United States Department of the Interior

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In Reply Refer To:

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22410-1993-F-167R1

February 27, 2008

Email Transmission
Memorandum

To: Deputy Regional Director, Bureau of Reclamation, Upper Colorado Region, Salt Lake City, Utah

From: Field Supervisor

Subject: Final Biological Opinion for the Operation of Glen Canyon Dam

Thank you for your request for formal consultation with the U.S. Fish and Wildlife Service (FWS) pursuant to section 7 of the Endangered Species Act of 1973 (16 U.S.C. 1531-1544), as amended (Act). We received your request on November 13, 2007. At issue are impacts that may result from the proposed adoption of the experimental dam operations of Glen Canyon Dam in Coconino County, Arizona. The proposed action may affect humpback chub (*Gila cypha*) and its critical habitat, and the Kanab ambersnail (*Oxyloma haydeni kanabensis*).

You also requested our concurrence that the proposed action is not likely to adversely affect the razorback sucker (*Xyrauchen texanus*) and its critical habitat, the southwestern willow flycatcher (*Empidonax traillii extimus*) and its critical habitat, and the bald eagle (*Haliaeetus leucocephalus*). The bald eagle is no longer listed so section 7 consultation is not necessary. We concur with Reclamation's determinations for razorback sucker and southwestern willow flycatcher and their critical habitat and have provided our rationales in Appendix A of this biological opinion.

This biological opinion is based on information provided in your December 21, 2007, biological assessment (U.S. Bureau of Reclamation 2007a), subsequent exchanges of information with the Bureau of Reclamation (Reclamation), and other sources of information. Literature cited in this biological opinion is not a complete bibliography of all literature available on the species of concern, dam operations and its effects, or on other subjects considered in this opinion. A complete administrative record of this consultation is on file at our office.

We note that one of the purposes of the proposed action is to benefit the Grand Canyon population of humpback chub. Although the status of the Grand Canyon population of humpback chub has been improving, there is no clear indication for the cause of this improvement. Thus the proposed action takes a conservative approach to changes in dam releases in an attempt to capitalize on this trend in status without unduly risking these gains with more drastic changes in dam operations. However, there exists the possibility that the population could decline, despite the current trend and potential for beneficial effects from Reclamation's proposed action. Reclamation has agreed to reinitiate consultation if the trend in humpback chub status should reverse and the population decline, as described below in our biological opinion.

In keeping with our trust responsibilities to American Indian Tribes, we have provided for participation of the Bureau of Indian Affairs in this consultation and, by copy of this biological opinion, are notifying the following Tribes of its completion: the Chemehuevi Indian Tribe, Havasupai Tribe, Hopi Tribe, Hualapai Tribe, Kaibab Band of Paiute Indians, Navajo Nation, Pueblo of Zuni, and San Juan Southern Paiute Tribe.

Introduction

The proposed action for this biological opinion is a logical extension of a series of experiments conducted under the Glen Canyon Dam Adaptive Management Program (AMP), which include high flow tests, steady flows, removal of non-native fish, and non-native fish suppression flows. It consists of Reclamation's implementation of Modified Low Fluctuating Flows (MLFF) and experimental dam operations for the five-year experimental period (the remainder of water year 2008 through 2012). This biological opinion replaces the 1995 Final Biological Opinion on the Operation of Glen Canyon Dam (U.S. Fish and Wildlife Service 1995, consultation number 2-21-93-F-167). At the end of the five-year period of the proposed action, it is expected that Reclamation will reconsult with FWS. Annual operations of Glen Canyon Dam (annual water volumes released) for this period will be defined by the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Shortage Guidelines). Section 7 consultation for the Shortage Guidelines was completed on December 12, 2007 (U.S. Fish and Wildlife Service 2007, consultation number 22410-2006-F-0224), and a record of decision (ROD) implementing the Shortage Guidelines was signed by the Secretary of the Interior on December 13, 2007 (Shortage Guidelines ROD, U.S. Bureau of Reclamation 2007b).

Glen Canyon Dam will be operated in accordance with Reclamation's 1996 Record of Decision (U.S Bureau of Reclamation 1996). The proposed action is to continue Modified Low Fluctuating Flow releases as described in the 1996 ROD and associated 1995 Environmental Impact Statement (1995 EIS, U.S. Bureau of Reclamation 1995, 1996). As Reclamation implements the Shortage Guidelines, MLFF will be released as provided in the 1996 ROD, which places significant constraints on allowable fluctuations of powerplant releases (summarized in Table 1). Exception criteria as outlined in the 1997 Operating Criteria for Glen Canyon Dam (62 FR 9447) would also continue.

Reclamation's current operational approach has a minimum objective release of 8.23 million acre feet (maf) annually from Glen Canyon Dam. The proposed action would allow Reclamation to change these operations by allowing for potential annual releases less than the minimum objective release under certain, identified conditions as described in the Shortage Guidelines. However, even in years with an annual release less than 8.23 maf, daily and hourly releases would continue to be made according to the parameters of the 1996 ROD, which would not be affected by the proposed Federal action. Operations for the proposed experimental 5-year period would deviate from the 1996 ROD in only 2 ways: 1) a March 2008 experimental high flow test; and 2) stable flow releases in September and October from 2008-2012. These actions are further defined in the Proposed Action section below.

The 1996 ROD directed the formation and implementation of an adaptive management program to assist in monitoring and future recommendations regarding the impacts of Glen Canyon Dam operations. The AMP was formally established in 1997 to comply with the Grand Canyon Protection Act of 1992 (GCPA), the 1995 EIS, and the 1996 ROD, and provides a process for assessing the effects of current operations of Glen Canyon Dam on downstream resources and using the results to develop recommendations for modifying dam operations and other resource management actions. This is accomplished through the Adaptive Management Work Group (AMWG), a Federal advisory committee. The AMWG consists of stakeholders that are Federal and State resource management agencies, representatives of the seven Basin States, Indian Tribes, hydroelectric power marketers, environmental and conservation organizations, and recreational and other interest groups. The duties of the AMWG are of an advisory capacity only, but recommendations of the AMWG are conveyed by the Secretary's Designee to the Secretary of the Interior and play an important role in the decisions of the Department of the Interior. Coupled with this advisory role are long-term monitoring and research activities that provide a continual record of resource conditions and new information to evaluate the effectiveness of the operational modifications to Glen Canyon Dam and other management actions, including actions undertaken to conserve Act-listed species.

The AMP consists of the following major components:

- The AMWG, a Federal advisory committee that makes recommendations on how to adjust the operation of Glen Canyon Dam and other management actions to fulfill the obligations of the GCPA.

- The Secretary of the Interior's Designee that serves as the chair of the AMWG and provides a direct link between the AMWG and the Secretary of the Interior.

- The Technical Work Group (TWG) which translates AMWG policy into information needs, provides questions that serve as the basis for long-term monitoring and research activities, and conveys research results to AMWG members.

- The U.S. Geological Survey (USGS) Grand Canyon Monitoring and Research Center (GCMRC), which provides scientific information on the effects of the operation of Glen Canyon Dam and related factors on natural, cultural, and recreational resources along the Colorado River between Glen Canyon Dam and Lake Mead.

- The independent review panels (IRPs), which provide independent assessments of the program to ensure scientific validity. Academic experts in pertinent areas make up a group of Science Advisors (SAs).

Consultation History

Reclamation and the FWS have completed a number of consultations related to the AMP. Important consultations are summarized briefly here; additional information on past consultations is also provided in the Environmental Baseline.

- May 25, 1978 – We issued a jeopardy biological opinion to Reclamation on the operation of Glen Canyon Dam on humpback chub, and stated that operations were limiting the recovery of the Colorado pikeminnow (squawfish) (*Ptychocheilus lucius*). The suggested alternative to eliminate jeopardy consisted of recommending that Reclamation fund four long-term studies on: (1) the potential impact of warming downstream releases from Glen Canyon Dam; (2) the ecological needs of endangered species between Glen Canyon Dam and Lake Mead; (3) methods of reducing or eliminating factors that limit native fish habitat (flow fluctuations and low temperatures), and (4) the relationship between mainstem and tributary habitats and their utilization by endangered species.

- January 7, 1995 – We issued a biological opinion to Reclamation that the implementation of the MLFF alternative was likely to jeopardize the continued existence of the humpback chub and razorback sucker and was likely to destroy or adversely modify their critical habitat, but was not likely to jeopardize the bald eagle, Kanab ambersnail and peregrine falcon. The biological opinion identified one reasonable and prudent alternative (RPA) containing four elements that were necessary to avoid jeopardizing the continued existence of the humpback chub and razorback sucker: (1) development of an adaptive management program that implements studies and recommendations to increase the likelihood of both survival and recovery of listed species; (2) development of a management plan for the Little Colorado River; (3) sponsoring a workshop for developing a management plan for razorback sucker in Grand Canyon; and (4) establishing a second spawning aggregation of humpback chub below Glen Canyon Dam.

- February 16, 1996 – We issued a biological opinion to Reclamation that a proposed high flow test at Glen Canyon Dam in March 1996 was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail and southwestern willow flycatcher, and was not likely to destroy or adversely modify humpback chub critical habitat, and included a conference opinion that the test was not likely to destroy or adversely modify proposed southwestern willow flycatcher critical habitat.

- October 30, 1997 – We issued a biological opinion to Reclamation that a proposed fall test flow at Glen Canyon Dam in November 1997 was not likely to jeopardize the continued existence of the humpback chub or Kanab ambersnail and was not likely to destroy or adversely modify designated critical habitat for the humpback chub.

- December 6, 2002 – We issued a biological opinion on a proposal by Reclamation, the National Park Service (NPS), and the USGS for: (1) experimental releases from Glen Canyon Dam, (2) mechanical removal of nonnative fish from the Colorado River in an approximately 9-mile reach in the vicinity of the mouth of the Little Colorado River to potentially benefit native fish, and (3) release of nonnative fish suppression flows having daily fluctuations of 5,000-20,000 cubic feet per second (cfs) from Glen Canyon Dam during the period January 1-March 31. We concluded the proposed action was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail, bald eagle, razorback sucker, California condor (*Gymnogyps califorianus*), and southwestern willow flycatcher.

- June 12, 2003 – We issued a biological opinion to modify an aspect of the proposed action from the December 6, 2002, biological opinion, specifically to alter some aspects of a conservation measure from that opinion to translocate young humpback chub to the reach of the Little Colorado River above Chute Falls. We concluded that this change in the proposed action was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail, bald eagle, razorback sucker, California condor, and southwestern willow flycatcher.

- August 12, 2003 – We issued a biological opinion to modify aspects of the proposed action from the December 6, 2002, biological opinion, including to extend the nonnative fish removal reach from 9 to 15 miles. We concluded that this change in the proposed action was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail, bald eagle, razorback sucker, California condor, and southwestern willow flycatcher.

- November 17, 2004 – We issued a biological opinion to modify aspects of the proposed action from the December 6, 2002, biological opinion, primarily to modify the timing of a high experimental flow event to occur in the Fall as early as November 15. We concluded that this change in the proposed action was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail, bald eagle, razorback sucker, California condor, and southwestern willow flycatcher.

- December 12, 2007 – We issued a biological opinion on the Shortage Guidelines which included actions within the geographic scope of the AMP, from Glen Canyon Dam to Lake Mead. The Shortage Guidelines specified a reduction of consumptive uses below Lake Powell during times of low reservoir conditions and modification of the annual release volumes from Lake Powell. We determined that implementation of the Shortage Guidelines was not likely to jeopardize the continued existence of the humpback chub, the southwestern willow flycatcher, or the Kanab ambersnail, and not likely to destroy or adversely modify designated critical habitat for the humpback chub or the southwestern willow flycatcher.

Specific events related to this reinitiated consultation on Glen Canyon Dam operations for the five-year experimental period are presented below.

- Fall 2007 – We met with Reclamation several times and conducted numerous telephone conversations to discuss specific aspects of the proposed action as they relate to this consultation.

- November 13, 2007 – We received Reclamation's request for formal consultation; we also responded with a memorandum initiating formal consultation.

- December 4, 2008 – Reclamation informally requested a species list for the consultation. December 5, 2007 – We sent Reclamation, via memorandum, a species list for the consultation.

- December 20, 2008 – We received a memorandum from Brenda Burman, Deputy Assistant Secretary's Designee to the AMWG, summarizing the Department of the Interior's considerations for an experimental high flow test in 2008 and responses of AMWG members in this regard.

- December 27, 2007 – We received Reclamation's biological assessment for the proposed action.

- February 14, 2008 – We sent a draft biological opinion to Reclamation.

BIOLOGICAL OPINION

DESCRIPTION OF THE PROPOSED ACTION

The proposed action is to continue MLFF releases as described in the 1995 EIS (U.S. Bureau of Reclamation 1995, 1996). Nothing in this proposed action would modify the annual volume of water released from Glen Canyon Dam, a determination made pursuant to the Shortage Guidelines, which were adopted via a ROD, signed by the Secretary of the Interior on December 13, 2007 (U.S. Bureau of Reclamation 2007b). As Reclamation implements the Shortage Guidelines ROD, MLFF flows will be released as provided in the 1996 ROD, which places constraints on allowable fluctuations of powerplant releases (Table 1). Exception criteria as outlined in the 1997 Glen Canyon Dam Operating Criteria would also continue.

As part of this experimental action, Reclamation also proposes to incorporate experimental flows that have been designed to benefit endangered humpback chub and conservation of sediment resources in Grand Canyon. The experimental proposed action is: (1) an experimental high flow test of approximately 41,500 cfs for a maximum duration of 60 hours in March 2008 (only one high flow test is proposed for the 5-year period), and (2) fall (September and October) steady flows over the next five years (2008-2012). The high flow test hydrograph will duplicate the November 2004 high flow test hydrograph and consists of the following elements:

- On the evening of March 4, 2008 (or other approximate date in early March 2008) the MLFF release pattern will increase at a rate of 1,500 cfs/hour until powerplant capacity is reached;

- Once powerplant capacity has been reached each of the four bypass tubes will be opened beginning on the morning of March 5, 2007, where once every three hours bypass releases will be increased by 1,875 cfs until all bypass tubes are operating at full capacity for a total bypass release of 15,000 cfs;

- An essentially constant flow of 41,500[1] cfs will be maintained for 60 hours, with flow changes less than 1,000 cfs/day;

- Discharge will then be decreased at a down-ramping rate of 1,500 cfs/hour until the normal powerplant releases scheduled for March have been reached[2].

The steady releases during September and October of 2008 through 2012 will include the following constraints:

- The typical monthly dam release volumes will be maintained in all water years except water year 2008, where reallocation of water would occur for the high flow test in March;

- The dam releases for September and October will be steady[3], with a release rate determined to yield the appropriate monthly release volume;

- If possible, the monthly dam release volumes should be managed and determined to produce similar volumes in the months of September and October (Tables 2 and 4).

Monthly dam release volumes during the period of the proposed action could vary depending on the annual water release volume, as determined by the Shortage Guidelines ROD. After 2012, releases would be made according to the 1996 ROD unless Reclamation proposes alternative experimental release patterns.

Water year 2008 monthly water release volumes would be adjusted to provide water for a March high flow test (Table 2), but this would not cause the annual release from Glen Canyon Dam in water year 2008 to change. Maximum releases during March 2008 under the proposed action would be approximately 41,500 cfs during the peak high experimental flows. Tables 3 and 4 provide monthly release volumes and mean, minimum, and maximum daily releases for 10th, 50th, and 90th percentiles determined for the Shortage Guidelines ROD (U.S. Bureau of Reclamation 2007b). The 7.48 maf release pattern corresponds to the 10th percentile category (dry hydrology), the 8.23 maf release pattern corresponds to the 50th percentile, and the 12.3 maf monthly release pattern (wet hydrology) corresponds to the 90th percentile volume for the period of the proposed action (2008-2012). All monthly volumes are modeled volumes and subject to change based on actual hydrology and operations.

Releases greater than 9.5 maf generally occur during periods of equalization of reservoir storage contents between Lake Powell and Lake Mead. Implementation of equalization and balancing

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[1] Maximum capacity value calculated from the November 24-Month Study projected March 2008 Lake Powell reservoir elevation of 3586 feet and interpolated from the maximum full gate turbine capacity for seven units. One of the powerplant units will be off-line for repairs and unavailable for use in the experiment.

[2] If this element of the proposed action is undertaken, implementation of the high flow experiment will not affect the annual volume of water released from Glen Canyon Dam during water year 2008.

[3] Regulation release capacity of +/- 1,200 cfs will be available if needed for hydropower system regulation within each hour during the steady flow periods. Also, spinning reserves will be available if needed for emergency response purposes.

will follow the Shortage Guidelines ROD. When operating in the equalization tier, the upper elevation balancing tier, or the lower elevation balancing tier, scheduled water year releases from Lake Powell will be adjusted each month based on forecasted inflow and projected September active storage at Lake Powell and Lake Mead, as discussed in the Shortage Guidelines ROD.

The high flow test is intended to create and improve eddy complexes including backwater habitats and beaches. With respect to potential benefits for native fish, the hypothesis to be tested is that widespread beach building and sediment retention will result from controlled releases from the dam under sediment-enriched conditions in Grand Canyon. It is also hypothesized that high releases from the dam will increase sandbar crest height, while increasing return channel depth through scouring. If these geomorphic changes occur as a result of the high flow test, greater and more persistent backwaters could be created, which may benefit conservation of the humpback chub and other native fish species by providing more of these productive nearshore habitats utilized by young fish.

Steadying flows during September and October is intened to cause backwater and other nearshore habitat used by young native and endangered fish to become more hydraulically stable, with potentially warmer water temperatures than would exist under regular MLFF operations. These changes could improve conditions for survival and growth of young-of-year (<90 mm total length [TL, 3.54 in]) and juvenile (90-199 mm [3.54-7.83 in] TL) humpback chub, by providing more persistent suitable habitat (depth and velocity over preferred substrates), and increased productivity of algal and invertebrate prey items for use by humpback chub.

