United States Department of the Interior

U.S. Fish and Wildlife Service
2321 West Royal Palm Road, Suite 103
Phoenix, Arizona 85021-4951
Telephone: (602) 242-0210 FAX: (602) 242-2513

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Memorandum

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

From: Field Supervisor

Subject: Supplement to the 2008 Final Biological Opinion for the Operation of Glen Canyon Dam

On February 27, 2008, we issued our biological opinion on the operation of Glen Canyon Dam for the period 2008-2012 (2008 Opinion). On May 26, 2009, the District Court of Arizona, in response to a lawsuit brought by the Grand Canyon Trust, ordered the U.S. Fish and Wildlife Service (FWS) to reevaluate the conclusion in the 2008 Opinion that the Modified Low Fluctuating Flow (MLFF) does not violate the Endangered Species Act of 1973 (16 U.S.C. 1531-1544), as amended (Act) (Case number CV-07-8164-PHX-DGC). The Court Ordered the FWS to provide an analysis and a reasoned basis for its conclusions in the 2008 Opinion, and to include an analysis of how MLFF affects critical habitat and the functionality of critical habitat for recovery purposes by October 30, 2009. A copy of the new opinion is to be provided to counsel for the Grand Canyon Trust on or before the close of business on November 2, 2009.

The court noted that other portions of the biological opinion, the two components analyzing the U.S. Bureau of Reclamation's (Reclamation) proposed action for steady flow releases in September and October 2008-2012 and the 2008 experimental high flow test, were adequate and would remain in effect. The court further ordered that "Reclamation may continue operating the Dam in accordance with the 2008 Experimental Plan" in the interim.

This document is a supplement to the 2008 Opinion in response to the Court Order, pursuant to section 7 of the Act. It provides a new analysis of the effects of MLFF on endangered humpback chub (*Gila cypha*) and its critical habitat, and the endangered Kanab ambersnail (*Oxyloma haydeni kanabensis*). It also provides an explanation for why MLFF does not destroy or adversely modify humpback chub critical habitat and addresses whether MLFF will advance or impede chub recovery.

Reclamation, in its original November 13, 2007, request for consultation, also requested our concurrence that the proposed action was not likely to adversely affect the razorback sucker (*Xyrauchen texanus*) and its critical habitat, or the southwestern willow flycatcher (*Empidonax traillii extimus*) and its critical habitat. FWS had concurred with these determinations on February 27, 2008. However, in light of the Court Order, FWS reevaluated these determinations. Upon reevaluation of the effects of MLFF on these species, we continue to 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.

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.

SUPPLEMENTAL BIOLOGICAL OPINION ON THE OPERATION OF GLEN CANYON DAM 2008-2012

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INTRODUCTION

Consultation History

This document is a court ordered supplement to the 2008 biological opinion on the operation of Glen Canyon Dam (U.S. Fish and Wildlife Service 2008a) (2008 Opinion) that was issued on February 27, 2008, pursuant to section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq) (Act). Litigation brought by the Grand Canyon Trust on the 2008 Opinion resulted in a court order from the District Court of Arizona (Court Order) (No. CV-07-8164-PHX-DGC, document 172, May 26, 2009) (U.S. District Court of Arizona 2009) that remanded a portion of that biological opinion back to the U.S. Fish and Wildlife Service (FWS). The court ordered FWS to reevaluate the effects of Reclamation's action, specifically the effect of implementing the Modified Low Fluctuating Flow (MLFF), including the effect of MLFF on the humpback chub and its critical habitat, and whether the implementation of MLFF does or does not jeopardize the humpback chub or adversely modify its critical habitat, and whether MLFF will advance or impede humpback chub recovery. This supplemental biological opinion is the FWS response to the Court Order. The court ruled that analysis in the 2008 Opinion concerning other components of Reclamation's proposed action other than MLFF was adequate and remains in effect.

Our approach to respond to the Court Order in evaluating the effects of MLFF on humpback chub critical habitat and recovery is to utilize the best available scientific information. In this case, descriptions of critical habitat and the features that define critical habitat, the Primary Constituent Elements (PCEs), are provided by the final rule designating critical habitat and two supporting documents (U.S. Fish and Wildlife Service 1994, Maddux et al. 1993a, 1993b). We have evaluated the effect of MLFF on these PCEs to determine the effect of the action on critical habitat. To evaluate how the effects to critical habitat advance or impeded recovery, we have utilized the FWS draft Humpback Chub Recovery Goals (Recovery Goals) (U.S. Fish and Wildlife Service 2009). The Recovery Goals provide objective measurable recovery criteria to evaluate progress towards recovery. Two types of criteria are provided: demographic criteria and threat-based recovery factor criteria. The demographic criteria provide goals for numbers of adult humpback chub in the population, as well as trend in the size of the adult population. The recovery factor criteria provide site-specific management actions and tasks to implement to reduce specific threats such that recovery may be obtained. In our analysis, we have evaluated how the action affects the PCEs of critical habitat in light of the Recovery Goals, utilizing both the demographic criteria, and recovery factor criteria. This process is described where relevant throughout the document, and the recovery criteria from the Recovery Goals have been provided in Appendix B.

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. We have also relied upon the U.S. Fish and Wildlife Service and National Marine Fisheries Service Consultation Handbook (Consultation Handbook) (U.S. Fish and Wildlife Service and National Marine Fisheries Service 1998), which provides guidance on determining adverse modification of critical habitat, including the following (p. 4-34):

> Adverse effects on individuals of a species or constituent elements or segments of critical habitat generally do not result in jeopardy or adverse modification determinations unless that loss, when added to the environmental baseline, is likely to result in significant adverse effects throughout the species' range, or appreciably diminish the capability of the critical habitat to satisfy essential requirements of the species."

Thus, based on the statutory provisions of the Act and existing guidance, in evaluating whether Reclamation's action will result in adverse modification of humpback chub critical habitat, we have evaluated whether or not the effects of Reclamation's action appreciably diminish the capability of critical habitat to provide for the recovery of the species as currently defined by the Humpback Chub Recovery Goals (U.S. Fish and Wildlife Service 2009).

In this biological opinion, we have determined that Reclamation's proposed action, as defined here and in the 2008 Opinion, does not jeopardize the continued existence of the humpback chub, or result in destruction or adverse modification of its critical habitat. This is in contrast to our 1995 Final Biological Opinion on the Operation of Glen Canyon Dam (1995 Opinion) that concluded that Reclamation's implementation of MLFF would jeopardize the continued existence of the species, and destroy or adversely modify its critical habitat (U.S. Fish and Wildlife Service 1995a). The reason for the reversal of our conclusion in 1995 is because the population of adult humpback chub in Grand Canyon has been increasing in size since 2001, and recruitment of young chub into the adult population has been increasing since the mid to late 1990's (Coggins and Walters 2009), and this seems due, at least in part, to the implementation of MLFF through the Glen Canyon Dam Adaptive Management Program (GCDAMP), which includes related monitoring, research, management actions, and conservation measures designed to benefit the species. Further, since our 1995 Opinion, recovery goals have been completed for the species, and although currently only in draft form, indicate that the Grand Canyon population of humpback chub is near to, or has met, the demographic goal for consideration for downlisting to threatened status (U.S. Fish and Wildlife Service 2009). Although Reclamation's action has some adverse affects to humpback chub and its critical habitat critical habitat appears to be providing for recovery now, and Reclamation's action includes research needed to evaluate effects to critical habitat to further refine operations to meet recovery needs in future iterations of flow testing and adaptive management. We also now have new information from other populations of humpback chub regarding the relationship between water quality and hydrology, their affects on nonnative fish species, and the severity of the threat of nonnative fish species to humpback chub.

As we will explain further, Reclamation's proposed action, which continues actions believed beneficial to humpback chub, such as fall steady flows and high flows to improve nearshore habitats, removal and control of nonnative fishes, and research to meet recovery needs, will likely be beneficial to humpback chub, and further increases in recruitment are expected. The best available scientific information indicates that the implementation of MLFF, in an adaptive management context, along with these other aspects of Reclamation's action, has not resulted in jeopardy to humpback chub or destruction or adverse modification of its critical habitat since 1995. In fact, although MLFF results in adverse affects to humpback chub, Reclamation's implementation of MLFF through an adaptive management program appears to have benefited humpback chub, and we believe is likely to continue to do so. In 1995, the implementation of

the MLFF in an adaptive management program had not yet been implemented; in 2009, it has been implemented, tested, refined, and shown results in the conservation of humpback chub.

Throughout this document, we have updated sections of the 2008 Opinion in response to the Court Order. Where changes or updates were not necessary, we refer to the original 2008 Opinion, and we incorporate the entire 2008 Opinion here by reference. Both the 2008 Opinion and this supplement constitute our biological opinion on Reclamation's proposed action as defined in its December 21, 2007, biological assessment (U.S. Bureau of Reclamation 2007a) and related documents. The 2008 Opinion and this supplement replace the FWS 1995 jeopardy biological opinion on the operation of Glen Canyon Dam (U.S. Fish and Wildlife Service 1995a). The introduction and consultation history sections of the 2008 Opinion provide important background information on the structure, function, and history of the GCDAMP, the relationship between the GCDAMP and Reclamation in the operation of Glen Canyon Dam, and the history of prior consultations between FWS and Reclamation on the operation of Glen Canyon Dam. There are no additional changes needed to these sections, and we refer the reader to the 2008 Opinion.

For geographical reference purposes, this document uses the convention of river miles (RM) to indicate location in reference to Lees Ferry and Glen Canyon Dam as defined in Stevens (1983).

BIOLOGICAL OPINION

DESCRIPTION OF THE PROPOSED ACTION

This supplemental biological opinion focuses on the MLFF portion of Reclamation's proposed action, as requested by the Court Order. All other aspects of the proposed action remain the same as defined in the 2008 Opinion, except where noted, and continue to be addressed by the 2008 Opinion. Note that because the high flow test has already occurred in March of 2008, and the September-October steady flows continue to be addressed by the 2008 Opinion, the Glen Canyon Dam releases for the period of the proposed action considered in this supplemental biological opinion consist of MLFF flows from November 1, 2009 to August 31, 2010, November 1, 2010 to August 31, 2011, and from November 1, 2011 to August 31, 2012.

Glen Canyon Dam is a feature of the Colorado River Storage Project that is operated by Reclamation, an agency within the Department of the Interior, as a multipurpose storage facility. It is located in Coconino County near the town of Page in northern Arizona. Construction of the dam was authorized by the 1956 Colorado River Storage Project Act and operation of the dam is governed by a complex set of compacts, Federal statutes and regulations, court decrees, and an international treaty commonly referred to as the Law of the River. In the 1980s, Reclamation studied the relationship between the condition of downstream river resources and operations of Glen Canyon Dam, culminating in an environmental impact statement (EIS) finalized in 1995 (U.S. Bureau of Reclamation 1995). Based on the analyses in the EIS, the Secretary of the Interior determined, in a 1996 record of decision (ROD), that the dam should be operated using the Modified Low Fluctuating Flow (MLFF) Alternative. Region 2 of the U.S. Fish and Wildlife Service (FWS) issued a biological opinion on implementation of the MLFF in 1995 (U.S. Fish and Wildlife Service 1995a). The fundamental direction contained in the 1995 Opinion was that future modifications to Glen Canyon Dam operations be analyzed in the context of adaptive management. The 1996 ROD (U.S. Bureau of Reclamation 1996) established the GCDAMP for this purpose.

The Secretary of the Interior (Secretary), through Reclamation, determines Glen Canyon Dam releases based on regional hydrology and the Law of the River. The Colorado River Basin Project Act of 1968 (CRBPA), which authorized construction of a number of water development projects including the Central Arizona Project, required the Secretary to develop Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs (LROC), and issue an annual operating plan (AOP) that, among other information, identifies the anticipated annual operation for mainstem Colorado River reservoirs. The AOP is a single, integrated reference document required by section 602(b) of the CRBPA regarding both the past year's operations as well as projected operations that are anticipated in the current year. The 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Shortage Guidelines) further modified the range of releases that could be made under the Law of the River. These Guidelines were adopted pursuant to a record of decision (ROD), signed by the Secretary of the Interior on December 13, 2007. Reclamation consulted with FWS on implementation of the Shortage Guidelines which resulted in our December 12, 2007, biological opinion (U.S. Fish and Wildlife Service 2007).

Reclamation prepares an AOP each year which describes the past year's annual release and projects the current year's annual release. Since 1970, the annual volume of water released from Glen Canyon Dam has been made according to the provisions of the LROC that include a minimum objective release of 8.23 million acre feet (maf). The Shortage Guidelines and ROD (U.S. Bureau of Reclamation 2007b, c), which implements relevant provisions of the LROC for an interim period through 2026, allows Reclamation to modify these operations by allowing for potential annual releases both greater than and less than the minimum objective release under certain conditions. We refer to Reclamation's EIS for the Shortage Guidelines (U.S. Bureau of Reclamation 2007b) and our biological opinion on the Shortage Guidelines (U.S. Fish and Wildlife Service 2007) for a more thorough description of Reclamation's process for determining and implementing annual release volumes.

Although the Law of the River defines how annual release volumes are determined, and the Shortage Guidelines allow for more flexibility in annual release volumes, monthly and hourly release volume are still governed by the 1995 EIS and 1996 ROD for the operation of Glen Canyon Dam. Monthly and hourly dam releases are the subject of this biological opinion, and the proposed action is defined in Reclamation's 2007 biological assessment (U.S. Bureau of Reclamation 2007a) and 1995 EIS and 1996 ROD for the operation of Glen Canyon Dam (U.S. Bureau of Reclamation 1995, 1996), as well as the exception criteria as outlined in the 1997 Glen Canyon Dam Operating Criteria (U.S. Bureau of Reclamation 1997).

Following adoption of the 1996 ROD, Glen Canyon Dam has been operated in accordance with MLFF release constraints as defined in Table 1. MLFF applies flow constraints to Glen Canyon Dam releases such that no less than 8,000 cubic feet per second (cfs) during the day or 5,000 cfs at night may be released, and no more than 25,000 cfs at any one time, except in times of flood or emergency. The daily fluctuation limit is 5,000 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. Changes in release volumes (ramping rates) are constrained to 4,000 cfs/hour ascending and 1,500 cfs/hour descending.

Release volumes are dependent on area hydrology. Reclamation has modeled dry, median, and wet hydrologic scenarios to predict possible flow releases. Reclamation considers a dry year in these models to be 7.48 maf, the median, or most probable, to be 8.23 maf, and a wet year to be 12.3 maf. Predictions for the period 2009-2012 were provided in the 2008 Opinion, but are provided again here for reference in Table 2. Actual releases for 2008 and 2009 were 8.973 and 8.23 maf respectively (Table 3). A complete description of the modeling methods Reclamation employs, as well as historical hydrologic data for the Colorado River including Glen Canyon Dam release data, is provided in Reclamation's Shortage Guidelines EIS (U.S. Bureau of Reclamation 2007b).

Reclamation's proposed action as originally defined in the 1996 ROD includes, as a major component, the implementation of an adaptive management program. Adaptive management is a systematic approach for improving resource management by learning from management outcomes (Williams et al. 2007). The GCDAMP has been operating as an adaptive management program since 1997, implementing the adaptive management program requirement of the 1996 ROD. The GCDAMP is considered to be part of Reclamation's proposed action. The

GCDAMP provides funding annually to research, monitoring, and management actions that provide a significant benefit to many resources in Grand Canyon, including conservation benefits to ESA-listed species. The framework of the adaptive management program and the history of actions the GCDAMP has taken to benefit listed species, particularly humpback chub and Kanab ambersnail, are described in detail in the 2008 Opinion. Some of these actions are also conservation measures in the 2008 Opinion. The research and monitoring activities, management actions, and conservation measures carried out under the GCDAMP are a significant part of Reclamation's proposed action, and are summarized here because of their importance in considering the total effect of Reclamation's proposed action. These actions inform the GCDAMP in an adaptive management context. Thus the proposed action consists of the current flow experiment, the 2008 high flow test, the MLFF, and September and October steady flows from 2008-2012, as well as monitoring, research, and management actions implemented by Reclamation and the GCDAMP. The results of the current experiment inform the next period of experimentation and will be used by Reclamation to develop the next set of experimental flow operations.

The GCDAMP created a strategic plan that includes a list of 12 goals, two of which address species considered in this consultation: Goal 2, Maintain or attain viable populations of existing native fish; and Goal 5, Maintain or attain viable populations of Kanab ambersnail (Glen Canyon Dam Adaptive Management Program 2002). Other goals are closely related to these and also influence humpback chub and its critical habitat: Goal 1, Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels; Goal 7, Establish water temperature, quality, and flow dynamics to achieve the GCDAMP ecosystem goals; and Goal 8, Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve the GCDAMP ecosystem goals.

Ongoing monitoring and research and other activities of the GCDAMP are defined annually in work plans. The following is a list of key GCDAMP monitoring, research and other activities from the GCDAMP 2010-2011 Budget and Work Plan recently recommended for implementation by the Adaptive Management Work Group to the Secretary of the Interior (U.S. Bureau of Reclamation and U.S. Geological Survey 2009). Although these projects can change on an annual basis, they are essentially the implementation of the GCDAMP and are thus important parts of Reclamation's proposed action. Any take of humpback chub associated with these projects is permitted through FWS section 10(a)(1)(A) recovery permits.

BIO 2.R1.10—Little Colorado River Humpback Chub Monitoring Lower 13.6 km (Population Estimates)
BIO 2.R2.10—Little Colorado River Humpback Chub Monitoring Lower 1,200 m,
BIO 2.M1.11—Little Colorado River Humpback Chub Monitoring

These 3 projects constitute the GCDAMP's monitoring of humpback chub in its primary spawning tributary in Grand Canyon, the Little Colorado River (LCR). This monitoring provides an annual assessment of the humpback chub population in the LCR by collecting the mark-recapture data that supports an annual closed population estimate for the species in the LCR. These data are also critical for use in the Age-Structured Mark-Recapture model (ASMR) used in modeling the population structure and abundance of the LCR population of humpback

chub (Coggins and Walters 2009). These projects also provide information on humpback chub spawning, external parasite loads, and predation frequency, as well as important information on aspects of humpback chub critical habitat in the LCR, including relative abundance and distribution of nonnative fish in the lower 13.6 kilometers (km) (8.45 miles) of the LCR, and important physical parameters such as stream flow, water temperature, and turbidity.

BIO 2.M3.10–11—Humpback Chub Translocation and Monitoring Above Chute Falls

Translocating humpback chub above Chute Falls, a series of waterfalls approximately 16 km (8.5 miles) upstream on the LCR above the confluence with the Colorado River, has been conducted since 2003, and was a conservation measure of our 2002 biological opinion (U.S. Fish and Wildlife Service 2002a). The project essentially aims to improve survivorship of young humpback chub by removing them from an area where they are susceptible to being flushed into the mainstem Colorado River, where nursery habitat and survivorship is poor, to areas upstream in the LCR where nursery habitats are more suitable. Translocation of humpback chub is one of the conservation measures identified in Reclamation's proposed action in the 2008 Opinion, and the project consists of continuing to translocate small humpback chub annually from near the confluence with the Colorado River to above Chute Falls and obtaining population estimates for the reach of the LCR at and upstream of the falls. The project also serves to define physical and biotic factors of humpback chub habitat, and to determine the abundance and distribution of nonnative fishes in this reach and monitor for nonnative fishes that invade from upstream areas of the LCR basin. This project is contributing to recovery by expanding the range of humpback chub in the LCR, increasing the carrying capacity of the LCR, and thus likely increasing the overall population size of humpback chub in Grand Canyon in support of the demographic goal for recovery (U.S. Fish and Wildlife Service 2009).

BIO 2.M4.10–11—Monitoring Mainstem Fish

This project consists of monitoring native and nonnative fish in the Colorado River mainstem, which includes monitoring the nine mainstem humpback chub aggregations[1]. The data generated by this project provide the baseline for assessing the effect of Glen Canyon Dam operations on humpback chub and other native and nonnative fish in the mainstem. Analysis of the data the project generates provides insight into the mechanisms controlling population dynamics of native and nonnative fishes which is critical for the GCDAMP's ability to refine policy decisions to be consistent with the attainment of management goals. The project also provides an ongoing assessment of key PCEs of humpback chub critical habitat, the relative abundance and distribution of nonnative fishes that prey on and compete with humpback chub. This project is also essential in detecting any new nonnative fish species invading the system.

BIO 2.R7.10–11—Stock Assessment of Grand Canyon Native Fish

This project provides annual updates of size composition and capture rates of humpback chub and other native and nonnative fishes is Grand Canyon, and reports on changes in abundance and distribution of fishes over time. The stock assessments generated from this project support

[1] There are nine mainstem spawning aggregations of humpback chub in Marble and Grand canyons. These are described in the Status of the Species section, and were originally defined by Valdez and Ryel (1995).

assessment of implemented experimental actions, such as high flow tests and fall steady flow releases, information that is crucial to inform the GCDAMP as to attainment of identified goals, and to providing baseline status and trend information. The assembled data from the Grand Canyon fish monitoring projects will be incorporated into updates of the Age-Structured Mark-Recapture model.

BIO 2.R13.10–11—Remote PIT Tag Reading

Passive Integrated Transponder (PIT) tags are a type of radio tag employed to mark individual humpback chub. This project utilizes remote automated antennas and digital recording devices to detect and record marked fish that pass nearby in the LCR. The project will help refine methods for estimating the population size of humpback chub and other Grand Canyon fish, and determine movement patterns of fish in Grand Canyon into and out of the LCR. This project will also test monitoring methods that do not require repeated handling of fish, which reduce handling stress on humpback chub.

BIO 2.R15.10–11—Nearshore Ecology / Fall Steady Flows

The lack of suitable nursery habitats for young humpback chub in the mainstem Colorado River has long been identified as a likely cause of the decline of the species in Grand Canyon. Numerous factors may contribute to this, but water temperature and daily fluctuations in stage and flow are most often hypothesized as factors that limit the suitability of nearshore habitats important for rearing juvenile humpback chub (Lupher and Clarkson 1994, Valdez and Ryel 1995, Arizona Game and Fish Department 1996, Stone and Gorman 2006). Another consideration is the effect of Glen Canyon Dam and its operation on sediment-formed habitats such as backwaters that may provide important nursery habitats. A conservation measure from the 2008 Opinion, the Nearshore Ecology Study (NSE) will attempt to relate river flow variables and ecological attributes of nearshore habitats to better understand the relative importance of the biotic and abiotic attributes of various habitats to juvenile (< 200mm total length [TL]) native and nonnative fish. The project will help answer key questions on the importance of different habitat types to juvenile humpback chub and the effect dam operations have on physical and biological characteristics of these habitats, including the PCEs of critical habitat for young humpback chub: water quality (e.g. temperature and turbidity), physical habitat (e.g. backwaters, talus slopes), and the biological environment (food availability, and predation and competition from nonnative fishes). The draft Recovery Goals (U.S. Fish and Wildlife Service 2009) indentify the need to define the relationship between life stages and habitats of humpback chub in the mainstem Colorado River and humpback chub in the Little Colorado River, and to determine the necessary flow regime for releases from Glen Canyon Dam to support a recovered population (as defined by the demographic criteria). This project will directly address these recovery research needs.

BIO 2.R16.10–11—Mainstem Nonnative Fish Control

Control of nonnative fishes is one of the key conservation measures from the 2008 Opinion. Predation and competition from nonnative fishes is a significant, and perhaps the most significant, threat to humpback chub (Minckley 1991, Hilwig et al. 2009). This threat, and the

need to ameliorate it through control, is recognized in the biological environment PCE of critical habitat (U.S. Fish and Wildlife Service 1994), the draft Recovery Goals for the species (U.S. Fish and Wildlife Service 2009), and the GCDAMP's Comprehensive Plan for the Management and Conservation of Humpback Chub (*Gila cypha*) in the Lower Colorado River Basin (HBC Comprehensive Plan, Glen Canyon Dam Adaptive Management Program 2009). This project focuses on controlling nonnative fishes, and in particular rainbow trout (*Onchorynchus mykiss*) and brown trout (*Salmo trutta*), in the reach of the Colorado that spans the mouth of the LCR. This reach has been targeted because of its importance to humpback chub; the highest concentrations of juvenile humpback chub occur here as they exit the LCR, and are most vulnerable to predation here due to thermal shock as they exit the warm LCR and enter the cold mainstem.

The project utilizes electrofishing primarily to capture and remove nonnative fish, mostly trout, and provides additional information on the relative abundance and distribution of native and nonnative fishes. Nonnative fish removal was first implemented from 2003 to 2006. That effort demonstrated that rainbow trout, brown trout, and other nonnatives could be mechanically controlled in a limited reach of river. Yard et al. (2008) found that although rainbow trout have only limited ability to successfully prey on humpback chub, at the high densities that occurred in 2003 and are occurring now, they can have a measureable, negative impact on humpback chub. The project will also identify alternatives to mechanical control in this reach that could potentially be more effective and cost-effective. This project provides important information about the biological environment PCE of critical habitat, as well as improving this PCE through removal of nonnative fishes.

While mechanical removal efforts in the LCR inflow reach have been demonstrated to be effective in reducing the numbers of trout and other nonnative fish, there are long-standing concerns by Native American stakeholders about conducting this effort in this culturally sensitive reach. Mechanical removal efforts in this portion of the river are also both expensive and logistically demanding. In 2010, the Grand Canyon Monitoring and Research Center (GCMRC) will also examine alternatives to mechanical control in this reach, such as mechanically removing trout upstream of the confluence in sections of Marble Canyon, using discrete flows to limit recruitment of , and increasing turbidity through augmentation. Scoping will be conducted during 2010 to include GCDAMP stakeholders, relevant Federal and State agencies, and other interested parties.

