENDIX D. Project Ranking

Table C-1. In October 2006, the Ad Hoc was asked to rate the 14 humpback chub projects in this plan (some with subprojects) using 5 criteria (on a scale of 1-5, 5 being best): benefit, cost, feasibility, learning, and timeframe. The results are summarized in the table below by a percentage score of the total points possible, the mean score (Avg), the sample variance (Var), and the overall rank. The results for the project rankings were summarized using a weighted value for the "benefit" criteria (by a factor of 10), which provides a ranking that emphasizes the potential benefit of a project to humpback chub over the other criteria; the Ad Hoc preferred this method to the unweighted ranking. The Average and Variance are not weighted. Ten Ad Hoc members participated in the project ranking. Note that subprojects are ranked separately within their parent project and are italicized.

Number	Project Title	Weighted Score	Avg	Var	Weighted Rank	Subproject Rank
2	Humpback Chub Refuge Creation	85.6	3.9	1.1	1	
1	Humpback Chub Genetics Management Plan	84.6	4.3	0.9	2	
10	Effects of Scientific Work and Recreational Activities on Humpback Chub	79.4	3.7	0.9	3	
11	Monitoring and Control of Humpback Chub Diseases and Parasites	76.9	3.5	0.9	4	
12	Translocation of Native fishes in Grand Canyon	76.0	3.8	1.2	5	
	a. Translocation of humpback chub above Chute Falls in the Little Colorado River.	*75.9*	*4.0*	*1.2*		*1*
	b. Translocation of native fish to Grand Canyon tributaries other than the Little Colorado River	*68.5*	*3.5*	*1.6*		*2*
13	Monitor Humpback Chub Population Dynamics, Distribution, and Habitat	74.4	3.7	1.4	6	
	a. Monitor hydrology and water quality in the Little Colorado River	*69.9*	3.7	1.3		*3*
	b. Maintain a core monitoring effort for humpback chub in Grand Canyon	*75.1*	3.8	1.3		*1*
	c. Monitor the status and trends of the downstream fish community in Grand Canyon	*72.8*	3.6	1.4		*2*
	d. Monitor the status and trends of fishes and crayfish below Diamond Creek	*62.2*	3.4	1.6		*4*
6	Aquatic Food Base Monitoring and Research	73.6	3.4	1.3	7	
8	Fate of Young Humpback Chub in the Colorado River in Grand Canyon	73.6	3.2	1.1	8	
4	Glen Canyon Dam Selective Withdraw Structure	71.7	2.9	2.7	9	
9	Nonnative Control	70.4	3.0	1.4	10	
	a. Nonnative control in tributaries of the Colorado River	*59.3*	2.9	1.1		*4*
	b. Nonnative control near the mouth of, and/or in the lower 15 km, of the Little Colorado River	*73.7*	3.4	1.1		*2*
	c. Develop nonnative and invasive species control plan for the Grand Canyon region	*77.0*	3.6	1.4		*1*
	d. Develop nonnative stocking procedures for Grand Canyon region	*65.7*	3.4	2.0		*3*
14	Planning Documents to Assist Conservation of Humpback Chub	63.9	3.2	1.2	11	
	a. Develop watershed management plan for the Little Colorado River.	*67.4*	3.2	1.3		*3*
	b. Develop emergency response/contingency plan for the Little Colorado River.	*77.9*	3.7	1.5		*1*
	c. Develop pollution control plan for Little Colorado River.	*67.6*	3.2	1.7		*2*

7	Young Humpback Chub Habitat Enhancement in Grand Canyon Tributaries	58.8	2.8	0.7	12	
3	Glen Canyon Dam Operations	53.9	2.7	1.7	13	
5	Sediment Augmentation	45.2	2.0	0.9	14	

APPENDIX E. Deleted Projects

The following projects were included in previous versions of this plan, but were deleted from this version of the plan for various reasons, as listed below in bold/italics. Citations of completed projects are also listed, where applicable.

Determine genetic relationships within and among populations of the endangered humpback chub (*Gila cypha*) in the Colorado River Basin. ***COMPLETED:*** Douglas, M. E. and M. R. Douglas. 2006. Conservation Genetics of Gila Cypha in the Colorado River Ecosystem. Report prepared for the Glen Canyon Dam Adaptive Management Program.

Assess genetics of humpback chub being held at Willow Beach National Fish Hatchery for their potential as a refugium stock and as brood stock for captive propagation. ***COMPLETED:*** Strand, A. 2006. Analysis of a preliminary microsatellite dataset for wild and captive populations of Humpback chub, Gila cypha**.**

Determine feasibility of developing a program to augment the population of humpback chub (*Gila cypha*) in Grand Canyon. ***COMPLETED:*** Van Haverbeke, D. R. and R. L. Simmonds. 2004. The feasibility of developing a program to augment the population of humpback chub (*Gila cypha*) in Grand Canyon. Final Report, July 2004. Document No. - USFWS-AZFRO-FL-03-007.

Humpback Chub Hatchery Evaluation and Evaluation of Prospective Refuge Facilities. ***COMPLETED:*** Childs, M. 2005. Humpback chub hatchery evaluation: prospective refuge facilities. Arizona Game and Fish Department, Research Branch, Heritage Program, May 2005.