Reclamation considers the high flow test and the steady fall releases experimental actions to better understand benefits to humpback chub and native fish. Hence, the evaluation of the high flow test will focus on benefits to shaping humpback chub habitat, especially nursery backwaters, and the possible downstream transport of young-of-year and juvenile humpback chub. Evaluation of the steady fall flow is important to better understand the contrast between fluctuating flows and steady flows with respect to the extent of longitudinal warming, warming of shoreline habitats and nursery backwaters, stability of shoreline habitats, and the effect on humpback chub survival, growth, and bioenergetic expenditure. Full evaluation of this aspect of the proposed action is important to better understand how such test flows affect humpback chub and long-term species conservation. There is a high likelihood that dam releases during this proposed five-year experiment will be cool or cold. If so, this experiment also could provide the opportunity to contrast recent years of cool to warm release temperatures (2003-2005) with cool to cold release temperatures during the test period.

The purpose of the experimental high flow test is to take advantage of large amounts of sediment available in Marble and Grand canyons that currently exist, due to storm events and tributary inflow and sediment inputs in 2006 and 2007, in order to further analyze, through a high flow test, the effectiveness of such an approach to protect and improve downstream resources in Grand Canyon.

Following the proposed experimental high flow test, data collected during the test will be analyzed, as well as information collected during the previous 1996 and 2004 high flow experiments, along with other information, in order to develop predictive models and other analytical tools to better inform future decision making regarding dam operations and other related management actions, as described in the Science Plan for Potential 2008 Experimental

High Flow at Glen Canyon Dam (U.S. Geological Survey 2007a). The proposed action does not include any additional experimental high flow testing, and none will be implemented until the information from the 2008 high flow test is fully analyzed, presented to the Adaptive Management Work Group and the general public and can be integrated into an appropriate analytical framework based on predictive models and other analytical tools.

The experimental high flow test will build on extremely favorable sediment conditions afforded by recent high-volume 2006-2007 sediment inputs into Grand Canyon below Glen Canyon Dam. The high flow experiment will not modify, in any manner, the current long-term management approach to implementation of "beach-habitat building flows" as described in section 3 of the Operating Criteria for Glen Canyon Dam, published at 62 FR 9447 (March 3, 1997). As provided in section 3 of the Operating Criteria, in adopting the management approach for "beach-habitat building flows" the Secretary found that releases pursuant to such an approach "are consistent with the 1956 Colorado River Storage Project Act, the 1968 Colorado River Basin Project Act, and the 1992 Grand Canyon Protection Act." Id. While no modification is proposed or anticipated at this time, any future potential modification of the 1996 ROD or 1997 Glen Canyon Dam Operating Criteria would only occur after public review, comment and consultation, as well as any required environmental compliance efforts.

Conservation Measures

Reclamation has included the following conservation measures for listed species in the action area as part of its proposed action. As described above, the AMP provides a process for assessing the effects of current operations of Glen Canyon Dam on downstream resources and using the results to develop recommendations for modifying dam operations and other resource management and conservation actions. The AMP also provides for long-term monitoring and research activities to evaluate the effectiveness of the operational modifications to Glen Canyon Dam and other management actions. Many of the conservation measures listed below have already been occurring through the AMP at various levels. We believe conservation measures carried out through the AMP have resulted in significant conservation benefits to humpback chub and Kanab ambersnail. The existence of the AMP and the history of conservation of these species through the AMP serve to substantiate that the following conservation measures will be implemented as proposed by Reclamation. Implementation of some of these conservation measures may require additional compliance. FWS is currently investigating the feasibility of developing a recovery program for humpback chub in Grand Canyon. All of the conservation measures listed here could fall under such a program. Agreements would need to be developed to facilitate cost sharing with other agencies and organizations, both within and outside of the AMP, to fully implement a recovery program.

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 m^2 [180 ft^2]) 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.

Action Area

The action area for this proposed action is the Colorado River corridor from Glen Canyon Dam in Coconino County, Arizona downstream to Separation Canyon, Mohave County, Arizona at and below the 41,500 cfs stage level of the Colorado River, as shown in Figure 1. Below Separation Canyon, ESA compliance is not addressed within the AMP but within the Lower Colorado River Multi-Species Conservation Program (MSCP; U.S. Fish and Wildlife Service 2005a). The MSCP addresses Section 7 and Section 9 responsibilities for areas up to and including the full-pool elevation of Lake Mead, and downstream areas along the Colorado River within the U.S.

STATUS OF THE SPECIES AND CRITICAL HABITAT

Humpback chub

The humpback chub was listed as endangered on March 11, 1967 (32 FR 4001). Critical habitat for humpback chub was designated in 1994. Seven reaches of the Colorado River system were designated as critical habitat for humpback chub for a total river length of 379 miles in the Yampa, Green, Colorado, and Little Colorado rivers in Arizona, Colorado and Utah. Known constituent elements include water, physical habitat, and biological environment as required for each life stage (59 FR 13374; U.S. Fish and Wildlife Service 1994). Water includes a quantity of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, and turbidity) that is delivered to a specific location in accordance with a hydrologic regime that is required for the particular life stage. Physical habitat includes areas of the Colorado River for use in spawning, nursery, feeding, and rearing or corridors to these areas. The biological environment includes food supply and habitats with levels of nonnative predators and competitors that are low enough to allow for spawning, feeding, and rearing.

The humpback chub is a medium-sized freshwater fish (to about 20 inches) of the minnow family, Cyprinidae. The adults have a pronounced dorsal hump, a narrow flattened head, a fleshy snout with an inferior-subterminal mouth, and small eyes. It has silvery sides with a brown or olive-colored back. The humpback chub is endemic to the Colorado River Basin and is part of a native fish fauna traced to the Miocene epoch in fossil records (Miller 1955, Minckley et al. 1986). Humpback chub remains have been dated to about 4000 B.C., but the fish was not described as a species until the 1940s (Miller 1946), presumably because of its restricted distribution in remote whitewater canyons (U.S. Fish and Wildlife Service 1990). Because of this, its original distribution is not known.

Populations of this species occur in the Little Colorado and Colorado rivers in the Grand Canyon, Black Rocks area of the Colorado River, Westwater Canyon, Cataract Canyon, Desolation/Grey Canyon, and Yampa Canyon (Valdez and Clemmer 1982, U.S. Fish and Wildlife Service 1990, 2002a). The largest population in the upper basin is in Westwater Canyon, with an estimated population size of about 2,400 adult fish (age 4+; ≥ 200 mm [7.87 in] TL); humpback chub are currently rare in the Yampa River and in Cataract Canyon (Finney et al. 2004, McAda 2004, Jackson 2004a, 2004b, and Utah Division of Wildlife Resources 2004). In Grand Canyon, adult population estimates based on the ASMR model ranged from 10,000-11,000 in 1989 to 3,100-4,400 in 2001 (Coggins et al. 2006). However, between 2001 and 2006, numbers of adult fish, based on newer analyses using the ASMR model, appear to have increased from about 4,500-5,700 in 2001 to an estimated 5,300-6,700 in 2006 (Coggins 2007).

Adult humpback chub occupy swift, deep, canyon reaches of river (Valdez and Clemmer 1982, Archer et al. 1985, Valdez and Ryel 1995), with microhabitat use varying among age-groups (Valdez et al. 1990). Within Grand Canyon, adults demonstrate high microsite fidelity and occupy main channel eddies, while subadults use nearshore habitats (Valdez and Ryel 1995, Robinson et al. 1998, Stone and Gorman 2005). Young-of-year humpback chub use shoreline talus, vegetation, and backwaters typically formed by eddy return current channels (Arizona Game and Fish Department (AGFD) 1996). These habitats are usually warmer than the main channel especially if they persist for a long time and are not inundated or desiccated by fluctuating flows (Stevens and Hoffnagle 1999). Subadults also use shallow, sheltered shoreline habitats but with greater depth and velocity (Valdez and Ryel 1995, Childs et al. 1998).

Valdez and Ryel (1995, 1997) reported on adult humpback chub habitat use in the Colorado River in Grand Canyon. They found that adults used primarily large recirculating eddies, occupying areas of low velocity adjacent to high-velocity currents that deliver food items. Adults also congregated at tributary mouths and flooded side canyons during high flows. Adults were found primarily in large recirculating eddies disproportionate to their availability, with lesser numbers found in runs, pools, and backwaters. Hoffnagle et al. (1999) reported that juveniles in Grand Canyon used talus shorelines at all discharges and apparently were not displaced by a controlled high flow test of 45,000 cfs in late March and early April, 1996. Valdez et al. (1999) also reported no displacement of radiotagged adults, with local shifts in habitat use to remain in low-velocity polygons within large recirculating eddies.

As young humpback chub grow, they exhibit an ontogenic shift toward deeper and swifter offshore habitats that usually begins at age 1 (about 100 mm [3.94 in] TL) and ends with maturity at age 4 (≥200 mm [7.87 in] TL; Valdez and Ryel 1995, 1997, Stone and Gorman 2005). Valdez and Ryel (1995, 1997) found that young humpback chub (21–74 mm [0.83-2.91 in] TL) remain along shallow shoreline habitats throughout their first summer, at water velocities of 0.0, 0.06, and 0.30 m/s and at depths less than 1 m, and shift to more offshore habitats as they grow larger (75–259 mm [2.95-10.20 in] TL) by fall and winter, into deeper habitat with water velocities of 0.0, 0.18, and 0.79 m/s (0.0, 0.59, 2.6 ft/s), respectively, and at depths up to 1.5 m (4.9 ft). Stone and Gorman (2005) found similar results in the Little Colorado River, finding that humpback chub undergo an ontogenesis from diurnally active, vulnerable, nearshore-reliant young-of-year (30–90 mm [1.81-3.54 in] TL) into nocturnally active, large-bodied adults (180 mm [7.09 in] TL), that primarily reside in deep midchannel pools during the day, and move inshore at night.

Movement of adult humpback chub is substantially limited compared to other native Colorado River fishes (Valdez and Ryel 1995). Adults have a high fidelity for site-specific habitats in the Colorado River and generally remain within a 1-km (0.6 mi) area, except during spawning ascents of the Little Colorado River in spring. Adult radio-tagged humpback chub demonstrated a consistent pattern of greater near-surface activity during the spawning season and at night, and day-night differences decreased during moderate to high turbidity.

The humpback chub is an obligate warm-water species that requires relatively warm temperatures of about 16-22 °C (61-72 °F) for spawning, egg incubation, and survival of young. Spawning is usually initiated at about 16 °C (61 °F)(Hamman 1982). Highest hatching success is at 19–20 °C (66-68 °F) with incubation time of 3 days, and highest larval survival is slightly warmer at 21–22 °C (70-72 °F)(Marsh 1985). Hatching success under laboratory conditions was 12 percent, 62 percent, 84 percent, and 79 percent in 12–13 °C (54-54 °F), 16–17 °C (61-63 °F), 19–20 °C (66-68 °F), and 21–22 °C (70-72 °F), respectively, whereas survival of larvae was 15 percent, 91 percent, 95 percent, and 99 percent, at the same respective temperatures (Hamman 1982). Time from fertilization to hatching ranged from 465 hours at 10 °C (50 °F) to 72 hours at 26 °C (79 °F), and time from hatching to swim-up varied from 372 hours at 15 °C (59 °F) to 72 hours at 21–22 °C (70-72 °F). The proportion of abnormal fry varied with temperature and was highest at 15 °C (59 °F) (33 percent) and was 17 percent at 25 °C (77 °F). Marsh and Pisano (1982) also found total mortality of embryos at 5, 10, and 30 °C (41, 50, 86 °F). Bulkley et al. (1981) estimated a final thermal preference of 24ºC (75 °F) for humpback chub during their first year of life (80–120 mm [3.2-4.72 in]).

Humpback chub are broadcast spawners with a relatively low fecundity rate compared to cyprinids of similar size (Carlander 1969). Eight humpback chub (355–406 mm [14.0-16.0 in] TL), injected with carp (*Cyprinus carpio*) pituitary and stripped in a hatchery, produced an average of 2,523 eggs/female, or about 5,262 eggs/kg of body weight (Hamman 1982). Egg diameter ranged from 2.6 to 2.8 mm (0.10-0.11 in; mean, 2.7 mm [0.11 in]). Eleven humpback chub from the Little Colorado River (LCR) yielded 4,831 eggs/female following variable injections of carp pituitary and field stripping (Clarkson 1993).

Humpback chub in Grand Canyon spawn primarily during March–May in the lower 13 km of the Little Colorado River (Kaeding and Zimmerman 1983, Minckley 1996, Gorman and Stone 1999, Stone 1999) and during April–June in the upper basin (Kaeding et al. 1990, Valdez 1990, Karp and Tyus 1990). Most fish mature at about 4 years of age. Gonadal development is rapid between December and February to April, at which time somatic indices reached highest levels Kaeding and Zimmerman (1983). Adults stage for spawning runs in large eddies near the confluence of the Little Colorado River in February and March and move into the tributary from March through May, depending on temperature, flow, and turbidity (Valdez and Ryel 1995). Spawning has not been observed, but ripe males have been seen aggregating in areas of complex habitat structure (boulders, travertine masses, and other sources of angular variation) associated with deposits of clean gravel, and it is thought that ripe females move to these aggregations to spawn (Gorman and Stone 1999). Habitats where ripe humpback chub have been collected are typically deep, swift, and turbid. As a result, spawning in the wild has not been directly observed. Abrasions on anal and lower caudal fins of males and females in the LCR and in Cataract Canyon (Valdez 1990) suggest that spawning involves rigorous contact with gravel substrates.

At hatching, larvae have nonfunctional mouths and small yolk sacs (Muth 1990). Robinson et al. (1998) found larvae drifting in the LCR from April through June, and evidence suggesting that larvae actively disperse to find suitable nearshore habitats. Robinson et al. (1998) quantified numbers of larval humpback chub that are transported by LCR flows into the mainstem, and Robinson et al. (1998) and Stone and Gorman (2005) suggested that daily fluctuations in the mainstem river may reduce the quality of nearshore habitat for young-of-year and juvenile humpback chub, which may be particularly important during the monsoon period (July to November) when storms cause floods in the LCR, displacing large numbers of young humpback chub into the mainstem (GCMRC unpubl. data). Pre-dam annual peak Colorado River flows (April–July) ponded canyon-bound tributary mouths (Howard and Dolan 1981), including the LCR. Robinson et al. (1998) theorized that because ponding probably retained drifting larvae or slowed their passage, it probably allowed greater time for development in a warm, low-velocity environment. Without this ponding effect, presumably more young-of-year and juvenile humpback chub are likely transported into a now-harsher mainstem river while still at a size that is more vulnerable to thermal shock and predation.

Humpback chub attain a maximum size of about 480 mm (18.9 in) TL and 1.2 kg (2.6 lbs.) in weight (Valdez and Ryel 1997) and can live to be 20-30 years old (Hendrickson 1993). Humpback chub grow relatively quickly at warm temperatures until maturity at about 4 years of age, then growth rate slows substantially. Humpback chub larvae are approximately 7 mm (0.30 in) long at hatching (Muth 1990). In a laboratory, post-larvae grew at a rate of 10.63 mm (0.419 in)/30 days at 20 °C (68 °F), but only 2.30 mm (0.090 in)/30 days at 10 °C (50 °F)(Lupher and Clarkson 1994). Similar growth rates were reported from back-calculations of scale growth rings in wild juveniles at similar water temperatures from the Little Colorado River (10.30 mm (0.406 in)/30 days at 18–25 °C (64-77 °F)) and the mainstem Colorado River in Grand Canyon (3.50–4.00 mm (0.138-0.157 in)/30 days at 10–12 °C (50-54 °F); Valdez and Ryel 1995). Clarkson and Childs (2000) found that lengths, weights, and specific growth rates of humpback chub were significantly lower at 10 °C and 14 °C (50-57 °F; similar to hypolimnetic dam releases) than at 20 °C (68 °F; i.e., more characteristic of Little Colorado River temperatures during summer months).

Hendrickson (1993) aged humpback chub from the Little Colorado River and the mainstem Colorado River in Grand Canyon and showed a maximum of 23 annular rings. Based on polynomial regression of average number of annuli from otoliths (lapillus and asteriscus) and opercles, age-3 fish were 157 mm (6.18 in) TL and age-4 fish were 196 mm (7.72 in) TL. Valdez and Ryel (1995) recorded size at first observed maturity (based on expression of gametes, presence of spawning tubercles) of humpback chub in Grand Canyon at 202 mm (7.95 in) TL for males and 200 mm (7.87 in) TL for females; computed length of age-4 fish with a logarithmic growth curve was 201 mm (7.91 in) TL.

Humpback chub are typically omnivores with a diet consisting of insects, crustaceans, plants, seeds, and occasionally small fish and reptiles (Kaeding and Zimmerman 1982, Kubly 1990, Valdez and Ryel 1995). 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. Valdez and Ryel (1995) examined diets of humpback chub in Grand Canyon. Guts of 158 adults from the mainstem Colorado River, flushed with a nonlethal stomach pump, had 14 invertebrate taxa and nine terrestrial taxa, including simuliids (blackflies, in 77.8 percent of fish), chironomids (midges, 57.6 percent), Gammarus (freshwater shrimp, 50.6 percent), Cladophora (green alga, 23.4 percent), Hymenoptera (wasps, 20.9 percent), and cladocerans (water fleas, 19.6 percent). Seeds and human food remains were found in eight (5.1 percent) and seven (4.4 percent) fish respectively.

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), competition with and predation by nonnative fish species, parasitism, hybridization with other native *Gila*, and pesticides and pollutants (U.S. Fish and Wildlife Service 2002a). Streamflow regulation, in general, eliminates flows and temperature needed for spawning and successful recruitment, which is exacerbated by predation and competition from nonnative fishes. In Grand Canyon, brown trout (*Salmo trutta*), channel catfish (*Ictalurus punctatus*), black bullhead (*Ameiurus melas*), and rainbow trout (*Oncorhychus mykiss*) 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). Valdez and Ryel (1997) also suggested that common carp could be a significant predator of incubating humpback chub eggs in the LCR. In the upper basin, channel catfish have been identified as the principal predator of humpback chub in Desolation/Gray Canyons (Chart and Lentsch 2000), and in Yampa Canyon (U.S. Fish and Wildlife Service 2002a). Smallmouth bass (*Micropterus dolomieu*) have also become a significant predator in the Yampa River (T. Chart, FWS, pers. comm., 2007). Parasitism, hybridization with other native *Gila*, and pesticides and pollutants are also factors in the decline (U.S. Fish and Wildlife Service 2002a).