The Recovery Goals include threat factor-based recovery criteria that directly address the threat of predation of nonnative fishes. The recovery factor criteria include developing and implementing nonnative fish control programs for both warm water species, and for brown and rainbow trout, to identify levels of control that will minimize negative interactions on humpback chub in the Colorado River through Grand Canyon, and to implement identified levels of control to benefit humpback chub. This project directly addresses this recovery need by developing and implementing these control programs.

BIO 2.R17.10–11—Nonnative Control Science Support

The Grand Canyon Monitoring and Research Center (GCMRC) completed a draft plan in July of 2009, "Nonnative Fish Management Plan for Grand Canyon—A Comprehensive Approach to Management and Research of Nonnative Fish Species" (Nonnative Fish Management Plan) (Hilwig et al. 2009), for the control of nonnative fishes in Grand Canyon. This project provides science support efforts to monitor nonnative fish in Grand Canyon and to recommend appropriate control methods, implementing the analysis functions of the Nonnative Fish Management Plan to control nonnative fish species. The project will also produce a risk assessment of the relative risks to native fish from nonnative species in Grand Canyon, an assessment of habitat use by nonnatives, and a report summarizing the known sources of nonnative fish found in Grand Canyon and recommendations for targeted removal efforts.

Climate change is expected to result in lower Lake Powell reservoir levels (Seager et al. 2007) and a warmer Colorado River mainstem which could expand the potential for an increased threat from warm water-adapted nonnative fishes (Eaton and Scheller 1996, Rahel and Olden 2008). There is an immediate need to begin investigating which species pose the greatest threats to native fishes in Grand Canyon, so as to understand how those species might be better monitored and controlled and to test control approaches for efficacy. This project will refine methods for removing nonnative fishes already present in the Colorado River, analyze the potential for new species to invade, and explore ways to prevent and control the expansion of nonnative fish in the Colorado River. This project provides important information about the biological environment PCE of critical habitat, as well information on methods of improving this PCE through removal of nonnative fishes and protecting against new invaders. This project also addresses the recovery need of the Recovery Goals to develop and implement identified levels of nonnative fish control in the Colorado River in Marble and Grand Canyons by providing science support to evaluate and refine these control programs.

BIO 2.R18.10–11—Natal Origins of Rainbow Trout in Grand Canyon

Although maintaining a quality rainbow trout sport fishery at Lees Ferry is a goal of the GCDAMP, rainbow trout are a threat to humpback chub and other native fish species downstream due to competition and predation. Although available literature from the GCMRC, the Arizona Game and Fish Department (AGFD), and Ecometric, Inc. indicate that the majority of rainbow trout are spawned above Lees Ferry, this has not been definitively determined. Rainbow trout do spawn below Lees Ferry in tributaries such as Nankoweap Creek, though favorable conditions have not been present in many years. If important spawning areas can be established more conclusively, then this will allow for more targeted removal efforts. This project will combine results from available literature and currently collected data to develop a report describing the evidence for where rainbow trout are reproducing, or their location of natal origin. This information will help inform and assist efforts to improve the biological environment PCE of critical habitat, and will support attainment of the Recovery Goals criteria to develop and implement identified levels of nonnative trout control (U.S. Fish and Wildlife Service 1994, 2009)

BIO 5.R1.10–11—Monitor Kanab Ambersnail

This project monitors the Kanab ambersnail and its habitat in the Grand Canyon at its primary habitat at Vaseys Paradise and at a site where it was translocated, Elves Chasm. The project

determines the extent and kind of vegetation that exists as habitat for the Kanab ambersnail and tracks its abundance and distribution. This information is important to determining the status of the species in Grand Canyon, and evaluating how proposed Glen Canyon Dam flow regimes will affect the snail and its habitat.

Other GCDAMP Monitoring, Research, and Modeling

A number of other GCDAMP projects also provide important information on factors that influence the status and trend of humpback chub and its critical habitat, and are thus important aspects of Reclamation's proposed action. These projects provide important monitoring, research, and modeling of the aquatic food base, water quality (turbidity, water temperature), and sediment (which may influence nearshore habitat quality), which are important aspects of the PCEs of humpback chub critical habitat. We only list these projects here and refer the reader to the GCDAMP 2009 budget and work plan (U.S. Bureau of Reclamation and U.S. Geological Survey 2009) for a complete description. The contribution of these projects to the overall effect of the proposed action is discussed in the succeeding sections. The projects are:

- BIO 1.R1.10—Aquatic Food Base
- BIO 1.R4.10—Impacts of Flows on the Aquatic Food Base
- BIO 1.M1.11—Aquatic Food Base Monitoring
- BIO 7.R1.10–11—Water-quality Monitoring of Lake Powell and the Glen Canyon Dam Tailwater
- PHY 7.M1.10–11—Integrated Quality of Water Monitoring (below Glen Canyon Dam)
- PHY 7.R2.10—Integrated Flow, Temperature, and Sediment Modeling
- PHY 7.R3.11—Modeling Support
- PHY 8.M2.10–11— Integrated Long-term Monitoring of Systemwide Changes in Sediment Storage

Conservation Measures

The conservation measures of the 2008 Opinion are also an important aspect of Reclamation's proposed action, and relevant measures are included again here for reference in discussion of the effects of the proposed action. We note one modification to these conservation measures. Because GCMRC only has the capability to employ the ASMR model once every three years (U.S. Bureau of Reclamation and U.S. Geological Survey 2009), the ASMR would not be utilized annually, but only employed to test the humpback chub consultation trigger if other data, such as annual mark-recapture based closed population estimates of humpback chub abundance in the Little Colorado River (Van Haverbeke and Stone 2008, 2009), indicate that the population is declining to the abundance level defined in the trigger.

As we explained in the 2008 Opinion, we are confident that Reclamation will implement these measures because of their continued demonstration of effectiveness in implementing past and ongoing conservation measures. In fact, as will be discussed throughout this document, essentially all of these conservation measures are currently being implemented by Reclamation to some degree. It is important to note that Reclamation's continuing implementation of these measures is in marked contrast to conditions at the time of the 1995 jeopardy biological opinion;

none of these elements were funded and implemented at that time, although some had been identified as potential conservation measures.

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 millimeter [mm] [7.87 in] TL) in Grand Canyon declines significantly, or, if in any single year, based on the ASMR (Coggins 2008a), 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 2002b), 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 2008a). 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 or appropriate.

Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon – Reclamation has been a primary contributor to the development of the GCDAMP's Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon. Reclamation will continue to work with GCDAMP cooperators to develop a comprehensive approach to management of humpback chub. Reclamation has committed to specific conservation measures in the 2008 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) GCDAMP participants and through the GCDAMP, Reclamation will assist the National Park Service (NPS) and the GCDAMP in funding and implementation of translocating 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. These plans will consider and utilize genetic assessments (Douglas and Douglas 2007), 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 GCDAMP will also fund and implement translocation of up to 500 young humpback chub from the lower Little Colorado River to above Chute Falls if FWS determines that a translocation is warranted. Reclamation and the GCDAMP 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 GCDAMP participants and through the GCDAMP, continue efforts to assist NPS and the GCDAMP 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 GCDAMP, and may utilize other methods, to help to reduce this threat. GCMRC is preparing a nonnative fish control plan through the GCDAMP process that addresses both cold and warm-water species that will further guide implementation of this conservation measure [Hilwig et al. 2009].

Humpback Chub Nearshore Ecology Study – In coordination with other DOI GCDAMP participants and through the GCDAMP, Reclamation will implement a nearshore ecology study [during the period of the proposed action, 2008-2012] 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 five-year period of steady flow releases in September and October. A research plan will be developed with FWS via the GCDAMP for this study by August 1, 2008, [completed in 2008] and a five-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.

Action Area

The action area (Figure 1) for this proposed action is the Colorado River corridor from Glen Canyon Dam in Coconino County, Arizona, downstream to RM 235 near Bridge Canyon Rapid (Figure 1). Because the action affects aquatic organisms such as fishes that can emigrate out of the Colorado River, the action area also includes perennial reaches of major tributaries in this reach: the Paria River, the LCR, Bright Angel Creek, Tapeats Creek, Kanab Creek, Shinumo Creek, and Havasu Creek. Below this point, which is the approximate location of the full pool elevation of Lake Mead (1,229 ft), ESA compliance is not addressed within the GCDAMP 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 status of the species throughout its range remains much the same as in the 2008 Opinion. We provide several updates, as well as a more detailed look at the current status of critical habitat, to comply with the Court Order. We discuss new information on the Grand Canyon population of humpback chub in more depth in the Environmental Baseline.

There are six populations of humpback chub in the Colorado River basin; five in the upper basin, and one in the lower basin (Figure 2). The status of the five populations of humpback chub located above Glen Canyon Dam in the Upper Colorado River Basin has changed little since the 2008 Opinion. These populations include three in the Colorado River: at Cataract Canyon, Utah; Black Rocks, Colorado; and Westwater Canyon, Utah; one in the Green River in Desolation and

Grey canyons, Utah; and one in the Yampa River in Yampa Canyon in Dinosaur National Monument, Colorado. Population estimates for humpback chub using mark-recapture estimators began in 1998 with the Black Rocks and Westwater Canyon populations, and were conducted during 1998-2000 and 2003-2005. These estimates show the Black Rocks population between about 1,000 and 2,000 adults (age 4+) and the Westwater Canyon population between about 1,700 and 5,100 adults (McAda 2004, 2006, 2007, Hudson and Jackson 2003). Population estimates for Desolation/Gray Canyon in 2001-2003 show the population between about 1,000 and 2,600 adults (Jackson and Hudson 2005). The Cataract Canyon population was recently estimated at about 100 adults. In Yampa Canyon, too few adults were captured to estimate population size (Finney 2006, Badame 2008).

As reported in the 2008 Opinion, mark-recapture methods have been used since the late 1980s to assess trend in adult abundance and recruitment of the LCR aggregation of humpback chub, the primary aggregation constituting the Grand Canyon population, the only population in the lower Colorado River basin. These estimates indicate that the adult population declined through the 1980s and early 1990s but has been increasing for the past decade (Coggins et al. 2006a, Coggins 2008a, Coggins and Walters 2009) (Figure 3). Coggins (2008a) summarized information on abundance and analyzed monitoring data collected since the late 1980s and found that the adult population had declined from about 8,900- 9,800 in 1989 to a low of about 4,500-5,700 in 2001. Current methods for assessment of humpback chub abundance rely on the Age-Structured Mark-Recapture model (ASMR)(Coggins et al. 2006b, Coggins and Walters 2009). Although Coggins and Walters (2009) caution that the ASMR has limited capability to provide abundance estimates, and that the most important finding in their report is that the population trend in humpback chub is increasing, they conclude that "considering a range of assumed natural mortality-rates and magnitude of ageing error, it is unlikely that there are currently less than 6,000 adults or more than 10,000 adults" and estimate that the current adult (age 4 years or more) population is approximately 7,650 fish. This is an increase from the 2006 estimate of 5,300-6,700 (Coggins 2008a).

Translocation of juvenile humpback chub from near the mouth of the LCR upstream to above Chute Falls was undertaken in 2008 and 2009 as a conservation measure of the 2008 Opinion. In 2008, 299 juvenile humpback chub were translocated, and an additional 194 were moved in 2009. The purposes of the conservation measure are to extend the range of the species upstream in the LCR into reaches previously unoccupied (presumably due to the presence of the falls), to improve the survivorship of juvenile humpback chub by moving juveniles to areas of the LCR with better nursery habitats, and to glean information on the life history of the species. Monitoring of this upstream reach was also conducted in 2008 and 2009. Translocation also took place into Shinumo Creek in June 2009, when 300 juvenile humpback chub that were being held at Dexter National Fish Hatchery and Technology Center were translocated. Translocation is further discussed in the Environmental Baseline section.

Humpback Chub Critical Habitat

Critical habitat for humpback chub was designated in 1994 (59 FR 13374; U.S. Fish and Wildlife Service 1994). Seven reaches of the Colorado River system were designated for a total river length of 379 miles in the Yampa, Green, Colorado, and Little Colorado rivers in Arizona,

Colorado and Utah. "Critical habitat," as defined in Section 3(5)(A) of the Act, means: (i) the specific areas within the geographical area occupied by the species at the time it is listed, on which are found those physical and biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by a species at the time it is listed upon a determination by the Secretary that such areas are essential for the conservation of the species. The term "conservation," as defined in Section 3(3) of the Act, means: the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this Act are no longer necessary. Therefore, in the case of critical habitat, conservation represents the areas required to recover a species to the point of delisting (i.e., the species is recovered and is removed from the list of endangered and threatened species). In this context, critical habitat preserves options for a species' eventual recovery.

In our analysis of the effects of the action on critical habitat, we consider whether or not the proposed action will result in the destruction or adverse modification of critical habitat. In doing so, we must determine if the proposed action will result in effects that appreciably diminish the value of critical habitat for the recovery of a listed species (see p. 4-34, U.S. Fish and Wildlife Service and National Marine Fisheries Service 1998). To determine this, we analyze whether the proposed action will adversely modify any of those physical or biological features that were the basis for determining the habitat to be critical. The physical or biological features that determine critical habitat are known as the primary constituent elements (PCEs). To determine if an action results in an adverse modification of critical habitat, we must also evaluate the current condition of all designated critical habitat units, and the PCEs of those units, to determine the overall ability of all designated critical habitat to support recovery. Further, the functional role of each of the critical habitat units in recovery must also be defined.

Recovery for the humpback chub is currently defined by the FWS Humpback Chub Recovery Goals (U.S. Fish and Wildlife Service 2002b, 2009). In 2006, a U.S. District Court ruling set aside the recovery goals, essentially because they lacked time and cost estimates for recovery. The court did not fault the recovery goals as deficient in any other respect, thus the FWS and the GCDAMP, and the Upper Colorado River Endangered Fish Recovery Program (UCRRP), the program that addresses conservation of all of the upper Colorado River basin populations of humpback chub, continue to utilize the underlying science in the recovery goals. This supplemental opinion therefore relies on the draft 2009 revisions to the recovery goals to define recovery (Recovery Goals) (U.S. Fish and Wildlife Service 2009) as those goals represent the best available scientific information. The Recovery Goals provide measureable recovery criteria which were not available at the time of the 1995 Opinion.

The Recovery Goals define recovery as specific demographic goals that must be attained, and recovery factors that must be met to achieve downlisting and delisting of humpback chub. The recovery factors were derived from the five listing threat factors and state the conditions under which threats are minimized or removed sufficient to achieve recovery; a list of site-specific management actions and tasks is also provided to assist in meeting recovery factors. The management actions and tasks consist of specific actions (e.g. the development and implementation of nonnative fish control programs). They also include the need to identify,

implement, evaluate, and revise (as necessary through adaptive management) flow regimes to benefit humpback chub for all the rivers in which the species occurs. Essentially, the goals identify actions (management actions and tasks and associated recovery factor criteria) needed to maintain the habitat features (i.e. the PCEs of critical habitat) to accomplish recovery. But the measure of whether or not actions are working with regard to recovery, and the basis for altering management actions through adaptive management, are the demographic criteria. The site-specific management actions and tasks and recovery actions, as well as the demographic Recovery Goals, are provided in Appendix B. We summarize here the Recovery Goal demographic criteria for downlisting as follows (population demographics in both recovery units must be met in order to achieve downlisting):

Upper basin recovery unit

1. Each of the five self-sustaining populations is maintained over a 5-year period, starting with the first point estimate acceptable to the Service, such that:
   a. the trend in adult (age 4+; ≥ 200 mm TL) point estimates does not decline significantly, and
   b. mean estimated recruitment of age-3 (150–199 mm TL) naturally produced fish equals or exceeds mean annual adult mortality, and

2. One of the five populations (e.g., Black Rocks/Westwater Canyon or Desolation/Grey Canyons) is maintained as a core population such that each point estimate exceeds 2,100 adults (Note: 2,100 is the estimated MVP number; see section 3.3.2 of the Recovery Goals).

Lower basin recovery unit

1. The Grand Canyon population is maintained as a core over a 5-year period, starting with the first point estimate acceptable to the Service, such that:
   a. the trend in adult (age 4+; ≥ 200 mm TL) point estimates does not decline significantly, and
   b. mean estimated recruitment of age-3 (150–199 mm TL) naturally produced fish equals or exceeds mean annual adult mortality, and
   c. each core population point estimate exceeds 2,100 adults (MVP).

The Recovery Goal demographic criteria for delisting are as follows:

Upper basin recovery unit

1. Each of the five self-sustaining populations is maintained over a 3-year period beyond downlisting, starting with the first point estimate acceptable to the Service, such that:
   a. the trend in adult (age 4+; ≥ 200 mm TL) point estimates does not decline significantly, and
   b. mean estimated recruitment of age-3 (150–199 mm TL) naturally produced fish equals or exceeds mean annual adult mortality, and

2. Two of the five populations (e.g., Black Rocks/Westwater Canyon and Desolation/Grey Canyons) are maintained as core populations such that each point estimate exceeds 2,100 adults (MVP).

Lower basin recovery unit

1. The Grand Canyon population is maintained as a core over a 3-year period beyond downlisting, starting with the first point estimate acceptable to the Service, such that:

    a. the trend in adult (age 4+; ≥ 200 mm TL) point estimates does not decline significantly, and
    b. mean estimated recruitment of age-3 (150–199 mm TL) naturally produced fish equals or exceeds mean annual adult mortality, and
    c. each core population point estimate exceeds 2,100 adults (MVP).

Because the Recovery Goals consist of actions to improve habitat and minimize threats that are ultimately measured for success by the status and trend (i.e. the demographic state) of the population through adaptive management, we have evaluated the contribution of each critical habitat unit by examining how the PCEs are, or are not, serving to achieve the demographic criteria. In some cases, population-dynamics information is not statistically adequate to evaluate the demographic goal as defined in the Recovery Goals. In those cases, we rely on what data there are to make an informed, albeit subjective, evaluation of the PCE/critical habitat unit.

Primary Constituent Elements (PCEs)

In accordance with section 3(5)(A)(i) of the Act and regulations at 50 CFR 424.12, in determining which areas to propose as critical habitat, we are required to base critical habitat determinations on the best scientific data available and to consider those physical and biological features (PCEs) that are essential to the conservation of the species, and that may require special management considerations and protection. These include, but are not limited to: space for individual and population growth and for normal behavior; food, water, air, light, minerals, or other nutritional or physiological requirements; cover or shelter; sites for breeding, reproduction, and rearing (or development) of offspring; and habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of a species. The general primary constituent elements required of humpback chub critical habitat are listed below, and the current conditions of PCEs in individual critical habitat reaches, the factors responsible for these conditions, and the conservation roles of individual critical habitat reaches are described, based upon U.S. Fish and Wildlife Service (1994), Maddux et al. (1993a), and Maddux et al. (1993b), and updated with the most current scientific information. This information is also summarized in Table 4.

General PCEs

Critical habitat was listed for the four big river fishes (Colorado pikeminnow [*Ptychocheilus lucius*], humpback chub, bonytail [*Gila elegans*], and razorback sucker) concurrently in 1994, and the PCEs were defined for the four species as a group (U.S. Fish and Wildlife Service 1994).

However, note that the PCEs vary somewhat for each species on the ground, particularly with regard to physical habitat, because each of the four species has different habitat preferences.

Water--Consists of water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, turbidity, etc.) (W1) that is delivered in sufficient quantity to a specific location in accordance with a hydrologic regime that is required for the particular life stage for each species (W2).

Physical Habitat--This includes areas of the Colorado River system that are inhabited by fish or potentially habitable for use in spawning (P1), nursery (P2), feeding (P3), or corridors between these areas (P4). In addition to river channels, these areas also include bottomlands, side channels, secondary channels, oxbows, backwaters, and other areas in the 100-year floodplain, which when inundated provide spawning, nursery, feeding, and rearing habitats, or access to these habitats.

Biological Environment--Food supply (B1), predation (B2), and competition (B3) are important elements of the biological environment and are considered components of this constituent element. Food supply is a function of nutrient supply, productivity, and availability to each life stage of the species. Predation, although considered a normal component of this environment, is out of balance due to introduced fish species in some areas. This is also true of competition from nonnative fish species.

The PCEs are all integrally related and must be considered together. For example, the quality of water and quantity of water (PCE W1 and W2) affect the food base (PCE B3) directly because changes in water chemistry, turbidity, temperature, and flow volume all affect the type and quantity of organisms that can occur in the habitat that are available for food. Likewise, river flows and the river hydrograph have a significant effect on the types of physical habitat available. Changes in flows and sediment loads caused by dams may have affected the quality of nearshore habitats utilized as nursery areas for young humpback chub. Increasingly the most significant PCE seems to be the biological environment, and in particular PCEs B2 and B3, predation and competition from nonnative species. Even in systems like the Yampa River, where the water and physical PCEs are relatively unaltered, nonnative species have had a devastating effect on the ability of that critical habitat unit to support conservation (Finney 2006, Fuller 2009). In fact, as we will describe in more detail, the conservation of humpback chub in the future will depend on our ability to control nonnative species, and manipulating the water and physical PCEs of critical habitat to disadvantage nonnatives may play an important role.

Specific Critical Habitat Reaches and PCEs

Humpback Chub Critical Habitat Reach 1 (HBC 1) -Yampa River - Dinosaur National Monument

The most northerly segment of humpback chub critical habitat is a 44-mile long reach of the Yampa River in Moffat County, Colorado, in Dinosaur National Monument. The boundaries are from T6N, R99W, section 27 (6th Principal Meridian) to the confluence with the Green River in T7N, R103W, section 28 (6th Principal Meridian); land ownership is National Park Service, with

1 percent private ownership. The reach is dominated by steep canyon walls, and low current velocities. Occasional boulder fields create rapids, but the predominant substrate is gravel/cobble with patches of sand. In the lower portion of the canyon the river meanders through soft sandstone cliffs. The Yampa River exits the canyon at Echo Park, where it meets the Green River (Maddux et al. 1993b). This critical habitat unit contains the Yampa population, one of the five populations of humpback chub in the upper basin. This population of humpback chub has declined precipitously in recent years, likely due to increasing predation and competition from nonnative fish species (Finney 2006).

As the Yampa River has minimal water development compared to other rivers in the basin, the current hydrograph reflects flows which are usually representative of historical volume and timing, and habitat of the Yampa River has not been as extensively affected by streamflow regulation as in other rivers of the basin (Roehm 2004, Johnson et al. 2008). Flow recommendations have been developed that specifically consider flow-habitat relationships in habitats occupied by humpback chub in Yampa Canyon (Roehm 2004). Yampa River flows also have been identified as critical for maintaining native fish habitat in the Green River below their confluence (Roehm 2004). There are water diversions upstream which can impact flow, especially during very dry years such as 2002-2003 when flows were very low, however, evidence of juvenile humpback chub indicates successful spawning continues to occur (Finney 2006, T. Jones, FWS, pers. comm., 2009). Water temperatures in this portion of the Yampa River have not been altered to any significant degree by human activities and remain suitable for native fishes, although temperature is a function of streamflow, and at low flows, temperatures can become more suitable for nonnative fishes such as smallmouth bass (Fuller 2009). No chronic problems with water quality have been identified. Although upstream diversions have some impact on the water PCE W2, both the necessary quality and quantity appear to be provided by this unit (Roehm 2004).

This reach of the Yampa also provides adequate physical habitat (U.S. Fish and Wildlife Service 1990, Karp and Tyus 1990, Finney 2006). Yampa Canyon within Dinosaur National Monument is typical of the deep canyon habitat preferred by the species (U.S. Fish and Wildlife Service 1990). This reach provides the humpback chub habitat characteristics of fast current, deep pools, shoreline eddies and runs (Holden and Stalnaker 1975, Tyus and Karp 1989, U.S. Fish and Wildlife Service 1990). The Yampa reach of critical habitat remains relatively unaltered from pre-development times in terms of hydrology and geomorphology (Johnson et al. 2008), successful spawning is still occurring (Finney 2006) and we believe that all aspects of appropriate physical habitat (P1, P2, P3 and P4) are available.

Nutrient inputs and food sources for humpback chub are present within the reach. The relatively unmodified nature of the Yampa River system likely results in foods similar to predevelopment, thus PCE B1 continues to be met. The introduction of nonnative fishes is probably the greatest alteration to the historical Yampa system. Nonnative fish species abundance has increased significantly in recent years (Fuller 2009). From 2001-2003 a rapid increase in numbers of smallmouth bass was followed by a decline in humpback chub (Finney 2006, Johnson et al. 2008). A Strategic Plan for Nonnative Fish Control was developed for the Upper Colorado River Basin and implemented by the UCCRP in 1997 (Fuller 2009). The UCRRP identified smallmouth bass (*Micropterus dolomieu*) and channel catfish (*Ictalurus punctatus*) as the

principal predators of humpback chub (U.S. Fish and Wildlife Service 2009). Efforts to control smallmouth bass and channel catfish have met with mixed success, although efforts to control northern pike (*Esox luscious*) have been successful (Fuller 2009, R. Valdez, pers. comm., 2009).