Improve rearing habitat for early life stage humpback chub in the Little Colorado River to improve growth and survival, particularly of those individuals who would disperse to the mainstream. ***REPLACED BY PROJECT 7.***

Mechanical removal of warm-water nonnative fishes from the Colorado River in Grand Canyon**.** ***COMBINED WITH PROJECT 9B.***

Monitoring humpback chub in the Little Colorado River above Chute Falls ***COMBINED WITH PROJECT 13B.***

Conduct concurrent estimates of humpback chub in Little Colorado River and mainstem to develop/confirm population estimates. Evaluate the age group survivability for all age classes, including recruitment. ***COMBINED WITH PROJECT 13B.***

Develop an Adaptive Management Work Group Outreach Program. ***COMPLETED:*** **http://www.AMP.gov/index.html.**

APPENDIX F. Conservation Measures

Conservation measures from the Final Biological Opinion for the Operation of Glen Canyon Dam, February 27, 2008

Humpback Chub

Humpback Chub Consultation Trigger – Pursuant to 50 CFR § 402.16 (c), reinitiation of formal consultation is required and shall be requested by the Federal agency or by the FWS, where discretionary Federal involvement or control over the action has been retained or is authorized by law and if new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered. Reclamation and FWS agree to specifically define this reinitiation trigger relative to humpback chub, in part, as being exceeded if the population of adult humpback chub (≥200 mm [7.87 in] TL) in Grand Canyon declines significantly, or, if in any single year, based on the age-structured mark recapture model (ASMR; Coggins 2007), the population drops below 3,500 adult fish within the 95 percent confidence interval. FWS and Reclamation have agreed on this trigger based on the current estimated population size and past population trend, genetic considerations, and the capabilities of the ASMR model to estimate population size. This number was derived as a conservative approach to preventing the population from declining to the minimum viable population size for humpback chub, estimated to be 2,100 adult fish (U.S. Fish and Wildlife Service 2002a), with consideration for a buffer and acknowledging the variance inherent in the ASMR resulting from age estimation based on recent results from this model (Coggins 2007). This trigger provides additional protection against possible adverse affects to humpback chub from the proposed action. If the population of humpback chub declines to this level, Reclamation and FWS will consider appropriate actions through reinitiated section 7 consultation, for example, extending the period of steady releases to include July and August. Conversely, if the population of humpback chub expands significantly, FWS and Reclamation will consider the potential for reinitiation of consultation to determine if steady flows continue to be necessary.

Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon – Reclamation has been a primary contributor to the development of the AMP's Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon. Reclamation will continue to work with AMP cooperators to develop a comprehensive approach to management of humpback chub. Reclamation has committed to specific conservation measures in this biological opinion, but will also consider funding and implementing other actions not identified here to implement the plan.

Humpback Chub Translocation – In coordination with other Department of the Interior (DOI) AMP participants and through the AMP, Reclamation will assist NPS and the AMP in funding and implementation of translocation of humpback chub into tributaries of the Colorado River in Marble and Grand canyons. Nonnative control in these tributaries will be an essential precursor to translocation, so Reclamation will help fund control of both cold and warm-water nonnative fish in tributaries, as well as efforts to translocate humpback chub into these tributaries. Havasu, Shinumo and Bright Angel creeks will initially be targeted for translocation, although other

tributaries may be considered. Reclamation will work with FWS, NPS and other cooperators to develop translocation plans for each of these streams, utilizing existing information available such as SWCA and Grand Canyon Wildlands (2007) and Valdez et al. (2000a). These plans will consider and utilize genetic assessments (Douglas and Douglas 2007, Keeler-Foster in prep.), identify legal requirements and jurisdictional issues, methods, and assess needs for nonnative control, monitoring and other logistics, as well as an implementation schedule, funding sources, and permitting. Reclamation and the AMP will also fund and implement translocation of up to 500 young humpback chub from the lower Little Colorado River to above Chute Falls in 2008 if FWS determines that a translocation is warranted. Reclamation and the AMP will continue to monitor humpback chub in the reach of the Little Colorado River above Chute Falls for the 5-year period of the proposed action, and will undertake additional translocations above Chute Falls as deemed necessary by FWS.

Nonnative Fish Control – As first presented in the biological opinion on the Shortage Guidelines, Reclamation will, in coordination with other DOI AMP participants and through the AMP, continue efforts to assist NPS and the AMP in control of both cold- and warm-water nonnative fish species in both the mainstem of Marble and Grand canyons and in their tributaries, including determining and implementing levels of nonnative fish control as necessary. Because Reclamation predicts that dam releases will be cool to cold during the period of the proposed action, control of nonnative trout may be particularly important. Control of these species will utilize mechanical removal, similar to recent efforts by the AMP, and may utilize other methods, to help to reduce this threat. GCMRC is preparing a nonnative fish control plan through the AMP process that addresses both cold and warm-water species that will further guide implementation of this conservation measure.

Humpback Chub Nearshore Ecology Study ¬– In coordination with other DOI AMP participants and through the AMP, Reclamation will implement a nearshore ecology study that will relate river flow variables to ecological attributes of nearshore habitats (velocity, depth, temperature, productivity, etc.) and the relative importance of such habitat conditions to important life stages of native and nonnative fishes. This study will incorporate planned science activities for evaluating the high flow test on nearshore habitats as well as the 5-year period of steady flow releases in September and October. A research plan will be developed with FWS via the AMP for this study by August 1, 2008, and a 5-year review report will be completed by 2013. The plan will include monitoring of sufficient intensity to ensure significant relationships can be established, as acceptable to the FWS. This conservation measure is consistent with the Sediment Research conservation measure in the Shortage Guidelines biological opinion. This study will help clarify the relationship between flows and mainstem habitat characteristics and availability for young-of-year and juvenile humpback chub, other native fish, and competitive or predaceous nonnative fish, and support continued management to sustain mainstem aggregations. The feasibility and effectiveness of marking small humpback chub (<150 and <100 mm TL [5.91 and 3.93 in]) will also be evaluated as part of the study, and if effective, marking young fish will be utilized in the study. Marking young humpback chub, if feasible and effective, could greatly aid in developing information on the early life history, growth and survival of young humpback chub.

Monthly Flow Transition Study – Transitions between monthly flow volumes can often result in drastic changes to nearshore habitats. For example, past transitions from August to September in some years have consisted of a transition from a lower limit of 10,000 cfs in August to an upper limit of 10,000 cfs in September. Such a transition results in a river stage level that is below the varial zone of the previous month's flow, and may be detrimental to fishes and food base for fish. Reclamation has committed to adjusting daily flows between months to attempt to attenuate these transitions such that they are more gradual, and to studying the biological effects of these transitions, in particular to humpback chub. If possible, Reclamation will work to adjust September and October monthly flow volumes to achieve improved conditions for young-of-year, juvenile, and adult humpback chub, as acceptable to the FWS.