Many section 7 consultations have occurred on the humpback chub in both the upper and lower basins of the Colorado River. Activities that continue to adversely affect the humpback chub and its habitat throughout its range include dam operations, recreation, land uses that impact water quality, and the presence of nonnative species. However many surveys, and numerous projects to improve the species status, such as translocation and nonnative species removal, have occurred for the species. Although the recovery goals for humpback chub that amend and supplement the 1990 Recovery Plan (U.S. Fish and Wildlife Service 2002a) are currently in revision, the document provides a complete discussion of the taxonomy, distribution, and life history of the species.

Kanab ambersnail

The Kanab ambersnail was listed as an endangered species without critical habitat in 1992 (57 FR 13657). The species is undergoing a 5-year review by the FWS, including a genetic evaluation of the species relatedness to other *Oxyloma*.

The genus *Oxyloma* has a broad distribution (North America, Europe and South Africa) with two species recognized in the southwestern United States: *O. retusa* in New Mexico and *O. haydeni* in Arizona and Utah. Within *O. haydeni* there are two subspecies, the Niobrara ambersnail (*O. h. haydeni*) and the Kanab ambersnail (*O. h. kanabensis*), both of which are found in Arizona and Utah. Populations of Kanab ambersnail presently occur from only four springs: two near

Three Lakes, near Kanab, Utah, and two in Grand Canyon National Park, Arizona, one at a spring and hanging garden at River Mile (RM, as defined in Stevens 1983) 31.5 known as Vaseys Paradise, and a translocated population at Upper Elves Chasm, at RM 116.6 (Sorensen 2005). A third population in the Kanab area, near "the Greens," a seep-fed marsh, was believed to be lost due to dewatering in the last decade (U.S. Fish and Wildlife Service 1995a). The remaining populations near Three Lakes are located on private lands at several small spring-fed ponds on cattail (*Typha* sp.).

The population at Elves Chasm was created via translocation of snails from Vaseys Paradise. In 1998, the AGFD in coordination with the NPS, translocated snails to three sites in Grand Canyon National Park: Elves Chasm, Keyhole Spring, and Deer Creek. Although Elves Chasm was the only successful translocation, it has shown success including recruitment, overwinter survival, and increased density of snails (Sorensen and Nelson 2002). Recently Kanab ambersnail has become rare at Elves Chasm, although the species remains abundant at Vaseys Paradise (J. Sorensen, AGFD, pers comm., 2007).

The Kanab ambersnail is dependent upon wetland vegetation for food and shelter, living in association with wetland plants including watercress (*Nasturtium*), monkeyflower (*Mimulus*), cattails, sedges (*Carex* spp.), and rushes (*Juncus* spp.). Stevens et al. (1997) found that Kanab ambersnail populations in the Grand Canyon region occur in areas where water sources originate from limestone or sandstone geologic strata. Kanab ambersnail at Vaseys Paradise predominantly use crimson monkeyflower and water-cress for food and shelter (Stevens et al. 1997a). The other Grand Canyon population, Upper Elves Chasm, is located above the 100,000 cfs stage of the river and is characterized by predominately crimson monkeyflower and maidenhair fern (*Adiantum capillus-veneris*), with lesser amounts of sedges, rushes, cattails, water-cress, helleborine orchids (*Epipactis gigantea*) and grasses (Poaceae)(Sorensen and Nelson 2002). From evidence collected in laboratory conditions, microclimatic conditions such as higher humidity and lower air temperatures relative to the surrounding environments and high vegetative cover may be important habitat features related to Kanab ambersnail survival (Sorenson and Nelson 2002).

Kanab ambersnails are hermaphroditic and capable of self-fertilization (Pilsbry 1948, Clarke 1991). Mature Kanab ambersnail mate and reproduce during the summer months (July and August), and deposit clear, gelatinous egg masses on undersides of moist to wet live stems, on the roots of water-cress, and on dead stems of crimson monkey-flower (Stevens et al. 1997a). In some years with relatively warm winters, more than one reproductive period can occur. Adult mortality increases in late summer and autumn leaving the overwintering population dominated by subadults. Young snails enter dormancy in October-November and typically become active again in March-April. Over-winter mortality of Kanab ambersnail can range between 25 and 80 percent (Stevens et al. 1997a & 1997b). Kanab ambersnail feed on plant tissue, bacteria, fungi and algae that are scraped off of dead plant tissue by means of a radula or rasp tongue. Stevens et al. (1997b) observed Kanab ambersnail feeding largely on crimson monkey-flower and water-cress.

Ongoing taxonomic studies indicate that although the population at Vaseys Paradise appears to be unique, the taxon itself may not be valid. Mitochondiral and cellular (microsatelite) DNA analysis indicates that the Kanab ambersnail may be part of a larger taxonomic group. However, these results are preliminary; the study is ongoing and should be completed in 2008 (M. Culver, University of Arizona, pers. comm. 2007).

Numerous biological opinions have been completed on the Kanab ambersnail. Most of these have been on the Grand Canyon population addressing the effects of experimental flows from Glen Canyon Dam. Activities that continue to adversely affect the Kanab ambersnail include water use, dam operations, and recreation-related trampling. However, many surveys, several research projects, and habitat salvage projects have occurred for the species. Stochastic events also continue to affect the distribution, quality, and extent of Kanab ambersnail habitat, predominantly drought.

ENVIRONMENTAL BASELINE

The environmental baseline includes past and present impacts of all Federal, State, or private actions in the action area, the anticipated impacts of all proposed Federal actions in the action area that have undergone formal or early section 7 consultation, and the impact of State and private actions which are contemporaneous with the consultation process. The environmental baseline defines the current status of the species and its habitat in the action area to provide a platform to assess the effects of the action now under consultation.

Status of the species and critical habitat within the action area

Humpback Chub and its Critical Habitat

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 LCR, constituting the Grand Canyon population, which also represents the lower basin recovery unit (U.S. Fish and Wildlife Service 2002a). 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 of the LCR 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 are present and functional throughout designated critical habitat in the action area, primarily in the LCR; 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 Granite Spring Canyon (221.0).

The Grand Canyon population consists primarily of adults residing in and near the LCR, 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); LCR 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 (AGFD 2006). The LCR 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 LCR Inflow aggregation, to the overall Grand Canyon population are not known, but is thought to be small.

The relationship between fish in the LCR inflow area and the LCR is uncertain; Douglas and Marsh (1996) suggested that two populations exist: one resident population in the LCR and one that migrates between the LCR and LCR inflow reach. However, Gorman and Stone (1999) suggested that the majority of adult humpback chub larger than 300 mm [11.81 in] TL live in the LCR inflow reach except during the spawning migration. Movement between the LCR, the LCR inflow, and other mainstem aggregations has been documented, although most movement is between the LCR and the LCR inflow, with less movement between the other mainstem aggregations (Paukert et al. 2006).

Douglas and Douglas (2007) 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. The Little Colorado River population would be the primary source, but contribution from occasional local reproduction by mainstem aggregates cannot be excluded. The 30-mile aggregation in Marble Canyon was recorded as having two individuals 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. Douglas and Douglas (2007) recommended further study of the 30-mile aggregation to evaluate the potential distinctiveness of these fish.

Coggins et al. (2006) summarized information on abundance and analyzed monitoring data collected since the late 1980s and found that data from all sources using various methods consistently indicated that the adult population had declined since monitoring began. 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. ASMR results suggest a peak in recruitment in the late 1970s to early 1980s of 13,500-18,500 age-2 fish. After that peak, an overall decline was evident to the early 1990s, when annual recruitment stabilized at about 2,000 age-2 fish (Coggins et al. 2006). Recent ASMR analyses indicate that the Grand Canyon population appears to have increased from about 4,500-5,700 in 2001 to an estimated 5,300-6,700 in 2006 (USGS 2007, Figure 2). While the recent increase in population size and stability 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 et al. 2007). 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.

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, Figure 3). 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 (Ackmerman 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 LCR (mean = 67 mm [2.64 in] TL), indicate that the natal source is upstream of RM 50 and not from the LCR. The causes for these recent increases in young humpback chub in the mainstem Colorado River are uncertain, but declines in nonnative trout over this same 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 LCR 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, AGFD 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 LCR 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 mainstream aggregations since 1993 (Trammell et al. 2002).

The range and size of the LCR Inflow aggregation has also increased as a result of a conservation measure for humpback chub to minimize adverse effects of the 2002 proposal for experimental flows and nonnative fish suppression. 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 and downstream movement below Chute Falls has also been documented (Stone 2006). The Chute Falls aggregation now appears to be a source of recruitment to the lower portions of the Little Colorado River and the mainstem Colorado River (Stone 2007).

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 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 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).

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 (U.S. Bureau of Reclamation 1996). Necessary to maximize the value of hydropower generation, 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 create dramatic changes in diurnal river stage, 2 meters (m, 6.6 ft) or greater 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; Glen Canyon Dam releases hypolimnetic water (the deeper layer of the reservoir) with a relatively constant temperature which ranges from 6-8 °C at high reservoir levels (43-46 °F), 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 1990). More than 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 10 miles of the LCR. The LCR 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. During floods, the LCR carries large sediment loads and is extremely turbid. Water temperatures range from near freezing to about 25 °C (77° F). At low flow, the middle

LCR at Cameron is dry, with flow in the lower river supplied entirely by Blue Springs, about 12.5 miles upstream from the confluence.

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) 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 LCR 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 are relatively constant at 6-8 °C (43-46 °F), they are influenced by lake elevation, inflow hydrology, and to a lesser extent, release volumes and meteorological conditions. Release temperatures have varied from 7 to 16 °C (45-60 °F) through 2006. Between 1999 and 2005, Lake Powell elevations dropped more than 140 feet as a result of a basin-wide drought. While winter release temperatures remained cold, Glen Canyon Dam release temperatures increased to 16 °C (60 °F) in the fall of 2005. The drop in Lake Powell elevation 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. However, current reservoir level, though low, is high enough that releases are cold, and Reclamation predicts that reservoir levels will remain high and release temperatures 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 2007a).

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 (AGFD 1996). Hoffnagle (1996) found that mean, minimum, maximum and diel range 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.

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).

Reductions in sediment supply have likely reduced the number and quality of nearshore habitats such as backwaters that young humpback chub utilize as nursery habitats. Glen Canyon Dam and Lake Powell trap most of the sediment transported by the Colorado River. 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.

The high flow tests of 1996 and 2004 were found effective at building or rebuilding sandbars, although persistence of the sandbars is variable. 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 2007a). Together with inputs from the Little Colorado River in 2006 and unexpected retention of sediment from both tributaries during 2006, sand inputs are currently at least 3 times the amount that triggered the 2004 high flow test, and greater than since at least 1998 (U.S. Geological Survey 2007a). This presents a unique opportunity to evaluate effects of a high flow test under sand-enriched conditions greater than ever tested before.

Backwaters are thought to be important rearing habitat for native fish due to low water velocity, warm water and high levels of biological productivity. 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. Reattachment sandbars are the primary geomorphic feature which functions 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 LCR (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 LCR 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 tend 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 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).

Biologically, 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.

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 m^2 (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.

Nonnative fish species have been present in the lower Colorado River, and likely in Grand Canyon, for over a century (Mueller and Marsh 2002). 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 suggested that common carp could be a significant predator of incubating humpback chub eggs in the LCR.

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 LCR (Van Haverbeke 2006) but can occur in the mainstem, especially downstream of the confluence of the LCR (Johnstone and Lauretta 2007). These small-bodied species may be important predators and competitors of young humpback chub.

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 LCR has recently been documented (Stone et al. 2007)

Below the Little Colorado River, rainbow trout numbers drop dramatically, although brown trout are common near Bright Angel Creek where they spawn and maintain a resident tributary population. Warm-water species such as common carp, channel catfish, and fathead minnow increase in numbers downstream of the Little Colorado River and are most abundant between Shinumo and Diamond creeks (Ackerman 2007). Red shiner and plains killifish are common in backwaters immediately below the Little Colorado River and occur sporadically downstream from that point (Lauretta and Serrato 2006, Johnstone and Lauretta 2007).

The Grand Canyon fish community has 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, AGFD 2006, Lauretta and Serrato 2006, Ackerman 2007). Electrofishing catch rates of flannelmouth (*Catostomus latipinnis*) and bluehead suckers (*Pantosteus discobolus*) have increased four to six-fold in the past seven years, whereas trout catch rates have correspondingly declined (AGFD 2006); 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 are 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 than average water temperatures, although the decline of coldwater salmonid competitors (due to mechanical removal or temperature increases) also has been implicated (USGS 2006, Ackerman 2007).

Recent declines in trout abundance in the Lees Ferry tailwater are attributed less to increased daily fluctuations during 2003-2005 and more to increased water temperatures and trout metabolic demands coupled with a static or declining food base, periodic oxygen deficiencies and nuisance aquatic invertebrates (New Zealand mudsnails; *Potamopyrgus antipodarum*). Whirling disease was discovered in the rainbow trout population below Glen Canyon Dam in June of 2007. Additionally, highly invasive quagga mussels (*Dreissena* sp.) were discovered in Lake Powell 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. Kennedy (2007) performed a risk assessment on establishment potential of quagga mussels in the Colorado River below Glen Canyon Dam, concluding that there is low risk of these mussels becoming established in high densities in the Colorado River or its tributaries below Lees Ferry. In contrast, conditions in the clear tailwater reach 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 river), which indicates that the LCR 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 mainstream, respectively (Valdez 1994, Valdez et al. 1995). Other common fish species found below Bridge

Canyon Rapid include the 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 part of the decline is attributed to warmer main channel temperatures and higher daily flow fluctuations (GCMRC unpublished data). 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.

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, as both trout species experienced a considerable system-wide decline in abundance between the two removal periods.

Multi-pass backpack electrofishing was also 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 (ca. 1-2 y) fulfillment of baseline information needs followed by implementation of longer-term (8+ y) nonnative fish control and management programs.

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 mainstream 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).

A number of actions have been undertaken and are continuing under the auspices of the Glen Canyon Dam Adaptive Management Program to benefit the Grand Canyon population of humpback chub, including the AMP itself, its charter renewed in 2006. The AMP continues to provide a high level of monitoring and research on the Grand Canyon population of humpback chub, via the Grand Canyon Monitoring and Research Center. Annual mark-recapture monitoring of the species provides accurate estimates of population size of adult and sub-adult (150-199 mm TL [5.9-7.83 in]) humpback chub (Coggins 2007), important information for tracking progress on recovery (U.S. Fish and Wildlife Service 2002). Research and monitoring of native fishes in Grand Canyon, as well as their predators, competitors, diseases, and parasites is being carried out largely under the auspices of the GCMRC with funding provided by the AMP. Much of the research and monitoring work accomplished through GCMRC is accomplished through competitive proposals that are peer-reviewed by independent scientists. Results of this work are presented on a regular basis at TWG and AMWG meetings, and are published as reports and peer-reviewed articles in technical journals. Research on life history requirements, habitat needs, effects of dam operations, parasitism, predation, effects of handling stress, and numerous conservation actions described further below all continue (U.S. Geological Survey 2007b). Effects of these actions and experiments on fish populations and on the Grand Canyon ecosystem and are summarized in this section and in the Effects of the Action section.

In January 2003, the AMWG directed that an ad hoc committee be formed with the responsibility of developing a comprehensive plan for future research, monitoring, and management of the endangered fish. In August 2003, the humpback chub Ad Hoc Committee delivered the plan to the Science Advisors and then to AMWG, and the plan was used to fund projects in the 2004 and 2005 fiscal years. The plan, now referred to as the Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon, is presently being revised by the humpback chub Ad Hoc Committee and will be resubmitted to AMWG after projects are assessed by an AMWG ad hoc committee to determine which of them would be recommended for inclusion in the AMP.

Other aspects of the adaptive management planning process for humpback chub include development of a Strategic Science Plan, Core Monitoring Plan, several Beach Habitat Building Science Plans, and a study plan for the 2000 Low Steady Summer Flows and Nonnative Fish Mechanical Removal protocols. Many of these efforts are presently ongoing. In May and July of 2005, workshops to assess the knowledge gained through the AMP were conducted in Phoenix and Flagstaff, Arizona, respectively (Melis et al. 2005). At the workshops all aspects of the AMP were evaluated and assessed for the level of science and knowledge that had been gained to date. The workshops and resulting publications also helped to define and refine research questions and to prioritize research projects in the future on all aspects or resource management authority of the AMP including humpback chub. A science symposium was also conducted on October 25–27, 2005, (Gloss et al. 2005), providing a further synthesis of research and monitoring in the Colorado River ecosystem for the years 1991-2004.

Reclamation and the AMP conducted the first high flow experiment in March-April 1996, a week-long, 45,000 cfs beach habitat-building flow. Objectives were to rebuild high-elevation sandbars, restore backwater channels, retain fine silts and clays, restore the pre-dam disturbance regime, preserve and restore camping beaches, displace nonnative fishes, scour vegetation from camping beaches, and protect cultural resources, all without significant adverse impacts to endangered species, cultural resources, the Lees Ferry trout fishery, or hydropower production. Results of the 1996 experimental flood were documented by Webb et al. (1999), and are described in this section and in the Effects of the Action section.
In 1997, a fall flow test consisting of a powerplant release of 31,000 cfs for 48 hours was conducted.

In 1999, Reclamation funded a contractor to convene a panel of experts to develop a program of experimental flows for endangered and native fishes of the Colorado River in Grand Canyon (Valdez et al. 2000a). As part of this program, the third large experiment conducted by the AMP was an experimental flow for native fishes from March-September 2000. Flow components included: (1) short-term 8,000 cfs initiating the study for aerial photography; (2) stable, spring flows of 14,000-19,000 cfs to measure hydraulics and water temperatures at the mouth of the Little Colorado River; (3) spring and autumn powerplant capacity spike flows; (4) an extended period of 8,000 cfs during May, June, July, and August; and (5) a period of 8,000 cfs steady flows following the autumn spike flow to measure its effects and to conduct a second round of aerial photography. In October 2003 GCMRC convened a science symposium that was largely directed at presentation of results from the low summer steady flows (LSSF) research and monitoring. Effects of the experiment on fish populations were documented by Trammell et al. (2002), Rogers et al. (2003) and Speas et al. (2004), and are summarized in this section and in the Effects of the Action section.