Channel catfish numbers have actually increased as a result of removal, although the average size of channel catfish in the Yampa reach has decreased, which may help reduce predation (Fuller 2009). A combination of cold high flows and mechanical removal may have suppressed smallmouth bass production in 2007-2008, and numbers of young of year humpback chub have increased (Fuller 2009). The ability of this critical habitat unit to fully function in humpback chub conservation in the future will depend on the success of efforts to remove smallmouth bass and channel catfish (Johnson et al. 2008, Fuller 2009). Given the best available information, the predation and competition aspects of the biological environment PCE (B2 and B3) are not currently met for this species, and prevent this unit from providing for recovery at this time.

The Yampa River is relatively pristine in all the PCEs with the exception of B2 and B3, predation and competition from nonnative fish species. The case of the Yampa illustrates that if nonnative species are abundant (i.e. B2 and B3 are not met), good condition of other aspects of critical habitat (water and physical PCEs) may not be sufficient to provide for the recovery of the species. This also provides insight into efforts to improve the PCEs in other reaches of critical habitat such as Grand Canyon where dam emplacement has adversely altered the water and physical PCEs. Water temperatures in the Yampa River during the summer of 2002 were much warmer than typical, and a longer growing season in 2002 appears to have facilitated recruitment of smallmouth bass in 2003 (Fuller 2009), resulting in a precipitous decline in the humpback chub population. In the last three years, cold high flows may have suppressed bass production (along with removal efforts), and numbers of young of year humpback chub have increased. So not only does flow affect the water PCE of necessary hydrology and water quality for critical habitat for humpback chub, but it is also directly linked to the biological environment PCEs of predation and competition from nonnative fish species. Because of this relationship between the physical and biological PCEs, efforts focused on restoring attributes of critical habitat, such as a natural hydrograph and warmer water temperatures, as appear necessary in Grand Canyon, could have the unintended consequence of benefiting nonnative species, offsetting any gains from habitat improvement from a rapid increase in abundance of nonnative predators and competitors.

Humpback Chub Critical Habitat Reach 2 (HBC 2) - Green River - Dinosaur National Monument

This unit is a 38-mile reach in Uintah County, Utah, and Moffat County, Colorado, from the confluence with the Yampa River in T7N, RI03W, section 28 (6th Principal Meridian) to the southern boundary of Dinosaur National Monument in T6N., R24E, section 30 (Salt Lake Meridian). The land ownership of the unit is predominantly National Park Service in Dinosaur National Monument, except for about 4.5 percent of privately-owned lands. The Green River enters Echo Park at its confluence with the Yampa River as a wide, deep, and slow moving stream. Substrate is a mixture of sand and silt with some large gravel and cobble riffles. After a short distance, the river passes through Whirlpool Canyon, an area of steep cliffs, large pools, deep eddies, rapids, and large boulders. The substrate in the canyon is boulder/bedrock, but large deposits of sand exist in eddies. After leaving the canyon, the Green River meanders

through Island and Rainbow Parks. The river in this area is shallow and side channels are common. Further downstream, the river enters Split Mountain Canyon. This stretch contains large boulder fields, swift waters, and major rapids. Some significant sandbars exist in the slower moving parts of this reach (Maddux et al. 1993b).

Humpback chub have never been common in this reach, despite what appears to be suitable habitat, especially in Whirlpool Canyon, indicating other unknown elements may be missing that are needed to support a population of humpback chub (R. Valdez, pers. comm., 2009). Only eight humpback chub were captured in Whirlpool Canyon from 2002 to 2004 (Bestgen et al. 2006), although recently young of year chub have been found in Island Park which may be humpback chub (T. Jones, FWS, pers. comm., 2009). The area is considered to be part of the Yampa River population along with the Yampa River upstream, but this critical habitat unit does not appear to currently support humpback chub.

Flows in this reach are primarily a product of the flows released from Flaming Gorge Dam and flows from the Yampa River. During an average hydrologic year, a spring peak of at least 13,000 cfs should occur in this reach. Because of the distance between this reach and the dam and unregulated flows of the Yampa River, water temperatures in this reach approach historical levels. However, when releases during summer and fall from the dam are greater than historical, water temperatures may be lower than under normal conditions. Water quantity and quality needs (PCEs W1 and W2) are believed met for the species, and the UCRRP has completed and implemented flow recommendations for the Green River below Flaming Gorge Dam, including specific seasonal flow recommendations, that should serve to meet the needs of humpback chub in this reach of critical habitat (Muth et al. 2000). All four physical variables also appear to be present (PCEs P1-4), and young of year *Gila* found in the last year may be an indication that spawning is occurring, although at low levels (T. Jones, FWS, pers. comm., 2009).

This portion of the Green River has large numbers of red shiner (*Cyprinella lutrensis*), channel catfish, smallmouth bass, and common carp (*Cyprinus carpio*), all of which are known to compete with and/or prey upon native fishes. The recent invasion of smallmouth bass has likely greatly reduced the value of this PCE for humpback chub (Finney 2006). Because water and physical PCEs appear to be met for humpback chub in this reach of critical habitat, the presence of nonnative fishes (PCEs B2 and B3) may be the primary factor limiting the capability of this critical habitat unit to meet recovery needs.

Humpback Chub Critical Habitat Reach 3 (HBC 3) - Green River - Desolation and Gray Canyons

The Green River in Desolation and Gray Canyons contains one of the 5 upper basin populations of humpback chub. Population estimates for Desolation/Gray Canyon in 2001-2003 show the population was composed of 1,254 individuals in 2001, 2,612 individuals in 2002, and 937 individuals in 2003 (Jackson and Hudson 2005). The 73 mile reach of critical habitat in the Green River is in Uintah and Grand Counties, Utah, from Sumners Amphitheater in T12S, R18E, section 5 (Salt Lake Meridian) to Swasey's Rapid in T20S, R16E, section 3 (Salt Lake Meridian). The reach is about 50 percent Tribal ownership, 49 percent Bureau of Land Management, and 1.0 percent private. Desolation Canyon is a deep canyon of the Green River with many rapids.

Habitats include eddies, rapids, and riffles, with some deep pools. Boulders make up the primary substrate within Desolation Canyon. This canyon is followed by Gray Canyon which contains larger and deeper pools than are found in Desolation Canyon. Other habitats within the canyon include eddies, rapids, and riffles, side channels and backwaters. Substrate in Gray Canyon is composed mainly of boulder/rubble with some gravel (Maddux et al. 1993b).

Because of water depletions which occur above this reach, historic water levels are seldom if ever obtained, and thus flooding of bottomlands is infrequent (Muth et al. 2000). However, water quantity and quality needs (PCEs W1 and W2) are believed met for the species; and the UCRRP has completed and implemented flow recommendations for the Green River below Flaming Gorge Dam, including specific seasonal flow recommendations, that should serve to meet the needs of humpback chub in this reach of critical habitat (Muth et al. 2000). This canyon reach contains both deep, swift areas and low-velocity eddies that are associated with steep cliffs and large boulders. Spawning habitat is available based on consistent evidence of recruitment and collection of juvenile fish (Jackson and Hudson 2005). Physical habitat parameters (PCEs P1-4) also appear to be sufficient in this reach of critical habitat.

Little is known on the quantity or quality of the food supply in this reach. Sources of input include the river above and washes and side channels. The flooded bottomlands along this reach were probably once sources of food input into the system, but are now not as extensively flooded. Common nonnative fishes include red shiner, channel catfish, smallmouth bass, common carp, and fathead minnow (*Pimephales promelas*) (Jackson and Hudson 2005). Similar to the scenario seen in the Yampa River, an increase in smallmouth bass over the 2001-2003 period co-occurred with a decline in humpback chub over the same period, although Jackson and Hudson (2005) felt the decline in humpback chub was likely too soon to have been solely caused by increases in smallmouth bass. Much as in other critical habitat reaches, water and physical PCEs appear met, but biological PCEs B2 and B3 are not, and limit the capability of this critical habitat unit to meet recovery needs.

Humpback Chub Critical Habitat Reach 4 (HBC 4) - Colorado River - Black Rocks/Westwater Canyon

The Black Rocks and Westwater populations of humpback chub occur in this 30-mile reach of critical habitat. The reach extends from Black Rocks (RM 137) in T1S, R104W, section 25 (6th Principal Meridian) in Mesa County, Colorado, downstream to Fish Ford River (RM 106) in T21S, R24E, section 35 (Salt Lake Meridian) in Grand County, Utah. Land ownership is 66.6 percent Bureau of Land Management, 33.4 percent private. Historically, the largest known concentrations of humpback chub in the upper basin have been found at Black Rocks and Westwater Canyons (Valdez and Clemmer 1982, U.S. Fish and Wildlife Service 2009), and this is still the case currently. Population estimates for humpback chub using mark-recapture estimators began in 1998 with the Black Rocks and Westwater Canyon populations, and were conducted during 1998-2000 and 2003-2005. These estimates show the Black Rocks population between about 1,000 and 2,000 adults (age 4+) and the Westwater Canyon population between about 1,800 and 4,700 adults (McAda 2006, Hudson and Jackson 2003, Eleverud 2007).

Black Rocks occurs near the Colorado-Utah state line where the Colorado River flows through a mile of upthrust black metamorphic gneiss rock. Some five miles downstream the river again flows through upthrust gneiss for 14 miles through Westwater Canyon. The geology forms narrow, deep, canyon-bound channels with rapids, strong eddies, and turbulent currents. In both canyons, habitat consists of deep runs, eddies, and pools, with few backwaters, although gravel bars, floodplains, and backwaters do occur above and below the canyons (Maddux et al. 1993b). Habitats have been altered by water use that altered the natural flow regime. Annual peak flows of the Colorado River immediately upstream of the Black Rocks and Westwater Canyon populations have decreased by 29–38 percent due mainly to the presence of dams upstream (Van Steeter and Pitlick 1998). However, Black Rocks and Westwater Canyon continue to provide deep eddies, pools, runs, rapids, with strong turbulent currents. The quantity and quality of water in this reach (PCEs W1 and W2) are presently sufficient, and support stable populations of humpback chub (Valdez and Clemmer 1982, McAda 2006, Hudson and Jackson 2003, Eleverud 2007).

This reach provides deep pools, eddies, and runs for feeding and movement corridors, and spawning and rearing habitat is available as evidenced by successful recruitment. Flow recommendations have been developed that specifically consider flow-habitat relationships in habitats occupied by humpback chub in Black Rocks and Westwater Canyon (McAda 2003). All physical habitat PCEs (P1-4) are met based on the stability of the population and evidence of recruitment (McAda 2006, Hudson and Jackson 2003, Eleverud 2007). Red shiner, channel catfish, black bullhead (*Ameiurus melas*), and largemouth bass (*Micropterus salmoides*) all occur here, but because these canyons are very narrow, and large floods are fairly frequent, flooding generally keeps numbers of nonnative fishes low (R. Valdez, pers. comm., 2009), and there currently is no nonnative control effort in this unit. All PCEs are fully functional, and this critical habitat unit is functioning in support of recovery. But, as with other reaches, there appears to be a correlation between low water years and increases in nonnative species; climate change could lead to an increase in low water years and nonnative fishes, challenging the ability of this unit to support recovery (Rahel et la. 2008, R. Valdez, pers. comm., 2009).

Humpback Chub Critical Habitat Reach 5 (HBC 5) - Colorado River - Cataract Canyon

A 13-mile reach of critical habitat in Cataract Canyon on the Colorado River upstream of Lake Powell contains the most southerly population of humpback chub occurring in the upper basin. The reach extends along the Colorado River from Brown Betty Rapid in T30S, R18E, section 34 (Salt Lake Meridian) to Imperial Canyon in T31S, R17E, section 28 (Salt Lake Meridian) in Garfield and San Juan counties, Utah. Land ownership is 100 percent National Park Service. Lake Powell likely eliminated the majority of the habitat that humpback chub utilized in this section of the Colorado River historically, leaving only about 13 miles (20.9 km) of suitable river habitat when Lake Powell is at full pool. Comprehensive surveys for humpback chub did not begin until about 1979, shortly after Lake Powell had filled. Although the population of humpback chub in the Colorado River in Cataract Canyon above the inflow area to Lake Powell has never been large since consistent surveys began in the 1980s, historically it may have been much larger.

The Cataract Canyon population of humpback chub appears to be declining. Badame (2008) estimated the adult population, using closed point estimates, at 126 individuals in 2003, 91 in 2004, and 70 in 2005. Population estimates based on fish density and total amount of available habitat were 468-262 over the period. Evidence of successful spawning has been inferred from several size classes present in past surveys (Valdez 1990), but no juvenile humpback chub were encountered in the 2003-2005 surveys, and the smallest humpback chub encountered was 195 mm TL (7.7 inches). It is not known if juvenile humpback chub are not encountered because they are not present, or because survey techniques do not detect them, but electrofishing is employed, a technique that reliably captures juvenile humpback chub elsewhere (Badame 2008). Young humpback chub may also be lost to some extent to downstream movement into Lake Powell (D. Elverud, Utah Division of Wildlife Resources, pers. comm., 2009).

The Colorado River in Cataract Canyon cuts deeply through steep canyons and talus slopes, and is characterized by deep, swift runs, large eddies and pools, with a few shallow runs, riffles, and backwaters. Large angular rock and steep gradient have created approximately 13 miles of rapids before the river flows into the upper end of Lake Powell where it resembles a large, deep, slow-flowing river with high sandstone walls (Maddux et al. 1993b). River flows in Cataract Canyon are greater than in other reaches in the Upper Basin because of the numerous upstream tributaries which enter the Colorado River as a result of its location low in the system. While all life stages of humpback chub were captured in this reach in surveys in the late 1980s (Valdez 1990), indicating adequate habitat for successful reproduction, recent surveys have not located any young humpback chub, indicating possible recruitment failure (Babame 2008), although there is no indication this is due to recent changes in water quality or quantity, and PCEs W1 and W2 of humpback chub critical habitat appear to be functional.

Cataract Canyon provides deep eddies and pools, with swift currents and large boulders, preferred habitat of humpback chub, and flow recommendations have been developed that specifically consider flow-habitat relationships in habitats occupied by humpback chub in Cataract Canyon (McAda 2003, Muth et al. 2000). Causes of the apparent current lack of recruitment of the population do not appear to be due to changes in the physical habitat PCEs (P1-4). Valdez (1990) reported humpback chub of all age classes in Cataract Canyon (indicating a reproducing population) and the presence of preferred physical habitats; there appear to be no changes to the physical habitat since that time that would explain the current lack of recruitment. Cataract Canyon has many nonnative fish species, with channel catfish, black bullhead, and red shiner being the most common (D. Elverud, Utah Division of Wildlife Resources, pers. comm., 2009, R. Valdez, pers. comm. 2009), and striped bass were captured in past surveys (Valdez 1990). The water and physical PCEs appear met, but the presence of Lake Powell likely eliminated much of the historical habitat, and provides a robust population of nonnative species. It is not clear if the remaining habitat since Lake Powell filled would have sufficient carrying capacity to support a large population of humpback chub, but the lack of the biological environment PCEs B2 and B3 seem more likely to be the reason this unit is not functioning currently in humpback chub recovery and the reason for recent declines in the population.

Humpback Chub Critical Habitat Reach 6 (HBC 6) - Little Colorado River (LCR)

Critical habitat in the LCR includes the lowermost eight miles from T32N., R6E, section 12 (Salt and Gila River Meridian) to the confluence with the Colorado River in T32N, R5E, section 1

(Salt and Gila River Meridian) Coconino County, Arizona. Land ownership is 81.3 percent Tribal (Navajo Tribe), and 18.8 percent National Park Service (Grand Canyon National Park). The Grand Canyon population of humpback chub occurs in both critical habitat reach 6 and 7, from the Colorado River at about River Mile (RM) 30 to RM 240, and in the LCR in the lowermost 11.5 miles (Glen Canyon Dam Adaptive Management Program 2009, Stone 2009)(Figure 1). The Grand Canyon population is the largest population of humpback chub, the only population in the lower basin, and constitutes the lower basin recovery unit (Coggins and Walters 2009, U.S. Fish and Wildlife Service 2009). While the vast majority of spawning of humpback chub in Grand Canyon occurs in the LCR, humpback chub utilize the mainstem Colorado River also, and condition factor[2] of adult humpback chub in the mainstem has been reported to be better than that of adults in the LCR (Hoffnagle et al. 2006). Additionally eight other spawning aggregations occur in the mainstem Colorado River, all of which, including the LCR, constitute what is considered a single reproducing population (Douglas and Douglas 2007).

Perennial flows in the LCR are maintained through a series of springs, the largest of which is Blue Spring approximately 13 miles upstream from the mouth of the Colorado River. The LCR above Blue Spring was once perennial, but is now intermittent throughout most of its 356-mile length, flowing only in floods, from spring thaws or summer rain events (Colton 1937, Miller 1961, Valdez and Thomas 2009). Flows during floods can be between 500-2000 cfs. Base flow of the lower reach containing critical habitat is about 225 cfs (Cooley 1976). Water from these springs is high in chloride salts, relatively constant in flow, warm (20°C), highly charged with carbon dioxide, and saturated with calcium carbonate (Gorman and Stone 1999). This water chemistry forms the mineral travertine, layered deposits of hard, dense calcite. Travertine deposition in the LCR is an ongoing process, forming extensive reefs, terraces, and dams throughout the lower 14.5 miles (23.3 km). Large boulders and cobble fallen from canyon walls or transported by debris flows from side canyons are common in the stream channel (Gorman and Stone 1999). The unique geology forms a complex habitat matrix of pools, shallow runs, and races. Uncemented calcium carbonate particles form part of the stream bottom and contribute to the mild turbidity of the river at base flow (Kubly 1990), and flood flows are extremely turbid.

Flows in the LCR maintain acceptable habitat for all sizes and age classes of humpback chub. The historic hydrograph has been altered by the reduction in flows coming into the reach from the watershed, but seasonal variations remain (Valdez and Thomas 2009). Fluctuating flows in the Colorado River affect the lowermost portion of the reach by raising and lowering water levels and altering temperatures, but this affects less than a quarter mile of the reach. Water quality has not been significantly altered by changes in flow from the historical condition, however salinity levels may be higher now during low-flow periods when there are no additional flows in the Little Colorado to dilute the inflow from the springs. Temperatures in the upper portion of the reach may have changed slightly in response to altered seasonal water levels, but water temperature in the LCR is suitable for spawning, and egg and larval development (Gorman and Stone 1999). Although flows have changed in the LCR with development throughout the basin (Valdez and Thomas 2009) and the shift to intermittency upstream of Blue Spring, humpback chub continue to occupy and thrive in this reach of critical habitat (Coggins and Walters 2009, VanHaverbeke and Stone 2009). Thus reach 6 of critical habitat continues to

[2] A mathematical function which utilizes the length and weight of a fish to assess its overall health.

provide PCEs W1 and W2, although threats exist, and are described in more detail in the Environmental Baseline.

Humpback chub utilize a variety of habitat types in the reach. Larval to juvenile humpback chubs have been found in shallow shoreline areas, sand-bottomed runs, and silt-bottomed backwaters with low-current velocities (U.S. Fish and Wildlife Service 1990, Robinson et al. 1998). Adult humpback chub in the LCR utilize shoreline areas, pools and eddies, quiet waters under rock ledges, large still pools, areas below travertine dams, and the deeper water at the confluence (Minckley et al. 1981). Spawning humpback chub have been found over rapidly flowing water among large angular boulders and shoreline outcrops or along shoreline eddy habitats of moderate depth with swirling currents and sand and boulder substrates (Gorman and Stone 1999). Although humpback chub larvae are common in midstream drift, larvae do appear to actively seek out calmer nearshore habitats as they age (Robinson et al. 1998). Stone and Gorman (2006) found that humpback chub undergo an ontogenesis from diurnally active (active during the day), vulnerable, nearshore-reliant young-of-the-year (YOY; 30–90 mm TL [1.2 inches]) into nocturnally active, large-bodied adults (>180 mm TL [3.5 inches]). Adult humpback chub reside in deep mid-channel pools during the day, and move inshore at night (Stone and Gorman 2006). All aspects of the physical habitat PCEs (P1, P2, P3, and P4) are present in Reach 6, based upon the current status of the population (VanHaverbeke and Stone 2008, Coggins and Walters 2009).

Information from stomach contents and other observations indicate that food resources utilized by humpback chub in the LCR include bottom-dwelling invertebrates such as *Gammarus lacustris* and chironomid larvae, planktonic crustaceans, terrestrial invertebrates and algae such as *Cladophora glomerata* (Minckley 1979, Minckley et al. 1981, Valdez and Ryel 1995). Food utilized in the mainstem Colorado River are in different proportions than those utilized in the mainstem, reflecting food availability (Kaeding and Zimmerman 1983, Valdez and Ryel 1995). The extent of competition by nonnative fishes is unknown, but predation has been documented by rainbow trout, channel catfish, and black bullhead (Marsh and Douglas 1997). Numbers of nonnative fish are low in the LCR, and nonnative fish comprised only 7 percent of total catch in 2007 monitoring (Van Haverbeke and Stone 2008). All of the PCEs are provided for in the Little Colorado Reach of critical habitat, although significant threats exist and are discussed in the Environmental Baseline.

Humpback Chub Critical Habitat Reach 7 (HBC 7) - Colorado River - Marble and Grand Canyons

The 173-mile reach of critical habitat in the Colorado River in Marble and Grand Canyons extends from Nautiloid Canyon (RM 34) in T36N, R5E, section 35 (Salt and Gila River Meridian) to Granite Park (RM 208) in T30N, RI0W, section 25 (Salt and Gila River Meridian). Land ownership is 87.8 percent National Park Service, and 12.2 percent Tribal (Navajo Nation). As discussed above, Reach 6 and 7 constitute critical habitat occupied by the Grand Canyon population of humpback chub. While the vast majority of adult humpback chub in Grand Canyon occur in the LCR Inflow aggregation (at RM 57.0-65.4), humpback chub also occur at other aggregations in the mainstem Colorado River throughout Marble and Grand canyons, and there is movement of humpback chub between the aggregations (Paukert et al. 2006) (Table 5).

All nine aggregations constitute what is considered a single reproducing population (Douglas and Douglas 2007).

The eight other spawning aggregations are (per Valdez and Ryel 1995): 30 mile (RM 29.8 to 31.3); 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 humpback chub have been caught at the Havasu Inflow and Pumpkin Spring aggregations since 2000 (Ackerman 2008). Humpback chub have also been caught infrequently downstream of Pumpkin Spring (Valdez 1994). The LCR Inflow is the largest aggregation, which is in the lower 15 km (9.3 miles) of the LCR and the adjoining 15 km (9.3 miles) of the Colorado River (RM 57.0-65.4) (Valdez and Ryel 1995). This aggregation has been expanded upstream of Chute Falls through translocation (Stone 2009). 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. Young of year are consistently found throughout Grand Canyon, especially associated with spawning aggregations at 30-mile, Middle Granite Gorge, Shinumo, and Randy's Rock, and recruitment appears to be occurring at low levels given that these aggregations continue to be documented over time (Figure 4) (Valdez and Ryel 1995, Trammel et al. 2002, Ackerman 2008).

The Colorado River in Grand Canyon has a restricted channel with limited floodplain development. Channel widths vary from 180 to 390 feet (Valdez and Ryel 1995). Gradients are often high, resulting in areas of rapids separated by long pools and runs. Steep, rocky shorelines, talus slopes with alluvial boulder fans, and undercut ledges border the channel. Substrates range from boulders to cobbles, gravels, and sand. Numerous small tributaries enter the Colorado River in the canyon. These are of two types: (1) perennial tributaries such as the LCR, Bright Angel, Kanab , Shinumo, and Havasu creeks provide varying amounts of base flow to the river and create shallow water habitats for use by native fish. Substrates here tend to be more rocky with fewer fine materials; (2) the ephemeral tributaries which provide flows during flood periods and contribute significant amounts of sediment to the river. Alluvial fans form at the mouth of these ephemeral streams, contributing to the formation of rapids (Maddux et al. 1993b, Valdez and Ryel 1995).

Water releases from Glen Canyon Dam emphasize hydropower production. Releases now vary between 5,000 and 25,000 cfs per the constraints of the MLFF (Table 1). The dam blocks the primary sediment inflow to the river in the canyon, reducing the sediment load to the amount contributed by the tributaries. Constant scouring of sediment from the canyon has continually eroded beaches and other sand-formed habitats such as backwaters since dam closure. The greatly reduced sediment load of the Colorado River post-dam increased water clarity, which increased primary productivity, especially in Marble Canyon, and algae and associated invertebrates dominate upstream reaches (Maddux et al. 1993b).

Water temperatures were altered significantly by emplacement of the dam. Water released from Glen Canyon Dam is cold (8.9 °C) year round when the reservoir is full. Water temperatures downstream from the dam warm seasonally and with increasing distance from the dam due to

solar insolation. However, fluctuations in water flow and associated stage change carry cold water continually into nearshore habitats extending the range of cold water influence. Nonnative fish species, most notably rainbow trout, channel catfish and carp, are established in the river in Marble and Grand canyons (Maddux et al. 1993b, Valdez and Ryel 1995). Of the native fish species that historically occurred in the Grand Canyon, three have been extirpated. Extirpated species include the bonytail and Colorado squawfish. Reproducing populations include the humpback chub, bluehead sucker (*Catostomus discobolus*), flannelmouth sucker (*Catostomus latipinnis*), and speckled dace (*Rhinichthys osculus*). As discussed later in the document, the razorback sucker still occurs in the Grand Canyon, but is very rare.