Humpback Chub Refuge – Once appropriate planning documents are in place, and refuge populations of humpback chub are created (as a conservation measure of the Shortage Guidelines biological opinion), Reclamation will assist FWS in maintenance of a humpback chub refuge population at a Federal hatchery or other appropriate facility by providing funding to assist in annual maintenance. In case of a catastrophic loss of the Grand Canyon population of humpback chub, a humpback chub refuge will provide a permanent source of sufficient numbers of genetically representative stock for repatriating the species. This action would also be an important step toward attaining recovery.

Little Colorado River Watershed Planning – Reclamation will continue its efforts to help other stakeholders in the Little Colorado River watershed develop watershed planning efforts, with consideration for watershed level effects to the humpback chub in Grand Canyon.

Kanab Ambersnail

Habitat Protection – Reclamation will, through the AMP, temporarily remove and safe-guard all Kanab ambersnails found in the zone that would be inundated during the high flow test, as well as approximately 15 percent (17 m2 [180 ft2]) of the Kanab ambersnail habitat that would be flooded by the experimental high flow test. The ambersnails would be released above the inundation zone, and habitat would be held locally above the level of inundation until the high flow test has ended (approximately 60 hours). Habitat will be replaced in a manner that will facilitate regrowth of vegetation. Subsequent monitoring of this conservation measure will be coordinated with GCMRC.

Conservation measures from the Final Biological Opinion for the Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead, December 12, 2007

Humpback Chub

Nonnative Fish Control – In coordination with other DOI AMP participants and through the AMP, Reclamation will continue efforts to control both cold- and warm-water nonnative fish species in the mainstem of Marble and Grand canyons, including determining and implementing levels of nonnative fish control as necessary. Control of these species using mechanical removal and other methods will help to reduce this threat.

Humpback Chub Refuge – Reclamation will assist FWS in development and funding of a broodstock management plan and creation and maintenance of a humpback chub refuge population at a Federal hatchery or other appropriate facility by providing expedited advancement of $200,000 in funding to the FWS during CY 2008; this amount shall be funded from, and within, the amount identified in the MSCP BO (FWS 2005a; page 26). Creation of a humpback chub refuge will reduce or eliminate the potential for a catastrophic loss of the Grand Canyon population of humpback chub by providing a permanent source of genetically representative stock for repatriating the species.

Genetic Biocontrol Symposium – Reclamation will transfer up to $20,000 in fiscal year 2008 to FWS to help fund an international symposium on the use and development of genetic biocontrol of nonnative invasive aquatic species which is tentatively scheduled for October 2009. Although only in its infancy, genetic biocontrol of nonnative species is attracting worldwide attention as a potential method of controlling aquatic invasive species. Helping fund an effort to bring researchers together will further awareness of this potential method of control and help mobilize efforts for its research and development.

Sediment Research – In coordination with other DOI AMP participants and through the AMP, Reclamation will monitor the effect of sediment transport on humpback chub habitat and will work with the GCMRC to develop and implement a scientific monitoring plan acceptable to FWS. Although the effects of dam operation-related changes in sediment transport on humpback chub habitat are not well understood, humpback chub are known to utilize backwaters and other habitat features that require fine sediment for their formation and maintenance. Additional research will help clarify this relationship.

Parasite Monitoring – In coordination with other DOI AMP participants and through the AMP, Reclamation will continue to support research on the effects of Asian tapeworm (Bothriocephalus acheilognathi) on humpback chub and potential methods to control this parasite. Continuing research will help better understand the degree of this threat and the potential for management actions to minimize it.

Kanab Ambersnail

Monitoring and Research – Through the AMP, Reclamation will continue to monitor Kanab ambersnail and its habitat in Grand Canyon and the effect of dam releases on the species, and Reclamation will also continue to assist FWS in funding morphometric and genetic research to better determine the taxonomic status of the subspecies.

Southwestern Willow Flycatcher

Monitoring and Research – Through the AMP, Reclamation will continue to monitor southwestern willow flycatcher and its habitat and the effect of dam releases on the species throughout Grand Canyon and report findings to FWS, and will work with the National Park Service (NPS) and other AMP participants to identify actions to conserve the flycatcher.

A REVIEW OF
A COMPREHENSIVE PLAN FOR THE MANAGEMENT AND CONSERVATION OF HUMPBACK CHUB (*GILA CYPHA*) IN GRAND CANYON, ARIZONA

BY
GCD AMP SCIENCE ADVISORS

JUNE, 2007

A REVIEW OF A COMPREHENSIVE PLAN FOR THE MANAGEMENT AND CONSERVATION OF HUMPBACK CHUB (*GILA CYPHA*) IN GRAND CANYON, ARIZONA

BY
GLEN CANYON DAM ADAPTIVE MANAGEMENT PROGRAM (GCD AMP) SCIENCE ADVISORS[1]

INTRODUCTION AND BACKGROUND

In 2003, the Adaptive Management Work Group (AMWG) formed an Ad Hoc Committee to respond to science analyses developed between 2000 and 2002 that suggested the adult Humpback Chub (HBC) populations in the Grand Canyon area were in significant decline and approaching minimal viable population levels. That Ad Hoc Committee deliberated and proposed a broad set of actions to insure that chub populations be protected and enhanced and that new knowledge bases be created. Those recommendations were summarized in an initial draft set of Humpback Chub Actions.

By 2005 several of the key management action recommendations were being implemented by managers. These activities included predation control experiments, the evaluation of refugia, and translocation of fish, among others. In 2005 the AMP science community released additional assessments in the Score Report that sustained the argument that the HBC adult populations were continuing to decline and approaching critical minimal levels. The AMWG decided to continue the HBC Ad Hoc Committee and broaden its charge to develop the original set of proposed HBC actions into a HBC Comprehensive Plan that would:

- Describe linkages, sequences and feed back loops among projects
- Identify project priorities and completion timelines

[1] The GCD AMP Science Advisors include Dale Robertson, USGS; Jill Baron, USGS; Virginia Dale, Oak Ridge Laboratories; Jim Kitchell, University of Wisconsin; Lance Gunderson, Emory University; Don Fowler, University of Nevada Reno; Harold Tyus, University of Colordo Boulder; and Lawrence D. Garrett, M3 Research, as the Executive Secretary. Due to conflicts Jim Kitchell could not contribute to this review.