In September 2002, Reclamation completed the Environmental Assessment on Proposed Experimental Releases from Glen Canyon Dam and Removal of Nonnative Fish (U.S. Bureau of Reclamation 2002), which proposed a program of experimental flows and nonnative fish removal. Mechanical removal of nonnative fish from the Colorado River above and below the LCR was started in January 2003 (Coggins and Yard 2003) and was continued through 2006. Rainbow trout and brown trout were removed from a 10-mile reach adjacent to the LCR. Nonnative suppression releases from Glen Canyon Dam were implemented from January to March 2003 to test the effectiveness of high fluctuating flows on limiting the recruitment of nonnative fish (Davis and Batham 2003). The high fluctuating flows for nonnative suppression were continued in 2004 and 2005.

In November 2004, a second high flow experiment was conducted. The duration of this release was reduced to 60 hours on peak and the magnitude was reduced to 41,500 cfs due to repairs being made on one of the dam turbines. Another important difference with the 1996 high flow experiment was that the 2004 release occurred only after sediment input triggers, based largely on antecedent input from the Paria River, had been met. The trigger required that at least 1 million metric tons of fine sediment had been received by the Colorado River prior to the high release.

In September and October of 2005, a series of two-week dam releases occurred that alternated between steady and fluctuating releases. The purpose of this short-term experiment was to examine the effects of daily fluctuations on water quality parameters and biotic constituents (phytoplankton, macroinvertebrates, and fishes) of associated shoreline habitats (Ralston et al. 2007).

In 2006, Reclamation initiated development of a long-term experimental plan which was proposed to include both dam releases and other management actions. This effort originated with a science planning group that produced four options which were recommended by the AMWG to the Secretary of the Interior. GCMRC provided an assessment of the effects of the four options (GCMRC 2006). Reclamation conducted public scoping meetings in December 2006 and January 2007 and identified the purpose and need for the Proposed Action as improving the understanding of the Colorado River ecosystem below Glen Canyon Dam and protection of key resources (humpback chub, sediment, and cultural resources). In April 2007, GCMRC convened a science workshop to evaluate the four options for their use in development of EIS alternatives. Workshop participants also developed a fifth alternative for consideration by Reclamation and its cooperating agencies.

In January 1999, Reclamation released a draft environmental assessment on a temperature control device (TCD) for Glen Canyon Dam. Such a device is also referred to as a selective withdrawal structure as its utility extends to other water quality issues as well as temperature control. The preferred alternative was a single inlet, fixed elevation design with an estimated cost of $15,000,000. Sufficient concern was evidenced in the review of the environmental assessment (Mueller et al. 1999) for unintended negative effects (i.e., nonnative fish proliferation) as a result of the operation of a TCD, as well as the lack of a detailed science plan to measure those effects, that the environmental assessment was withdrawn and not finalized. In 1999 and in 2001, Reclamation convened workshops to evaluate the feasibility of a temperature control device and to further develop research and monitoring for evaluating ecosystem responses to warmer temperatures.

In 2003, Reclamation completed a review of other selective withdrawal facilities, subsequently published in Vermeyen (2003). No major environmental complications were identified in the survey results. A risk assessment of the Glen Canyon Dam TCD proposal from the AMP Science Advisors (Garrett et al. 2003) recommended the installation of a TCD for Glen Canyon Dam as soon as possible and the construction of a pilot TCD in the interim. Reclamation continued to work on assessment of the TCD utilizing the U.S. Army Corps of Engineers' CE-QUAL-W2 model (Cole and Wells 2000) to model Glen Canyon Dam release temperatures, the 1-D Generalized Environmental Modeling System for Surface waters model (GEMSS; Kolluru and Fichera 2003) to model flow temperatures from Glen Canyon Dam to Separation Canyon, and the 3-D GEMSS model to model backwaters below the confluence of the LCR. The analysis showed an average increase in release temperature of about 3 °C (5 °F) with installation of a 2-unit TCD. Positive deviations with the 2-unit TCD begin in late April, peak in late summer to early autumn at about 7° C (13 °F), and remain positive until the end of November. The relationship between release temperature and downstream temperature is nonlinear and is limited by the ambient atmospheric conditions. During colder months release temperatures would cool as dam release waters moved downstream.

Reclamation also completed a risk assessment to help evaluate responses of aquatic resources in Grand Canyon to the construction and implementation of a TCD (Valdez and Speas 2007). The risk assessment utilized standard protocols and a mathematical model was used as a tool to quantify risks and benefits to fish, fish parasites, zooplankton, and macroinvertebrates from water temperature changes resulting from modification of 2 of the 8 generation units on the dam. All taxa present or with known potential to access the area were inventoried for each of six regions, including lower Lake Powell, Glen Canyon Dam to Paria River, Paria River to LCR, LCR to Bridge Canyon, and Bridge Canyon to Pearce Ferry. Results suggested benefits to all native fishes, but correspondingly higher benefits to many nonnative fish species that may compete with or prey upon native species. Fish species carrying the highest risk for benefiting from warmer water were rainbow trout, brown trout, common carp, fathead minnow, red shiner, channel catfish, and smallmouth bass. Preliminary results also show more suitable conditions for warmwater fish parasites, including anchor worm and Asian fish tapeworm. Results also predicted an increase in periphyton biomass and diversity with warmer water, which could lead to increased food and/or substrate for epiphytes, aquatic invertebrates, fish, and waterfowl. Warm water impacts to macroinvertebrates include minor shifts in relative abundance of existing taxa with the possibility of increased taxa richness, which could be beneficial if limited to insect taxa. However, increased potential for invasion by crayfish and other nuisance species is significant.

Reclamation has concluded that a TCD designed to allow only warmer water to be released downstream is technically feasible, but that the risks in terms of increases in nonnative species and their effects to humpback chub are significant. In light of these concerns and with the recommendation of an independent scientist panel convened in April 2007 to discuss long-term experimental planning, Reclamation also briefly investigated whether construction of a TCD with both warm- and cold-water release capability is possible and under what circumstances cold water would be available for release. Due to the high cost of design investigation, no specific design work or feasibility analysis was completed, thus feasibility of a TCD with both warm- and cold-water release capability remains a question and an information need. Since dam release temperatures during the experimental period are likely to be cold, new information on temperature effects during the experimental period will inform a potential future decision on construction of the TCD.

Reclamation has worked to help develop watershed planning efforts in the Little Colorado River. A Little Colorado River Management Plan was prepared in 1999 (SWCA 1999, SWCA 2005), but not finalized. Reclamation has had numerous meetings with representatives from various stakeholders that have constituted Little Colorado River watershed groups. Currently, there is a Statewide Water Resources Advisory Group that provides technical assistance and advice to interested parties. The Little Colorado River Plateau Resources Conservation and Development (RC&D) is focused on implementing a strategic plan developed by sponsors and Council Members with the priority goal of formulating and publishing an all inclusive watershed management plan. There are 32 participants in the RC&D. The Little Colorado River Watershed Coordinating Council operates under the umbrella of the RC&D and is developing the Little Colorado River Watershed Management Plan. The Bureau of Reclamation Lower Colorado Region has committed to fund 50 percent of the estimated $600,000 to develop the plan with the other 50 percent coming from the non-federal stakeholders. Reclamation will continue to work with these organizations to better understand how to affect land and water management in the LCR watershed in a manner that conserves water quantity and quality to benefit the endangered humpback chub. Reclamation will also continue to assist in developing a watershed management plan, emphasizing actions that could be accomplished to address the threats to the endangered humpback chub arising in the Little Colorado River Basin and the potential roles to be taken by various participants and watershed organizations as a conservation measure in this biological opinion.

Reclamation has also contributed to a better understanding of the genetic relatedness among populations of humpback chub in the Colorado River basin and aggregations of humpback chub in Grand Canyon by funding research and planning efforts. Valdez and Ryel (1995) established the presence of nine aggregations of humpback chub, including the individuals in the LCR. Genetic evaluations by Colorado State University (Douglas and Douglas 2007) on the entire taxon and by the FWS on humpback chub collected in the LCR and held at Willow Beach National Fish Hatchery have provided important information in making these determinations. Reclamation also funded, through the AMP, development of a genetics management plan for humpback chub in Grand Canyon, which is currently being developed (Keeler-Foster in prep.).

In 2003, as a conservation measure to the biological opinion on the 2002 experimental flows and nonnative fish removal proposal, the FWS began a translocation program funded by Reclamation for humpback chub above Chute Falls in the LCR. From 2003-05, a total of 1,150 young-of-year humpback chub were translocated from the lower LCR to the LCR above Chute Falls. Preliminary results indicate that translocated fish survival and growth rates are high; limited reproduction and downstream movement to below Chute Falls has also been documented (Sponholtz et al. 2005, Stone 2006, 2007). Reclamation has also investigated the feasibility of developing a second spawning population of humpback chub in Grand Canyon, utilizing translocation and actions to improve mainstem habitat (Valdez et al. 2000b). In 2002, 2003 and 2006 NPS funded nonnative rainbow trout and brown trout removal from Bright Angel Creek with backpack electrofishers and a fish weir (SWCA 2006, Sponholtz and VanHaverbeke 2007), to help control nonnative trout in the mainstem Colorado River and evaluate the potential for translocation of humpback chub into Bright Angel Creek.

Other actions in Grand Canyon that affect humpback chub include actions under the authority of the NPS under various management plans at Glen Canyon National Recreation Area and Grand Canyon National Park. These plans include activities such as commercial and noncommercial river trip permits, research permits, regulations on recreational use, and monitoring and management actions of the NPS. NPS recently completed its Colorado River Management Plan for management of recreation in Grand Canyon National Park, and completed consultation on the plan with FWS (U.S. Fish and Wildlife Service 2006). The plan includes implementing research on determining the possible effects of recreation on humpback chub; currently there is little available information on this subject. Actions undertaken within Grand Canyon National Park by NPS and other entities overlap with actions under the AMP; there is a need for improved coordination between these actions to better understand the overall effects to humpback chub.

The AGFD regulates recreational fishing for trout in Glen and Grand canyons. As previously discussed, nonnative trout are a predator and competitor of humpback chub. AGFD prohibits angling at the confluence area of the LCR and mainstem. Available information indicates that few rainbow trout in the Lees Ferry reach emigrate downstream (Maddux et al. 1987), although the lack of evidence of spawning and recruitment between Lees Ferry and the LCR suggests rainbow trout must emigrate from either upstream or downstream areas (GCMRC unpubl. data).

AGFD also conducts a variety of monitoring activities, in conjunction with FWS and GCMRC, on humpback chub in Grand Canyon. Despite the essential need to monitor humpback chub status, netting and electrofishing can cause mortality (Ruppert and Muth 1997, Paukert et al. 2005).

Although the timeframe of the proposed action is relatively short, 5 years, the effects of climate change should be considered. 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. 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 is 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), but, as documented in the Shortage Guidelines EIS (U.S. Bureau of Reclamation 2007c; Appendix N), these projections are not at the spatial scale needed for Colorado River Simulation System (CRSS), the model used to project future flows.

The CRSS hydrologic model, used as the primary basis of Reclamation's effects analysis, does not project future flows or take into consideration projections such as those cited above, but rather relies on the historic record of the Colorado River Basin to analyze a range of possible future flows. Using CRSS, projections of future Lake Powell reservoir elevations are probabilistic, based on the 100-year historic record. This record includes periods of drought and periods with above average flow. However, studies of proxy records, in particular analyses of tree-rings throughout the upper Colorado River Basin indicate that droughts lasting 15-20 years are not uncommon in the late Holocene. Such findings, when coupled with today's understanding of decadal cycles brought on by El Niño-Southern Oscillation and Pacific Decadal Oscillation (and upstream consumptive use), suggest that the current drought could continue for several more years, or the current dry conditions could shift to wetter conditions at any time (Webb et al. 2005). Thus, the period of the proposed action may include wetter or drier conditions than today.

Although precise estimates of the future impacts of climate change throughout the Colorado River Basin at appropriate spatial scales are not currently available, these impacts may include decreased mean annual inflow to Lake Powell, including more frequent and more severe droughts. Such droughts may decrease the average storage level of Lake Powell, which could correspondingly increase the temperature of dam releases. Increased release temperatures have been cited as one potential factor in the recent increase of young-of-year and juvenile humpback chub (USGS 2006) but concerns also exist that warmer aquatic habitat will also increase the risk of warm-water nonnative fish predation. To allay this risk if such warming occurs, in the Shortage Guidelines biological opinion Reclamation has committed to the monitoring and control of nonnative fish as necessary, in coordination with other Department of the Interior agencies and working through the AMP (U.S. Fish and Wildlife Service 2007).

Previous consultations on humpback chub in Grand Canyon have included the recently completed Shortage Guidelines biological opinion mentioned above, as well as consultations on the preferred alternative on the operations of Glen Canyon Dam, above powerplant-release experimental flows, nonnative trout removal, and various NPS management plans. Recent consultations are further summarized below.

Operation of Glen Canyon Dam

In January 1995, FWS concluded that the preferred alternative, the modified low fluctuating flow (MLFF) alternative, was likely to jeopardize the continued existence of the humpback chub and was likely to destroy or adversely modify their critical habitat. The 1995 biological opinion on the operation of Glen Canyon Dam identified a reasonable and prudent alternative (RPA) that was necessary to avoid jeopardizing the continued existence of the humpback chub. The RPA contained four elements that were necessary to avoid jeopardizing the continued existence of the humpback chub and razorback sucker: (1) development of an adaptive management program that implements studies and recommendations to increase the likelihood of both survival and recovery of listed species; (2) development of a management plan for the Little Colorado River; (3) sponsoring a workshop for developing a management plan for razorback sucker in Grand Canyon; and (4) establishing a second spawning aggregation of humpback chub below Glen Canyon Dam. The biological opinion also anticipated take in the form of displacement of juvenile fish downstream during beach habitat building flow (BHBF) tests. BHBF releases are scheduled high releases of short duration that are in excess of power plant capacity in accordance with hydrologic triggering criteria, designed to rebuild high elevation sandbars, deposit nutrients, restore backwater channels, and provide some of the dynamics of a natural system.

Spring 1996 Beach Habitat Building Flow from Glen Canyon Dam

The first test of a BHBF was conducted in spring of 1996. BHBF tests were included as part of the proposed action of the FWS January 1995 biological opinion on the preferred alternative for the Operation of Glen Canyon Dam. Consultation with the FWS was re-initiated on the preferred alternative from the 1995 EIS because a new species was listed since the original consultation, the southwestern willow flycatcher with proposed critical habitat. The FWS concluded that the proposed test flow was not likely to jeopardize the continued existence of the humpback chub, and determined take from the proposed action in the form of 25 humpback chub due to harm, harassment, and mortality due to displacement from the BHBF.

Fall 1997 Test Flow from Glen Canyon Dam

In November 1997 Reclamation conducted a fall test flow as a test of a powerplant release of 31,000 cfs for 48 hours. These smaller powerplant capacity flows, called Habitat Maintenance Flows (HMFs), were designed to help maintain results achieved from BHBF events. Because such a test in the fall was not addressed in prior consultations, consultation was reinitiated. FWS concluded that the test flow was not likely to jeopardize the continued existence of the humpback chub and was not likely to destroy or adversely modify designated critical habitat for the humpback chub. Take of humpback chub was anticipated from harm, harassment and mortality from displacement of juvenile humpback chub downstream.

2002 Proposed Experimental Releases from Glen Canyon Dam and Removal of Nonnative Fish

The FWS 2002 biological opinion covered the following actions: (1) experimental releases from Glen Canyon Dam (2) mechanical removal of nonnative fish from the Colorado River in an approximately 9-mile reach in the vicinity of the mouth of the Little Colorado River to potentially benefit native fish and; (3) release of nonnative fish suppression flows having daily fluctuations of 5,000-20,000 cfs from Glen Canyon Dam during the period January 1-March 31.

FWS concluded that the proposed action was not likely to jeopardize the continued existence of the humpback chub, nor adversely affect its critical habitat. The December 2002 biological opinion included the incidental take of up to 20 humpback chub during the nonnative fish removal efforts. The action included, as a conservation measure, translocation of 300 humpback chub above Chute Falls, to increase the survivorship of young humpback chub by providing habitats with reduced predation and improved conditions for growth via temperature and food base. This consultation was reinitiated twice in 2003, to modify the number and size of humpback chub that could be translocated, and to alter the geographic extent of nonnative fish removal.

2004 Fall BHBF Test

Consultation was conducted in 2004 to conduct a BHBF test in the fall because existing compliance only allowed for a full BHBF test in the spring. FWS concluded that the action was not likely to jeopardize the continued existence of the humpback chub nor adversely modify its critical habitat. Reclamation included several conservation measures for humpback chub including the continuation of humpback chub translocation in the Little Colorado River, and further study and monitoring of the results and study of effects on humpback chub from dam operations including BHBF tests and stable and fluctuating flows. No additional take of humpback chub was anticipated beyond that provided in the 2002 biological opinion.

Grand Canyon National Park Colorado River Management Plan

On January 3, 2006, FWS completed its biological opinion on the NPS Colorado River Management Plan, a visitor-use management plan which specifies actions to preserve park resources and the visitor experience while enhancing recreational opportunities. FWS concluded that the action was not likely to jeopardize the continued existence of the humpback chub nor adversely modify its critical habitat. Conservation measures for humpback chub included restricting recreational use in the Little Colorado River, and implementing research to better determine the effect of recreational use on the species, as available funding permits. FWS anticipated incidental take in the form of harassment of humpback chub at the confluence of the Little Colorado River, from recreation-related disturbance, up to an amount that results in physical injury or morality; reasonable and prudent measures and terms and conditions included implementing research to determine the effect of recreation on humpback chub.