Fluctuations in flow are now on daily, weekly, and monthly cycles based on needs for power generation and downstream water deliveries instead of the natural seasonal extreme flows of pre-dam years. Water depths and velocities are altered by the change in flows. The humpback chub is mostly found in backwaters, shoreline areas, and eddies, all areas of low-current velocity. These areas may expand or contract in response to changes in flows. Existing water quality is adequate to support aquatic communities; however, changes in turbidity and temperature due to Glen Canyon Dam have had affects on the suitability of the mainstem Colorado River for humpback chub, with resulting effects to reproduction, predation, and foraging behavior (Glen Canyon Dam Adaptive Management Program 2009). The degree to which the water PCEs (W1 and W2) provide for recovery in this reach of critical habitat is an ongoing research question.

The Colorado River in this reach provides a variety of main channel habitats, including eddies, shorelines, and backwaters. The confluence of the Colorado and LCRs is an important habitat area. Access to both systems provides both adult and juvenile humpback chubs with a variety of physical habitat conditions (water depth, velocity, turbidity, temperature, and substrate). Habitats formed by fine substrates such as backwaters that may be important nursery habitats are negatively impacted by the reduction in sediment supply and constant scour of periodic changes in flow volume (Glen Canyon Dam Adaptive Management Program 2009). The physical habitat PCEs are at least partially met, but the suitability of spawning and rearing habitats (PCEs P1 and P2) to fully function in meeting recovery needs is not known, and this is discussed further in the Environmental Baseline.

Food resources do not appear to be limiting in the reach for adult humpback chub, and in fact Hoffnagle (2000) found that condition factor for humpback chub in the mainstem was better than that of adult fish in the LCR. However, fluctuating flows may limit food base in near shore areas (Grand et al. 2006), and research on food base in the mainstem is ongoing (U.S. Bureau of Reclamation and U.S. Geological Survey 2009). There are fewer nonnative species established in the Colorado River in this reach than in other reaches of critical habitat, due in part to the harsh physical conditions present. The cold mainstem water temperatures in particular have likely limited the invasion and expansion of warm-water species. As discussed earlier, providing warmer water through flow manipulations or dam modifications, or warmer water due to climate change, could improve the W1 PCE for humpback chub, but, more seriously, degrade the B2 and B3 PCEs of critical habitat by increasing predation and competition from nonnative fish species. All of the PCEs may be provided for in this reach of critical habitat, although significant questions exist about water temperature (W1), spawning habitat (P1), nursery habitat (P2), and

nonnative fish predation and competition (B2 and B3); these are discussed in detail in the Environmental Baseline.

Kanab ambersnail

The status of the Kanab ambersnail has changed little since the 2008 Opinion, although new information on the species taxonomy could dramatically change its status. Early (unpublished) results of an ongoing taxonomy study indicate that the Kanab ambersnail may actually be part of a much more widespread and abundant taxon (Culver et al. 2008). Specific changes to the species and its habitat in the action area are discussed in the Environmental Baseline section.

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

The status of the species in the action area has improved since the 2008 Opinion. We refer to the original opinion for a complete picture of the status of humpback chub in Marble and Grand canyons, and provide the following updates.

The Grand Canyon population consists primarily of adults residing in and near the LCR (the LCR Inflow aggregation), 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). 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).

Coggins and Walters (2009) recently assessed the status and trend of the humpback chub in the LCR (the LCR Inflow aggregation) utilizing the ASMR and found that the population size continues to increase, and is now between 6,000 adults and more than 10,000 adults, and estimate the current adult (age 4 years or more) population is approximately 7,650 fish. This is an increase from the 2006 estimate of 5,300-6,700, and an increase of about 50 percent since 2001 (Coggins 2008a, Coggins and Walters 2009). Coggins and Walters (2009) found that the additional data analyzed in the ASMR continue to indicate a decline in the status of the

humpback chub since monitoring began in 1989 that reached its lowest point in 2001, and then began to reverse and increase. The change in status was due to an increase in recruitment that began before many actions predicted to improve its status such as mechanical removal of nonnative fishes or warming of mainstem water temperatures in the Colorado River. Mainstem warming and mechanical removal effects both started in 2003 and could have begun affecting the abundance of age-2 recruits in 2004 and later, (brood-years 2002 and later). But the increase in recruitment appears to have at least doubled from the mid-1990s before the population was exposed to warmer Colorado River water temperatures and reduced nonnative abundance near the mouth of the LCR. However, Coggins and Walters (2009) state that the low summer steady flow conducted during the summer of 2000 (primarily a low flow of 8,000 cfs from June to September; see Ralston and Waring 2008), which warmed the mainstem river, may have resulted in increased recruitment of the 1999, 2000, and possibly 1998 brood-years. The increase in recruitment in the 1990s could also have been due to the implementation of the MLFF. Although the contribution of the mainstem aggregations, other than the LCR Inflow aggregation, to the overall Grand Canyon population is not known, and most of the population likely occurs in the LCR Inflow aggregation, the Grand Canyon population of humpback chub (i.e. the lower Colorado River basin recovery unit) is nevertheless the largest of the humpback chub populations, and the only one with an increasing trend. It is important to note that population-dynamics information for humpback chub is much improved since the 1995 opinion, with much more available information on humpback chub recruitment and abundance since the time of the 1995 Opinion, as a result of ongoing monitoring of the GCDAMP and the development of the ASMR (Coggins and Walters 2009).

FWS monitoring efforts in the LCR in 2008 and 2009 also indicate increasing recruitment and abundance. Despite three months of flooding in the LCR in early 2008, the Spring 2008 monitoring found the highest captures of unique humpback chub ≥150 mm TL (5.9 inches) since semiannual, mark-recapture stock assessments were first initiated in the LCR in 2000 (Stone 2008a). Van Haverbeke and Stone (2009) also note that the 2007 and 2008 estimates of abundance are also statistically comparable to the 1992 spring abundance estimates obtained by Douglas and Marsh (1996). This is significant because the Recovery Goals require an increasing trend relative to prior abundance estimates (U.S. Fish and Wildlife Service 2009), and Douglas and Marsh (1996) provided one of the earliest robust estimates of humpback chub abundance in the LCR. Thus it now appears that humpback chub have returned to levels of abundance first documented in the early 1990s. As a caveat to this, there is some evidence to indicate continued decline of the oldest adult chub in the population, the largest fish, age 11 years and older; however, this could be an artifact of earlier declines in population trend such that the recent increase in recruitment and abundance has yet to result in an increase in this largest and oldest size class (R. Johnson, Grand Canyon Trust, pers. comm., 2009).

Reclamation's conservation measures for humpback chub from the 2008 Opinion have either been implemented or are in the process of being implemented. The AMWG accepted the completed HBC Comprehensive Plan in August 2009, and Reclamation is currently implementing many aspects of the plan (Glen Canyon Dam Adaptive Management Program 2009). Translocations above Chute Falls were conducted in 2008 and 2009, and a translocation into Shinumo Creek was also conducted in 2009. A nonnative removal trip was conducted in 2009 and two trips are planned for 2010. GCMRC has also completed a draft Nonnative Fish

Management Plan. The NSE began in 2008, and now includes the Monthly Flow Transition Study conservation measure. Development of refuges began in 2008 and is ongoing; 795 juvenile humpback chub were transferred to Dexter National Fish Hatchery and Technology Center in 2008 and 2009, all captured from the LCR near its mouth. Reclamation recently completed a draft watershed plan for the LCR (Valdez and Thomas 2009) and continues to assist the Little Colorado River Watershed Coordinating Council in watershed planning efforts.

As described earlier, translocation of humpback chub from near the mouth of the LCR to upstream of Chute Falls also took place in 2008 and 2009 as a conservation measure of the 2008 Opinion. Monitoring of this upstream reach was also conducted in 2008 and 2009. Thus far, a total of 1,643 humpback chub have been translocated above Chute Falls from 2003 to 2009. This upstream reach has been monitored since the first translocation in 2003; humpback chub have consistently been found above the falls since then, adult chub have moved upstream on their own (thus the falls do not actually constitute a barrier to humpback chub) and 156 humpback chub were captured above Chute Falls in monitoring in 2009 (Stone 2009).

A number of interesting results of the translocation have been observed, all of which seem beneficial to the Grand Canyon population of humpback chub. The abundance of humpback chub in the upper reach immediately below Chute Falls in the Atomizer Falls complex appears to have increased dramatically, with hundreds of fish present, likely as a result of translocation efforts, although the humpback chub present are a mix of some translocated fish, some that have moved up from downstream areas of the LCR (upriver migrants), and fish of unknown origin that did not appear to have previously been tagged (Figures 5, 6) (Stone 2009, D. Stone, FWS, pers. comm. 2009). Growth rates of translocated humpback chub are very high. Fish that are translocated at age 0-1 year have grown to maturity, over 200 mm TL (7.9 inches), within one year of being translocated. Typically a 200 mm TL fish in the Grand Canyon population is considered to be 4 years old. Translocated fish appear to have spawned based on the presence of ripe fish and fry above Chute Falls, although only three fry have so far been captured, so spawning may be minimal (Van Haverbeke and Stone 2009). Four humpback chub have been documented moving up Chute Falls on their own (Stone 2009, Van Haverbeke and Stone 2009), and in May of 2009 an adult female did so during base flow conditions, illustrating that even at base flow the falls are not a barrier to humpback chub movement (Stone 2009, D. Stone, FWS, pers. comm. 2009). Because PIT tagging was not initiated until the fourth translocation in 2008, there is not enough data to say with certainty what the contribution of translocated fish has been to the overall population. Given the high growth rate, the increase in numbers between Atomizer and Chute falls, and the continued presence of humpback chub above Chute Falls, it seems reasonable that survivorship of translocated fish has been quite high, and may have contributed to the improvement in status of the overall population, although most humpback chub have moved below Chute Falls, calling the range extension somewhat into question (Van Haverbeke and Stone 2009).

In June of 2009, Grand Canyon National Park and Grand Canyon Wildlands Council translocated 300 age-1 humpback chub into Shinumo Creek. This is also a conservation measure of the 2008 Opinion. In advance of the translocation, another 2008 Opinion conservation measure, nonnative removal, was undertaken in Shinumo Creek. To facilitate a successful translocation, rainbow trout, potential predators and competitors of humpback chub (Valdez and

Ryel 1995, Marsh and Douglas 1997, Coggins 2008b), were removed from Shinumo Creek. Over 900 non-native rainbow trout were removed from Shinumo Creek in May and June 2009, in preparation for the humpback chub release. Following the release, two monitoring trips, pre-and post-monsoon, were scheduled. The pre-monsoon monitoring trip was completed in July 2009. To help monitor potential downstream movement of translocated fish, two remote PIT tag antennas were installed in the lower end of the system above a waterfall near the mouth of Shinumo Creek. Monitoring thus far has indicated good retention of fish in the creek; 108 were captured in July, only six of which were below the falls, the rest in the two mile reach above the falls, the majority of these fish in the same general location where they were released. Of the six humpback chub captured in the short reach below the falls, three (two young of year, and one 1-year old) were unmarked (Grand Canyon Wildlands Council 2009). There is a spawning aggregation at Shinumo Creek, and captures of young fish, an indication of successful spawning, are not uncommon (Ackerman 2008).

Mainstem humpback chub spawning aggregations other than the LCR inflow have not been specifically monitored since 2006, so any change in their status since the 2008 Opinion is unknown. The report for the mainstem fish sampling activities for 2007 and 2008 has also not yet been completed. But, data collected through 2006 indicate that humpback chub may have spawned and recruited at 30-mile (M. Andersen, GCMRC, pers. comm. 2007). The 30-mile aggregation is the furthest upstream and thus would be warmed the least by warmer Glen Canyon Dam release temperatures because the river gets warmer as it moves downstream from the dam, but temperatures at the dam in 2005 were above the thermal minima needed for successful humpback chub spawning and recruitment, so it is conceivable that the 30-mile aggregation did so. Monitoring of other mainstem humpback chub aggregations in recent years also indicated that spawning and possible recruitment was occurring (Figure 4) (Trammel et al. 2002, Ackerman et al. 2006, Ackerman 2008). Monitoring will be modified in 2010 to include mainstem aggregations as a result of recommendations from the 2009 GCMRC fish monitoring program protocol evaluation panel (U.S. Bureau of Reclamation and U.S. Geological Survey 2009).

Spring inflows to Lake Powell in 2008 brought some relief to the long-term drought conditions seen in the Colorado River basin since 2000, and dam operations in 2008 were relatively wet. Reclamation conducted a high flow test initiated on March 5, 2008, and completed on March 9, 2008. During the high flow experiment, Reclamation released water through Glen Canyon Dam's powerplant and bypass tubes to a maximum amount of 41,500 cfs (1,180 cms) for 60 hours. As a result of the high flow test, the elevation of Lake Powell dropped by approximately 2.3 feet. However, the annual volume of water released from Lake Powell for water year 2008 was not modified as a result of the high flow experiment. Although 2008 was originally projected to be an 8.23 maf release year, the April 24-month study projected the September 30, 2008, Lake Powell elevation to be above 3,636 feet (the equalization level for water year 2008), based on the April 1st final inflow forecast. Consistent with Section 6.B.3 of the Shortage Guidelines, if the April 2009 24-Month Study projects the September 30 Lake Powell elevation to be greater than that year's equalization level, Section 6.A (Equalization Tier) of the Shortage Guidelines will govern the release of water from Lake Powell for the remainder of water year (through September). As a result, releases for 2008 were 8.973 maf (U.S. Bureau of Reclamation 2008).

A test of steady flows (steady daily releases), as described and analyzed in the 2008 Opinion, was conducted during September and October in 2008. The steady flows in 2008 were about 12,100 cfs mean steady flow for both months (Table 3). Annual releases from Lake Powell during water year 2009 have been consistent with Section 6.B (Upper Elevation Balancing Tier) of the Shortage Guidelines. Consistent with Section 6.B.1 of the Shortage Guidelines, the water year release from Lake Powell in 2009 has been 8.23 maf. The distribution of release volumes throughout water year 2009 was fairly typical of median MLFF operations consistent with the 1996 ROD for an 8.23 maf year (Table 3).

Release temperatures from Glen Canyon Dam have remained elevated relative to operations during the 1980s and 1990s due to continued drought-induced lower Lake Powell reservoir levels, and somewhat due to relatively high inflow in 2008 and 2009. Water temperature in the mainstem river at Lees Ferry reached about 14 °C in 2008 (U.S. Geological Survey 2009a), similar to temperatures in 2003 when drought effects from low Lake Powell levels began to raise Glen Canyon Dam release temperatures. The 2008 temperatures are warm enough to provide some benefit to humpback chub, though not as much as the high temperatures of 16° seen at Lees Ferry in 2005 (Figure 7).

Glen Canyon Dam release temperature is a result of a combination of several factors: reservoir elevation (because warm water in the epilimnion, the warmest uppermost layer of a lake, is closer and more available to be released through the penstock intakes); temperature and volume of inflow (larger runoff volumes deepen the epilimnion, creating a larger, deeper body of warm water that is relatively closer to the penstocks at a given reservoir elevation, and therefore available to be released, than do smaller runoff volumes); and climate (water temperature and solar insolation directly affect water temperature). Releases from Glen Canyon Dam effect downstream temperature as a result of release temperature, volume, and changes in volume over time (fluctuations). Wright et al. (2008a) found that mainstem temperatures at the Little Colorado River 124 km (77 miles) downstream of Glen Canyon Dam were influenced by both temperature and volume, but release temperature had the greater effect; generally, release temperature is more important closer to the dam, and volume more so the further downstream. Release temperature peaked in 2005 when Lake Powell reached its lowest point since filling in the 1970s of 3,555.1 feet elevation on April 8. Since the 2008 Opinion, Lake Powell elevation has ranged from 3,588.26 feet on March 11, 2008 to 3,642.29 on July 12, 2009. Global climate change is predicted to result in drier conditions in the Colorado River basin, thus lower Lake Powell reservoir elevations (and warmer release temperatures) may become the norm (Seager et al. 2007, U.S. Climate Change Science Program 2008a, 2008b).

Geomorphologists working in Grand Canyon have for some time asked the question "what flow magnitude and duration is needed to resuspend sediment and create and maintain sandbars?" (Andrews 1991, Schmidt 1999, Goeking et al. 2003, Schmidt et al. 2007). One hypothesis is that without occasional periods of sustained high releases (powerplant capacity and above), high elevation sandbars will erode and not rebuild (Andrews 199l). The GCDAMP has been experimenting with high flow tests as a means to restore sand bars in Grand Canyon since 1996, most notably in 1996, 2004, and 2008. These tests have had varying results, and although a best

case scenario of dam operations that permanently sustains existing sand bars appears feasible, this approach is still a research question (Wright et al. 2008).

The high flow tests of 1996 and 2004 high flow tests were found effective at building or rebuilding sandbars, although persistence of the sandbars was variable, as described in the 2008 Opinion, and in Reclamation's 2007 biological assessment (U.S. Bureau of Reclamation 2007a). In 2007, sand inputs from the Paria River were at least 2.5 million metric tons, or about 2.5 times the historic average (Topping and Melis 2007). Together with inputs from the Little Colorado River in 2006 and unexpected retention of sediment from both tributaries during 2006 (U.S. Geological Survey 2006), sand inputs were at least 3 times the amount that triggered the 2004 high flow test. This presented a unique opportunity to evaluate effects of a high flow test under sand-enriched conditions greater than ever tested before. Detailed results of the 2008 high flow test are not yet available, but comprehensive reporting on the high flow test should be available in late 2009. A lack of sediment inputs since the 2008 high flow test has resulted in erosion, and the mass balance of sand in Marble and Grand Canyons (between Lees Ferry and the Grand Canyon gauge) in now negative relative to conditions at the recession of the 2008 high flow test. But because sand concentrations during the 2008 high flow test were much higher than during the 1996 test at all measurement locations, and much higher than during the 2004 test at two locations (61-mile to 225-mile), and as high as the 2004 test at one location (30-mile) (Grams 2009, U.S. Geological Survey 2009a), results of the 2008 high flow test are expected to exceed previous tests over a wider area in Marble and Grand canyons.

Although backwaters appear to be important habitat types of young humpback chub (Arizona Game and Fish Department 1996, Hoffnagle 1996), their overall importance relative to habitat suitability, availability, and humpback chub survival and recruitment are still in question, and additional research on this relationship has long been needed. A conservation measure of the 2008 Opinion aimed at meeting this need, the Nearshore Ecology Study, began in 2008. This study will help clarify the relationship between flows and mainstem habitat characteristics and habitat availability for young-of-year and juvenile humpback chub, other native fish, and competitive or predaceous nonnative fish.

In August of 2009, GCMRC also developed a draft Fall Steady Flow Plan (FSFP) (U.S. Geological Survey 2009b). This plan will coordinate and augment several ongoing studies to optimize research that evaluates the steady releases from Glen Canyon Dam in September and October from 2008-2012. Four existing projects are collecting data that will be used to determine whether biological resources benefitted from steady flows (including humpback chub PCEs of water temperature (W1), nursery habitat (P2), feeding areas (P3), food supply (B1), predation (B2), and competition (B3)). The plan will incorporate multiple lines of evidence to evaluate humpback chub response to fall steady flows using measurements of variables in the Little Colorado River inflow reach (i.e., water temperature and food resources) and rainbow trout studies in Lees Ferry (e.g. flows may strongly benefit rainbow trout juvenile survival and insights on fish—flow interactions may apply downstream). The four studies are: Nearshore Ecology - effects of experimental flows on native fish habitat use and survival/growth; Stock Assessment of Grand Canyon Native Fish - effects of experimental flows on populations of adult native fish; Aquatic Food Base Monitoring - effects of experimental flows on food availability, and water residence time in backwaters; and Rainbow Trout Monitoring –effects of experimental

flows on populations of juvenile and adult rainbow trout. The four studies collectively should provide a comprehensive ecosystem assessment of the effects of steady versus fluctuating flows, addressing the recovery need of determining flow needs of humpback chub in the mainstem (U.S. Fish and Wildlife Service 2009).

An important feature of the environmental baseline is ongoing global climate change. Several recent studies predict continued drought in the southwestern United States due to global climate change, including the lower Colorado River basin. Seagar et al. (2007) analyzed 19 different computer models of differing variables to estimate the future climatology of the southwestern United States and northern Mexico in response to predictions of changing climatic patterns. All but one of the 19 models predicted a drying trend within the Southwest. A total of 49 projections were created using the 19 models and all but three predicted a shift to increasing aridity in the Southwest as early as 2021–2040 (Seager et al. 2007). Recently published projections of potential reductions in natural flow in the Colorado River Basin by the mid-21st century range from approximately 45 percent by Hoerling and Eischeid (2006) to approximately six percent by Christensen and Lettenmaier (2006). The U.S. Climate Change Science Program recently completed a report entitled "Abrupt Climate Change, A report by the U.S. Climate Change Science Program and the Subcommittee on Global Climate Change Research" (U.S. Climate Change Science Program 2008a) that concluded, if model results are correct, the southwestern United States may be beginning an abrupt period of increased drought (U.S. Climate Change Science Program 2008b).

If predicted effects of climate change result in persistent drought conditions in the Colorado River basin similar to or worse than those seen in recent years, water resources will become increasingly taxed as supplies dwindle. Increased demand on surface and groundwater supplies throughout the Colorado River basin is also likely. The upper Colorado River basin states have not fully allocated their water rights to the Colorado River, and will likely look to implement projects to utilize additional water. For example, the Lake Powell Pipeline project is currently proposed to provide water from Lake Powell to communities in southwest Utah. The pipeline is anticipated to deliver approximately 100,000 acre-feet of water, likely resulting in lower Lake Powell reservoir elevations, and warmer Glen Canyon Dam release temperatures, on average, especially in the face of climate change (U.S. Fish and Wildlife Service 2008b).

Changes to climatic patterns may warm water temperatures, alter stream flow events, and increase demand for water storage and conveyance systems (Rahel and Olden 2008). Resulting warmer water temperatures across temperate regions are predicted to expand the distribution of existing aquatic nonnative species by providing 31 percent more suitable habitat for aquatic nonnative species, based upon studies that compared the thermal tolerances of 57 fish species with predictions made from climate change temperature models (Mohseni et al. 2003). Eaton and Scheller (1996) reported that while several cold-water fish species in North America are expected to have reductions in their distribution due to the effects of climate change, several warmwater fish species are expected to increase their distribution. In the southwestern United States, this may occur where water remains perennial but warms to a level suitable to nonnative species that were previously physiologically precluded from these areas. Species that are known or suspected to prey on or compete with humpback chub populations such as black bullhead, fathead minnow, common carp, channel catfish, and largemouth bass are expected to increase

their distribution by 5.9 percent, 6.0 percent, 25.2 percent, 25.4 percent, and 30.4 percent, respectively (Eaton and Scheller 1996). Rahel and Olden (2008) also predict that changing climatic conditions will benefit warmwater nonnative species such as red shiner (*Cyprinella lutrensis*), common carp, mosquitofish (*Gambusia affinis*), and largemouth. All of the above-mentioned species already occur in the Colorado River in Marble and Grand canyons, but climate change and warmer water temperatures could lead to their proliferation and range expansion within the river. The effect of water temperature (and flow volume and fluctuation, which affect water temperature) on the abundance and composition of nonnative fish species, and the tradeoff this represents to natives that benefit from warmer water, is an important consideration that was apparently identified at the time of the 1995 Opinion and earlier; however, the severity of this threat appears underestimated by biologists of the time, given newer information available on the effects of nonnative species population increases and concomitant decreases in humpback chub populations in the Yampa and Green rivers, and how closely this now appears linked to temperature and hydrology (U.S. Fish and Wildlife Service 1978, 1995a, Finney 2006, Fuller 2009, Johnson et al. 2008, R. Valdez, pers. comm., 2009).

Rahel et al. (2008) also noted that climate change could facilitate expansion of nonnative parasites. This could be an important threat to humpback chub. Optimal Asian tapeworm development occurs at 25-30 °C (Granath and Esch 1983), and optimal anchorworm temperatures are 23-30 °C (Bulow et al. 1979). Cold water temperatures in the mainstem Colorado River in Marble and Grand Canyons have prevented these parasites from completing their life cycles and limited their distribution. Warmer climate trends could result in warmer overall water temperatures, increasing the prevalence of these parasites.

As discussed in the 2008 Opinion, predation and competition from nonnative fish species continue to constitute a serious threat to humpback chub (Minckley 1991, Mueller 1995, Hilwig et al. 2009), and nonnative fish control is a conservation measure of the 2008 Opinion. Levels of nonnative fish species in Marble and Grand Canyon are similar to that at the time of the 2008 Opinion with one exception. The abundance of nonnative rainbow trout in the important LCR inflow reach has apparently increased since the 2008 Opinion was completed (Makinster et al. 2009a, 2009b). Mainstem fish monitoring detected increases in nonnative rainbow trout in the LCR inflow reach of the Colorado River in 2008, prompting a removal trip in May of 2009. AGFD removed 1,873 rainbow trout during the May 2009 removal trip, which is about the same abundance encountered in February of 2003. This indicates that rainbow trout are likely increasing throughout Marble Canyon, and in fact AFGD found more rainbow trout in the control reach upstream of the removal reach than had previously been detected. Unlike the situation in 2003, however, the four native fish species occurring in Grand and Marble Canyons, flannelmouth sucker, bluehead sucker, speckled dace, and humpback chub, are still very abundant in the LCR inflow reach (Makinster et al. 2009b).