- Identify a broad array of alternatives that address threats, define criteria and steps for action should a crisis develop; i.e., severe population decline

An Implementation Committee was also formed by AMWG to:

- Determine proposed actions that would be completed under GCD AMP and,
- Explore opportunities to complete actions that did not fall under AMP direction.

In 2005 the science advisors reviewed the initial draft HBC Actions, and recommended the document be improved in two areas. The first would be to more clearly articulate the goals and objectives of the program, and the second was to clarify how management activities, programs and projects would meet those goals and objectives. That plan was revised, and a revised draft was completed in 2007 under the title; A Comprehensive Plan For The Management and Conservation of Humpback Chub (*Gila cypha*) In Grand Canyon, Arizona. The remainder of this report provides comments and suggestions on the 2007 Comprehensive Plan.

GENERAL COMMENTS ON PLAN

The 2007 HBC Comprehensive Plan represents significant improvement over the 2005 document, in that goals and objectives are more clearly specified in Sections 4.0, 4.1 and 4.3 and implementation strategies and procedures are articulated more clearly in Sections 5.0-5.4 and in Appendix B in association with individual projects.

However, we do not feel this document, as presented, is a "Comprehensive Plan" of the GCD AMP for HBC science and management programs, but more clearly a "HBC Comprehensive Activities Proposal". We suggest using the former title connotes a much more robust treatment of science and management planning than is intended for this document. For example, the former would include more extensive treatment of project schedules, procedures, linkages, budgets, etc. than is provided in this plan. Further, it would also include more extensive contingency planning to address potential threats to the HBC. Without these changes, a title change might be considered.

There is concern about mixed reference to the intent or goal of the proposed activities to contribute to "HBC recovery" and "removal of jeopardy". There is no official recovery implementation program for the HBC in the Grand Canyon segment of the Colorado River and these references should be dropped. There is an official jeopardy opinion and the proposed

activities clearly address necessary and prudent actions under the opinion. That should be the basis for the plan.

The 2007 draft plan addresses present GCDAMP efforts for conservation of the humpback chub (HBC) in the Grand Canyon. It contains a great deal of important information but it still could be improved in focus, organization and clarity. It needs to be issue driven and clearly specify applied science as the paradigm for management of conservation problems. Because of a potential diverse audience, the report could benefit from an abstract or executive summary section, and a conclusions section. These will aid comprehension and use as a briefing document.

The purpose of the GCDAMP as stated in the "Background" section of the report is: "to make recommendations to the Secretary of the Interior regarding Glen Canyon Dam operating criteria and effects on downstream resources". Clearly, the focus of the document should be on the effects caused by the operation of the dam on the humpback chub. It should contain enough information about past and proposed future operation of the dam, including resultant effects on the population and habitats of the fish, to allow policy makers at various government levels and disciplines to understand implicated cause and effect relationships. The document correctly identifies GCDAMP goals for the humpback chub as those needed to avoid jeopardizing the continued existence of the species and destruction or adverse modification of critical habitat. These goals are the direct result of the Section 7 ESA finding from the U.S. Fish and Wildlife Service, which is a mandate to the Bureau of Reclamation as a federal agency affected by the Act. These goals may be related to recovery issues, but they are not sufficient or intended to result in recovery of the species. By organizing the document by broad recovery goals the focus on adverse effects caused by operation of GCD is obscured and clarity lost.

We suggest text revisions wherein the focus of the science and management activities proposed would be on the actions to remove jeopardy and not on recovery. This is currently partly obscured in the text by discussions arranged around recovery goals. However, it is clearly stated in Appendix B in introducing all proposed projects as follows. "All projects are directed at achieving Goal 2 of the GCDAMP, which is to maintain or attain viable populations of existing native fish, remove jeopardy for humpback chub and razorback sucker, and prevent adverse modification to their critical habitat". This statement does raise another general

question. Does it mean that there will be comprehensive plans to address other general questions? Should other native fishes and razorback sucker be considered as part of this comprehensive plan?

SPECIFIC COMMENTS ON VARIOUS SECTIONS OF THE PLAN

1.0 Introduction. An effective Introduction section should clearly identify and define the problem being addressed, provide a review of relevant information to orient the reader, and indicate how an investigation might proceed on selected goals. Subheadings in the introduction might include, General, Environmental Setting, Effect of Dam on Grand Canyon HBC, Program Goals, etc.

The present Introduction section goals statement should be rewritten i.e., "The GCDAMP goals for humpback chub are to ***operate GCD to*** maintain or attain, etc."

The introduction section should clearly identify the purpose of this report in a straight forward manner to provide the reviewer with the nature and scope of the problem being addressed. At present it is more like a preface to the report than an introduction.

The goals appear to be correctly stated and the audience is targeted, however the focus here should be directed to the effects caused by the operation of Glen Canyon Dam. There should be a brief discussion of the historic environmental setting of the Colorado River and associated riparian zone in Grand Canyon, and the environmental impacts associated with the construction and operation of Glen Canyon Dam.

It should be clearly noted that construction effects of the dam occurred before 1973 and are thus not under Section 7 authority, while operations of the dam are. The plan should identify potential downstream impacts on HBC associated with operation of the dam in a general way that have affected the fish "e.g. changes in the river caused by the dam". ***(***Chapter 6, NRC 1996). In this way, the Plan would provide the necessary background for identifying how the environment for humpback chub has been changed by the dam, and for seeking ways to avoid or mitigate those effects that pose a threat to the fish. At a minimum, it is necessary to identify the magnitude of changes that have occurred to historic habitat, changes that constitute a threat, and how threats might be avoided or reduced by operation of the dam.

In addition to a summary of past findings about effects of dam operation, the Introduction section also should relate how future impacts will be evaluated, i.e., what methodology will be used to evaluate/rank perceived threats, how future studies will be selected or ranked, etc.

1.1 Background. This section could be summarized into a preface or as one paragraph in the introduction. Use of acronyms should be minimized.