2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead

FWS completed a biological opinion on the Shortage Guidelines on December 12, 2007. The Shortage ROD specified reduction of consumptive water uses below Lake Powell during times of low reservoir conditions and modification of the annual release volumes from Lake Powell. Adverse effects to humpback chub were determined to come primarily from the potential for beneficial effects to nonnative fish, resulting in subsequent competition with or predation on humpback chub, and beneficial effects to Asian tapeworm that could cause increased parasitism. FWS concluded that the Shortage Guidelines were not likely to jeopardize the continued existence of the humpback chub, the southwestern willow flycatcher, or the Kanab ambersnail, and not likely to destroy or adversely modify designated critical habitat for the humpback chub or the southwestern willow flycatcher. FWS anticipated incidental take of humpback chub in the form of harm and mortality, and was determined to be exceeded if the proposed action results in an increase in nonnative species and subsequent decrease in the status of the humpback chub, despite efforts by Reclamation through the AMP to control nonnative fish species; specifically: (1) a 50 percent increase in nonnative fish species abundance in the mainstem Colorado River at the confluence of the LCR from 2007 levels; and (2) efforts to control nonnative fish species by Reclamation in collaboration with GCMRC and other DOI agencies and AMP participants are ineffective such that the increase persists over a consecutive 5-year period; and (3) during this consecutive 5-year period, monitoring indicates a significant decline in humpback chub recruitment or survivorship that is solely attributable to the proposed action.

The Shortage Guidelines included conservation measures to offset the adverse affects of the proposed action. There is broad overlap in the proposed action being investigated in this biological opinion and the Shortage Guidelines, and the AMP will be Reclamation's vehicle and authority to carry out conservation actions with regard to both actions. The conservation measures from the Shortage Guidelines biological opinion will therefore largely be implemented concurrently with those of this biological opinion, and consist of the following:

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 (U.S. Fish and Wildlife Service 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 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

In the action area, the Kanab ambersnail occurs in the vegetation at the spring-fed Vaseys Paradise. Vaseys Paradise is a popular water source and attraction site for Colorado River boat trips; however, access is limited by a dense cover of poison ivy (*Toxicodendron rydbergii*). The habitat and population size of Kanab ambersnail is influenced by interseasonal and interannual conditions, including drought-induced variation in spring flow, die-back of vegetation, killing frosts, monsoon-related scour, browsing by ungulates (primarily bighorn sheep [*Ovis canadensis*]) and other factors. The population size may vary 10-fold between the end of the winter season and the peak of summer reproduction.

Historically, the Grand Canyon experienced annual floods of 100,000+ cfs and Kanab ambersnail were likely swept downstream and drowned (Stevens et al. 1997a). Today, Glen Canyon Dam limits such flood events, although several high flows above power plant capacity, such as BHBFs, have resulted in discharges of up to 45,000 cfs. Flows of this magnitude will inundate and scour the occupied habitat of the Kanab ambersnail at Vaseys Paradise. Most, if not all, snails in the vegetation would be washed down river or covered with sediment. Based on estimates calculated in August 2004, a flow of 45,000 cfs would scour approximately 1,285.2 ft^2 of habitat, approximately 17 percent of available habitat. During the 2004 BHBF, AGFD and GCMRC removed portions of ambersnail habitat in the potential inundation zone prior to the flood and later replaced these habitat pieces after flooding subsided. The conservation measure was deemed successful, as these lower habitat areas had recovered completely in 6 months. Recovery of this habitat from previous high flow tests that did not include habitat mitigation efforts required 3 years for ambersnail habitat to recover completely from scouring (Sorensen 2005).

Trampling by recreationists and flash floods from the talus slope above Vaseys Paradise also contribute to habitat loss and can results in direct Kanab ambersnail mortality. However, impacts from recreationists are likely minimal due to steep slopes and a dense cover of poison ivy. Additionally, plateau-origin flash floods are rare in the region (Stevens et al. 1997a).

Evidence exists that a small number of Kanab ambersnails at Vaseys Paradise were parasitized by a trematode, tentatively identified as *Leucochloridium* sp. (Stevens et al. 1997b). Potential vertebrate predators include rainbow trout (in submerged areas), summer breeding Say's and black phoebe (*Savornis savi* and *S. niaricans*), canyon wren (*Catherpes mexicanus*), winter resident American dipper (*Cinclus mexicanus*), and canyon mice (*Peromyscus crinitus*) (Stevens et al. 1997b, U.S. Fish and Wildlife Service 1995a). Predation rates by birds and mice are not available, but analysis of mice feces indicates that snails are not regularly eaten by rodents (Meretsky and Wegner 1999).

Water sedge, a plant with patchy distribution in Kanab ambersnail habitat, is a source of forage for bighorn sheep, especially during a drought. Vaseys Paradise is now regularly used by bighorn sheep, resulting in vegetation used by the snails being trampled (Gloss et al. 2005). Drought conditions from 2001-2003 caused one of the two prominent spring caves to go completely dry in 2004. The drought conditions and increased grazing by bighorn sheep in the snail's habitat at Vaseys Paradise caused a shift in vegetation resulting in more mixed plots with less watercress and apparently reduced the amount and quality of ambersnail habitat; as a result, numbers of ambersnails declined. Wetter conditions since then have resulted in both spring caves flowing again; habitat appears to have improved, although numbers of ambersnails detected in plot sampling are still relatively low (Sorensen 2005).

Reproduction has been documented in the population introduced at Elves Chasm, and the population is self-sustaining, although recently the ambersnail has become rare at this location. In 1999, an expert panel was convened to evaluate the status of this species and related mollusk species. Ongoing questions about taxonomic status remain, although ongoing mitochondiral and cellular (microsatelite) DNA analysis should clarify this issue (M. Culver, University of Arizona, pers. comm. 2007). An "Interim Conservation Plan of *Oxyloma (haydeni) kanabensis* complex and Related Ambersnails in Arizona and Utah" has been developed by AGFD (Sorensen and Nelson 2002) and guides current management.

Previous consultations for this species in Grand Canyon have included the preferred alternative on the operations of Glen Canyon Dam, above powerplant release experimental flows, and other actions; these consultations are summarized below.

Operation of Glen Canyon Dam

In January 1995, FWS concluded that the preferred alternative on operations of Glen Canyon Dam, the MLFF alternative, was not likely to jeopardize the continued existence of the Kanab ambersnail. Take of Kanab ambersnail was anticipated in the form of harm, harassment and mortality from the scouring loss of habitat during BHBF tests in the amount of 10 percent of occupied habitat at Vaseys Paradise.

Spring 1996 Beach Habitat Building Flow from Glen Canyon Dam

Consultation was reinitiated on the proposed action of the January 1995 biological opinion to allow for a proposed test of a BHBF from Glen Canyon Dam in the spring of 1996, because a new species had been listed (southwestern willow flycatcher), and in part because new information revealed that incidental take for the Kanab ambersnail would be exceeded. FWS concluded that the action was not likely to jeopardize Kanab ambersnail, and anticipated take in the form of harm, harassment, and mortality from the scouring loss of habitat during the BHBF would be in the amount of 17 percent of the Kanab ambersnail habitat at Vaseys Paradise. Reasonable and prudent measures and terms and conditions included monitoring of effects of the test on the Vaseys Paradise population, and translocating snails out of the inundated zone into higher elevation habitat.

Fall 1997 Test Flow from Glen Canyon Dam

In November 1997, Reclamation conducted a fall test flow as a test of a powerplant release of 31,000 cfs for 48 hours, an HMF. Because such a test in the fall was not addressed in prior consultations, consultation was reinitiated. FWS concluded that the action was not likely to jeopardize Kanab ambersnail, and anticipated take in the form of harm and mortality from the scouring loss of habitat during the HMF in the amount of 1 percent of the Kanab ambersnail habitat at Vaseys Paradise. Reasonable and prudent measures and terms and conditions included monitoring of effects of the flow on the Vaseys Paradise population, and establishing a refuge population and a second wild population.

2002 Proposed Experimental Releases from Glen Canyon Dam and Removal of Nonnative Fish

The December 2002 biological opinion included the following actions: (1) experimental releases from Glen Canyon Dam; (2) mechanical removal of nonnative fish from the Colorado River in an approximately 9-mile reach in the vicinity of the mouth of the Little Colorado River to potentially benefit native fish and; (3) release of nonnative fish suppression flows having daily fluctuations of 5,000-20,000 cfs from Glen Canyon Dam during the period January 1-March 31.

FWS concluded that the action was not likely to jeopardize Kanab ambersnail. The proposed action included a conservation measure consisting of temporary removal and safeguard of approximately 25 to 40 percent of Kanab ambersnail habitat that would be flooded by the experimental release. The relocated habitat would be replaced once the high flow was complete to facilitate re-establishment of vegetation. Take was anticipated in the form of harm and mortality from the scouring loss of 117 m^2 (1,259.4 ft^2) of habitat during a BHBF.

2004 Fall BHBF Test

Consultation was re-initiated in 2004 to conduct a BHBF test in the fall because existing compliance only allowed for a test in the spring. FWS concluded that the action was not likely to jeopardize the continued existence of the Kanab ambersnail. The proposed action included a conservation measure consisting of temporary removal and safeguard of approximately 25 to 40 percent of Kanab ambersnail habitat that would be flooded by the experimental release. The relocated habitat would be replaced once the high flow was complete to facilitate re-establishment of vegetation. Take was anticipated in the form of harm and mortality from the scouring loss of 119.4 m^2 (1,285.2 ft^2) of habitat during a BHBF.

Grand Canyon National Park Colorado River Management Plan

On January 3, 2006, FWS completed its biological opinion on the NPS Colorado River Management Plan, a visitor-use management plan which specifies actions to preserve park resources and the visitor experience while enhancing recreational opportunities. FWS concluded that the action was not likely to jeopardize the continued existence of the Kanab ambersnail. Conservation measures included educating river guides about the presence of the species and potential for recreation-induced impacts, monitoring, and, as available funding permits, implementing research to assess the effects of recreation on Kanab ambersnails. Take was anticipated in the form of harm and mortality in the amount of 10 m^2 (107.6 ft^2) of Kanab ambersnail habitat at Vaseys Paradise from recreational use.

2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead

FWS completed a biological opinion on the Shortage Guidelines on December 12, 2007. The Shortage ROD specified reduction of consumptive uses below Lake Powell during times of low reservoir conditions and modification of the annual release volumes from Lake Powell. Adverse effects to Kanab ambersnail were anticipated due to scouring of habitat during high flows following periods of low flow and new habitat establishment compared to no action conditions. Take was anticipated in the form of harm and mortality due habitat scouring, and was determined to be exceeded if the proposed action results in a long-term decrease in the amount of Kanab ambersnail habitat; specifically: (1) ongoing monitoring by Reclamation, in collaboration with GCMRC and other DOI agencies and AMP participants, reveals that there is a reduction of the amount of Kanab ambersnail habitat present at Vaseys Paradise of more than 20 percent from 2007 that is solely attributable to the proposed action; and (2) efforts to prevent habitat loss by Reclamation, in collaboration with other AMP participants, prove ineffective such that this reduction in Kanab ambersnail habitat at Vaseys Paradise continues over a 5-year period. Reclamation included the following conservation measure:

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 assist FWS in funding morphometric and genetic research to better determine the taxonomic status of the subspecies.

EFFECTS OF THE ACTION

Effects of the action refer to the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated and interdependent with that action that will be added to the environmental baseline. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration. Indirect effects are those that are caused by the proposed action and are later in time, but are still reasonably certain to occur.

Humpback Chub and Its Critical Habitat

The proposed action consists of five years of MLFF flows (U.S. Bureau of Reclamation 1995, 1996) with a one-time high flow test in March of 2008 of approximately 41,000 cubic feet per second and stable flows in September and October in all five years. Reclamation intends this action to assist in the conservation of endangered species as well as providing benefits to sediment conservation, increasing scientific understanding, and to collect data for use in determining future dam operations. Overall, the proposed action should have a positive benefit to humpback chub and its critical habitat compared to current conditions by improving nearshore habitat important for young humpback chub, although there may be some short-term minor impacts to the species, primarily via temporary downstream displacement of humpback chub during experimental high flow releases designed to enhance areas of backwater habitat and the potential to benefit nonnative species with steady flow releases.

Small-bodied humpback chub may be vulnerable to displacement by high flows (above 30,000 cfs) conducted during periods of cold dam releases (8-10 °C [46.4-50.0 ºF]) when their swimming performance is reduced (Bulkley et al. 1982). The high flow test proposed for 2008 would not occur until March, which historically has been viewed as the timeframe posing the least amount of risk to a number of species, including humpback chub (Hoffnagle et al. 1999, U.S. Bureau of Reclamation 1995), the young of which are generally thought to utilize deeper eddies and shoreline cover in the fall and winter months (Valdez and Ryel 1995). However, as in 2004, the Colorado River currently supports high numbers of young-of-year and juvenile humpback chub (Ackerman 2007) that would theoretically be vulnerable to displacement by high flow tests.

Reclamation evaluated effects of high flows by comparing retention rates (i.e. percentage of fish able to maintain their position in a given reach) expected during a high flow test to those predicted for the median monthly flow in March under MLFF (U.S. Bureau of Reclamation 2007a). Retention rates over a range of flows were modeled using a particle-tracking algorithm in conjunction with velocity predictions from a 2-D hydrodynamic model developed by Korman et al. (2004). This model was developed using channel bathymetry from seven transects located from RM 61.5 to 66.5, below the LCR confluence. The model contains four assumptions of fish swimming behavior: 1) passive, no swimming behavior; 2) rheotactic, in which particles (or "fish") swim toward lower velocity currents at 0.1 to 0.2 m/s (0.33 to 0.66 ft/s); 3) geotactic, in which particles swim toward the closest bank at 0.2 m/s (0.66 ft/s); and 4) upstream, in which the particle attempts to move upstream at 0.2 m/s (0.66 ft/s). Temperature of the Colorado River in the LCR inflow reach during the proposed time period for high flow tests (early March) typically ranges from 8 to 10 °C (46-50 ºF, AGFD 1996). At these levels, young-of-year and juveniles may fatigue rapidly and may be unable to withstand swift currents, forage efficiently, or escape predators. Bulkley et al. (1982) reported that swimming ability of young-of-year and juvenile humpback chub (73–134 mm [2.87-5.28 in] TL) in a laboratory swimming tunnel was positively and significantly related to temperature. Humpback chub forced to swim at a velocity of 0.51 m/sec (1.67 ft/sec) fatigued after an average of 85 minutes at 20 °C (68 ºF), but fatigued after only 2 minutes at 14 °C, a reduction in time to fatigue by 98 percent. Time to fatigue is presumably further reduced below 14 °C (57 ºF), especially for the smallest individuals. For these reasons, and also to identify the "worst case scenario" of fish displacement, Reclamation focused primarily on results for passive swimming behavior in their analysis.

Adult humpback chub will likely be little affected by high flows (Hoffnagle et al. 1999, Valdez and Hoffnagle 1999), although high flows would occur at a time of the year prior to the historical spring run-off that would result in the rise of the pre-dam hydrograph. Little is known about the extent to which humpback chub rely on changes in flow as a reproductive cue. Valdez and Ryel (1995) held that neither water quantity or quality serve as cues for gonadal development or staging behavior in humpback chub; rather they hypothesized that climatic factors, such as photoperiod, were important. Humpback chub typically begin to spawn on the receding hydrograph as water temperatures start to rise (Kaeding and Zimmerman 1983, Tyus and Karp 1989, Kaeding et al. 1990, Valdez and Ryel 1995), but the LCR population also spawns in years with little appreciable runoff.

Korman et al. (2004) predicted that retention rates of small-bodied fish in the Colorado River immediately below the LCR will decrease with increased discharge, but that this pattern tended to vary considerably with reach geomorphology and assumptions on swimming behavior of the fish. Passively drifting fish were the most susceptible to displacement, but also the least sensitive to the effects of variable discharge magnitude. Assuming that passively drifting fish can be used to represent the poor swimming ability of humpback chub at low temperatures, then we would expect that about 21 percent of these fish would be able to maintain their position within a given river reach during high flow tests of 41,500 (Korman et al. 2004). The retention rate at mean monthly flows for March under MLFF (about 9,400 cfs), by contrast, is predicted to be about 36 percent. Therefore we would expect retention to decrease by 15 percentage points during the proposed action; absolute numbers of fish swept downstream would be dependent on young-of-year and juvenile population size at the time of the high flow test in March 2008.

Total suitable habitat would also be at a low level across the continuum of flow elevations during the high flow test. However, available habitat over talus and debris fan substrates is not expected to change during high flows as compared to regular MLFF releases (about 9,700 cfs), and area of vegetated shorelines would actually be near its maximum predicted values. Thus if the fish could exploit these unchanged or improved habitats as refuge from high flows, displacement could be minimized (see also Converse et al. 1998).

A reasonable, although very approximate, estimate of numbers of young-of-year and juvenile humpback chub that could be present during the high flow test, based on catch rates and hoop net catch data, is about 6,000 (L. Coggins, U.S. Geological Survey, pers. com. 2007). Thus, based on Korman et al. (2004), approximately 900 young-of-year and juvenile humpback chub could be displaced. Conducting a high flow test during the month of March nevertheless appears to pose the fewest risks to young-of-year and juvenile humpback chub. During this period, occurrence of larval humpback chub in the Colorado River should be minimal or nonexistent. In contrast to the November 2004 high flow test, humpback chub would be about 10 months old in March (as opposed to five months), and presumably stronger and better able to adjust position with varying flows. Depending on habitat use and growth rate assumptions, humpback chub should be from five to 20 mm (0.79 in) larger in March than in November at 8-12 °C (46-54 °F) (Lupher and Clarkson 1994, Valdez and Ryel 1995, Gorman and VanHoosen 2000, Petersen and Paukert 2005). Hoffnagle et al. (1999) reported no statistically significant change in catch rates of young humpback chub along shorelines before and after the March-April 1996 controlled flood of 45,000 cfs. Catch rate of humpback chub did significantly decline in 2004 after the high flow test, although this may also have been caused by increased turbidity, confounding these results (GCMRC, unpublished).

Nonnative fish are also likely to experience negative impacts of the high flow tests, perhaps more so than humpback chub due to their preferences for lower water velocities (Minckley and Meffe 1987). Hoffnagle et al. (1999) noted that the 1996 test had few discernable effects on native fish, but reduced numbers of fathead minnow and plains killifish, presumably by downstream displacement. Trammell et al. (2002) found similar results for fathead minnow during the September 2000 habitat maintenance flow. Similar results involving other native and nonnative species have also been found in other streams in the southwest (Minckley and Meffe 1987, Schultz et al. 2003).