At least two species of crayfish, the red swamp crayfish (*Procambaris clarki*) and the northern or virile crayfish (*Orconectes virilis*), have been introduced into the action area. The red swamp crayfish is well established downstream in Lake Mead, and northern crayfish is well established in Lake Powell (Johnson 1986). In 2007, northern crayfish were observed in Lees Ferry, although only three northern crayfish were observed, and none were captured in further intensive efforts to capture crayfish (A. Makinster, Arizona Game and Fish Department, pers. comm.,

2009). Red swamp crayfish were also found as far upstream from Lake Mead as Spencer Canyon (RM 246) in 2003 (L. Stevens, Grand Canyon Wildlands Council, pers. comm., 2009). Presumably crayfish would have become established by now in Marble and Grand Canyons if conditions were suitable, given their close proximity in Lakes Powell and Mead, although precisely what conditions have prevented this are not known. Crayfish appear to negatively impact native fishes and aquatic habitats through habitat alteration by burrowing into stream banks and removing aquatic vegetation, resulting in decreases in vegetative cover and increases in turbidity (Lodge et al. 1994, Fernandez and Rosen 1996). Crayfish also prey on fish eggs and larvae (Inman et al. 1998), and alter the abundance and structure of aquatic vegetation by grazing, which reduces food and cover for fish (Fernandez and Rosen 1996). Creed (1994) found that filamentous alga (*Cladophora glomerata*) was at least 10-fold greater in aquatic habitats absent crayfish. Filamentous alga is an important component of aquatic vegetation in Marble and Grand Canyons that is part of the food base for humpback chub (Valdez and Ryel 1995). Carpenter (2005) found that crayfish reduced growth rates of flannelmouth sucker, but Gila chub (*Gila intermedia*, a closely related species to humpback chub) were more affected by intraspecies competition than from competition with crayfish. Marks et al. (2009) found that, following eradication of nonnative fishes and flow restoration in Fossil Creek, Arizona, crayfish abundance increased significantly, but this had no apparent effect on native roundtail chub (*Gila robusta*, a species closely related to humpback chub), which also increased in numbers significantly following removal of nonnative fish. Thus the threat posed to humpback chub in Grand Canyon by nonnative crayfish is unclear, although climate change could result in their spread in Marble and Grand Canyons due to warmer mainstem water temperatures (Valdez and Speas 2007, Rahel et al. 2008).

To further address the needs of the GCDAMP to address the threat of nonnative fish species, GCMRC completed a draft Nonnative Fish Management Plan in July 2009 (Hilwig et al. 2009). The plan coordinates monitoring, control, and research on management of nonnative fishes in Grand and Marble Canyons. The plan utilizes the conservative approach of assuming that all nonnative fishes are a threat to native fish, that reduction in nonnatives will benefit native fish, that there are multiple sources of nonnative fish, both in the mainstem and in the tributaries, and that targets for control of nonnatives are more realistic than complete eradication. Plan monitoring is comprehensive, and recognizes the importance of tributaries as vectors and the need for early detection. The plan focuses control efforts on mechanical removal of rainbow trout to 10-20 percent of 2003 levels; mechanical removal of channel catfish in the LCR inflow reach; and tributary removal (such as that associated with the Shinumo translocation); and recommends chemical renovation and barriers in tributary streams. Recommended research includes utilizing an existing nonnative species risk assessment (Valdez and Speas 2007) and energetic modeling to determine which species pose the biggest threat to humpback chub given climate change and other effects on mainstem temperatures, identification of sources of nonnatives, and testing targeted flow and temperature manipulations of dam releases to disadvantage nonnative fish.

Humpback Chub Critical Habitat

Critical habitat for humpback chub in the action area consists of Critical Habitat Reach 6, the LCR, and Critical Habitat Reach 7, the Colorado River in Marble and Grand Canyons (Figure 1).

Reach 6, consists of the lowermost 8 miles (13 km) of the LCR to its mouth with the Colorado River. Reach 7, consists of a 173-mile reach of the Colorado River in Marble and Grand Canyons from Nautiloid Canyon (RM 34) to Granite Park (RM 208). The PCEs, as described in the Status of the Species section, are: Water of sufficient quality (W1)(i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, turbidity, etc) that is delivered to a specific location in accordance with a hydrologic regime that is required for the particular life stage for each species (W2); Physical Habitat, areas for use in spawning (P1), nursery (P2), feeding (P3), and movement corridors (P4) between these areas; and Biological Environment, food supply (B1), predation (B2), and competition (B3) (Maddux et al. 1993a, 1993b, U.S. Fish and Wildlife Service 1994).

Critical Habitat Reach 6 – Little Colorado River

The current condition of critical habitat in Reach 6, the LCR, is probably similar to historical conditions in many ways. As discussed in the Status of the Species section, all of the PCEs are provided for in this reach of humpback chub critical habitat, and this segment supports the majority of the Grand Canyon population, the largest of the humpback chub populations.

With regard to the PCE for water, water quality and quantity have likely been altered by land uses such as livestock grazing and development in the LCR basin in numerous ways, although little monitoring or research has been conducted on changes to this critical habitat segment from historical conditions. Water use in the basin has clearly diminished surface flows because the LCR is now an intermittent stream, and it was perennial historically (Valdez and Thomas 2009). But data for the USGS Cameron gauge (which only go back to 1947) show that the LCR hydrograph has been highly variable with frequent floods as well as periods of low to no flow, with no discernable pattern. Flow in the reach of critical habitat is reduced annually to base flow from Blue Springs of about 225 cfs, although floods are common, and may even exceed historical floods in magnitude given that development results in greater peak runoff, and frequency and magnitude of flooding events (Hollis 1975, Neller 1988, Booth 1990, Clark and Wilcock 2000, Rose and Peters 2001, Wheeler et al. 2005). Livestock grazing, a land use that has touched every corner of the LCR basin, similarly impacts aquatic and riparian habitats at a watershed level though soil compaction, altered soil chemistry, and reductions in upland vegetation cover, changes which lead to an increased severity of floods and sediment loading, lower water tables, and altered channel morphology (Rich and Reynolds 1963, Orodho *et al*. 1990, Schlesinger *et al*. 1990, Belsky *et al*. 1999).

Development can affect water quality in a number of ways. Urban runoff contains a variety of chemical pollutants including petroleum, metals, and nutrients from a variety of sources such as automobiles and building materials (Wheeler et al. 2005). Development also leads to increases in the number of dumps and landfills that leach contaminants into ground and surface water, reducing water quality and thereby degrading fish habitat, and there is evidence of this in the LCR, which contains surges of trash with each flooding event. Similarly, wastewater treatment plants that accompany development also can contaminate ground and surface water (Winter et al. 1998). Pharmaceuticals and personal care products also may contain hormones, which are present in wastewater, and can have significant adverse effects to fishes, particularly fish reproduction (Kime 1994, Rosen et al. 2007). The use of pesticides is also a source of water

quality contamination from agricultural and residential use, which can have lethal and sublethal effects to fish (Ongley 1996). Despite the presence of much development in the LCR basin, we know of no water quality issues with W1 of critical habitat in Reach 6.

Whatever effect land and water use of the LCR basin has had on modification of the lower LCR and its hydrograph, it is not readily apparent from the physical habitats available to humpback chub. This could be because of the continued spring-fed base flow and the unique travertine geology of the system which forms a complex habitat matrix of pools, shallow runs, and races. Uncemented calcium carbonate particles form part of the stream bottom and contribute to the turbidity of the river (Kubly 1990), and flood flows are extremely turbid. This also could contribute to the lower levels of nonnative predators in the LCR, which generally evolved and survive better in clear water. Perhaps also important, development of the LCR basin is widespread, but not dense, so effects of land uses are mediated by large expanses of open space and the sheer size of the basin. Regardless, all of the physical PCEs (P1-4) are provided for in the LCR, and the stream appears to fully support all life stages of the species, and all life stages appear to have been increasing in recent years (Coggins and Walters 2009, Stone 2008a, 2008b).

Although the biological PCE for food supply (B1) is met in this reach (as described in the Status of the Species section), there appears to be greater food availability for adult humpback chub in the mainstem Colorado River based on body condition. Hoffnagle (2000) reported that condition and abdominal fat were greater in the mainstem Colorado River than in the LCR during 1996, 1998, and 1999. Alternatively, this may have been due to the increased prevalence and abundance of parasites (especially *Lernaea cyprinacea* and *Bothriocephalus acheilognathi*) in the LCR fish as opposed to greater food availability in the Colorado River.

The biological PCEs of predation (B2) and competition (B3) from nonnative species are also met. Nonnative fish species that prey on and compete with humpback chub are present, but in very low numbers relative to native fishes including humpback chub (see Tables 6 and 7). For example, although channel catfish captures increased between the spring and fall 2008 monitoring trips (from 1 fish in spring to 66 fish in the fall), even the increased number of channel catfish captured (n=66) was a small fraction of the total number of humpback chub captured (n=3,084)(Stone 2008a, 2008b). Although fish remains were found in nonnative species in 2007 in the LCR, no direct evidence of humpback chub predation was documented, although predation on humpback chub by catfish and trout has been documented in the past (Marsh and Douglas 1997, Yard et al. 2008). The primary indication that the biological, as well as the other PCEs, are met, is the increasing abundance of humpback chub and recruitment that has characterized the population in the LCR in recent years (Stone 2008a, Stone 2008b, Coggins and Walters 2009).

Role of Reach 6 of Humpback Chub Critical Habitat in Recovery

The LCR reach of critical habitat plays a important role in the recovery of the species because this is the primary spawning and rearing area for the Grand Canyon population, which also constitutes (along with the mainstem Colorado River) the lower Colorado River Recovery Unit. As described in the Status of the Species section, demographic goals must be met for this Recovery Unit, as well as for one or two core populations in the upper Colorado River basin, for

downlisting and delisting, respectively, to occur (U.S. Fish and Wildlife Service 2009). Although the Recovery Goals are only draft at this time, FWS is working to finalize these in response to a Court Order. The draft goals constitute the best available scientific information with which to analyze the performance of critical habitat reaches in meeting the recovery needs of the species. As described earlier, in addition to the demographic goals, the Recovery Goals also contain site-specific management actions and tasks and corresponding recovery factor criteria that must be met for downlisting and delisting to occur (see Appendix B). In evaluating the effectiveness of the critical habitat unit in meeting recovery, the primary measure is the status of the population in relation to the demographic goal, and the secondary measure is the state of the recovery factors and the implementation of their associated management actions and tasks.

The current abundance of humpback chub in the LCR is estimated to be 7,650 adults (between 6,000-10,000, age 4+; ≥ 200 mm TL) which is nearing the 10,000-11,000 adults the ASMR estimates constituted the adult LCR population when marking began in 1989, and appears to have been in an upward increasing trend since 2001 (Coggins et al. 2006a, Coggins 2008a, Coggins and Walters 2009). The demographic goal for the Grand Canyon population for downlisting is that the humpback chub population is maintained as a core population over a 5-year period, starting with the first point estimate acceptable to the Service, such that the trend in adult (age 4+; ≥ 200 mm TL [7.9 inches]) point estimates does not decline significantly, the mean estimated recruitment of age-3 (150–199 mm TL [5.9-7.8 inches]) naturally produced fish equals or exceeds mean annual adult mortality, and the population point estimate exceeds 2,100 adults. The FWS (Region 6) has not yet determined that the demographic goal for the Grand Canyon population has been met, but the best available science indicates that the demographic goal is at least nearing being met. Given this, the PCEs in Critical Habitat Unit 6, the LCR, appear to be meeting the needs of recovery.

The recovery factor criteria and associated management actions and tasks that relate to this critical habitat unit are based on the five listing factors (all are listed in Appendix B). Most of these are directed at improving and protecting humpback chub habitat including critical habitat and the PCEs of critical habitat. In general, those that relate to the LCR and Reach 6 of critical habitat include:

- Factor A: Adequate habitat and range for recovered populations provided, identifying and providing a flow regime in the LCR that meets the needs necessary for all life stages of humpback chub to support a recovered Grand Canyon population;

- Factor B: Protect humpback chub populations from overutilization for commercial, recreational, scientific, or educational purposes through implementation of identified actions to ensure adequate protection for humpback chub populations from overutilization;

- Factor C: Adequate protection from diseases and predation, identifying and implementing levels of control of nonnative fish in the LCR and the fish parasite Asian tapeworm (*Bothriocephalus acheilognathi*), and developing and implementing procedures for stocking sport fish to minimize escapement of nonnative fish species into the Colorado River and its tributaries through Grand Canyon;

- Factor D: Adequate existing regulatory mechanisms, determine and implement mechanisms for legal protection of adequate habitat in the Little Colorado River through instream-flow rights, contracts, agreements, or other means;

- Factor E: Other natural or manmade factors for which protection has been provided, identify and implement measures to minimize the risk of hazardous-materials spills from transport of materials along U.S. Highway 89 at and near the Cameron Bridge spanning the Little Colorado River.

For Factor A, an adequate flow regime for the LCR that meets the needs necessary for all life stages of humpback chub to support a recovered Grand Canyon population appears to be met in recent years, given the status and trend of the LCR population (Stone 2008a, 2008b, Coggins and Walters 2009). However, a specific definition of the LCR flow regime that provides for these habitats, or a specific model that relates flow to habitat conditions, has not been developed and has been identified as a need by Valdez and Thomas (2009) who provide a comprehensive look at the LCR flow regime and the needs of the humpback chub in the LCR in a management plan for the LCR basin that focuses on the needs of humpback chub. This plan was developed in response to an element of the reasonable and prudent alternative of the 1995 Opinion (U.S. Fish and Wildlife Service 1995a) which required that Reclamation be instrumental in developing a management plan for the LCR. LCR watershed planning is also a conservation measure of the 2008 Opinion and a project in the HBC Comprehensive Plan (Glen Canyon Dam Adaptive Management Program 2009).

Valdez and Thomas (2009) discuss the effects of human land uses of the LCR watershed and how they affect ground and surface water and ultimately flow and humpback chub habitat in the lower LCR. Key water uses of the basin are associated with the communities of Flagstaff and Winslow and several regional power plants and associated withdrawals from the C-aquifer, the same aquifer that feeds Blue Spring. However, they also note that although these clearly must have reduced inputs of surface flow causing the river to become intermittent, the change in the LCR hydrograph is not easy to detect. For example, for the period of record for the U.S. Geological Survey Cameron stream flow gauge (since 1947), there is no discernable pattern of no-flow days, although maximum daily flows have lowered since 1988, perhaps indicating an effect of drought and water use. Valdez and Thomas (2009) provide numerous recommendations on LCR watershed management that pertain to Factor A, including: research to better determine the relationship between ground water pumping of the C-aquifer and flows in the lower LCR, particularly base flows from Blue Spring and associated springs; development of a model that links flow with important physical and biological characteristics of humpback chub habitat and defines instream flow needs of humpback chub in the LCR; and investigating the potential to augment surface flows throughout the basin to increase surface flows in the lower LCR.

Factor B, overutilization, is not relevant to the status of critical habitat. For Factor C, the focus of the Recovery Goals is on controlling the proliferation and spread of nonnative species that prey on, compete with, and parasitize humpback chub. The Recovery Goals identify in the LCR rainbow trout, channel catfish, black bullhead, and common carp, as well as the nonnative internal fish parasite Asian tapeworm, and require identifying and implementing levels of control

as necessary to recover the Grand Canyon population. Current levels of control of nonnative fish species appear adequate in the LCR. Nonnative fish in Reach 6 of critical habitat continue to be at low levels (see Tables 6 and 7). Clearly such low levels should be maintained, but a specific target level as alluded to in the Recovery Goals has not been identified. Better regulation of sport fish stocking through development and implementation of stocking goals with the relevant basin states has not occurred, is still needed, and is a project of the HBC Comprehensive Plan (Glen Canyon Dam Adaptive Management Program 2009). Stocking, both legal and illegal, throughout the LCR basin, likely results in nonnative fish moving into the lower LCR and into critical habitat (Stone et al. 2007).

Asian tapeworm has been documented at infestation rates of 31.6–84.2 percent in the LCR, and has been hypothesized as a factor in poor condition factor of humpback chub in the LCR (Meretsky et al. 2000, Hoffnagle et al. 2006). Nevertheless, the status and trend of the LCR population indicates that the negative effect of Asian tapeworm is not significant. Recent research efforts have also noted that infestation rates are highly variable, and may be dependent on river flow, size class of fish, or other factors. More research is needed to determine the population-level effect of Asian tapeworm and the need and scope of a possible control program for the parasite (D. Ward, AGFD, pers. comm., 2009). The HBC Comprehensive Plan includes a project for the monitoring and control of humpback chub parasites and diseases (Glen Canyon Dam Adaptive Management Program 2009).

For Factor D, Adequate existing regulatory mechanisms, the Recovery Goals identify the need to determine and implement mechanisms for legal protection of adequate habitat in the Little Colorado River through instream-flow rights, contracts, agreements, or other means. The most thorough accounting of the mechanisms and stakeholders needed to accomplish this for the LCR are provided by Valdez and Thomas (2009). As mentioned above, a primary need is to develop a model to define the instream flow needs of humpback chub to provide for all life stages of the species and relate flow to habitat needs of all life stages (Valdez and Thomas 2009). The current status and upward trends in population abundance and recruitment (Stone 2008a, 2008b, Coggins and Walters 2009) indicate that the current hydrograph is adequate to achieve recovery.

For Factor E of the Recovery Goals, other natural or manmade factors for which protection has been provided, the primary element relative to the LCR is to identify and implement measures to minimize the risk of hazardous-materials spills from transport of materials along U.S. Highway 89 at and near the Cameron Bridge spanning the Little Colorado River. This is also a project of the HBC Comprehensive Plan (Glen Canyon Dam Adaptive Management Program 2009). A plan is needed to address this threat and efforts to develop one have not been initiated, though the need has been identified since at least 2002, and would likely require minimal expense. Reclamation has, as a conservation measure of the 2008 Opinion, agreed to assist in implementing the HBC Comprehensive Plan.

Critical Habitat Reach 7 – Colorado River in Marble and Grand Canyons

Critical habitat in Reach 7, in Marble and Grand canyons, has been altered dramatically from historical conditions, primarily due to emplacement of Glen Canyon Dam. But the degree to which all of the PCEs are being provided in this reach of humpback chub critical habitat in

attainment of recovery remains a research question. Reach 7 provides an important role in support of the Grand Canyon population (the largest of the humpback chub populations and the lower basin recovery unit) although the relationship with the LCR and the overall importance of habitats in the mainstem to recovery is not yet known. This is because most of the humpback chub population occurs in the largest aggregation, the LCR inflow aggregation, which utilizes the LCR to a large degree. To put this in perspective, the population estimate produced for the population, currently estimated at 7,650 adult fish, is essentially the LCR inflow aggregation (Coggins and Walters 2009) because there is little movement between the LCR inflow aggregation and the other mainstem aggregations (Paukert et al. 2006). All the other aggregations are much smaller than this, and the largest of these, the Middle Granite Gorge aggregation (RM 126.1-129.0) was estimated by Valdez and Ryel (1995) to be 98 adult fish. Most spawning takes place in the LCR, and some adults may never leave the LCR. Marsh and Douglas (1997) thought that there was a contingent of resident adult fish that never leave the LCR, and another contingent that migrated into the LCR to spawn. Valdez and Ryel (1995) hypothesized that large adult humpback chub may only utilize the LCR to spawn, and Gorman and Stone (1999) found that smaller adults remain in the LCR, but once they reach a certain size, they leave after spawning to spend non-spawning periods in the mainstem. Thus it is possible that the demographic goal for the Grand Canyon population could be met by providing for all of the PCEs of critical habitat in Reach 6, the LCR, and a set of PCEs in the mainstem focused on needs of non-spawning adult fish. However, this seems unlikely, and at the least, providing for all the PCEs in Reach 7 would add resiliency to the overall population by maintaining some recruitment from the mainstem aggregations. The lack of understanding of the relative importance of Reach 6 and Reach 7 is identified in the Recovery Goals, which include a recovery factor criterion research to determine the relationship between habitats in the mainstem and the LCR, and to use this information to implement a flow regime from Glen Canyon Dam accordingly to achieve recovery.

The flow of the Colorado River in Marble and Grand canyons has been modified by Glen Canyon Dam since dam completion in 1964, and the dam is a primary factor in the function of PCEs in this reach, with minimal influence on habitat from the flow of tributary streams (a caveat to this is global climate change and its potential affect on the hydrology of the Colorado River). Flows since Reclamation's 1995 EIS and 1996 ROD have been limited to 5,000 to 25,000 cfs (see Table 1) except during experimental flows such as in 1996, 2004, and 2008, when experimental high flows were tested of from 41,500 to 45,000 cfs. Prior to the current MLFF period of flow releases, daily fluctuations were greater, from 1,000 to 31,500 with unrestricted ramping rates (U.S. Bureau of Reclamation 1995). To put this in context, historically 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). Releases from Glen Canyon Dam are now varied on an annual and daily time scale 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 daily 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).

An important aspect of the water quality PCE of critical habitat for humpback chub is water temperature. Humpback chub require temperatures of 16-22 °C for successful spawning, egg incubation, and survival of young (Hamman 1982, Marsh 1985, Valdez and Ryel 1995). Water temperature of downstream releases from Glen Canyon Dam is affected by release temperature, which is a function of reservoir elevation, temperature and volume of inflow, and air temperature. Downstream warming of the river is a function of Glen Canyon Dam release temperatures, release volumes, and volume fluctuations (Wright et al. 2008a). Since closure of the dam the river has usually been perennially cold because Glen Canyon Dam releases hypolimnetic water (the deepest, coldest layer of the reservoir) with a relatively constant temperature which ranges from 6-8 °C at high reservoir levels. Although releases from 2003 to present have been warmer due to low Lake Powell reservoir levels, and reached as high as 16 °C in the Lees Ferry reach in 2005, and were 13-14 °C in 2008, and are predicted to peak at about 13 °C in 2009 (Vernieu et al. 2005, U.S. Geological Survey 2009a, c). A low summer steady flow experiment in 2000 also warmed river temperatures significantly, and may have been responsible for increased recruitment of the 1999-2001 brood years (Trammel et al. 2002, Coggins and Walters 2009). Climatologists predict that the southwest will experience extended drought, so lower Lake Powell Reservoir elevations and warmer release temperatures may be the norm (Seager et al. 2007, U.S. Climate Change Science Program 2008a, b).

The water temperature of nearshore habitats that are important as humpback chub nursery habitats are also a key part of the water quality PCE (Valdez and Ryel 1995, Robinson et al. 1998, Stone and Gorman 2006). Temperature differences between mainchannel and nearshore habitats can be pronounced in backwaters and other low-velocity areas. The amount of warming that occurs in backwaters is affected by daily fluctuations, which cause mixing with cold mainchannel waters (Arizona Game and Fish Department 1996). Hoffnagle (1996) found that mean, minimum, maximum, and diel range of water temperature in backwaters were higher under steady versus daily fluctuating flows, with mean daily temperatures (14.5 °C) under steady flows about 2.5 °C 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. Wright et al. (2008a) also found that fluctuations have minimal effect on mainstem water temperatures, with release temperature being the primary driver of mainstem water temperatures. However, release volume becomes more influential further downstream, and Wright et al. (2008a) note that fluctuations can have substantial effects to nearshore water temperatures. 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 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 mainchannel water. These effects were documented during the months of August and September, but not October, when cooler air temperatures caused backwaters to be about 1 °C cooler than the mainchannel, because the temperature difference between mainchannel and nearshore habitats varies with season, with the greatest effect in the summer months, a lesser effect in the spring and fall, and little if any effect in the winter, when air temperatures and low levels of solar insulation result in cool nearshore water temperatures even under steady releases.

Cold water is also a factor in causing juvenile humpback chub to be more susceptible to predation by nonnative fishes. Mass movement of larval and juvenile humpback chub out of the LCR occurs during the summer, especially during monsoon rain storms in late summer (Valdez and Ryel 1995, Robinson et al. 1998). Young humpback chub that are washed into the mainstem are subjected to a drastic change in water temperature which can be as much as 10 °C or more. This results in thermal shock of young fish (Berry 1988), and a reduction in swimming ability (Berry and Pimentel 1985, Ward and Bonar 2003), which also increases their vulnerability to predation (Lupher and Clarkson 1994, Valdez and Ryel 1995, Marsh and Douglas 1997, Clarkson and Childs 2000, Ward et al. 2002). Cold water by itself also likely results in mortality of eggs and larval fish (Hamman 1982, Marsh 1985).

Glen Canyon Dam operations also modify the hydrograph (the timing of water delivery in the river). The MLFF produces a hyrdrograph with the highest flow volumes in the winter and summer months to meet increased demand for electricity (Figure 8). Humpback chub evolved with a historically variable hydrograph in Grand and Marble canyons, but with consistently high flows in the spring following snow melt and low flows in the summer (Topping et al. 2003). The high spring flows of the natural hydrograph provided a number of benefits. Bankfull and overbank flows provide allochthonous energy input to the system in the form of terrestrial organic matter and insects that are utilized as food. High spring flows clean spawning substrates of fine sediments and provide physical cues for spawning. High flows also form large recirculating eddies used by adult fish. High spring flows have been implicated in limiting the abundance and reproduction of some nonnative fish species under certain conditions and have been correlated with increased recruitment of humpback chub (Chart and Lentsch 1997). During other seasons, base flows were relatively stable and sufficiently warm to provide suitable nursery environments for humpback chub larvae and young of year, and to provide young chubs a variety of low-velocity habitats (e.g., shorelines, backwaters, and eddies) with abundant structure (e.g., talus, debris fans, and vegetation). Valdez and Ryel hypothesized that, in the post-dam era, the maximum release at powerplant capacity (31,500 cfs) is likely too low to provide many of the spring-flood benefits to native fishes (Valdez and Ryel 1995), although Schmidt et al. (2007) found that these flows can provide a moderate increase in sandbar area and total backwater habitat area. High flow tests that utilize the outlet works (such as the March 2008 high flow test of 41,500 cfs) provide more significant positive flood-flow benefits to humpback chub, by building sandbars, rearranging sand deposits in recirculating eddies, and effectively reshaping reattachment bars and eddy return current channels (see discussion of high flow tests here and in the 2008 Opinion).