2.0 Status of Humpback Chub in the Colorado River Basin. This subsection should be merged with other information and placed in the Introduction section in a subsection dedicated to the environmental setting. The first part (2.1) is confusing. What is the significance of humpback chub aggregations? What are the sizes of these aggregations? Are these aggregations purported subpopulations or just places where a certain life history stage is captured?

You might want to consider a first sentence that reads; “There is one known population of HBC in GC, and 9 locations support higher densities of the fish”. Two different views about population size of HBC in GC are given on P 3. The authors should resolve the differences in those numbers clearly with reference to the scientific basis for each number. The presentation should have sufficient scientific rigor and clarity to convince the reader that the population values determined earlier (2002-2005) were not as accurate as values determined in 2006. For example, why in a five year period has the AMP position on this species shifted from near apparent crisis to a position of a stable adult population of 5000 adult fish. These measures are the driving force in major policy shifts and require clear scientific explanation.

As presented in this document, the concept of stabilizing a declining population is confusing. Results of sampling the humpback chub population show a declining post-dam trajectory from 1989, with no detectable increase and further, that declines below 2100 individuals would presumably occur in 10 to 15 years. Perhaps the wording could be changed to: “presently stabilized at a lower level" to avoid giving the impression that the population is recovering. The humpback chub population in Grand Canyon apparently is supported entirely by habitat in the Little Colorado River and may be at or near the capacity of the Little Colorado River to support it. At present it seems that the few adult chub in the mainstream are not contributing to population size.

In the last paragraph on P 3, the current population is given as 5,000 fish, presumably a population mean? In view of the importance of this number it requires more elucidation. The

value should be given as a mean with appropriate confidence limits. To be meaningful, this population value should be considered with respect to the presumed size of the historic population of humpback chub in the affected area, such as a percent of the historic size.

A discussion of minimum viable population (MVP) size in respect to the humpback chub in Grand Canyon would be helpful. It appears that the Grand Canyon fish are isolated from humpback chub populations in the remainder of the Colorado River basin. Thus, downlisting criteria provided earlier will probably need revision if the Grand Canyon/Little Colorado population is isolated and not considered part of a larger metapopulation . In this case MVP requirements may be greater than the 2100 number that is often given to protect local adaptations. For wild vertebrate populations this number could be near 7000 individuals to insure persistence (e.g. 99% confidence of persistence for 40 generations; Reed et al. 2003). All animal populations will fluctuate, and maintenance of a target population size will require a much larger geometric mean population size to avoid future fluctuations that could reduce the number below the target. (e.g., see Thomas 1990, Reed et. al. 2003). If such a target population size cannot be determined at this time, those factors that need to be considered for doing so in the future should be identified.

Section 2.2 gives status of HBC in the upper Colorado river basin. We suggest that this be changed to status in the entire basin and provide the same information in table 1 for all areas for comparison, and appear before information presented in the present Section 2.1. In Table 1, "Occasions" needs to be defined. What percentage of the historic HBC range remains?

The last paragraph on P 4 seems out of place. Perhaps this should be merged with a Preface or placed in the Introduction after some rewriting.

There appears to be two Section 2.2, one on P 3 and the other on P 5. We suggest that the Section 2.2 beginning on P 5 be removed or placed in an appendix. It adds little to this report.

3.0 Threats to Humpback Chub. This should be renamed, "Threats to Humpback chub from GCD Operation". As presented, some threats are not threats (e.g. food base is not a threat, but a declining food base is a threat). Also, threats should be organized according to those changes from historic conditions that have resulted from operation of the dam, e.g., hydrological change, changes in water temperature, and changes in sediment or turbidity.

We think the Plan would be greatly improved by using some type of conceptual approach to indicate the magnitude and interaction of various threats. The use of Recovery Factors A - E are inappropriate and confusing because the goal of this plan is to reduce jeopardy and avoid adverse modification of critical habitat from operation of GCD, not species recovery.

It could be argued that some threats listed are not directly or indirectly attributable to operation of GCD. However, it must be recognized that operation of the dam has reduced the abundance and distribution of humpback chub in the GC. Extinctions of widespread species have been associated with major events that produce stresses of the type or magnitude not previously been experienced by the species. Such an event can result in a lower population size and restricted range, which make the species vulnerable to stresses that would previously have had little or no effect.

It might be argued that HBC population vulnerability to disease, handling, contaminants, and other impacts may be related to construction and operation of GCD. In other words, GCD was a major event (i.e., catastrophic) that could have made the HBC vulnerable to stressors that would not normally have threatened its historic population. As a major event, GCD has at least three catastrophic components for the fish. The first is habitat destruction and alteration on a major scale, the second is fragmentation of range and the third is the speed at which it was accomplished. Natural processes would have taken thousands of years to accomplish such changes and thus natural selection cannot produce adaptations fast enough to compensate.

How were five threats identified for immediate attention, P 8, last paragraph.? (Note: six items were presented on P 9 instead of five). The process needs to be outlined. We suggest that these threats be highlighted after they have been identified in the preceding section. Add to "Cold water releases" an increase in predation risk in HBC. The part about "Flow regimes from dam releases" is inadequate. Much is known about the impact of flows on the habitat and life histories of native fishes. The part on "Threat interactions" needs to be expanded. Reduced population size and restricted range of HBC induces vulnerability to multiple threats. This section should be immediately followed by another section that address how each threat will be reduced by changing GCD operation or by further study to find out how it could be changed. Instead the next section (4.0) falls short of this need, and needs to be more robust.

The Strategy for Improving Conditions for Humpback Chub. This section should provide contingency planning for dealing with threats identified in previous sections and needs to include a list of recommendations to avoid jeopardy from the operation of GCD. Instead it purports to expand that goal to include assisting in

achieving recovery goals in the Grand Canyon. It should be stated that avoiding jeopardy will assist in achieving recovery goals, and thus it is not a new concept. However, this choice of direction clouds the real issue. Even though the actions needed to remove the threats imposed by GCD also are related to recovery, they cannot result in recovery unless the fish is also recovered elsewhere in the basin. Thus, the concept introduced here of recovery in the Grand Canyon seems obscure. Perhaps it should be restated to assist with recovery of the fish throughout its range, or in keeping with the theme, to indicate the goal is to avoid jeopardy which also will assist in attaining recovery goals.