Although results of the 2004 high flow test support predictions made in Korman et al. (2004), no attempt has been made to validate the assumptions of the model with empirical data, so displacement rates of young-of-year and juvenile humpback chub over a range of operational and experimental flows remain uncertain and should be evaluated. The fate of displaced humpback chub in downstream reaches is also unknown; the exact river reaches and habitat conditions they are likely to arrive at are not known. Also, the exact number of fish displaced by high flows will vary markedly by the distribution of fish among discrete shoreline types, as certain shoreline types afford more refuge from high flow velocities than others (e.g., talus slopes provide better cover as compared to sandbars). Downstream displacement could provide positive effects for some humpback chub if they are carried to downstream aggregations, survive, and increase the size of these groups.

The high flow test may also create or improve backwater habitats. Impacts of high flow tests on backwater habitats occur at both short-term (i.e., weeks to months following high flow tests) and long-term (i.e. months to years) time scales. Information is available on short-term effects to backwater habitats following high flow tests (Parnell et al. 1997, Brouder et al. 1999, Wiele et al. 1999), but long-term effects are not well documented, and likely vary depending on sediment availability prior to the test and differences in post-test flow regimes.

Reclamation assumed in its biological assessment that backwaters in Grand Canyon are mostly inundated, but non-flowing, eddy return current channels, and as such, sandbars are a requisite condition for their occurrence. The elevation of sandbars and depth of recirculation channels are significant correlates reflecting the availability of backwaters over a range of flows. The higher the sandbar elevation, the more likely the separation of the backwater from mainchannel currents would occur over a range of flows. The depth of the recirculation channel serves the same function as the height of the sandbar, with the greatest depths creating more frequent availability of backwaters over the greatest range of flows. High flow tests tend to increase the elevation of the sandbar and deepen the return current channel (Andrews 1999, Goeking et al. 2003), although there are exceptions to this general pattern (Parnell et al. 1997).

Immediate physical impacts of high flow tests on backwater habitats include increased relief of bed topography, increased elevation of reattachment bars and deepened return current channels (Andrews et al. 1999). Biologically, the 1996 test significantly reduced backwater macroinvertebrate standing stocks due to scouring of the return current channel, but key taxa (i.e., chironomids) recovered to pre-flood levels within three months (Brouder et al. 1999). Nutrient enrichment due to burial and decomposition of organic matter during the high flow test (Parnell et al. 1999) probably enhanced recovery of benthic macroinvertebrates. As a result, reductions of invertebrate prey had little or no impact on food availability to fish (McKinney et al. 1999, Valdez and Hoffnagle 1999). Further, since humpback chub probably do not commonly utilize backwaters in March (Valdez and Ryel 1995) (proposed time frame for the 2008 high flow test), negative effects due to reduced food availability in backwaters at this time of year is less likely to have an adverse effect to humpback chub.

One goal of test flows conducted during 1996 and 2004 was redistribution of channel bottom sediment to the channel margins to establish and maintain habitats for young life stages of humpback chub in the mainstream. The chief difference between the proposed 2008 high flow test and previous experiments is that the amount of fine sediment in the system is about three times greater than that which triggered the 2004 high flow test. This greater sediment availability during 2008 should lead to more widespread construction of sandbars (Schmidt 1999, U.S. Geological Survey 2007a), which should increase the likelihood of backwater formation and more nursery habitat for humpback chub. This assumption is an uncertainty and will be considered in this test using comparisons of before and after habitat mapping.

The relationship between backwater bathymetry and suitability as fish habitat in Grand Canyon, specifically the relationship between dam operations, depth, area, volume and thermal characteristics, is a longstanding information need. Goeking et al. (2003) point out that 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). 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.

Persistence of backwaters created during 1996 appeared to be strongly governed by post-high flow dam operations. Whereas the 1996 test resulted in creation of 26 percent more backwaters available as rearing areas for Grand Canyon fishes, most of these newly created habitats disappeared within two weeks due to reattachment bar erosion (Parnell et al. 1997, Brouder et al. 1999, Hazel et al. 1999, 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). Similarly, following the 2004 test, high flows of 5,000-25,000 in January to early April of 2005 appeared to contribute to the rapid degradation of newly created backwaters utilized by humpback chub (R. VanHaverbeke, FWS, pers. com. 2006).

Because sediment erosion and transport increases with discharge volume and range of fluctuation (U.S. Geological Survey 2008), post-high flow test flows will determine in part the long-term persistence of created habitats. Post-test flow regimes to minimize erosion have yet to be developed and tested, and are not part of the proposed action. However, MLFF flows in the months following the March 2008 test flow will consist of moderately low fluctuating flows (Tables 3 and 4), with a maximum flow and range of fluctuations of 9,300-17,300 cfs occurring in July and August of 2008. Thus if the high flow test is successful in creating backwaters they should persist over a longer period than previous tests.

Reclamation used a 2-D hydrodynamic model to predict two-dimensional fields of depth and velocity over a range of daily flow fluctuations and monthly volumes (Korman et al. 2004) to determine how changes in flow from the proposed action to current conditions would affect fish habitat. Specifically, the model evaluated young-of-year fish habitat availability and suitable habitat persistence in Grand Canyon under MLFF and the proposed action. Depth and velocity at seven transects in the first 10 km (6.2 mi) below the LCR were modeled over the range of flows proposed in the alternative. This model was developed using channel bathymetry from seven transects located from RM 61.5 to 66.5 (Wiele et al. 1996, 1999). Transects ranged from 253 to 993 m (830 to 3259 ft) in length and represented the full range of shoreline types typically utilized by young-of-year humpback chub: talus slopes, debris fans, vegetated shorelines, cobble bars, bedrock and sandbars. Descriptions of these shoreline types can be found in Converse et al. (1998). The hydrodynamic model was used successfully to predict patterns of sand deposition following the 1993 flood from the Little Colorado River and during and after the 1996 high flow test (Wiele et al. 1996, 1999), illustrating the accuracy of the model.

The amount of total suitable habitat at a given flow elevation was computed by summing the total wetted area of each reach where velocity was less than or equal to critical values. Two criteria were evaluated for suitable water velocity: < 0.25 m/s (0.82 ft/s) and <0.10 m/s (0.33 ft/s). The first criterion was a composite of several field and laboratory studies published previously, including Bulkley et al. (1982), Valdez et al. (1990) and Converse et al. (1998). The second criterion was selected to be more representative of a suite of nonnative species currently found in the Little Colorado River or the adjacent main channel Colorado River (Minckley and Meffe 1987). Depths of <1 m (3.3 ft, maximum depth of most humpback chub habitats sampled in Converse et al. 1998) were used to further restrict predictions on suitable humpback chub and nonnative fish habitat. To further simulate young-of-year and juvenile humpback chub habitat availability, habitat predictions were limited to areas that intersected the streambed and computed habitat over shoreline types. Persistent suitable habitat was used to determine the area of suitable habitat that is stable across daily ranges in discharge (Bowen et al. 1998, Freeman et al. 2001, Korman et al. 2004). The suitable habitat areas at 5,000 cfs, 8,000 cfs, and 15,000 cfs were calculated for each transect. The total area of habitat common to flow elevations is referred to as the amount of "persistent suitable habitat."

Reclamation also presented absolute values for suitable habitat specific to discrete shoreline types to show habitat availability over a range of discharge found in the proposed action and MLFF, and considered the three shoreline types most commonly utilized by humpback chub (talus, vegetated shorelines, debris fans) as well as the total habitat area (<0.25 m/s [0.82 ft/s], <1 m [3.3 ft] depth) intersecting all shoreline types. Reclamation examined the relationship of flows on fish habitat across a range of flows using previously published predictions for flows to approximate effects of the proposed action (Korman et al. 2004). The assumption is that predictions for habitat persistence at a steady release of 8,000 cfs would approximate September and October steady releases in the proposed action (8,000 or 9,000 to 10,000 cfs per day), and that daily ranges between 5,000 cfs and 8,000 cfs would approximate MLFF conditions for the same period (5,000 to 12,000 cfs/day). Higher fluctuations of 8,000 cfs to 20,000 cfs were used to approximate fluctuations at higher flow elevations such as those in July and August.

The net effect of steady flows during September and October on habitat persistence is most likely to be positive. Depending on river location, the amount of persistent habitat increases by 63 to 400 percent when flows are held steady at 8,000 cfs as compared to fluctuations between 5,000 and 8,000 cfs (Korman et al. 2004) (Figure 15). The increase is even more dramatic when compared to higher fluctuations (8,000 to 20,000 cfs). So predictions for persistence of fish habitat for flows of the proposed action (i.e., relatively steady flows of 9,000-10,000 cfs as compared to fluctuations between 5,000 to 12,000 cfs per day) should be similar, that is that stable flows will dramatically increase the amount and persistence of suitable habitat.

The same benefits of a more stabilized nearshore environment would be accrued for nonnative fish; however, their general preference for slightly lower water velocities restricts them to a smaller area than for humpback chub and perhaps other native fish, which tend to be more tolerant of higher velocities (Meffe and Minckley 1987, Minckley and Meffe 1987). Reclamation found that, depending on the transect, humpback chub have available for their use at any given point under steady flows 16 to 34 percent more habitat than nonnative fish, which presumably translates into a competitive advantage for humpback chub and other native fish (U.S. Bureau of Reclamation 2007a).

One consequence of allocating volumes of water released by Glen Canyon Dam throughout the year by month is that, during wet years and years of high reservoir elevation, flow volumes during the transition from September to October could diminish by over 50 percent depending on real-time dam operations decisions; similar transitions could occur, and have occurred in the past, between August and September. With that change comes a dramatic decrease in daily minimum flows, which is expected to increase available habitat for humpback chub. However, the rate at which this shift from one month to another is a very rapid change in flow regime. This may entail bioenergetic costs to humpback chub as they are forced to relocate to favorable habitat as habitats under the preceding month become dewatered or flooded as new habitats are created. This effect could be exacerbated, for example, if chub are using the vegetated portion of the channel inundated at high flows but then need to move to talus or debris fans habitat at the lower elevations. The risk of stranding is also a concern. So more gradual transitions from one water year or one monthly allocation to the next, especially during wet years, may have important benefits to humpback chub; as a conservation measure, Reclamation has committed to researching this issue to minimize potential impacts to humpback chub.

Humpback chub growth rates vary as a function of water temperatures (Lupher and Clarkson 1995, Clarkson and Childs 2000). Flow regime (monthly volume and degree of flow fluctuation) can have a profound effect on water temperatures in the Colorado River in Grand Canyon (Trammel et al. 2002, Korman et al. 2006) (monthly volume, steady and fluctuating flows during September and October). Flow regimes in the proposed action will be the same as MLFF, with the exception of steady flows in September and October.

To analyze effects of steady and fluctuating flows on temperature-influenced growth of humpback chub, Reclamation (2007a) used models and empirical backwater and main channel temperatures (from Trammell et al. 2002) and information on young-of-year and juvenile humpback chub growth rates at different temperatures from observations from laboratory and field studies (Lupher and Clarkson 1995, Valdez and Ryel 1995, Clarkson and Childs 2000, Gorman and VanHoosen 2000, Peterson and Paukert 2005).

Reclamation (2007a) found that, based on historic data (Trammell et al. 2002), main channel water temperatures in September are predicted to be 1-2 °C (1.8-3.6 °F) warmer under steady flow conditions than under fluctuating flows, and backwater temperatures are predicted to be 0.9-1.8 °C (1.6-3.2 °F) warmer than the mainchannel. Depending on river reach, humpback chub growth rates during the month of September are predicted to increase by 12 to 36 percent in the mainchannel environment and nine to 19 percent more in backwaters. This increase in growth is due solely to changes in temperature; additional increases in growth could also accrue from bioenergetic benefits via increased habitat stability and increased abundance in prey. No assessment was possible for October due to a lack of information, although Korman et al. (2005) found backwaters to be about 1 °C (1.8 °F) cooler than the main channel during that period. Modeling results predicted much smaller increases in temperature under steady flows than under fluctuating flows, but this may have been due to the coarseness of river units in the model. Additional monitoring and model validation will help clarify this relationship.

The steady flows in September and October should also increase the productivity of backwaters, both as a result of temperature increases, but perhaps more because of a reduction in water exchanged with the main channel. 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. This reduction was caused by dewatered substrates (see also Blinn et al. 1995), exchange of water (and invertebrates) between the main channel and backwaters, and reduced temperature. Grand et al. (2005) found that as the magnitude of within-day fluctuations increase, so does the proportion of backwater water volume exchanged, resulting in a net export of as much as 30 percent of daily invertebrate production.

Prey availability may be further enhanced simply by the creation of new backwaters and improvement of existing backwaters from the proposed high flow test in March 2008. AGFD (1996) hypothesized that the 1993 Little Colorado River flood expanded the availability of stable backwater habitats, which coincided with increases of benthic invertebrate standing stocks the following year. Also, following the 1996 high flow test, burial of autochthonous vegetation resulted in increased levels of dissolved organic carbon, nitrogen and phosphorus in sandbar ground water and in adjacent backwaters, making these nutrients available for uptake by aquatic or emergent vegetation in the backwater (Parnell et al. 1999). Increases in benthic standing stocks caused by stable flows in September and October (and perhaps greater availability of backwaters) would benefit humpback chub via potential for added growth prior to the onset of winter, when invertebrate standing stocks are much reduced.

The same benefits of increased temperature and invertebrate prey availability that benefit humpback chub, will also likely benefit nonnative fish, primarily small-bodied cyprinids that utilize the same backwater habitats. Reclamation has been aggressive in developing nonnative control methods in Grand Canyon through the AMP, and has committed, as a conservation measure of the proposed action to continue to develop and implement, with GCMRC and other AMP participants, a nonnative fish control plan for both coldwater and warmwater nonnative fish.

The AMP has thus far not attempted removal of nonnative fish from backwaters. In the Upper Colorado Basin, Trammell et al. (2004) found that the feasibility of using mechanical removal to reduce nonnative cyprinid fish species in backwater habitats was limited to short-lived, site-specific reductions in abundance. However, they concluded that such programs could be beneficial to native fish if efficiency was improved and reductions were timed to be most beneficial to listed fish species. Because backwaters in Grand Canyon tend to have much higher densities of fish relative to the mainstem than in the Upper Basin (AGFD 1996, Parnell et al. 1997), removal of small-bodied nonnative fishes from backwaters in Grand Canyon could be more effective, as recolonization of backwaters from the mainstem may be much lower (Reclamation 2007).

Humpback Chub Critical Habitat

The known constituent elements of water and physical habitat will not be affected in the lower eight miles of the LCR. However, because the proposed action could result in an increase in the presence of nonnative fish species that could invade the LCR, the proposed action could reduce the quality of critical habitat in the LCR in terms of the biological constituent element. Critical habitat from RM 34 (Nautiloid Canyon) to RM 208 (Granite Park) along the Colorado River will be affected in the ways described above. The constituent element of physical habitat in the mainstem will be most affected, likely from an increase in the number of backwaters. The quality of nearshore habitats, especially during September and October should also improve, becoming warmer and more productive relative to current conditions. This could have some adverse affects to humpback chub, by potentially increasing numbers of nonnative fish. The biological environment includes food supply and habitats with levels of nonnative predators and competitors that are low enough to allow for spawning, feeding, and rearing. Increases in the quality of nearshore habitats, particularly backwaters, should benefit the food base for young humpback chub, although levels of nonnative predators and competitors could increase in response to these changes.

Summary of Effects to Humpback Chub and Its Critical Habitat

The proposed action is likely to result in some adverse effects to humpback chub, mostly from displacement of young fish during the high flow test. However, these effects are expected to be short term, and outweighed by other beneficial aspects of the proposed action. The long-term effects on humpback chub and its critical habitat are expected to be positive, due to creation and improvement of rearing habitats for humpback chub in the mainstem. Effects of the fall steady flows are expected to be positive via improved growth and survival of young-of-year and juvenile humpback chub prior to the onset of winter. Beneficial effects of steady flows in fall months should be especially pronounced during the first few years following the 2008 high flow test. Creation and improvement of backwater rearing habitats expected from the high flow test would expand habitat spatial extent, and steady flow would improve overall habitat stability (persistence) and quality (temperature, prey availability), improving the physical and biological constituent elements of critical habitat, especially for young humpback chub.

In addition, Reclamation has committed to implementing a suite of conservation measures as part of its proposed action to reduce the adverse affects of the proposed action and promote long-term species conservation. As described under "Conservation Measures" in the Description of the Proposed Action section, these include a humpback chub consultation trigger, a comprehensive plan for the management and conservation of humpback chub in Grand Canyon, humpback chub translocation, nonnative fish control, a humpback chub nearshore ecology study, a monthly flow transition study, creation and maintenance of humpback chub refuges, and Little Colorado River watershed planning. As described in the conservation measures, some of these conservation measures will entail additional planning documents and compliance that will be developed by Reclamation in conjunction with the AMP and FWS. For a description of currently planned efforts to evaluate the proposed high flow test, see the Science Plan for Potential 2008 Experimental High Flow at Glen Canyon Dam (U.S. Geological Survey 2007a).

A confounding aspect to the attempts of the AMP to conserve humpback chub has been, and will continue to be, nonnative species. Many actions designed to benefit humpback chub, such as steady flows, will likely also benefit nonnative fish species. Reclamation will directly address this issue by continuing to develop and implement, with GCMRC and the AMP, a control plan for nonnative cold- and warm-water species in Grand Canyon. Reclamation's commitment to continue translocation of humpback chub, both in the Little Colorado River and into other tributaries in Grand Canyon should also serve in this regard by creating humpback chub populations in habitats free from high densities of nonnative species.

A number of research needs were identified by Reclamation and others in developing this proposed action. In particular, the effect of various flow regimes on mainstem nearshore habitats and the concomitant impact to the survival and recruitment of young humpback chub continues to raise many questions. These include: the efficacy of high flows to create backwaters; the suitability of backwaters as humpback chub rearing habitat; the persistence of backwaters created by a high flow test in relation to the post-test flows; response of young-of-year and juvenile humpback chub to steady and fluctuating flows in terms of growth, bioenergetics, survival, behavior and habitat use; differences in temperatures of mainchannel and nearshore habitats under steady and fluctuating flows and response of native and nonnative fishes; and changes in primary and secondary production under steady and fluctuating flows. Although the high flow test and stable flows that are the key components of Reclamation’s proposed action are expected to provide a conservation benefit to humpback chub, this is not known with any certainty. Reclamations proposed action and conservation measures, specifically the nearshore ecology and flow transition studies, should provide much needed insight into these questions.