The daily hydrograph under MLFF is also adjusted to meet the changing demand for electricity throughout the day within the constraints of MLFF. This typically results in a unimodal hydrograph for warmer months of the year, with peak releases during the day, and low releases at night when demand for electricity is lowest (Figure 9). During the colder months, the daily hydrograph is typically more bimodal, presumably because electricity demand wanes in the afternoon and resumes in the evening to meet heating needs of residences in the evening (Figure 9). Daily fluctuations can be highly variable, however, depending on electrical demand. Daily fluctuations have relatively little effect on warming mainstem temperatures, at least compared to release water temperatures or release volume, but they do result in a cooling effect on mainstem water temperatures (Wright et al. 2008a). As discussed earlier, daily fluctuations have a

significant effect on the water temperatures of nearshore habitats such as backwaters that may be important nursery habitats for juvenile humpback chub (Hoffnagle 1996, Robinson et al. 1998, Trammel et al. 2002, Korman et al. 2005).

Despite these dam-induced changes in the water PCEs in Reach 7 of critical habitat, humpback chub still spawn and evidence of spawning by presence of juvenile fish in the 8 mainstem spawning aggregations has been documented, and persistence of aggregations may indicate recruitment. Valdez and Ryel (1995) provided mark-recapture estimates for PIT-tagged humpback chub adults (≥200 mm [7.9 in] TL) for five of the mainstem 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). Data collected through 2006 indicate that humpback chub may have spawned and recruited at the 30-mile aggregation (Andersen, M., GCMRC, pers. comm., 2007). The 30-mile aggregation is the furthest upstream and thus would be warmed the least by warmer Glen Canyon Dam release temperatures because the river gets warmer as it moves downstream from the dam. However, temperatures at the dam in 2005 were above the thermal minima needed for successful humpback chub spawning and recruitment, so it is conceivable that the 30-mile aggregation did so.

Monitoring of other mainstem humpback chub aggregations in recent years also indicate that spawning and possible recruitment may have occurred (Trammel et al. 2002, Ackerman et al. 2006, Ackerman 2008). 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 (Arizona Game and Fish Department 1996, Trammell et al. 2002, Johnstone and Lauretta 2004, 2007, Ackerman 2008). Seine catches of all young-of-year humpback chub in 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 has been stable or increasing in size since 1993 (Trammell et al. 2002), but may be sustained via immigration from the LCR aggregation, as well as from local reproduction. Monitoring will be modified in 2010 to include mainstem aggregations as a result of recommendations from the 2009 GCMRC fish monitoring program protocol evaluation panel (U.S. Bureau of Reclamation and U.S. Geological Survey 2009).

The effect of Glen Canyon Dam release temperature on humpback chub critical habitat and conservation has long been recognized (U.S. Fish and Wildlife Service 1978), and Reclamation has made several attempts to investigate modifying the dam to release warmer water. In January 1999, Reclamation released a draft environmental assessment on a temperature control device (TCD) for Glen Canyon Dam (U.S. Bureau of Reclamation 1999). 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 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 et al. (2003). No major environmental complications were identified in the survey results. A risk assessment of the Glen Canyon Dam TCD proposal from the GCDAMP 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 2008) 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 with installation of a 2-unit TCD. Positive deviations with the two-unit TCD would begin in late April, peak in late summer to early autumn at about 7° C, 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 two of the eight 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 potential 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 (U.S. Geological Survey 2008) 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. The AMWG, at its August 12-13, 2009, meeting passed a motion recommending to the Secretary of the Interior that Reclamation report on the status of implementing a TCD at its next AMWG meeting in February 2010.

Another aspect of the changes in water quality in Grand Canyon that may affect humpback chub is turbidity. Predam, turbidity was very high much of the year except during base flows. As discussed later, the dam largely eliminated most of the sediment supply in the river, which greatly reduced turbidity in the mainstem. Most sediment in the mainstem now is derived from tributary inputs, and the mainstem is turbid now only at times of tributary flooding. With increases in nonnative fishes over the last century in Grand Canyon, especially sight-feeding predators like rainbow trout, this loss of turbidity may cause humpback chub to be more susceptible to predation by nonnative fishes (Ward and Bonar 2003, GCDAMP 2009). The Bureau of Reclamation completed a feasibility assessment for large-scale sediment augmentation in 2002. The project would collect sediment from Lake Powell and use a slurry pipeline to deposit it downstream of the dam. This would create a more turbid river and address the erosion of beaches and fine sediment-formed fish habitats by adding sediment directly to the river. The assessment concluded that such a project is feasible, though costs were estimated at $140 million for construction and $3.6 million annually for operation (Randle et al. 2007).

The physical PCEs (physical habitat for spawning [P1], nursery habitat [P2], feeding areas [P3], and movement corridors [P4]) of humpback chub critical habitat are also affected by dam releases. In general, the deep low-velocity habitats that adult humpback chub prefer are provided by the large deep pools and eddy complexes available in Marble and Grand canyons, and are sufficiently available to provide adequate habitat for adult humpback chub in the mainstem (Valdez and Ryel 1995), and condition factor of adult fish of the mainstem has been documented to be better than adult fish in the LCR (Hoffnagle et al. 2006), suggesting that food availability (PCEs P3 and B1) may be better for adults in the mainstem.

Juvenile humpback chub also prefer lower velocity habitats in the mainstem, but in shallow nearshore areas (Valdez and Ryel 1995). Fluctuating flows cause these nearshore habitats to be in constant change. Korman et al. (2006) found that nearshore areas affected by fluctuating flows warmed substantially for brief periods each day, which posits an ecological trade-off for fish utilizing these areas (also discussed in U.S. Bureau of Reclamation 2007a). 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 colder than the immediate near-shore margin. In a separate study, Korman et al. (2005) observed that slightly more than half of observed young of year rainbow trout in the Lees Ferry reach maintained their position as flows fluctuated rather than follow the stream margin up slope. Thus, for trout, it appears that the bioenergetic cost of changing stream position with fluctuations in discharge perhaps outweighs the benefits of exploiting the slightly warmer stream margins. Additionally, Korman and Campana (2009) found that juvenile rainbow trout in Lees Ferry did increase use of shallow nearshore habitats during periods of stable flow, and that growth of juvenile trout

increased as a result. Understanding the trade-off between temperature and fluctuating flows as it affects growth and survival of early life stages of Grand Canyon fish (native and non-native) is an important research question. As discussed earlier, the NSE and FSFP (U.S. Geological Survey 2009b) are aspects of the proposed action meant to address this need.

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 declines 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 features which function to isolate nearshore habitats from the cold, high velocity mainchannel environment (U.S. Bureau of Reclamation 2007a). Approximately 84-94 percent of the fine sediment input is now trapped behind the dam, and the post-dam median discharge of 12,600 cfs causes remaining fine sediment, and associated habitat types, to be lost continually (Topping et al. 2004, Topping et al. 2003, Wright et al. 2005). Beaches and associated habitats such as backwaters can be recreated with high flow tests as in March of 2008, but the long-term efficacy of this approach is unknown (Wright et al. 2008b).

The 1996 beach/habitat-building flow deposited more sandbars and at a faster rate than predicted. But because the 1996 experiment was conducted under sediment-depleted conditions in terms of sediment mass balance, more than half the sand deposited at higher elevations was taken from the lower portions of sandbars (Schmidt 1999). This resulted in a net decrease in total eddy-sandbar area and volume, and many sandbars built during the 1996 high flow test eroded in as little as several days following the experiment (Topping et al. 2004). In contrast to the 1996 high flow test, the 2004 high flow test was strategically timed to take advantage of highly sediment-enriched conditions (Wiele and Torrizo 2005). 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. As discussed earlier, detailed results of the 2008 high flow test are not yet available, but sand concentrations during the 2008 high flow test were much higher than previous tests (Grams 2009, U.S. Geological Survey 2009a, c).

Efficacy of high flow tests at creating or enlarging backwaters also depends on antecedent sediment load and distribution, and 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). 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 (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). Although the 2008 high flow test had optimal sediment load conditions, post-high flows were elevated due to mid-elevation balancing reservoir operations in 2008. Likewise, low sediment load due to little or no tributary sand inputs may have caused any gains in sediment formed habitats to be short-lived. Post high flow test dam regime appears to have eroded the results of past high flow tests in weeks or months (Wright et al. 2008b), and although high flow tests may be able to maintain sand bars with tributary inputs, this approach is still being tested (Wright et al. 2008b).

The physical PCE of physical habitat for spawning (P1) appears to be partially met, in that although mainstem aggregations are small, spawning does occur (Andersen, M., GCMRC, pers. comm., 2007, Ackerman 2008). Nursery habitat (P2) for juvenile humpback chub may be limited by fluctuating flows that alternately flood and dewater mainstem near shore habitats important to early life stages of humpback chub (Arizona Game and Fish Department 1996), and by the loss of sediment-formed habitats. Feeding areas are available to all life stages, especially for adult fish as indicated by condition factor of adult fish in the mainstem compared to those in the LCR (Hoffnagle et al. 2006), although again may be limiting for juvenile humpback chub due to the effect of fluctuations on nearshore habitats (Arizona Game and Fish Department 1996). Movement corridors (P4) appear to be adequate based on movements of humpback chub throughout the system (Valdez and Ryel 1995, Paukert et al. 2006).

The biological environment PCEs in Reach 7 of humpback chub critical habitat have also undergone responses to the post-dam changes to the ecosystem. Productivity is much higher in terms of algal and invertebrate biomass, thus food availability for fishes (PCE B1), especially adult fishes, is likely greater than pre-dam (Blinn and Cole 1991). Although the previously discussed effects of cold water temperatures and fluctuations on the nearshore environment may provide inadequate nursery habitats (P2) and feeding areas (P3) for juvenile warm water fishes like humpback chub. Grand et al. (2006) found that the most important biological effect of fluctuating flows on 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 (Blinn et al. 1995, Grand et al. 2006). The ability of this reach to provide adequate food base for both adults and juveniles is also an active research question, and pathways, linkages, and rates of flux between trophic levels of the food base, and how these variables effect higher trophic levels like the humpback chub population, are not currently understood, but are under intensive study via GCMRC's food base program, the NSE, and the FSFP (U.S. Bureau of Reclamation and U.S. Geological Survey 2009, U.S. Geological Survey 2009b).

Nonnative fish species that prey on and compete with humpback chub are important PCEs (B2 and B3) of the biological environment aspect of critical habitat. Minckley (1991) hypothesized that nonnative fish predation and competition may be the single most important threat to native

fishes in Grand Canyon. Catfishes (channel catfish and black bullhead), trouts (rainbow and brown trout), and common carp have been indentified or implicated as predators or competitors of humpback chub and are common in Grand Canyon (Valdez and Ryel 1995, Marsh and Douglas 1996, Coggins 2008b, Yard et al. 2008). Valdez and Ryel (1995) estimated that 250,000 humpback chub are consumed by channel catfish, rainbow, and brown trout annually. Small bodied species such as fathead minnow, red shiner, plains killifish (*Fundulus zebrinus*), and mosquitofish are also found in nearshore areas of Marble and Grand canyons and may be important predators and/or competitors of juvenile humpback chub in nearshore habitats (Hilwig et al. 2009). Marsh and Douglas (1997) suggested that entire year classes of humpback chub may be lost to predation by nonnative fish species, and Yard et al. (2008) estimated that, although predation rate of rainbow trout on humpback chub is likely low, at high densities, trout predation can result in significant losses of juvenile humpback chub. Efforts by the GCDAMP to mechanically remove nonnative fishes in the LCR inflow reach have been successful, especially in removing trout (Coggins 2008b). The ultimate causes of improved status of humpback chub is not known, and a causal link between removal and humpback chub population parameters has not been established (Coggins 2008b), but removal efforts are one suspected cause of recent increases in recruitment (Andersen 2009).

Species composition and abundance of nonnative fishes changes throughout the canyon, with colder water species dominating closer to the dam, and warm water species downstream (Table 8). Common nonnative fish species in Grand Canyon, such as channel catfish, black bullhead, common carp, rainbow trout, brown trout, and fathead minnow likely spawn in the mainstem river and in nearby tributaries or tributary mouths, although more information is needed on spawning locations to better target control efforts (Hilwig et al. 2009). Immigration of nonnative fishes from basins that feed into Grand and Marble canyons is also a source of nonnative fish (Stone et al. 2007), and stocking of sport fish in these basins is an action that may contribute to source populations of nonnative fish that invade the mainstem river. Lake Powell and Lake Mead are also sources of nonnative species as evidenced by the presence of walleye (*Sander vitreus*) and green sunfish in Glen Canyon (Arizona Game and Fish Department 2008) that either were illegally stocked or came through Glen Canyon Dam, and striped bass (*Morone saxatilis*), which likely move up from Lake Mead and are common in lower Grand Canyon.

A significant new consideration (since the 1995 Opinion) regarding the control of nonnative fish species in critical habitat in Marble and Grand canyons is climate change. Climate change is predicted to result in greater aridity in the southwest (Seager et al. 2007, U.S. Climate Change Science Program 2008a, b). Greater aridity is likely to reduce inflows to Lake Powell (Seager et al. 2007), which will lower Lake Powell reservoir elevations, and increase Glen Canyon Dam release temperatures. Warming downstream temperatures will benefit native fishes, and likely already has (Andersen 2009, Coggins and Walters 2009). But warmer Colorado River temperatures are just as likely to benefit nonnative species, and perhaps even more so (Valdez and Speas 2007, Rahel and Olden 2008, Rahel et al. 2008). Recent changes in the fishery of the Yampa River illustrate how these changes could occur. Drought significantly reduced stream flows in the Yampa River in 2002, which elevated river temperatures, resulting in a rapid spread of nonnative smallmouth bass (Fuller 2009). Prior to 2002, smallmouth bass were very rare in the system, and humpback chub were common, with a small but stable population of several hundred adults. This rapid expansion of smallmouth bass essentially eliminated the humpback

chub population in the Yampa in a matter of a few years (Finney 2006, T. Jones, FWS, pers. comm. 2009). The shift in the fish community in the Yampa River due to water temperature and hydrologic changes is now the greatest threat to the native fishery, and nonnative control efforts are so far not effective (Fuller 2009). The Yampa example illustrates what could happen if efforts by the GCDAMP to warm mainstem water temperatures (e.g. through the use of a TCD or seasonal steady flows) result in the unintended consequence of an invasion or expansion of nonnative fish species. Indeed, given global climate change predictions, an increased capacity to deliver cold water seems a more pressing need. The relationship between warmer water temperatures and nonnative fishes was recognized at the time of the 1995 Opinion, but was apparently not considered as severe a threat as it is today, especially given the newest information on climate change and its potential effect on the expansion of nonnative fishes.

The biological environment PCE for food base (B1) appears met for adult humpback chub, but may be limiting for juveniles. PCEs B2 (competition) and B3 (predation) are a serious issue for conservation of humpback chub, and may not be met with regard to juvenile humpback chub and the effect of nonnative fish predation on humpback chub recruitment in Reach 7. However, there appears to be an important relationship between the effects of dam operations on the water and physical PCEs of critical habitat and the biological PCEs of nonnative fish competition and predation that needs more careful consideration before additional efforts to manipulate water temperature are attempted.

Role of Reach 7 of Humpback Chub Critical Habitat in Recovery

Most of the Grand Canyon population relies on the LCR for spawning and in fact a proportion of the population may never leave the LCR. Nevertheless the recent improvement in status of the Grand Canyon population, which also constitutes the lower Colorado River Recovery Unit, has coincided with improvements in the PCEs in this mainstem reach of critical habitat, with no obvious changes in the PCEs of the LCR (Reach 6). As described earlier, the PCEs for water have improved largely due to serendipitous warmer water temperatures since 2004 from low Lake Powell reservoir levels, the physical PCEs have been improved through high flow tests that have created, albeit temporarily, improved nearshore habitats, and the biological environment PCEs of predation and competition have been directly improved by removal of nonnative fishes. Hence, maintaining high quality PCEs for humpback chub in this reach of critical habitat is likely important or even essential to recovery of the species.

As described in the Status of the Species section, demographic goals must be met for this Recovery Unit as well as for one or two core populations in the upper Colorado River basin for downlisting and delisting, respectively, to occur (U.S. Fish and Wildlife Service 2009) (see Appendix B). Although the Recovery Goals are only draft at this time, FWS is working to finalize these in response to a Court Order. The draft goals constitute the best available scientific information with which to analyze the performance of critical habitat reaches in meeting the recovery needs of the species. As described earlier, in addition to the demographic goals, the Recovery Goals also contain site-specific management actions and tasks and corresponding recovery criteria that must be met for downlisting and delisting to occur (see Appendix B). So in evaluating the effectiveness of the critical habitat unit in meeting recovery, the primary measure

is the status of the population in relation to the demographic goal, and the secondary measure are the recovery factors and their associated management actions and tasks.

As described earlier, the current abundance of humpback chub in the LCR is estimated to be 7,650 adults (between 6,000-10,000, age 4+; ≥ 200 mm TL [7.9 inches]); this is nearing the 10,000-11,000 adults the ASMR estimates constituted the adult LCR population when marking began in 1989, and appears to have been in an upward increasing trend since 2001 (Coggins et al. 2006a, Coggins and Walters 2009). FWS monitoring efforts in the LCR in 2008 and 2009 also indicate increasing recruitment and abundance. Van Haverbeke and Stone (2009) note that the 2007 and 2008 closed estimates of humpback chub abundance in the LCR are statistically comparable to the 1992 spring abundance estimates obtained by Douglas and Marsh (1996). This is significant because the Recovery Goals require an increasing trend relative to prior abundance estimates (U.S. Fish and Wildlife Service 2009a), and Douglas and Marsh (1996) provided one of the earliest robust estimates of humpback chub abundance in the LCR. Thus it now appears that humpback chub have returned to levels of abundance first documented in the early 1990s.

The demographic goal for the Grand Canyon population for downlisting is that the humpback chub population is maintained as a core over a 5-year period, starting with the first point estimate acceptable to the Service, such that the trend in adult (age 4+; ≥ 200 mm TL [7.9 inches]) point estimates does not decline significantly, the mean estimated recruitment of age-3 (150–199 mm TL [5.9 to 7.8 inches]) naturally produced fish equals or exceeds mean annual adult mortality, and the population point estimate exceeds 2,100 adults (U.S. Fish and Wildlife Service 2009). The FWS has not yet determined that the demographic goal for the Grand Canyon population has been met, but the best available science indicates the population is nearing this demographic criterion. Given this, the mainstem Colorado River in Marble and Grand canyons, i.e. Reach 7 and its PCEs, appear to be meeting the needs of recovery. Nevertheless, many questions remain about the role of the mainstem in recovery, and how best to improve the PCEs in this reach to best promote recovery. These questions are outlined in the Recovery Goals recovery factor criteria and management actions and tasks, and are currently the focus of a number of monitoring and research efforts of the GCDAMP, in particular, the FSFP and the NSE.

The recovery factor criteria and associated management actions and tasks (listed in Appendix B) that relate to this critical habitat unit are based on the five listing threat factors. These are directed at research to determine the role of the mainstem Colorado River in providing for recovery of humpback chub, and improving and protecting humpback chub habitat including critical habitat and the PCEs accordingly. Those that relate to the Colorado River in Marble and Grand Canyons and Reach 7 of critical habitat are summarized here:

- Factor A: Adequate habitat and range for recovered populations provided; investigate the role of the mainstem Colorado River in maintaining the Grand Canyon humpback chub population and provide appropriate habitats in the mainstem as necessary for recovery, including operating Glen Canyon Dam water releases under adaptive management to benefit humpback chub in the mainstem Colorado River through Grand Canyon as necessary and feasible, and investigate the anticipated effects of and options for providing suitable water temperatures (i.e. a TCD) in the mainstem Colorado River

through Grand Canyon that would allow for range expansion of the Grand Canyon humpback chub population and provide appropriate water temperatures if determined feasible and necessary for recovery;

- Factor B: Adequate protection from overutilization; protect humpback chub populations from overutilization for commercial, recreational, scientific, or educational purposes through implementation of identified actions to ensure adequate protection for humpback chub populations from overutilization;

- Factor C: Adequate protection from diseases and predation; identify and implement levels of control of nonnative fish, as necessary for recovery, and develop and implement procedures for stocking sport fish to minimize escapement of nonnative fish species into the Colorado River and its tributaries through Grand Canyon;

- Factor D: Adequate existing regulatory mechanisms; determine and implement mechanisms for legal protection of adequate habitat in the Colorado River in Marble and Grand Canyons through instream-flow rights, contracts, agreements, or other means;

- Factor E: Other natural or manmade factors; minimize the risk of hazardous-materials spills in critical habitat by reviewing and implementing modifications to State and Federal hazardous-materials spills emergency-response plans to ensure adequate protection for humpback chub populations from hazardous-materials spills, including prevention and quick response to hazardous-materials spills.

The Recovery Goal recovery factor criteria for Factor A in the mainstem require that life stages and habitats of humpback chub be identified and the relationship between individuals in the mainstem and the LCR be determined, and operations of Glen Canyon Dam are utilized to benefit humpback chub in the Colorado River through Grand Canyon to provide for adequate spawning, nursery, juvenile and adult habitat. The Recovery Goal criteria also require that the effects and feasibility of a temperature control device for Glen Canyon Dam to provide suitable water temperatures in the mainstem Colorado River through Grand Canyon that would allow for range expansion of humpback chub determined (see earlier discussion on the history and current state of TCD investigations).

Considering the Recovery Goals, and their focus on demographic criteria and determining the role of the mainstem in humpback chub recovery and the relationship of mainstem flow to habitat, the PCEs W1 and W2 in Reach 7 appear to be achieving recovery, with the caveat that the needs necessary for all life stages of humpback chub in the mainstem to support a recovered Grand Canyon population is still under investigation. As discussed earlier, important initiatives begun in 2008 will address Factor A in the mainstem Colorado River: the NSE, the FSFP (U.S. Geological Survey 2009b). These two efforts should provide much new information and address the recovery goal of determining the importance of the mainstem in recovery and defining a Glen Canyon Dam release flow that meets all the habitat needs of a recovered Grand Canyon population. Ongoing research should serve to provide much valuable information on the needs of the species in this reach of critical habitat in terms of Glen Canyon Dam flows and water temperature of releases, and how the PCEs function in meeting the recovery needs of the species.

For Factor C, the focus of the Recovery Goals in the mainstem Colorado River is on controlling the proliferation and spread of nonnative fish species that prey on and compete with humpback chub. The Recovery Goals identify the need to develop, implement, evaluate, and revise (as necessary through adaptive management) procedures for stocking sport fish to minimize escapement of nonnative fish species into the Colorado River and its tributaries through Grand Canyon to minimize negative interactions between nonnative fishes and humpback chub. Stocking, both legal and illegal, throughout the LCR basin, likely results in nonnative fish moving into the lower LCR and (Stone et al. 2007), and likely into the mainstem Colorado River as well. Better regulation of sport fish stocking through development and implementation of stocking goals with the relevant basin states has not occurred, is still needed, and is a project of the HBC Comprehensive Plan (Glen Canyon Dam Adaptive Management Program 2009).

The Recovery Goals also identify the need to develop and implement levels of control for rainbow trout, brown trout, and warmwater nonnative fish species (U.S. Fish and Wildlife Service 2009). Nonnative control has been a focus of the GCDAMP for some time. An intensive nonnative fish removal effort was conducted from 2003-2006 in the mainstem Colorado River at the LCR inflow reach, and a similar, although scaled-down effort was conducted in May 2009. These efforts have been most effective at removing nonnative trout species, but other warm water nonnative species were removed as well (Coggins 2008b, Yard et al. 2008). The degree to which these removal efforts have improved the PCEs B2 and B3 is still a research question, although Yard et al. (2008) estimated that the 2003-2006 removal of rainbow and brown trout contributed significantly to reduce predation losses of juvenile humpback chub. Andersen (2009) and Coggins and Walters (2009) noted the potential role these removal efforts may have had in improving the status of the humpback chub in Marble and Grand Canyons, but the available information is insufficient to evaluate the effects of removal alone. The GCDAMP and GCMRC have been testing various methods to monitor and remove warmwater nonnative fish species, so far with little success. GCMRC recently completed a draft Nonnative Fish Management Plan (Hilwig et al. 2009) that summarizes these efforts and outlines actions to implement to improve monitoring and control of nonnative fish species in Marble and Grand Canyons.

For Factor D, Adequate existing regulatory mechanisms, the Recovery Goals identify the need to determine and implement the mechanisms for legal protection of habitat in the mainstem Colorado River, through instream-flow rights, contracts, agreements, or other means. This relates directly to the water PCEs of critical habitat. The Law of the River may be sufficient to meet this need in reach 7 of critical habitat, but such an analysis has not been completed.