Separating section 4.0 from the rest of the document adds nothing and results in more confusion. We recommend that this section be significantly revised as stated above, or be dropped and the items listed under Sections 4.1, 4.2, and 4.3, be included with the rest of the items included as threats to the fish associated with the operation of GCD, and how to avoid threats as stated above.

The Strategy Implementation Section. This section, including proposed projects is not a strategic approach for implementing actions to reduce the threat of jeopardy from operation of GCD. Instead it seems that a tactical approach is used by promoting various projects whose value in addressing strategic needs is not presented. Although it is intuitive that the GCD Operations project would be ranked high, it was ranked at the bottom (i.e., 13 out of 14 projects; Appendix C).

In this section, various projects are listed but they are not directly linked to specific threats identified earlier. To be effective, the Plan should identify threats, prioritize the threats for needed action, and indicate which projects address them. In that way, progress toward avoiding jeopardy could be assessed.

Instead the projects seem to have a life of their own. For example, projects are prioritized in Section 5.2, but the threats are not. Under the circumstances, ranking of projects seems a moot exercise.

Reducing the Threat of Catastrophic Events. This section discusses two catastrophic events but the two could be combined. Regarding threat of extinction, a catastrophic event leading to extinction has been considered a natural or human change in the environment that species have not experienced and thus have not developed adaptations in response. In this context, construction and operation of GCD is a

catastrophic event because of the magnitude of habitat destruction and the rapidity of its action.

Section 5.4 Implications of Implementation. This section appears to be added as an after thought. It is an important issue, but as written it does not contribute to the document. The authors might want to consider developing a general risk differential assessment of implementing such a high cost program with related probabilities of success in various areas. It could provide some guidance on where budgets, at least in the short run, might best be spent.

Conclusions. This plan has no conclusion section. It needs one to indicate the direction of the program and to summarize progress in avoiding jeopardy to HBC. Without some sort of summary or conclusion one is left to ponder what is the point of this document.

Appendix B. Appendix B is significantly expanded from the previous SA review of this document. And, the additional information provided on most projects does help the reader understand selected elements of each project. However, the section could be improved significantly by documenting information that reviewers could use in evaluating the collection of projects as a "program".

First and foremost, a schematic or figure that provides an overall design as to how the projects are linked would be most helpful. Second, a table outlining several critical elements of each study would be helpful in better understanding each project, but also how the projects are integrated as a program. The authors might consider the following elements to describe each project and project linkages.

- Project title and area of contribution; i.e., predation, food base, etc.
- Objectives
- General procedures
- Linkage to other projects or management
- Science understanding sought

Appendix C. Project Ranking. Ranking of these projects by this small group does not seem to be a useful exercise. It could be a partial set of information from stakeholders that might be improperly used by policy makers.

References

Reed, D.H., J.J. O'Grady, B.W. Brook, J.D. Ballou and R. Frankham. 2003. Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. Biological Conservation 113(1):23-34

Thomas, C.D. 1990. What do real population dynamics tell us about minimum viable population sizes? Conservation Biology 4:323-327

DRAFT

Humpback Chub Comprehensive Plan Ad Hoc Group Response to the June 2007 Science Advisors' Review of March 2007 Comprehensive Plan for the Management and Conservation of Humpback Chub (*Gila cypha*) in the Lower Colorado River Basin

February 17, 2009

Introduction

This document is a summary of the comments received in a review by the Glen Canyon Dam Adaptive Management Program (AMP) Science Advisors of a document created by the Technical Work Group Humpback Chub Comprehensive Plan Ad Hoc Group (Ad Hoc) "A Comprehensive Plan for the Management and Conservation of Humpback Chub (*Gila cypha*) in Grand Canyon, Arizona" (Plan). The Ad Hoc provides a summary of the review by attempting to identify specific comments and provides a brief response to each identified comment, but the Ad Hoc refers the reader to the revised Plan and the June 2007 Science Advisor review for more information.

Comments and Ad Hoc Responses

1. The Plan is a comprehensive list of projects, not a comprehensive plan; consider "HBC Comprehensive Activities Proposal" for the title. Or include more extensive treatment of project schedules, procedures, linkages, budgets, etc. than is provided in this plan.

The Ad Hoc felt the title was appropriate, although the title has been changed to more accurately describe the geographic and programmatic scope. Also, a new table has been added that provides additional information regarding projects. The Ad Hoc feels that the detailed level of planning requested by the science advisors would be more appropriately accomplished by a recovery program, in concert with stakeholders tasked specifically with achieving recovery. While the AMP Comprehensive Plan will help guide such an effort, we lack the resources to provide that level of detail here.

2. Plan should focus on removal of jeopardy, because a recovery program is not in place in Grand Canyon.

The Adaptive Management Work Group (AMWG) motion that directed the revision of the Comprehensive Plan directed the Ad Hoc to identify actions to be taken that can be both accomplished within the AMP and those that may be considered outside the authority of the AMP. Thus, the Ad Hoc strived to create a plan to conserve the lower Colorado River basin recovery unit of humpback chub, as defined by the U.S. Fish and Wildlife Service. However, the plan is not a recovery plan or an outline for a recovery program. The Ad Hoc Group utilized the 2002 U.S. Fish and Wildlife Service Humpback Chub Recovery Goals and the 2008 Draft Revised Recovery Goals as the best

available information in preparation of the plan. A recovery program for the lower basin recovery unit in Grand Canyon is an identified need by the AMP. In a May 21, 2007, response to a December 6, 2006, Adaptive Management Work Group (AMWG) motion, in which the AMWG recommended that the Secretary of Interior task the U.S. Fish and Wildlife Service with developing a lower Colorado River Recovery Program to include humpback chub in Grand Canyon, Deputy Secretary Lynn Scarlett tasked the U.S. Fish and Wildlife Service with providing feedback to AMWG on a timeline, scope, and development of an outreach program to potentially involved stakeholders, and report findings to the DOI Policy Group and identify information needs to develop a recovery program. In response to this charge, the U.S. Fish and Wildlife Service created the "Draft Recovery Implementation Program (RIP) for the Humpback Chub (*Gila cypha*) in the Grand Canyon: Report on Analysis and Recommendations to Support Stakeholder Driven Outreach Program and Identification of Information Needs." This draft report utilizes information from the Comprehensive Plan. The Ad Hoc also added sections in the report to better explain the meaning of recovery, recovery units, and the lower Colorado River basin recovery unit of humpback chub.