Although the status of the Grand Canyon population of humpback chub has been improving, there is no clear indication for the cause of this improvement. Thus the proposed action takes a conservative approach to changes in dam releases in an attempt to capitalize on this trend in status without unduly risking these gains with more drastic changes in dam operations. However, there exists the possibility that the population could decline, despite the current trend and potential for beneficial effects from Reclamation’s proposed action. Reclamation has agreed to reinitiate consultation if the trend in humpback chub status should reverse and the population decline to a level of 3,500 adult fish. Reclamation will also help create and maintain humpback chub refuge populations at offsite facilities to protect the genetic diversity of the population, and to assist with watershed planning in the Little Colorado River watershed to help address potential threats that could arise from elsewhere in the watershed. These conservation measures will serve as insurance against unforeseen adverse effects, both from the proposed action and from elsewhere.

Kanab Ambersnail

The proposed action will have no effect on the water flow from the side canyon spring that maintains wetland and aquatic habitat at Vasey’s paradise. Kanab ambersnail habitat can be adversely affected by scouring at Colorado River flows exceeding 17,000 cfs. The high flow test will increase flows to 41,500 cfs. These flows will inundate Kanab ambersnail habitat and likely scour the vegetation and carry the snails downstream. During the March 1996 high flow test (45,000 cfs), all Kanab ambersnail habitat at Vaseys Paradise below the 45,000 cfs flow level was scoured away. It is likely that several hundred snails were lost, and it took 2.5 years for the habitat to recover to pre-flood conditions (IKAMT 1998; Stevens et al. 1997b). In 2004 during the high flow test, approximately 25 – 40 percent ($29m^2$ to $47m^2$; 312 ft^2 to 506 ft^2) of habitat that would normally be lost due to scour effects from the high flow test was temporarily removed prior to the test flow and replaced afterwards; 55 live Kanab ambersnails were also found and moved above the 41,500 cfs flow line. This conservation measure was successful, with essentially full recovery of the scoured snail habitat six months later, as opposed to 2.5 years to recover following the 1996 event when this conservation measure was not employed (Sorensen 2005). Reclamation will carry out this habitat-safeguarding conservation measure again for the 2008 experimental high flow test which will greatly reduce adverse effects to the snail and its habitat from the proposed action.

Steady flows in September and October will have little effect on snails and snail habitat. Snails are becoming dormant at that time of year as winter approaches, and the time period, two months, is brief. Thus, should steady flows result in lowering the elevation of the varial zone, little if any new habitat should become established at the new lower steady flow level which could be scoured when flows and fluctuations increase in November and December.

CUMULATIVE EFFECTS

Cumulative effects include the effects of future State, Tribal, local or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Native American use of the Colorado River in Grand Canyon includes cultural, religious, and recreational purposes, as well as land management of tribal lands (e.g. recreational use including rafting, hunting and fishing). Non-Federal actions on the Paria River and Kanab Creek are limited to small developments, private water diversions and recreation. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the Act. Since a significant portion of the project area is on Federal lands, all legal actions likely to occur would be considered Federal actions, and would be subject to additional section 7 consultation.

CONCLUSION

This biological opinion does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02. Instead, we have relied upon the statutory provisions of the Act to complete the following analysis with respect to critical habitat[4]. After reviewing the current status of the humpback chub and its critical habitat, the current status of the Kanab ambersnail, the environmental baseline for the action area, the effects of implementation of the proposed action, and the cumulative effects, it is our biological opinion that implementation of the March 2008 high flow test and the five-year implementation of MLFF with steady releases in September and October, as proposed, is not likely to jeopardize the continued existence of the humpback chub or the Kanab ambersnail, and is not likely to destroy or adversely modify designated critical habitat for the humpback chub.

We present this conclusion for the humpback chub and its critical habitat for the following reasons:

- In 1995, in a consultation on the operations of Glen Canyon Dam, specifically on the MLFF, we anticipated that operation of Glen Canyon Dam (the monthly, daily, and hourly operation as defined in the MLFF and the 1996 ROD) would jeopardize the continued existence of the species. Populations in the upper Colorado River basin have declined as of January 2008. The Grand Canyon population, which was the population analyzed in the 1995 biological opinion, appears to have recently improved to around 6,000 adult fish. This is less than the number of adult fish thought to be present in Grand Canyon in 1995, and indeed the status of the species is reduced overall from what it was in 1995. Much of the scope of dam operations for the next five years under the proposed action will contain elements of the 1996 (MLFF) and 2007 (Shortage Guidelines) RODs,

[4] See the December 27, 2004, memo from Acting Director, Fish and Wildlife Service.

such as the range of daily flow fluctuation and seasonal variations in monthly volume. However, the most recent and best available estimates of humpback chub population trend (Coggins 2007) indicate that there has been increased recruitment into the population from some year classes starting in the mid- to late-1990s, during the period of MLFF operations, causing the decline in humpback chub to stabilize and begin to reverse. This improvement in the population trend has been attributed in part to the results of nonnative fish mechanical removal, increases in temperature due to lower reservoir elevations and inflow events, the 2000 low steady summer flow experiment, and other experimental flows and actions (USGS 2006a). Considering though that the most recent population modeling indicates the increase was due to increased recruitment as early as 1996 but no later than 1999 (Coggins 2007), the increase in recruitment began at least four and as many as nine years prior to implementation of nonnative fish control, incidence of warmer water temperatures, the 2000 low steady summer flow experiment, and the 2004 high flow test. The exact causes of the increase in recruitment, and whether it is attributable to conditions in the mainstem or in the Little Colorado River are unclear. Nevertheless, removal of nonnative fish, increased temperature due to drought, and habitat conditions resulting from natural and experimental actions will likely be beneficial to humpback chub, and further increases in recruitment are likely based on recent catch rates of sub-adult humpback chub (Coggins 2007). These results indicate that some combination of conditions under MLFF has benefited humpback chub, and that more recent conservation actions likely have as well, and are likely to continue to.

- The proposed action will have some adverse effects from the displacement of young-of-year and juvenile humpback chub by the high flow test; however, these effects should be outweighed by the expected beneficial effects of the high flow test and fall steady flow components: creation or improvement of backwater habitats, the creation of more persistent suitable habitat conditions, the creation of warmer nearshore habitats, and the creation of more productive nearshore habitats. These effects will most benefit young-of-year and juvenile humpback chub, and should improve their survivorship, increasing total recruitment, thought to be the key factor in improving the status of this species.

- Reclamation is committed to implementing a suite of conservation measures, through the AMP. These conservation measures further increase our confidence in our opinion that all adverse affects of the proposed action are reduced to the point that the action will not jeopardize the species or result in adverse modification of critical habitat:

    - *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.

- We believe critical habitat will remain functional and continue to serve the intended conservation role for the humpback chub, and that elements of critical habitat will be improved by the proposed action (improved quantity and quality of nearshore habitats for young humpback chub) and that the suite of conservation measures implemented by Reclamation will serve to further benefit humpback chub critical habitat.

We present this conclusion for the Kanab ambersnail for the following reasons:

- Although implementation of the proposed action will result in some loss of Kanab ambersnails and their habitat, we anticipate this loss will be small and not impair the long-term stability of the population because Reclamation has agreed to implement the following conservation measure:

    - *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 m^2 [180 ft^2]) 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.

The conclusions of this biological opinion are based on full implementation of the project as described in the <u>Description of the Proposed Action</u> section of this document, including any Conservation Measures that were incorporated into the project design.

INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulations pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. “Take” is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. “Harm” is defined (50 CFR 17.3) to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. “Harass” is defined (50 CFR 17.3) as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns that include, but are not limited to, breeding, feeding or sheltering. “Incidental take” is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act, provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are non-discretionary and must be undertaken by Reclamation so that they become binding conditions of any grant or permit issued, as appropriate, for the exemption in section 7(o)(2) to apply. Reclamation has a continuing duty to regulate the activity covered by this incidental take statement. If Reclamation (1) fails to assume and implement the terms and conditions or (2) fails to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, Reclamation must report the progress of the action and its impact on the species to the FWS as specified in the incidental take statement [50 CFR § 402.14(i)(3)].

AMOUNT OR EXTENT OF TAKE

Humpback chub

The level of take that could occur from the proposed action would be in the form of harm or mortality, resulting primarily from the displacement of young-of-year and juvenile humpback chub during the experimental high flow test, stranding due to monthly flow transitions, and possibly from an increase in nonnative species via effects of the September and October steady releases. Reclamation estimates that displacement of juvenile humpback chub, based on Korman et al. (2004), will increase by about 15 percent as a result of the high flow test. In 2007, population size of sub-adult humpback chub in the mainstem could not be estimated because of low numbers captured. A past attempt to monitor this effect, during the 2004 high flow test, was confounded by the high turbidity that accompanies a high flow test; although catch of juvenile humpback chub decreased after the high flow test, catch rate is known to also decline with increased turbidity. A reasonable, although very approximate, estimate of numbers of young-of-year and juvenile humpback chub that could be present during the high flow test, based on catch rates and hoop net catch data, is about 6,000 (L. Coggins, U.S. Geological Survey, pers. com. 2007). Thus, based on Korman et al. (2004), approximately 900 young-of-year and juvenile humpback chub could be displaced. Humpback chub mortalities resulting from the high flow test will be difficult to detect, due to the small size of individuals transported downstream and the size and remoteness of the action area. And juvenile humpback chub that are displaced downstream are not necessarily killed, and could survive and even recruit into other aggregations. Given all of these factors, although take of juvenile humpback chub is reasonably certain to occur, in the form of harm and mortality as a result of the high flow test, the anticipated level of take of humpback chub is unquantifiable. Similarly, stable flows should benefit humpback chub, but the possibility exists that these flows may benefit nonnative species, which could result in take of humpback chub through harm or mortality. Again, due to logistical constraints and the difficulty in detecting take in this remote action area, we are unable to estimate the number of humpback chub that could be taken from this element of the proposed action. We anticipate, however, that because the proposed action will also have beneficial effects to humpback chub, and Reclamation is implementing a suite of conservation measures to help conserve the species, take of humpback chub from the proposed action is not anticipated to result in a decline in the overall Grand Canyon population. Reclamation's conservation measure to help develop a nearshore ecology study will provide important information in this regard. As a surrogate measure of take, we will consider anticipated take to be exceeded if the proposed action results in detection of more than 20 humpback chub mortalities during the high flow test, attributable to the high flow test.

Kanab Ambersnail

The level of take that could occur from the proposed action would be in the form of harm or mortality, resulting from scouring of habitat during the high flow test. Although the conservation measure to safe-guard habitat should offset much of the take to the species from the proposed action, and the actual level of take will be difficult to detect, as a surrogate measure of take, we will consider anticipated take to be exceeded if the proposed action results in more than 117 m^2 (1259 ft^2) of Kanab ambersnail habitat being removed at Vaseys Paradise and this loss is attributable to the high flow test.

EFFECT OF THE TAKE

In this biological opinion, we determine that this level of anticipated take is not likely to result in jeopardy to the humpback chub or Kanab ambersnail. The implementation of the proposed action will ensure that, while incidental take may still occur, it is minimized to the extent that habitat quality and quantity will be maintained in the planning area, and the species will be conserved.

REASONABLE AND PRUDENT MEASURES AND TERMS AND CONDITIONS

In order to be exempt from the prohibitions of section 9 of the Act, Reclamation must comply with the following terms and conditions, which implement the reasonable and prudent measures described above and outline required reporting/monitoring requirements. These terms and conditions are nondiscretionary.

Humpback Chub

The following reasonable and prudent measure is necessary and appropriate to minimize take of humpback chub:

> Monitor the effects of the proposed action on humpback chub and its habitat to document levels of incidental take and report the findings to the FWS. Reclamation shall work in

collaboration with the AMP participants including GCMRC and other cooperators to complete this monitoring.

The following term and condition will implement this reasonable and prudent measure:

Reclamation, in collaboration with the AMP participants including the GCMRC and other cooperators, shall submit a written report to the FWS annually documenting activities of the proposed action for the year, and any documented take. The report will include a discussion of the progress of the implementation of Reclamation's conservation measures included in the proposed action.

Kanab Ambersnail

The following reasonable and prudent measure is necessary and appropriate to minimize take of Kanab ambersnail:

Monitor the effects of the proposed action on Kanab ambersnail and its habitat to document levels of incidental take and report the findings to the FWS. Reclamation shall work in collaboration with the AMP participants including GCMRC and other cooperators to complete this monitoring.

The following term and condition will implement this reasonable and prudent measure:

Reclamation, in collaboration with the AMP participants including GCMRC and other cooperators, shall submit a written report to the FWS annually documenting activities of the proposed action for the year that resulted in documented take. The report will include a discussion of the progress of the implementation of Reclamation's conservation measure included in the proposed action.

Review requirement: The reasonable and prudent measures, with their implementing terms and conditions, are designed to minimize incidental take that might otherwise result from the proposed action. If, during the course of the action, the level of incidental take is exceeded, such incidental take would represent new information requiring review of the reasonable and prudent measures provided. Reclamation must immediately provide an explanation of the causes of the taking and review with FWS the need for possible modification of the reasonable and prudent measures.

Disposition of Dead or Injured Listed Species

Upon locating a dead, injured, or sick listed species, initial notification must be made to the FWS's Law Enforcement Office (2450 West Broadway Road, Suite 113, Mesa, Arizona, 85202, telephone: 480/967-7900) within three working days of its finding. Written notification must be made within five calendar days and include the date, time, and location of the animal, a photograph if possible, and any other pertinent information. The notification shall be sent to the Law Enforcement Office with a copy to this office. Care must be taken in handling sick or injured animals to ensure effective treatment and care and in handling dead specimens to preserve the biological material in the best possible state.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans or to develop information.

Humpback Chub

FWS recommends that Reclamation continue working with FWS to implement activities that will achieve the revised recovery goals for humpback chub when they become available in 2008. We also recommend that Reclamation utilize the Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon and work with FWS to determine what actions will remain to be accomplished, and find additional funding sources that would be provided by other willing partners to help achieve recovery.

Kanab Ambersnail

FWS recommends that Reclamation continue to work with FWS to implement the "Interim Conservation Plan for the *Oxyloma (haydeni) kanabensis* Complex and Related Ambersnails in Arizona and Utah" (AGFD 2002).

In order for the FWS to be kept informed of actions minimizing or avoiding adverse effects or benefiting listed species or their habitats, the FWS requests notification of the implementation of any conservation recommendations.

REINITIATION NOTICE

This concludes formal consultation on the action outlined in your request. As provided in 50 CFR 402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease, pending reinitiation.

We appreciate your continued efforts to conserve listed species. For further information, please contact Glen Knowles (602) 242-0210 or (x233) or Lesley Fitzpatrick (602) 242-0210 (x236). Please refer to consultation number (22410-1993-F-167R1) in future correspondence concerning this project.

Steven L. Spangle

cc: Regional Director, Fish and Wildlife Service, Albuquerque, NM
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Hopi Tribe, Kykotsmovi, AZ
Hualapai Tribe, Peach Springs, AZ
Kaibab Band of Paiute Indians, Pipe Springs, AZ
Navajo Nation, Window Rock, AZ
Pueblo of Zuni, Zuni, NM
San Juan Southern Paiute Tribe, Tuba City, AZ

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TABLES AND FIGURES

Table 1. Glen Canyon Dam release constraints as defined by Reclamation in the 1996 Record of Decision (U.S. Bureau of Reclamation 1996).

Glen Canyon Dam Release Constraints		
Parameter	**Release Volume (cfs)**	**Conditions**
Maximum Flow[1]	25,000	
Minimum Flow	5,000	Nighttime
	8,000	7:00 a.m. to 7:00 p.m.
Ramp Rates		
Ascending	4,000	Per hour
Descending	1,500	Per hour
Daily Fluctuations[2]	5,000 to 8,000	

1 May be exceeded for emergency and during extreme hydrological conditions.

2 Daily fluctuation limit is 5,000 cubic feet per second (cfs) for months with release volumes less than 0.6 maf; 6,000 cfs for monthly release volumes of 0.6 maf to 0.8 maf; and 8,000 cfs for monthly volumes over 0.8 maf.

Table 2. Projected Glen Canyon Dam releases for Water Year 2008 (U.S. Bureau of Reclamation 2007a).

	No Action				**Proposed Action**			
Month	**Monthly Volume (maf)**	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**	**Monthly Volume (maf)**	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**
Oct	600	9,758	6,800	12,800	601	9,774	6,800	12,800
Nov	600	10,083	7,100	13,100	604	10,134	7,200	13,200
Dec	800	13,011	9,000	17,000	800	13,011	9,000	17,000
Jan	800	13,011	9,000	17,000	800	13,011	9,000	17,000
Feb	600	10,804	7,800	13,800	600	10,804	7,400	13,400
Mar	600	9,758	6,800	12,800	830	13,499	7,200	13,200
Apr	600	10,083	7,100	13,100	550	9,243	6,200	12,200
May	600	9,758	6,800	12,800	555	9,042	6,000	12,000
Jun	650	10,924	7,900	13,900	650	10,924	7,900	13,900
Jul	850	13,824	9,800	17,800	820	13,336	9,300	17,300
Aug	900	14,637	10,600	18,600	820	13,336	9,300	17,300
Sep	630	10,588	7,600	13,600	600	10,083	10,083	10,083

Table 3. Projected releases from Glen Canyon Dam without the proposed action (under current conditions) under dry (7.48 maf), median (8.23 maf), and wet (12.3 maf) conditions, 2009-2012 (U.S. Bureau of Reclamation 2007a).