For Factor E, the Recovery Goals identify the need to review and recommend modifications to State and Federal hazardous-materials spills emergency-response plans to ensure adequate protection for humpback chub populations from hazardous-materials spills, including prevention and quick response to hazardous-materials spills. This applies mostly to the Highway 89 bridge at Cameron, although other bridges could be an issue, such as Navajo Bridge in Marble Canyon, although it carries much less traffic. A comprehensive evaluation of State and Federal hazardous-materials spills emergency-response plans to ensure adequate protection for

humpback chub populations from hazardous-materials spills has not been completed for the Colorado River.

Kanab Ambersnail

The status of the species within the action area for the Kanab ambersnail remains much the same as in the 2008 Opinion, with several updates. As a conservation measure of the 2008 Opinion, mats of vegetation were removed before the 2008 high flow test and replaced afterwards to reduce the amount of habitat loss from the high flow test. As with the 2004 test, this conservation measure worked well, and six months after the high flow test, the habitat had fully recovered and was occupied by snails (Sorensen 2009). Surveys in 2008 and 2009 indicated that overall, habitat at Vaseys Paradise is in good condition, and the species is in numbers that are comparable to recent years, although their numbers aren't as abundant as they were in the late 1990s and early 2000s. The abundance of Kanab ambersnail has not returned to levels seen before the 2002-2003 drought that severely reduced the amount of available habitat and likely cropped the population in that year (J. Sorensen, AGFD, pers. comm. 2009).

There has likely been some loss of snails and habitat from the highest MLFF flows, although this has been so minimal as to be undetectable in surveys conducted since the 2008 Opinion. Kanab ambersnail habitat only begins to be affected by flows at about 17,000 cfs (Sorensen 2009), and flows only slightly exceeded this recently in July and August of 2008 (Table 3). Meretsky and Wegner (2000) noted that even at flows from 20,000 to 25,000 cfs (MLFF allows flows up to 25,000 cfs), only one patch of snail habitat is much affected (Patch 12), and a second patch to a lesser extent at flows above 23,000 cfs (Patch 11). Very few Kanab ambersnail have been found in patches 11 and 12 historically, and habitat in these patches is of low quality (Sorensen 2009). Thus MLFF operations appear to have little effect on the Vaseys Paradise population.

Elves Chasm appears to have recovered from drought conditions, and surveys in 2009 found more snails than in previous years. The habitat also now has more wet habitat than in prior years (J. Sorensen, AGFD, pers. comm. 2009). Critical habitat for Kanab ambersnail has not been designated, thus none will be affected.

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

The Secretary implemented Interim Flows on August 1, 1991, thus flows essentially like MLFF have been the dominant flow regime for Glen Canyon Dam since that time. The MLFF as

defined in the 1995 EIS (U.S. Bureau of Reclamation 1995) was implemented following the 1995 EIS and 1996 ROD as part of an action that included formation of the GCDAMP, and with the intention of modifying the action over time based on the principles of adaptive management, which is utilizing science, monitoring, and stakeholder and public involvement to improve management decisions on implementing changes in management (Williams et al. 2007), in this case Glen Canyon Dam releases. Reclamation's proposed action for Glen Canyon Dam operations from 2008-2012 is the current iteration of this, and represents a decision by the Secretary, based on science and stakeholder input obtained to date, to implement the current experiment of flows for 2008-2012, consisting of MLFF, a March 2008 high flow test, and steady flow releases in the months of September and October, with the intention of learning from this, via ongoing research and monitoring, and modifying future operations based on new information. The FWS has identified for some time that the MLFF has adverse affects to humpback chub (U.S. Fish and Wildlife Service 1995), which we discuss here, but newer information also indicates that the status of humpback chub has been improving under the implementation of the MLFF, and that the MLFF also may have a key beneficial effect, as a flow that may disadvantage nonnative fishes that prey on and compete with humpback chub.

As discussed earlier, MLFF is a dam operation that results in hourly, daily, and monthly variations in flow from Glen Canyon Dam. These variations in flow affect many aspects of the ecosystem below Glen Canyon Dam downstream some 250 miles or so to Lake Mead. Effects are on the abiotic aspects of the ecosystem (e.g. water temperature, turbidity, sediment transport, riverine habitat formation) and on the biotic aspects (e.g. food base dynamics, fish species abundance and composition, fish growth, fish predation rates, prevalence of disease or parasites). Many of these effects are poorly understood at best, and adding to the complexity is the fact that few if any affects can be analyzed separately because they interact. But the GCDAMP is heavily engaged and invested in research to answer the questions of managers on how Glen Canyon Dam releases affect downstream resources. Thus the effects of the action are not just from MLFF alone, but also the ongoing research associated with analyzing how MLFF affects downstream resources, and how this information is used in an adaptive management context, in this case, to conserve humpback chub.

Water temperature has long been identified as an important factor of the physical ecosystem for humpback chub that is affected by dam operations. Humpback chub require temperatures of 16-22 °C for successful spawning, egg incubation, and survival of young (Hamman 1982, Valdez and Ryel 1995). Since closure of the dam and filling of Lake Powell, water temperatures in the mainstem Colorado River at the LCR inflow have been about 8-10 °C on average (Valdez and Ryel 1995). Water temperature of downstream releases from Glen Canyon Dam is affected by release temperature, which is a function of reservoir elevation, temperature and volume of inflow, and air temperature. Downstream warming of the river is a function of Glen Canyon Dam release temperatures, release volumes, and volume fluctuations, and warming is also along a longitudinal gradient that varies with air temperature, such that warming increases as water moves downstream and more so in the hotter months than in cooler months (Wright et al. 2008a).

Reclamation typically structures releases under the MLFF to increase hydropower production during months when power demand is greatest, releasing more water in the winter months of December-February and summer months of June-August (Figure 8). Increasing releases in the

winter months has little effect on warming of the river because air temperatures and release water temperatures are cold. In summer, however, the effect of increasing monthly releases to meet electricity demand (within the constraints of MLFF) has a significant effect on temperature. Lower release volume results in greater downstream warming (Wright et al. 2008a). This is most evident from the 2000 low summer steady flow. Releases during the summer months (June 1 – September 1) were limited to 8,000 cfs, and mainstem temperatures warmed somewhat more than at higher releases. The mainstem water temperature at the LCR inflow in June 2000 was 13.3 °C; release temperature at the dam was 9.5 °C, so releases had warmed 3.8 °C; June temperatures for the previous six years at the LCR inflow ranged from 10.3 °C to 11.8 °C and had warmed an average of 2.3 °C (Vernieu 2000). Thus Reclamation's action, by structuring monthly release volume to generate hydropower under a fluctuating regime, has a cooling effect on downstream water temperature, which likely results in, or contributes to, mortality to humpback chub eggs and juvenile fish due to cold temperatures (Hamman 1982, Marsh 1985) , or death of juvenile humpback chub from cold shock or increased predation due to cold shock (Berry 1988, Berry and Pimentel 1985, Lupher and Clarkson 1994, Valdez and Ryel 1995, Marsh and Douglas 1997, Robinson et al. 1998, Clarkson and Childs 2000, Ward et al. 2002).

MLFF also modifies the hydrograph (the timing of water delivery in the river). Monthly flows under MLFF produce a hyrdrograph with the highest flows in the winter and summer months. Humpback chub evolved with a historically variable hydrograph in Grand and Marble canyons, but with consistently high flows in the spring following snow melt and low flows in the summer (Topping et al. 2003). Muth et al. (2000) recommend releases from Flaming Gorge Dam mimic this natural pattern in the Green River to benefit humpback chub by providing high flows in the spring and base flows in other seasons. But the maximum release at powerplant capacity (31,500 cfs) is likely too low to provide any benefit to native fishes (Valdez and Ryel 1995), but flows that utilize the outlet works such as the March 2008 high flow test, do provide some of these positive benefits to humpback chub, such as by rearranging sand deposits in recirculating eddies, effectively reshaping reattachment bars and eddy return current channels, as described in the 2008 Opinion, and earlier in this document. Reclamation is testing steady flows in September and October of the current experiment to determine if these flows benefit humpback chub without undue risk from benefiting nonnative species, as described earlier.

Reclamation's action of fluctuating daily volume to meet power demand has direct and indirect effects to humpback chub, and in particular to juvenile humpback chub, because this life stage prefers nearshore habitats where the effects of fluctuations are concentrated (Valdez and Ryel 1995, Robinson et al. 1998, Stone and Gorman 2006, Korman and Campana 2009). Daily variation in discharge can result in a variety of adverse affects due to lateral movement of the shoreline, such as the direct effect of stranding juvenile fish (Cushman 1985). Stranding of fish is a common effect of fluctuations below hydroelectric dams, and is affected by numerous factors, such as riverbank profile, substrate type, fish size and age, species, time of day, exposure frequency, season, temperature, and the rate of stage change (Korman et al. 2006). Stranding of humpback chub has not been documented, but fluctuations do result in cutting off of backwaters so stranding is possible (Davis 2002).

Fluctuations also result in a cooling effect to nearshore habitats such as backwaters, which are important nursery areas for juvenile humpback chub. Daily fluctuations cause mixing of warm

waters contained in backwaters with cold mainchannel water (Arizona Game and Fish Department 1996, Grand et al. 2006). 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) under steady flows about 2.5 °C 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. Trammell et al. (2002) found backwater temperatures during the 2000 low steady summer flow experiment to be 2-4 °C above those during 1991-1994 under fluctuating flows. Korman et al. (2006) 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. Fluctuations thus likely result in some increased mortality to humpback chub eggs and juvenile fish due to cold temperatures (Hamman 1982, Marsh 1985).

Daily variation in discharge can also result in a variety of adverse sub-lethal effects due to colder water and lateral movement of the shoreline and potential displacement effect as fluctuations dewater these habitats daily, which can result in reduced growth rates, increased stress levels, predation risk, energy expenditure, or reduced feeding opportunities (Cushman 1985). As discussed earlier, Korman et al. (2006) hypothesized that fluctuation effects on nearshore habitats poses an ecological trade-off for fish utilizing these areas; 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 permanently wetted zone which is always wetted, but colder than the immediate near shore margin. Korman et al (2005) found that young rainbow trout in the Lees Ferry maintained their position as flows fluctuated rather than follow the stream margin up slope, indicating that the bioenergetic cost of changing stream position with fluctuations in discharge perhaps outweighs the benefits of exploiting the slightly warmer stream margins. If humpback chub chose to utilize warmer backwaters, movement into and out of these habitats as stage changes with fluctuation will be required. Korman and Campana (2009) found that, for rainbow trout in Lees Ferry, growth appeared to increase during stable flows, based on evidence of a distinctive line on the ototlith (inner ear bone) representing increased growth that corresponded to juvenile trout's increased use of immediate shoreline areas on Sundays (the only day of the week with steady flows), where higher water temperatures and lower velocities provided better growing conditions. If humpback chub are similarly affected, fluctuating flows could result in lower growth rates. Displacement from warm nearshore habitats by dewatering during fluctuations could also lead to death of juvenile humpback chub from cold shock or increased predation due to cold shock, as well as increased predation risk due to increased movement (Berry 1988, Berry and Pimentel 1985, Lupher and Clarkson 1994, Valdez and Ryel 1995, Marsh and Douglas 1997, Robinson et al. 1998, Clarkson and Childs 2000, Ward et al. 2002).

Understanding the trade-off between temperature and fluctuating flows as it affects growth and survival of early life stages of Grand Canyon fish (native and non-native) in mainstem nearshore habitats is an important research question. The NSE implemented by the GCDAMP in 2008, a conservation measure of the 2008 Opinion, will directly address needed research on the effects of fluctuations on these important habitats by evaluating native and nonnative fish use among different nearshore habitat types, assessing the vital rates (growth and survival) among different nearshore habitat types and during steady versus fluctuating flow operations; determining the key

factors (abiotic and biotic) influencing nearshore habitat selection of small-bodied and juvenile fish; and determining the effects of fluctuating and steady flow releases on nearshore habitat selection, movement, growth, and survival of native and nonnative fish. The FSFP (U.S. Geological Survey 2009b) will also help focus research on this need by coordinating and augmenting four ongoing studies to optimize ongoing research and monitoring to evaluate steady and fluctuating flows.

Structuring releases (within the MLFF constraints) to meet electricity demand also increases erosion of sandbars and backwaters, which could result in a reduction in habitat quality for juvenile humpback chub. Lovich and Melis (2007) hypothesized that the MLFF's annual pattern of monthly volumes released from the dam (with the greatest peak daily flows during the summer sediment input months of July and August) is a key factor in preventing accumulation of new sand inputs from tributaries over multi-year time scales. Also, the amount of sand exported is dependent on antecedent conditions, but if the supply of sand is sufficient, the amount transported by the river is exponentially proportional to flow volume (i.e., the rate of increase in sand load is much greater than the rate of increase in flow). As a result, daily flow fluctuations will transport more sediment than steady flows of the same daily average volume because the fluctuating flows are at a higher volume flow than steady flows during part of each day (U.S. Bureau of Reclamation 1995). But Wright et al. (2008b) evaluated Glen Canyon Dam releases relative to existing sediment supply from tributary inputs to determine if any operational regime could rebuild and maintain sandbars, and found that a "best case" scenario for Glen Canyon Dam operations to build and retain sandbars would be to utilize high flow tests followed by equalized monthly volumes, at the lowest volume allowable under the Law of the River, with a constant steady flow, because export increases with both volume and fluctuations. And Wright et al. (2008b) acknowledged that "The question remains open as to the viability of operations that deviate from the best-case scenario that we have defined." Thus Reclamation's action of varying flow seasonally and daily to meet electricity demand is not optimal for retaining sand in the system for use in maintaining sand bars and backwaters because it results in increased erosion. However, the degree to which dam operations may be able to deviate from this best case and still retain enough sediment to meet resources needs using high flow tests remains a research question (Wright et al. 2008b) which is currently being evaluated by research and monitoring of the effects of the 2008 high flow test.

Fluctuations and seasonal variation in flow volume to meet electricity demand also affects the food base available for fishes. As flow volume increases, Valdez and Ryel (1995) documented increasing densities of chironomids and simuliids in the drift on the descending limb of the diurnal hydrograph, and McKinney et al. (1999) documented a similar response for *G. lacustris*. Chironomids and simulids are important food items for adult humpback chub (Valdez and Ryel 1995), thus flow fluctuations may make these prey items more available in the drift. Flow fluctuations may have a negative effect on food availability in nearshore habitats, reducing food base of juvenile humpback chub. 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).

The effect of flows in Grand Canyon on nonnative fishes is not well understood, but in general, effects are similar to those described for humpback chub. The most relevant effect of dam operations on nonnative fishes for humpback chub conservation is how operations benefit or disadvantage nonnative fishes. This presents a tradeoff to managers that has been recognized since the 1970s (U.S. Fish and Wildlife Service 1978) and was discussed briefly in the 1995 Opinion : operations that benefit humpback chub are likely to also benefit nonnative fishes that prey on and compete with humpback chub. Because predation and competition from nonnative fishes is such a serious threat to humpback chub, any operations that disadvantage nonnative fishes could potentially be an advantage to humpback chub. For example, the 2000 low summer steady flow appeared to benefit all fish species as abundances for size classes < 100 mm TL (3.9 inches) of all species increased during the steady flow period compared to previous years (Trammell et al. 2002, Speas et al. 2004). There is also evidence that nonnative fish including fathead minnow and largemouth bass spawned in the mainstem above Diamond Creek during the low summer steady flow, and there was no record of largemouth bass reproducing above Diamond Creek prior to this (Trammel et al. 2002). As discussed above, changes in hydrology likely benefitted nonnative species in the Yampa River, and this appears to have led to increased predation on humpback chub and the collapse of that humpback chub population. A similar scenario also appears to be occurring in Desolation and Gray canyons (Jackson and Hudson 2005, Finney 2006, Fuller 2008, Jackson et al. 2008, R. Valdez, pers. comm., 2009). The degree of this threat, and this new evidence that changes in hydrology could result in rapid changes in nonnative fish species composition and abundance, which could decimate humpback chub populations, was not known at the time of the 1995 Opinion.

In summary, Reclamation's MLFF structuring of flow releases, both monthly release variations and diel flow fluctuations, have a net cooling effect on the mainstem river and nearshore mainstem habitats (Trammel et al. 2002, Korman et al. 2005, Wright et al. 2008a). Daily variation under the MLFF in discharge can also result in a variety of adverse sub-lethal direct effects due to lateral movement of the shoreline and the potential displacement effect as fluctuations dewater these habitats daily, which can result in reduced growth rates, increased stress levels, predation risk, energy expenditure, or reduced feeding opportunities (Cushman 1985). These adverse affects likely also disadvantage warm water nonnative fishes (Valdez and Speas 2007). Thus MLFF adversely affects humpback chub but it also may benefit humpback chub by disadvantaging nonnative fish species that prey on and compete with humpback chub, including common species such as channel catfish, common carp, rainbow trout, and brown trout, as well as potential invaders, such as largemouth bass, smallmouth bass, and green sunfish (Valdez and Speas 2007). Climatologists predict that the southwest will experience extended drought due to global climate change, and lower Lake Powell Reservoir elevations and warmer release temperatures are predicted (Seager et al. 2007, U.S. Climate Change Science Program 2008a, b). Warmer water conditions will benefit warm water nonnative fishes, resulting in invasions of new warm water nonnative fishes, and causing greater proliferation of existing nonnative fish species (Rahel et al. 2008). Thus operations, such as MLFF, that result in cooler water and suboptimal rearing habitat, that disadvantage warm water nonnative fish species, may become an increasingly important tool in conservation of humpback chub. Reclamation has also

included nonnative fish control as a conservation measure of the 2008 Opinion, and GCMRC has completed a Nonnative Fish Management Plan (Hilwig et al. 2009), which also address this threat.

Effects of the Action on Humpback Chub Critical Habitat Reach 6 – Little Colorado River

The water and physical habitat PCEs of critical habitat of the LCR reach will be little affected by MLFF because dam operations affect the mainstem Colorado River primarily, and would only affect the lower-most portion of the LCR via mainstem effects on the configuration of the mouth of the LCR, which is less than a quarter of a mile of the eight mile reach, approximately three percent, or less, of critical habitat in Reach 6. Protiva (Protiva, in Ralston and Waring 2008) found that optimal habitat conditions for juvenile humpback chub at the LCR inflow, in terms of temperature and flow, are achieved at about 13,000 cfs in the mainstem. Because daily fluctuations are constantly changing conditions at the mouth, this theoretically results in less-than-optimal habitat conditions for juvenile humpback chub much of the time (Protiva, in Ralston and Waring 2008). At high flows, ponding can also occur (Protiva, in Ralston and Waring 2008), which may provide a benefit by slowing current velocity in the LCR and reducing passive or active emigration from the LCR, thereby increasing the residence time of juvenile humpback chub in the LCR where they have higher survival rates. Ponding only occurs at flows of more than 40,000 cfs however (Protiva, in Ralston and Waring 2008). But the effect of dam operations on the mouth of the LCR is likely a minimal effect overall to humpback chub, and only occurs in a very small portion of Reach 6.

As discussed previously, MLFF likely affects the abundance and distribution of nonnative fish species, because MLFF results in a net cooling effect on mainstem river temperatures and mainstem nearshore habitats (Trammel et al. 2002, Korman et al. 2005, Wright et al. 2008a). Thus MLFF likely disadvantages nonnative fishes that prey on and compete with humpback chub, but the degree to which this occurs is unknown and has not been evaluated. Reclamation has also implemented mainstem mechanical removal of nonnative fishes as a conservation measure. Both MLFF and nonnative removal should serve to benefit the biological environment PCEs (B2 and B3) of critical habitat in Reach 6 by limiting or reducing the number of nonnative fishes present in the LCR inflow reach of the mainstem Colorado River that can move into the LCR itself to feed on and compete with humpback chub in the LCR.

Effects of the Action on the Role of Critical Habitat Reach 6 in Recovery

The LCR reach of critical habitat plays a critical role in the recovery of the species because this is the primary spawning and rearing area for the Grand Canyon population, which also constitutes the lower Colorado River Recovery Unit. As described in the Status of the Species section, demographic goals must be met for this Recovery Unit as well as for one or two core populations in the upper Colorado River basin for downlisting and delisting, respectively, to occur (U.S. Fish and Wildlife Service 2009). The draft goals constitute the best scientific information with which to analyze the performance of critical habitat reaches in meeting the recovery needs of the species. As described earlier, in addition to the draft demographic goals, the Recovery Goals also contain site-specific management actions and tasks and corresponding recovery factor criteria that must be met for downlisting and delisting to occur (see Appendix B).

So in evaluating the effectiveness of the critical habitat unit in meeting recovery, the primary measure is the status of the population in relation to the demographic goal, and the secondary measures are the state of the recovery factors and implementation of their associated management actions and tasks.

As stated previously, the current abundance of humpback chub in the LCR is estimated to be 7,650 adults (between 6,000-10,000, age 4+; ≥ 200 mm TL) which is nearing the 10,000-11,000 adults the ASMR estimates constituted the adult LCR population when marking began in 1989, and appears to have been in an upward increasing trend since 2001 (Coggins et al. 2006a, Coggins and Walters 2006). The service has not yet determined that the demographic goal for the Grand Canyon population has been met, but the best available science indicates that the PCEs in Critical Habitat Unit 6, the LCR, are meeting the needs of recovery, considering the demographic goal is near being met. Further, the net effect of implementation of MLFF in recent years does not appear to be restricting the ability of critical habitat in Reach 6 to meet the demographic goal of recovery.

The recovery criteria and associated management actions and tasks that relate to this critical habitat unit are based on the five listing factors (as discussed previously an as listed in Appendix B). Most of these are directed at improving and protecting humpback chub habitat including critical habitat and the PCEs. For Factor A, an adequate flow regime for the LCR that meets the needs necessary for all life stages of humpback chub to support a recovered Grand Canyon population appears to be met in recent years, given the status and trend of the LCR population (Stone 2008a, 2008b, Coggins and Walters 2009). However, a specific definition of the LCR flow regime that provides for these habitats, or a specific model that relates flow to habitat conditions, has not been developed (Valdez and Thomas 2009). MLFF will have minor effects to the flow regime in the LCR, limited to the effects on habitat suitability related to flow conditions in the immediate vicinity of the mouth of the LCR. This is a very small percentage of habitat available to humpback chub in the LCR, and thus these effects are likely negligible in terms of a population-level response.

Valdez and Thomas (2009) have a completed a draft management plan for the LCR basin that focuses on the needs of humpback chub, which was developed in response to an element of the reasonable and prudent alternative of the FWS 1994 jeopardy biological opinion (U.S. Fish and Wildlife Service 1994) which required that Reclamation be instrumental in developing a management plan for the LCR (U.S. Fish and Wildlife Service 1994). LCR watershed planning is also a conservation measure of the 2008 Opinion and thus part of Reclamation's proposed action, and is also a project in the HBC Comprehensive Plan (Glen Canyon Dam Adaptive Management Program 2009), and Reclamation's assistance in this regard will help protect critical habitat in the LCR.

For Factor C, the focus of the Recovery Goals is on controlling the proliferation and spread of nonnative species that prey on, compete with, and parasitize humpback chub. For the nonnative fish species, current levels of control appear adequate. Nonnative fish in Reach 6 of critical habitat continue to be at low levels (see Tables 6 and 7). Clearly such low levels should be maintained, but a specific target level as alluded to in the Recovery Goals has not been identified. Better regulation of sport fish stocking through development and implementation of

stocking goals with the relevant basin states has not occurred, is still needed, and is a project of the HBC Comprehensive Plan (Glen Canyon Dam Adaptive Management Program 2009). As a conservation measure of the 2008 biological opinion, Reclamation will continue to support the implementation of the HBC Comprehensive Plan, which will assist with this aspect of recovery.

Asian tapeworm has been documented at infestation rates of 31.6–84.2 percent in the LCR, and has been hypothesized as a factor in poor condition factor of humpback chub in the LCR (Hoffnagle et al. 2006, Meretsky et al. 2000). Nevertheless, the status and trend of the LCR population indicates that the negative effect of Asian tapeworm is not significant. Because MLLF results in net cooling effect to the mainstem and nearshore habitats of the mainstem, MLFF contributes to the suppression of both nonnative fish species and Asian tapeworm. Also, as described earlier, Reclamation has implemented mainstem mechanical removal of nonnative fish in the LCR inflow reach of the mainstem, which should help to reduce the abundance of nonnative fishes in Reach 6 of critical habitat as well, benefitting this aspect of recovery and the B2 and B3 PCEs in Reach 6.

For Factor D, Adequate existing regulatory mechanisms, the Recovery Goals identify the need to determine and implement mechanisms for legal protection of adequate habitat in the Little Colorado River through instream-flow rights, contracts, agreements, or other means. The most thorough accounting of the mechanisms and stakeholders needed to accomplish this for the LCR are provided in Valdez and Thomas (2009). As mentioned above, a primary need is to develop a model to define the instream flow needs of humpback chub to provide for all life stages of the species and relate flow to habitat needs of all life stages (Valdez and Thomas 2009). The current status and upward trends in population abundance and recruitment (Stone 2008a, 2008b, Coggins and Walters 2009) indicate that the current hydrograph is adequate to achieve recovery. Reclamation will also continue to support watershed management efforts as a conservation measure of the proposed action, such as creation of the Valdez and Thomas' (2009) management plan, which will also help achieve this aspect of recovery for Reach 6.