3. Improve focus, organization, and clarity of the report, and use applied science as a paradigm. Add abstract and conclusions.

The Ad Hoc added an abstract, preface, conclusions, and a discussion section, and provided additional information and tables to clarify the report.

4. Document should focus on the effects caused by the operation of the dam on the humpback chub, because this is the limit of Glen Canyon Dam AMP.

The responsibilities of the Adaptive Management Work Group as delineated in Bureau of Reclamation's 1995 Glen Canyon Dam Environmental Impact Statement, include the following:

"Develops recommendations to the Secretary of the Interior for modifying operating criteria and other resource management actions, policies, or procedures."

Further, the AMWG specifically directed in 2003 that the ad hoc "consider actions to implement a comprehensive research and management program for the humpback chub" and then in 2005, directed "the creation of a humpback chub implementation plan Ad Hoc Group" to "1. Determine which actions identified in the humpback chub comprehensive plan can be accomplished under the Glen Canyon Dam AMP" and "2. Explore the various options for completing actions that do not fall under the authorities of the Glen Canyon Dam AMP."

5. Appendix B correctly introduces all proposed projects as follows: "All projects are directed at achieving Goal 2 of the Glen Canyon Dam AMP, which is to maintain or attain viable populations of existing native fish, remove jeopardy for humpback chub and razorback sucker, and prevent adverse modification to their critical habitat". Will other comprehensive plans address other general questions?

Should other native fishes and razorback sucker be considered as part of this comprehensive plan?

The Ad Hoc added a discussion of the relevance of the report to Goal 2 and other native fishes in Grand Canyon. Generally, the recommendations of the report would benefit all native fishes and therefore work to achieve Goal 2.

6. The Introduction should identify and define the problem being addressed, provide a review of relevant information and indicate how investigations might proceed on selected goals. Consider including subheadings General, Environmental Setting, Effect of Dam on Grand Canyon HBC, Program Goals, etc.

The Introduction section has been revised and other sections revised and added to clarify the plan.

7. Introduction section goals statement should be rewritten i.e., "The Glen Canyon Dam AMP goals for humpback chub are to operate Glen Canyon Dam to maintain or attain, etc."

The AMWG charge to the Ad Hoc was to consider a comprehensive set of actions both within and outside of the AMP's responsibility to present a comprehensive approach to management of humpback chub in the lower Colorado River basin. The Ad Hoc has developed the Plan to meet that charge. The Ad Hoc also added to language in the Plan to help explain the applicability to AMP Goal 2.

8. Introduction is more like a preface. Focus should be directed to effects of operation of Glen Canyon Dam. Discuss the historic environment, impacts associated with the construction and operation of Glen Canyon Dam. Note construction effects occurred before 1973/ESA. Identify magnitude of changes from dam ops that have occurred, changes that constitute a threat, how threats might be avoided or reduced.

The Ad Hoc provided additional information in the Introduction to attempt to better explain the role of the AMP in conservation of humpback chub and provided a Preface section.

9. The Introduction section should relate how future impacts will be evaluated, i.e., what methodology will be used to evaluate/rank perceived threats, how future studies will be selected or ranked, etc.

The Ad Hoc attempted to address prioritization throughout the document, and a discussion of methodology of threat prioritization has been added. However, the Ad Hoc found that it lacks the resources to provide thorough analysis of threat prioritization for this plan and suggests that a Recovery Program would be more appropriate to provide this.

10. Summarize "1.1 Background" into a one-paragraph preface.

The Ad Hoc added a preface that provides information formerly in Section 1.1.

11. Minimize use of acronyms.

The Ad Hoc revised the report to reduce the use of acronyms.

12. Merge 2.0 Status with other information and place in the Introduction as subsection.

The Ad Hoc revised section 2.0 and the Introduction to address this comment.

13. Define significance and sizes of these aggregations relative to subpopulations or locations where a certain life history stage is captured.

The Ad Hoc made changes to the Plan to better define the aggregations, their size, location and significance to the Grand Canyon population.

14. Clarify and explain shift in view about population size of HBC in GC (near apparent crisis to a stable adult population of 5000 adult fish).

The Ad Hoc provided additional information on the status of the humpback chub in the lower Colorado River Basin. We refer to citations in the Plan utilized in the discussion of the status of the humpback chub for a complete discussion of the current status and changes in status over time.

15. Define the statement "stabilizing a declining population." Consider rewording to: "presently stabilized at a lower level." Define the relationship of the Little Colorado River to the mainstem relative to the size of the humpback chub population.

The Ad Hoc revised the section on status to explain that the status of humpback chub has apparently been in decline since monitoring began in the late 1980s but has improved and/or stabilized since about 2002. The lack of clarity on this issue is the result of the limitations of the current model in use to track humpback chub status, the Age-Structured Mark Recapture model, and we refer to relevant publications on the use of this model.

16. Is the current population estimate of 5,000 fish a population mean? Add confidence limits, describe in relation to historical population size, percent of historical size.

The Ad Hoc revised the status section to address this comment.

17. Discuss the minimum viable population (MVP) size for humpback chub in Grand Canyon. Because the species is isolated in this part of its range, and not a

metapopulation, downlisting criteria may need revision. Consider 7000 individuals to insure persistence (e.g. 99% confidence of persistence for 40 generations) and larger geometric mean population size to avoid fluctuations that could reduce the number below the target. If such a target population size cannot be determined at this time, those factors that need to be considered for doing so in the future should be identified.

The Ad Hoc felt that this discussion was outside its purview and more appropriately addressed in the ongoing revision of the U.S. Fish and Wildlife Services' revision of the recovery goals for humpback chub, and forwarded this comment to the U.S. Fish and Wildlife Service.