	7.48 maf			8.23 maf			12.3 maf		
Month	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**
Oct	7,502	5,300	10,300	9,758	6,800	12,800	9,378	6,800	12,800
Nov	7,563	5,900	10,900	10,083	7,100	13,100	9,075	7,100	13,100
Dec	9,378	6,800	12,800	13,011	9,000	17,000	12,503	9,000	17,000
Jan	12,503	9,000	17,000	13,011	9,000	17,000	17,510	14,200	22,200
Feb	8,470	7,800	13,800	10,804	7,800	13,800	13,903	13,700	21,700
Mar	9,378	6,800	14,800	9,758	6,800	12,800	14,776	11,400	19,400
Apr	7,563	5,900	10,900	10,083	7,100	13,100	14,551	12,200	20,200
May	9,378	6,800	12,800	9,758	6,800	12,800	14,880	11,500	19,500
Jun	9,075	7,100	13,100	10,924	7,900	13,900	17,009	14,900	22,900
Jul	12,503	9,000	17,000	13,824	9,800	17,800	19,776	16,600	24,600
Aug	12,503	9,000	17,000	14,637	10,600	18,600	23,883	20,900	25,000
Sep	9,075	7,100	13,100	10,588	7,600	13,600	21,056	19,400	25,000

Table 4. Projected releases from Glen Canyon Dam under the proposed action under dry (7.48 maf), median (8.23 maf), and wet (12.3 maf) conditions, 2009-2012 (U.S. Bureau of Reclamation 2007a).

	7.48 maf			**8.23 maf**			**12.3 maf**		
Month	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**
Oct	7,502	7,002	8,002	9,758	9,258	10,258	9,378	8,878	9,878
Nov	7,563	5,900	10,900	10,083	7,100	13,100	9,075	7,100	13,100
Dec	9,378	6,800	12,800	13,011	9,000	17,000	12,503	9,000	17,000
Jan	12,503	9,000	17,000	13,011	9,000	17,000	17,510	14,200	22,200
Feb	8,470	7,800	13,800	10,804	7,800	13,800	13,903	13,700	21,700
Mar	9,378	6,800	14,800	9,758	6,800	12,800	14,776	11,400	19,400
Apr	7,563	5,900	10,900	10,083	7,100	13,100	14,551	12,200	20,200
May	9,378	6,800	12,800	9,758	6,800	12,800	14,880	11,500	19,500
Jun	9,075	7,100	13,100	10,924	7,900	13,900	17,009	14,900	22,900
Jul	12,503	9,000	17,000	13,824	9,800	17,800	19,776	16,600	24,600
Aug	12,503	9,000	17,000	14,637	10,600	18,600	23,883	20,900	25,000
Sep	9,075	8,575	9,575	10,588	10,088	11,088	21,056	20,556	21,556

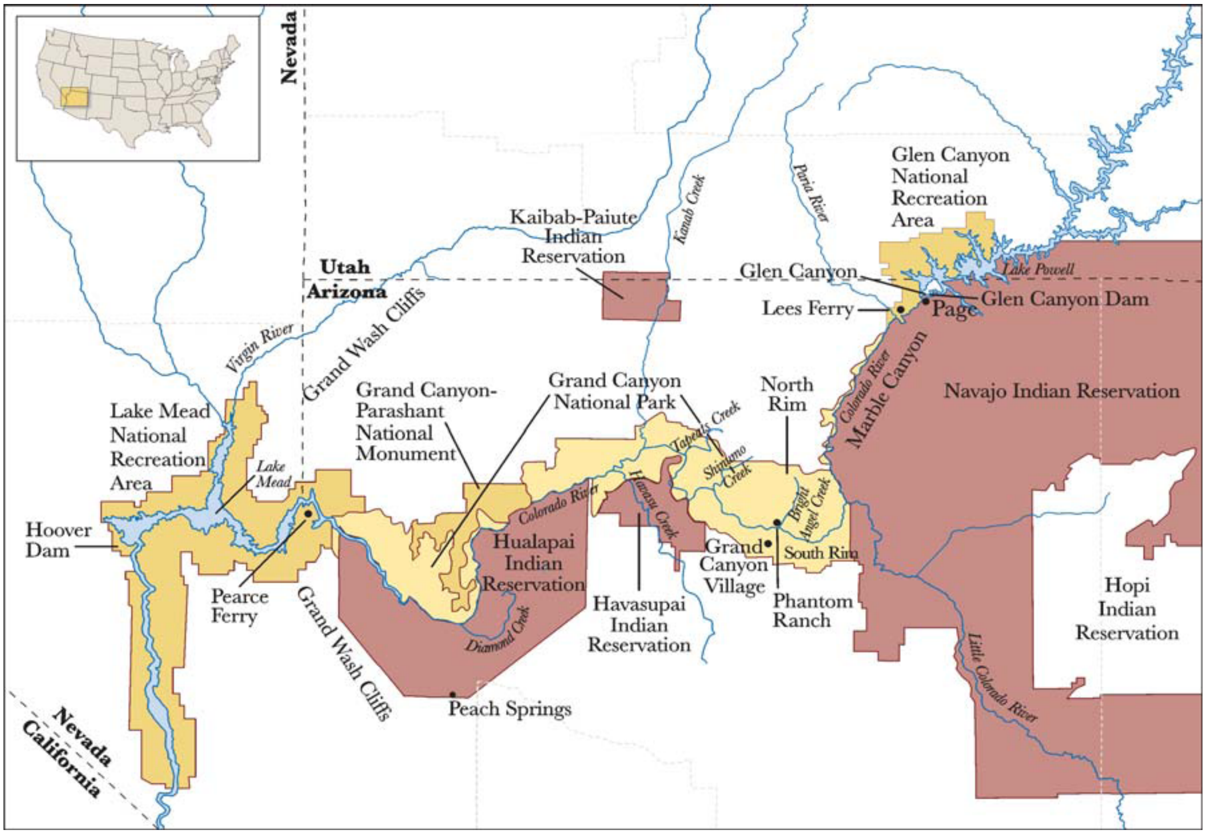

Figure 1. Action Area.

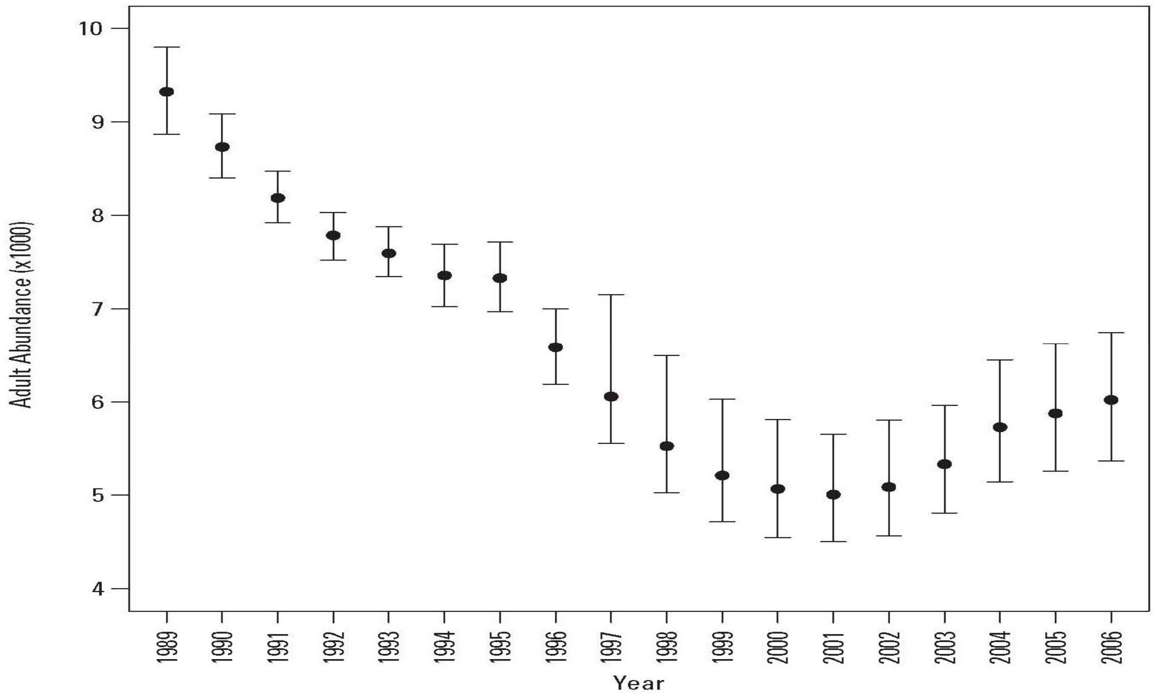

Figure 2. Adult (age 4+) humpback chub population estimates (1989-2005) for the Little Colorado River. Error bars are 95 percent Baysian credibility intervals and reflect uncertainties in assignment of age (Coggins 2007).

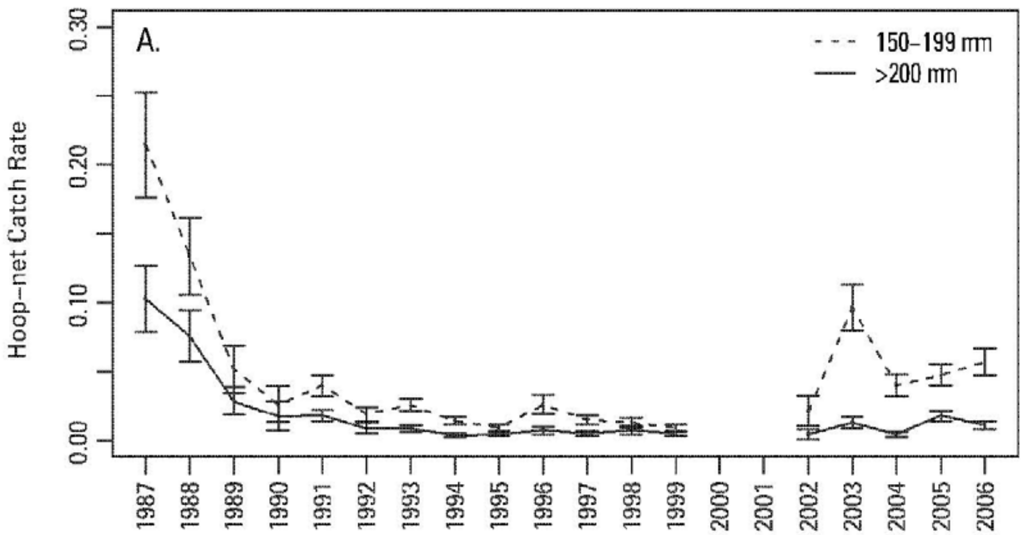

Figure 3. Relative abundance indices of sub-adult (150–199 mm [5.91-7.83 in] total length [TL]) and adult (≥200 [7.87 in] mm TL) humpback chub based on hoop-net catch rate (fish/hour) in the lower 1,200 m [3,937.0 ft] section of the Little Colorado River (Coggins 2007).

APPENDIX A: CONCURRENCES

Concurrence for Glen Canyon Dam Operations for the Period 2008-2012

FWS File No. 22410-1993-F-167R1

Proposed Project

This appendix contains the FWS concurrence with the determinations made by Reclamation for its implementation of proposed Glen Canyon Dam operations for the period 2008-2012 (U.S. Bureau of Reclamation 2007a). The proposed Federal action is described in the Proposed Action section of the attached biological opinion. Reclamation determined that the proposed action may affect, but is not likely to adversely affect, the razorback sucker and southwestern willow flycatcher, or adversely affect critical habitat for the razorback sucker. We concur with those determinations for the reasons described below.

RAZORBACK SUCKER AND ITS CRITICAL HABITAT

Status in the Action Area

The razorback sucker was listed as an endangered species October 23, 1991 (FR 56 54957; U.S. Fish and Wildlife Service 1991). The Razorback Sucker Recovery Plan was released in 1998 (U.S. Fish and Wildlife Service 1998). The Recovery Plan was updated with the Razorback Sucker Recovery Goals in 2002 (U.S. Fish and Wildlife Service 2002b). Critical habitat was designated in 15 river reaches in the historical range of the razorback sucker on March 21, 1994 (FR 59 13375; U.S. Fish and Wildlife Service 1994). Critical habitat includes portions of the Colorado, Duchesne, Green, Gunnison, San Juan, White, and Yampa rivers in the Upper Colorado River Basin, and the Colorado, Gila, Salt, and Verde rivers in the Lower Colorado River Basin.

Razorback sucker appear to use all riverine habitats available at some point in their lives in riverine reaches where they still occur, like the Green River, but habitat studies suggest that they may avoid whitewater reaches, and historically may have been uncommon in the turbulent canyon reaches of the Colorado River such as Grand Canyon. More typically, razorback sucker are found in calm, flatwater river reaches (Lanigan and Tyus 1989, Bestgen 1990). Razorback sucker have not been found in Grand Canyon (from Glen Canyon Dam to upper Lake Mead) since 1995, and only 10 razorback suckers (all adults) have been reported from Grand Canyon (Valdez 1996). A small, but reproducing population occurs in nearby Lake Mead, primarily in Las Vegas Bay, Echo Bay, and the Virgin and Muddy river inflow areas (Albrecht et al. 2007). Radiotagged razorback suckers released in spring of 1997 in the Lake Mead inflow eventually moved into the reservoir and no specimens have been reported from the inflow in recent surveys (Ackerman et al. 2006; Van Haverbeke et al. 2007). Critical habitat in the action area is present from the Paria River confluence to Hoover Dam (U.S. Fish and Wildlife Service 1994).

Reclamation has committed to investigating the potential to improve the status of razorback sucker in the action area, in collaboration with the AMP, MSCP, NPS, GCMRC and other stakeholders as part of their proposed action for the Shortage Guidelines. Reclamation will commit funding to evaluating potential habitat within the AMP for possible razorback sucker augmentation. If augmentation is deemed appropriate, the source of augmented fish and the spatial extent of augmentation will be coordinated with FWS.

Analysis of Effects

Adult razorback sucker are unlikely to be affected by the high flow test because they should be able to withstand high flows and cold temperatures with little or any adverse effect. Steady flows in September and October would likely benefit razorback suckers by providing for more stable and productive habitats. However, because the species is very rare or absent in the action area, the probability of an adverse or beneficial effect is extremely unlikely. Habitat suitability for razorback sucker in general in the action area remains in question. Reclamation's efforts to evaluate the potential for razorback sucker habitat and suitability for augmentation will address this need. If suitable habitat exists, augmentation could result in an expansion of the range of the species and an improvement in its status.

Conclusions

After reviewing the status of the razorback sucker including the environmental baseline for the action area, and the effects of the proposed action, we concur that the proposed action may affect, but is not likely to adversely affect the razorback sucker or its critical habitat, based upon the following:

- The species is extremely rare in the action area, and ongoing monitoring should detect changes in its occurrence;

- Reclamation will undertake an effort to examine the potential of habitat in Grand Canyon for the species, and institute an augmentation program in collaboration with FWS, if appropriate.

SOUTHWESTERN WILLOW FLYCATCHER

Status in the Action Area

The southwestern willow flycatcher was listed as endangered without critical habitat on February 27, 1995 (60 FR 10694; U.S. Fish and Wildlife Service 1995b). Critical habitat was later designated on July 22, 1997 (62 FR 39129; U.S. Fish and Wildlife Service 1997). On October 19, 2005, the FWS re-designated critical habitat for the southwestern willow flycatcher (70 FR 60886; U.S. Fish and Wildlife Service 2005b). A total of 737 river miles across southern California, Arizona, New Mexico, southern Nevada, and southern Utah were included in the final designation. The lateral extent of critical habitat includes areas within the 100-year floodplain. The primary constituent elements of critical habitat are based on riparian plant species, structure and quality of habitat and insects for prey. A final recovery plan for the southwestern willow flycatcher was completed in 2002 (U.S. Fish and Wildlife Service 2002b).

Flycatchers have consistently nested along the Colorado River in Grand Canyon over the last 30 years, with territories typically located in tamarisk-dominated riparian vegetation along the river corridor (James 2005). Suitable habitat is extremely disjunct from approximately RM 28 to RM 274 (Gloss et al. 2005, James 2005, Christensen 2007). Surveys conducted between 1992 and 2007 indicate a very small resident breeding population in upper Grand Canyon, mostly at RM 50-51 and the area around RM 28-29, although only 1 to 5 territories have been detected in any one year. Another area of importance in the mid-1990s was RM 71-71.5. However, that area does not appear to have been occupied for the last 10 years (Gloss et al. 2005, James 2005). The Lower Gorge area of Grand Canyon (RM 246-272) supported as many as 12 territories in 2001, but with drought and low reservoir elevations in Lake Mead, this area has since supported only a single successful nesting pair in 2004; new habitat is emerging and may soon be occupied.

Analysis of Effects

The southwestern willow flycatcher can be adversely affected by high flows through scouring and destruction of willow-tamarisk shrub nesting habitat or wetland foraging habitat, or conversely, through a reduction in flows that desiccate riparian and marsh vegetation. Willow flycatcher nests in Grand Canyon are typically above the 45,000 cfs stage (Gloss et al. 2005), which will not be exceeded for the high-flow test. Flycatchers breed from April through August (U.S. Fish and Wildlife Service 2002c), thus the time frame for the planned high-flow test is also outside of the nesting period for southwestern willow flycatchers. Flycatchers nest primarily in tamarisk shrub in the lower Grand Canyon which is quite common and is not an obligate phreatophtye, thus capable of surviving lowered water levels (DeLoach 1991). Therefore, neither the high flow test nor the potentially lower flows in September and October of the proposed action are expected to kill or remove tamarisk, and no loss of southwestern willow flycatcher nesting habitat is anticipated.

An important element of flycatcher nesting habitat is the presence of moist surface soil conditions (U.S. Fish and Wildlife Service 2002b). Moist surface soil conditions are maintained by overbank flow or high groundwater elevations supported by river stage. During September and October, steady flows under the proposed action will likely be somewhat lower than those found under the no-action peak releases. The potential exists for groundwater elevations adjacent to the channel to decline through the steady flows, which could desiccate nesting habitat. However, September and October are outside of the normal nesting period for southwestern willow flycatcher. The short time period and small change in flow volume lessens the likelihood that any flycatcher habitat will be permanently affected. Thus the proposed action will likely have little effect on the abundance or distribution of southwestern willow flycatcher in the action area or regionally.

Conclusions

After reviewing the status of the southwestern willow flycatcher including the environmental baseline for the action area, and the effects of the proposed action, we concur that the proposed action may affect, but is not likely to adversely affect the southwestern willow flycatcher. No southwestern willow flycatcher critical habitat occurs in the action area, thus none will be affected. We base our concurrence on the following:

- Flycatcher habitat in the action area consists of tamarisk, which is not likely to be affected by either the high flow test or the relatively brief periods of slightly lower flows during the proposed steady releases.

- The timeframe for the main elements of the proposed action are outside of the flycatcher breeding season.