18. Change status to include entire basin and provide same info for all areas and move to an earlier section. List the percentage of historical humpback chub range that remains occupided.

The Ad Hoc revised the status section to address this comment.

19. Rewrite the section discussing the recovery goals revision and move to Preface/Introduction.

The Ad Hoc made this revision.

20. The numbering of sections is in error. Suggest removing Section 2.2 on page 5 or place in an appendix.

This numbering was a typo that the Ad Hoc corrected. The Ad Hoc also revised these sections and the Appendices to address this comment.

21. Rename Section 3.0 Threats to "Threats to Humpback chub from Glen Canyon Dam Operation." Food base is not a threat – redefine as declining food base. Organize according to changes from historic conditions, e.g., hydrological change, changes in water temperature, and changes in sediment or turbidity.

The Ad Hoc respectfully disagrees with the scope of the Plan as discussed above, but did update threat information in the threats section (3.0) to better explain threats to humpback chub.

22. The goal of the Plan should be to reduce jeopardy and avoid adverse modification of critical habitat from operation of Glen Canyon Dam, not species recovery. Use a conceptual approach to indicate the magnitude and interaction of various dam-related threats instead of Recovery Factors A – E.

As explained above, the Ad Hoc respectfully disagrees with the Science Advisors view of the scope of the Plan and developed a comprehensive plan per the charge from AMWG.

23. Not all the threats listed are attributable to the operation of Glen Canyon Dam. However, the dam has resulted in reduced abundance and distribution of humpback chub. Lower population size and restricted range may make HBC more vulnerable to stresses that otherwise had little or no effect. Discuss threats in relation to Glen Canyon Dam. For example, vulnerability to disease, handling, contaminants, and other impacts may be related to construction and operation of Glen Canyon Dam. Glen Canyon Dam resulted in humpback chub being more vulnerable to stressors that would not normally have threatened its historic population via three catastrophic components: habitat destruction, fragmentation, speed of changes (too fast for natural selection to compensate).

The Ad Hoc interpreted its charge as comprehensive, not limited to an examination of the threats directly attributable to Glen Canyon Dam. The Ad Hoc revised the discussion of threats in the Plan and added a discussion of the interaction of threats that should serve to address this comment.

24. Define the threats identified for immediate attention. Suggest highlighting these after they have been identified in the preceding section. Add to "Cold water releases" an increase in predation risk in HBC. "Flow regimes from dam releases" is inadequate – more is known. Expand on "Threat interactions" (i.e. reduced population size and restricted range of HBC induces vulnerability to multiple threats).

The Ad Hoc revised the threat discussion to better discuss the baseline conditions for humpback chub and the suite of threats to the species including how these threats can interact.

25. Revise this section to address how each threat will be reduced by changing Glen Canyon Dam operations or by further study to find out how it could be changed.

The Ad Hoc found that dam operation is not the sole management action available to address the threats to humpback chub. The Ad Hoc has revised Section 4 to better explain how management actions can address threats, including dam operations.

26. Provide contingency planning for identified threats, and recommendations only to avoid jeopardy from Glen Canyon Dam operation, not for assisting in achieving recovery goals in the Grand Canyon (although removing jeopardy assists recovery). Or restate purpose to assist with recovery of the fish throughout its range, or that goal is to avoid jeopardy which also will assist in attaining recovery goals.

The Ad Hoc has attempted to revise the document to both better explain the relationship of the AMP to the recovery process for humpback chub and define how contingency planning for threats has been addressed. Contingency planning is met both with off site actions (creation of refuges) and within the wild with plans to prevent spills, for example, and overall through the improvement of habitat in the wild.

27. Consider deleting Section 4.0, or combine with Section 3.0 as to how to avoid threats as stated above.

We have revised section 4.0, but, the Ad Hoc lacks the capability to develop a plan that fully responds to the comment. As stated above, the Ad Hoc feels that the plan is responsive to the AMWG charge, but cannot provide a complete analysis of how threats will be addressed because this is not an appropriate for the Ad Hoc and is the function of a recovery team and planning process.

28. Section 5.0 is not a strategic approach for implementing actions to reduce the threat of jeopardy from operation of Glen Canyon Dam. The value of projects in addressing strategic needs is not presented. Why is Glen Canyon Dam Operations not ranked high, it was ranked at the bottom (i.e., 13 out of 14 projects; Appendix C). Plan should identify threats, prioritize threats, and indicate which projects address them (relative to jeopardy). Why rank projects if threats are not ranked.

As explained above, the Ad Hoc is not the appropriate entity to fully address threats to the species, this is the purview of a recovery program. The Ad Hoc provided some additional discussion on the ranking of projects, and some additional discussion on the strategic elements that the projects are meant to address.

29. Section 5.4 Implications of Implementation does not contribute to the document. Consider developing a general risk differential assessment for cost/benefit to prioritize budgets.

The Ad Hoc felt that Section 5.4 was necessary to identify how implementation of the Plan could affect other AMP resources. Development of a general risk differential assessment is more appropriately addressed by a recovery program, or by the AMWG with regard to the overall AMP budget.

30. Add a conclusions section to indicate direction of the program and summarize progress in avoiding jeopardy.

The Ad Hoc added a conclusions section.

31. Appendix B could be improved by documenting information that reviewers could use in evaluating the collection of projects as a "program." Provide schematic or figure for the overall design as to how the projects are linked and a table outlining critical elements of each study. Consider these elements to describe projects and project linkages.

- **Project title and area of contribution; i.e., predation, food base, etc.**
- **Objectives**
- **General procedures**
- **Linkage to other projects or management**
- **Science understanding sought**

The Ad Hoc revised Appendix B and added tables and a figure to address this comment.

32. Appendix C Project Ranking is not useful, and likely to be misused – delete.

The Ad Hoc has provided additional information about the project ranking process, as well as information on threat ranking methodology. The Ad Hoc determined that detailed threat ranking procedures are more appropriately carried out by a recovery program. The section was retained, with additional discussion on the limitations of the project ranking process.