For Factor E of the Recovery Goals, other natural or manmade factors for which protection has been provided, the primary element relative to the LCR is to identify and implement measures to minimize the risk of hazardous-materials spills from transport of materials along U.S. Highway 89 at and near the Cameron Bridge spanning the Little Colorado River. This is also a project of the HBC Comprehensive Plan (Glen Canyon Dam Adaptive Management Program 2009). A plan is needed to address this threat and efforts to develop one have not been initiated, though the need has been identified since at least 2002, and would likely require minimal expense. The HBC Comprehensive Plan includes a project to create this plan (Glen Canyon Dam Adaptive Management Program 2009). Reclamation will continue to support development and implementation of the HBC Comprehensive Plan as a conservation measure of the 2008 Opinion, which will serve to address this recovery need in Reach 6.

Effects of the Action on Critical Habitat Reach 7 – Colorado River in Marble and Grand Canyons

The MLFF affects the PCEs of humpback chub critical habitat in Reach 7 by manipulating Colorado River flow from releases from Glen Canyon Dam on a daily and monthly basis,

affecting the timing and volume of delivery of water, water quality, the formation and quality of nearshore habitats, the composition of the food base, and the abundance and distribution of native and nonnative fishes. Although some aspects of how the MLFF affects these variables are known, many questions remain, and additional research is needed.

As discussed previously, the MLFF directly affects water temperature, part of PCE W1 of Reach 7, by cooling mainstem water temperatures. The MLFF does this by increasing the monthly volume of releases in the winter and summer months to meet increased electricity demand. By releasing greater volumes in the summer, when air temperatures and solar insolation could warm lower volume releases, the MLFF cools the mainstem (Wright et al. 2009a). The MLFF also cools the water temperature of nearshore habitats because the MLFF also fluctuates release volume over the course of the day to meet electricity demand. This significantly cools mainstem nearshore habitats by alternately flooding and dewatering nearshore habitats, especially during warm seasons, when warm air temperatures and solar insolation greatly warm these habitats (Arizona Game and Fish Department 1996, Korman et al. 2006, Wright et al. 2008a). This cooling effect is additive to the already cold temperatures of the hypolimnetic releases coming out of Glen Canyon Dam, and limits the suitability of the mainstem to provide for successful spawning and rearing of humpback chub in the mainstem (Valdez and Ryel 1995), although as discussed previously, there is evidence of mainstem spawning and recruitment (Andersen, M., GCMRC, pers. comm., 2007, Ackerman 2008).

The MLFF affects the timing and volume of water delivery in Reach 7, directly effecting PCE W2, the quantity of water that is delivered to a specific location in accordance with a hydrologic regime that is required for the particular life stage for each species. The MLFF alters the hydrograph to deliver more water during months with higher electricity demand in the winter and summer. Historically, humpback chub evolved with a variable hydrograph in Grand and Marble canyons, but with consistently high flows in the spring following snow melt and low flows in the summer (Topping et al. 2003). As discussed earlier, the maximum release from Glen Canyon Dam at powerplant capacity (31,500 cfs) is likely too low to provide any benefit to humpback chub in terms of providing high spring flows to clean spawning substrates and rework sediment-formed habitats (Valdez and Ryel 1995). But flows that utilize the outlet works, such as the March 2008 high flow test, do provide some of these positive benefits to humpback chub, such as rearranging sand deposits in recirculating eddies, effectively reshaping reattachment bars and eddy return channels, creating and enlarging backwaters (as described in the 2008 Opinion). The post-dam hydrograph also no longer provides sufficiently high flows to constitute a physical spawning cue (Valdez and Ryel 1995); despite this, humpback chub continue to spawn in the mainstem based on the persistence of mainstem aggregations and presence of juvenile and young of year humpback chub at mainstem aggregations (Andersen, M., GCMRC, pers. comm., 2007, Ackerman 2008) (Figure 4). Valdez and Ryel (1995) hypothesized that humpback chub in the mainstem now rely on photoperiod as a physical cue for spawning, noting that gonadal maturation appears normal and timed to correspond to either suitable LCR conditions (March-May) or historic mainstem conditions (May-July).

The PCEs for Physical Habitat include areas for use in spawning (P1), nursery (P2), feeding (P3), or corridors between these areas (P4), such as river channels, bottomlands, side channels, secondary channels, oxbows, backwaters, and other areas in the 100-year floodplain, which when

inundated provide spawning, nursery, feeding and rearing habitats, or access to these habitats. As discussed earlier, the MLFF primarily affects the quality of nursery (P2) and feeding (P3) habitats. Backwaters are thought to be important nursery habitat for native fish due to low water velocity, warm water and high levels of biological productivity. There is a strong need for additional research on the relationship between backwaters and fish habitat suitability and humpback chub survival and recruitment. Converse et al. (1998) identified shoreline habitats used by subadult humpback chub and related spatial habitat variability with flow regulation. Most juvenile humpback chub utilized talus, debris fans or vegetated shorelines in shallow areas of low current velocity, and backwaters were a relatively rare habitat type. Korman et al. (2004) found that habitat stability as determined by flow was important to minimize displacement of young humpback chub. They also found that humpback chub suitable habitat (depth and velocity as based on Converse et al. 1998, among others) declines by about 78 percent as discharge increases from 3,000 to 32,000 cfs, but tends to increase slightly at higher elevations (Korman et al. 2004). But more information is needed on the relationship between flow and habitat availability, as well as the role of backwaters and other near shore areas in humpback chub survival and recruitment; these needs will be addressed through Reclamation's proposed action and ongoing monitoring and research efforts, in particular the NSE and FSFP.

The MLFF affects the formation of physical habitat and has an adverse affect of eroding sediment out of the system, which results in a continual loss of sediment downstream to Lake Mead (Lovich and Melis 2007, Wright et al. 2008b). Continual erosion and a lack of flood flows may not affect the total number of backwater habitats available as much as the flow volume at any given time, but likely does reduce the size and quality of sediment-formed habitats such as backwaters (Stevens and Hoffnagle 1999, Goeking et al. 2003) that may be important rearing habitat for young humpback chub (Arizona Game and Fish Department 1996). High flow tests, timed to utilize tributary sediment inputs, can reset the system, creating sand bars and sediment formed habitat, but the degree to which this is effective in counterbalancing the erosion loss of MLFF is unclear (Wright et al. 2008b). Reclamation's action included a high flow test, conducted in March of 2008. High flow tests are intended to create and improve eddy complexes, including backwater habitats and beaches. Widespread beach building and sediment retention was predicted to occur from the 2008 high flow test due to the sediment-enriched conditions from tributary sediment inputs present in of the Colorado River at that time. High releases were also hypothesized to increase sandbar crest height, while increasing return channel depth through scouring. These geomorphic changes would result in larger and more persistent backwaters created, which may benefit conservation of the humpback chub and other native fish species (U.S. Bureau of Reclamation 2007a). Wright et al. (2008b) showed that the optimal dam operation for retaining fine sediment and optimizing tributary inputs was essentially equalized monthly volumes with as low a monthly release allowable by law. MLFF thus has an adverse affect on the formation and retention of backwater habitats because the daily fluctuations and high volume months in the summer and winter result in increased erosion as compared to the optimal sediment conservation flow described by Wright et al. (2008b), thus negatively affecting PCEs P1 and P2 of Reach 7, but the degree to which this can be offset by frequent high flow tests is still a research question, currently being addressed by analysis of the 2008 high flow test.[3]

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[3] In its Order, the Court appeared to consider two exhibits to be statements of an official FWS position: (1) a February 13, 2006 memo that made a statement regarding daily fluctuations in flows (Order at p. 24, lines 13-14, referring to Docket Entry # 91, Exhibit 21); and (2) a 2007 article by USGS personnel in the International Journal of

The MLFF's fluctuations also dewater nearshore habitats daily. Because juvenile humpback chub prefer nearshore habitats (Valdez and Ryel 1995, Robinson et al. 1998, Stone and Gorman 2006), they are especially susceptible to the adverse effects that fluctuating flows have on these habitats. Daily fluctuations in discharge can result in a variety of adverse affects due to lateral movement of the shoreline, such as stranding of juvenile fish, or sub-lethal effects related to increased stress levels, predation risk, energy expenditure, or reduced feeding opportunities (Cushman 1985) as well as decreased growth rates (Korman and Campana 2009). Stranding of fish is a common lethal effect of fluctuations below hydroelectric dams that is affected by numerous factors (Korman et al. 2006). Stranding of humpback chub has never been documented in Marble or Grand canyons, and sublethal affects of fluctuations on humpback chub are poorly understood. MLFF therefore may likely adversely affect PCEs P2 and P3 from the displacement effect of fluctuations, but this is not known with certainty. As described earlier, Reclamation is addressing this very important research need directly with the ongoing NSE and FSFP. These efforts should provide much needed insight into the questions of how fluctuations affect humpback chub in nearshore habitats.

The biological environment PCEs of food base, predation and, competition (B1, B2, and B3) are also affected by MLFF, although in complex ways that are not fully understood. As described earlier, as flow volume increases, Valdez and Ryel (1995) documented increasing densities of chironomids and simuliids on the descending limb of the diurnal hydrograph, and McKinney et al. (1999) documented a similar response for *G. lacustris*. Chironomids and simulids are important food items for adult humpback chub (Valdez and Ryel 1995), thus flow fluctuations may make these prey items more available in the drift, and this seems supported by data provided by Hoffnagle (2000) that found adult humpback chub condition factor was higher in the mainstem than in the LCR.

Flow fluctuations may have a negative effect on food availability (PCE B1) in nearshore habitats, reducing food base of juvenile humpback chub. 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 was 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). Similar investigations of the effect of fluctuations on these habitats are currently ongoing in Grand Canyon as part of the NSE and FSFP.

MLFF likely negatively affects the abundance and distribution of nonnative fish species (PCEs B2 and B3) because MLFF results in a net cooling effect on mainstem river temperatures and mainstem nearshore habitats (Trammel et al. 2002, Korman et al. 2005, Valdez and Speas 2007,

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River Basin Management that summarized aspects of the 2005 SCORE Report and made a statement regarding sediment retention (Order at p. 24, line 15 through p. 25, line 6, referring to Docket Entry # 91, Exhibit 22). The statements in these documents were niether formal FWS conclusions in a Biological Opinion nor statements of an official FWS position. Instead, the 2006 document is an internal FWS memorandum, and the 2007 article is a publication by USGS personnel summarizing an earlier USGS report.

Wright et al. 2008a). Lower and steady mainstem flows, such as the seasonally adjusted steady flow (SASF) (see U.S. Bureau of Reclamation 1995) would lead to an increase in water temperatures that may promote spawning and minimize exposure of incubating and early larval stages of fishes, which appears to benefit nonnative fishes as well as native fish species (Trammell et al. 2002). Because MLFF has the effect of cooling mainstem waters, it may benefit humpback chub by disadvantaging nonnative fish species that prey on, and compete with, humpback chub including common species such as channel catfish, common carp, rainbow trout, and brown trout, as well as potential invaders, such as largemouth bass, smallmouth bass, and green sunfish (Valdez and Speas 2007). Climatologists predict that the southwest will experience extended drought due to global climate change, and lower Lake Powell Reservoir elevations and warmer release temperatures are predicted (Seager et al. 2007, U.S. Climate Change Science Program 2008a, b). Warmer water conditions will benefit warm-water nonnative fishes, result in invasions of new species, and cause greater proliferation of existing nonnative fish species (Rahel et al. 2008). Thus operations that disadvantage warm-water nonnative fish species may become an increasingly important tool in conservation of humpback chub. Reclamation has also included nonnative fish control as a conservation measure of the proposed action, which will also help in addressing this threat. GCMRC has also completed a draft Nonnative Fish Management Plan that will also assist in this regard. These effects of Reclamation's proposed action should benefit PCEs B2 and B3 of Reach 7. Although it was recognized that improving conditions for humpback chub could benefit nonnative fishes at the time of the 1995 Opinion, the degree to which this is a threat was not apparently understood, and the potential effects of climate change were also not known.

It is important to note that while the MLFF provides a hydrograph that differs markedly from the natural pre-dam hydrograph, and that the MLFF cools mainstem and nearshore water temperatures, Reclamation's action does provide a test of steady flows in the months of September and October. Steady flows have a variety of potential benefits discussed earlier, including warming downstream flows, and warming and stabilizing nearshore areas. However, a larger scale shift to longer periods of stable flows could have unintended consequences. As seen during the low summer steady flow, long periods of low steady flow can benefit nonnative fishes as much as native fishes (Trammel et al. 2002, Ralston and Waring 2008). Beneficial effects of steady flows in terms of improved water temperature (PCE W1) could be offset by losses of humpback chub to predation and competition (PCEs B2 and B3). Reclamation's action is a cautious approach that tests relatively long-term implementation (five years) of a short duration (two months) steady flow. The results of this test and associated research (e.g. the NSE) will guide future flow experiments.

The NSE implemented by the GCDAMP in 2008 as a conservation measure of Reclamation's proposed action will provide much needed research in determining the value of mainstem nearshore habitats and the effect of MLFF on the PCEs of critical habitat in the mainstem. Key aspects of this research include: evaluating native and nonnative fish use among different nearshore habitat types, assessing the vital rates (growth and survival) among different nearshore habitat types and during steady versus fluctuating flow operations; and determining the key factors (abiotic and biotic) influencing nearshore habitat selection of small-bodied and juvenile fish. The GCMRC has also developed a draft FSFP (U.S. Geological Survey 2009b) which will

also help address this research need by coordinating and augmenting ongoing studies to optimize research that evaluates September and October steady releases.

In summary, Reclamation's action of MLFF manipulates the Colorado River hydrograph in Marble and Grand canyons on a daily and monthly scale that has important effects to the PCEs of Reach 7 of humpback chub critical habitat. MLFF results in a cooling effect to the mainstem Colorado River and to nearshore areas. This negatively affects PCEs W1 and W2, and likely results in some loss of humpback chub spawning and rearing habitat (PCEs P1 and P2). The MLFF hydrograph also no longer provides seasonal flooding and its benefits (affecting PCE W2), although Glen Canyon Dam has only a limited capability to flood the system relative to pre-dam conditions. The daily fluctuations of the MLFF may result in stranding of juvenile humpback chub, as well as sub-lethal effects from displacement (adversely impacting PCE P2), although these effects are poorly understood. The MLFF may have both beneficial and adverse effects on food base, but likely adversely affects food base in nearshore habitats (PCE P2 and B1). The MLFF erodes sediment-formed habitats such as backwaters that may be important to juvenile humpback chub (adversely impacting PCE P2); high flow tests can offset this, but the degree to which erosion effects can be offset, and the importance of sediment-formed habitats to humpback chub, are research questions. Steady flows likely improve spawning and rearing habitat for both nonnative fishes as well as native fish species, thus MLFF may have an important beneficial effect in suppressing nonnative fishes. Reclamation's proposed action of including steady flows in September and October will provide steady flows for research purposes without unnecessary risk of longer-duration steady flows such as SASF which could benefit nonnative fishes. Reclamation's action also includes many research and monitoring aspects, as discussed in the Proposed Action; most notably the NSE and the FSFP are GCDAMP initiatives that should provide much needed insight into many of the uncertainties of the effects of the MLFF on humpback chub. The status of the Grand Canyon population of humpback chub, in terms of both recruitment and adult abundance, has improved since the implementation of MLFF. Much of this information was not known at the time of the 1995 Opinion, in particular the beneficial effects of conservation measures implemented through adaptive management, and the degree of the threat posed by nonnative fishes and their potential response to changes in hydrology and water temperature regimes.

Effects of the Action on the Role of Critical Habitat Reach 7 in Recovery

The Recovery Goals relevant to Reach 7 are the demographic criteria and the mainstem recovery factor criteria. The mainstem recovery factor criteria focus on determining the role of mainstem habitats in humpback chub recovery, the relationship of mainstem flow to habitat, providing the appropriate Glen Canyon Dam releases, and reducing other threats in the mainstem, in particular, the threat of predation and competition from nonnative fish species, as necessary to meet the demographic goal for the Grand Canyon population. Although not explicitly mentioned in the Recovery Goals, all of the critical habitat PCEs in reach 7, water quality and quantity (W1 and W2), physical habitat for spawning, nursery areas, feeding and movement (P1-4), and the food supply, predation and competition components of the biological environment (B1-3), must be addressed in determining the needs of the species in the mainstem.

As described in the Status of the Species section, demographic goals must be met for this Recovery Unit as well as for one or two core populations in the upper Colorado River basin for downlisting and delisting, respectively, to occur (U.S. Fish and Wildlife Service 2009, Appendix B). The current abundance of humpback chub in the LCR is estimated to be 7,650 adults (between 6,000-10,000, age 4+; ≥ 200 mm TL) which is nearing the 10,000-11,000 adults the ASMR estimates constituted the adult LCR population when marking began in 1989, and appears to have been in an upward increasing trend since 2001 (Coggins et al. 2006a, Coggins and Walters 2009). Van Haverbeke and Stone (2009) also note that closed estimates of abundance of humpback chub in the LCR in 2008 are now equivalent to closed estimates utilizing very similar methods conducted in the early 1990s (Douglas and Marsh 1996). The demographic goal for the Grand Canyon population for downlisting is that the humpback chub population is maintained as a core over a 5-year period, starting with the first point estimate acceptable to the Service, such that the trend in adult (age 4+; ≥ 200 mm TL) point estimates does not decline significantly, the mean estimated recruitment of age-3 (150–199 mm TL) naturally produced fish equals or exceeds mean annual adult mortality, and the population point estimate exceeds 2,100 adults. As discussed earlier, the FWS has not yet determined that the demographic goal for the Grand Canyon population has been met, but the best available science indicates that the PCEs in Critical Habitat Unit 7 are meeting the needs of recovery because the demographic goal is near to being met and the status of the species continues to improve.

The Recovery Goals identify the need to determine the role of habitats in the mainstem in meeting the demographic goal for humpback chub in Grand Canyon, and to determine and implement Glen Canyon Dam releases that will meet these needs in the mainstem. Reclamation is in the process of determining what flows are necessary in the mainstem to meet humpback chub habitat needs, which consist of all of the PCEs of critical habitat. The current focus of the GCDAMP is to complete the research needed to address the first criterion of Factor A in the Recovery Goals for Grand Canyon (provided in Appendix B), to determine the relationship between humpback chub and its habitat in the mainstem and humpback chub and its habitat in the LCR, and determine what Glen Canyon Dam releases are required to meet and maintain the demographic goal for the species. The current flow experiment, with the inclusion of steady flows in September and October, the 2008 high flow test, the NSE, and other research, monitoring, and management actions, test how the MLFF affects the PCEs of critical habitat, in comparison to how steady flows affect the PCEs of critical habitat. A key component of this research is the NSE, which will test the response of fish and other variables in nearshore habitats such as backwaters under steady and fluctuating flows to help clarify the relationship between flows and mainstem habitat characteristics and the availability of nursery habitat for young-of-year and juvenile humpback chub.

The NSE will also evaluate the response of nonnative fish to variations in flow, and how these flows affect food base, predation and competition in nearshore habitats. In August of 2009, GCMRC also developed a draft FSFP (U.S. Geological Survey 2009b). This plan will coordinate and augment several ongoing studies to optimize research that evaluates the steady releases from Glen Canyon Dam in September and October from 2008-2012. Also, ongoing sediment research will evaluate how the 2008 High Flow Test affected nearshore habitats, and if high flow tests can offset erosion loss of sediment from MLFF operations relative to humpback chub habitat needs. These research efforts of the proposed action will better define how the

PCEs in Reach 7 function in recovery, and will help meet the recovery criteria of determining the relationship of habitats in the mainstem and the LCR and defining operations of Glen Canyon Dam to achieve humpback chub recovery, as required by the Recovery Goals.

A critical aspect of recovery identified in the Recovery Goals (as Factor C) is the need to control predation and competition of nonnative fish species, and these are also important PCEs of critical habitat (PCEs B2 and B3). The Recovery Goals require that procedures for stocking sport fish be updated to minimize escapement of nonnative fish species into the Colorado River and its tributaries through Grand Canyon to minimize negative interactions between nonnative fishes and humpback chub. Reclamation has included as a conservation measure continued support for the implementation of the HBC Comprehensive Plan; the plan included a project to develop sport fish stocking procedures with the relevant basin states to minimize escapement of sport fish into humpback chub critical habitat (Glen Canyon Dam Adaptive Management Program 2009).

The Recovery Goals also identify the need to develop and implement levels of control of nonnative fish species. As a conservation measure of the proposed action, Reclamation has also committed to continue implementation of nonnative removal efforts. As discussed above, the GCDAMP has demonstrated that successful removal of nonnative trout is possible, and may benefit humpback chub (Coggins 2008b, Yard et al. 2008). The degree to which these removal efforts have improved the PCEs B2 and B3 is still a research question, although Yard et al. (2008) presented some preliminary results indicating that the 2003-2006 removal of rainbow and brown trout contributed significantly to reduce predation losses of juvenile humpback chub. Nonnative removal has been identified by several authors as a likely cause of improved status of humpback chub (Andersen 2009, Coggins and Walters 2009, Van Haverbeke and Stone 2009). GCMRC recently completed a draft Nonnative Fish Management Plan (Hilwig et al. 2009) discussed earlier, and Reclamation's action also includes nonnative control science support; these efforts will continue to refine methods of controlling nonnative fish species. Reclamation's effort to control nonnative fish species directly addresses this recovery need for the B2 and B3 PCEs of Reach 7.

In summary, the Recovery Goals provide specific criteria for Reach 7 of critical habitat and its PCEs, and the most important of these are to identify Glen Canyon Dam releases that maintain adequate humpback chub habitat to support recovery and to implement levels of nonnative fish control as necessary to support recovery. Reclamation's action includes an active adaptive management program that is progressively testing different flow regimes to benefit native fishes, utilizing the 2008 high flow test and steady flows in October and November of 2008-2012 in its current experiment. Reclamation has also included in its proposed action several projects to monitor and evaluate the effect of these experimental flows on the PCEs of critical habitat in this reach, including the NSE, the FSFP, and various monitoring and research projects of the GCDAMP annual work plans (as discussed earlier in the Proposed Action). Reclamation has also included Nonnative Fish Control as a conservation measure and is actively working to refine methods to remove and control the spread of nonnative fishes. The benchmark for success of these efforts is the Recovery Goals demographic criteria for humpback chub in the lower Colorado River basin Recovery Unit. Although FWS has not yet determined that the demographic goal has been met, recent monitoring and modeling suggests that it has (Coggins and Walters 2009, Van Haverbeke and Stone 2009).

Kanab Ambersnail

Kanab ambersnail habitat can be adversely affected by scouring at Colorado River flows exceeding 17,000 cfs. MLFF has been implemented since 1991, and flows have consistently scoured Kanab ambersnail habitat, removing habitat and snails below the 25,000 cfs flow level. Reclamation's action under MLFF includes flows up to 25,000 cfs, but flows of this magnitude would occur rarely, only in wet years. Nevertheless some loss of habitat and snails would occur as these flows scour the vegetation and carry the snails downstream. But the amount of habitat that is subjected to this effect, which is usually incremental and continuous (as opposed to the high magnitude and relatively instantaneous effect of a high flow test described in the 2008 Opinion), is a small proportion of habitat available to Kanab ambersnail at Vaseys Paradise. Meretsky and Wegner (2000) noted that at flows from 20,000 to 25,000 cfs, only one patch of snail habitat is much affected (Patch 12), and a second patch to a lesser extent at flows above 23,000 cfs (Patch 11). The largest these patches have been recently was in July 1998 when the area of both patches was 28.68 m^2 (308.7 ft^2) (Meretsky and Wegner 2000). Total habitat available in July 1998 (minus two patches that were not included in the total measurement) was 276.82 m^2 (2,979.7 ft^2). Thus patches 11 and 12, even in a good year, constitute less than 10 percent of total habitat available. Also, very few Kanab ambersnail have been found in patches 11 and 12 historically, and these patches are of low habitat quality for Kanab ambersnail (Sorensen 2009). Currently the amount of habitat loss at the 25,000 cfs flow level due to scour would be low, and is estimated to be about 300-350 ft^2 (27.9-32.5 m^2) or less (Meretsky and Wegner 2000). Thus the scouring effect of MLFF is predicted to have little effect on the overall population of Kanab ambersnail at Vaseys Paradise because scouring would occur infrequently, would affect only a small proportion of overall habitat available, habitat lost would be of low quality, and is expected to contain few snails.

The proposed action will have no effect on the water flow from the side canyon spring that maintains wetland and aquatic habitat at Vaseys Paradise. Kanab ambersnail at Elves Chasm would be unaffected by MLFF because the snails and their habitat are located up the chasm well above the Colorado River and the influence of dam operations on flow. No critical habitat has been designated for Kanab ambersnail, thus none would be affected.

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. Kanab ambersnail occurrence in the action area is entirely on Federal lands managed by the National Park Service in Grand Canyon National Park, and thus would not be subject to these effects, although their habitat is created by springs, and it is conceivable that some distant non-Federal action could affect the ground water that supply these springs. We are currently unaware of any possible future non-Federal actions that affect the aquifers that create Kanab ambersnail habitat.

Cumulative effects to the humpback chub and its critical habitat stem from Native American actions, and State, Tribal, local, or private actions in tributary watersheds upstream of the action area. 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). These uses affect humpback chub and its critical habitat in similar ways to uses permitted by the National Park Service, although on a much smaller scale thus far, and thus are projected to have minimal effects to humpback chub and its critical habitat. Non-Federal actions on the Paria River and Kanab Creek are limited to small developments, private water diversions and recreation, and are expected to continue to have little effect on humpback chub and its critical habitat. Non-Federal actions in the Little Colorado River drainage are extensive, but as discussed in the Environmental Baseline section, these effects have thus far not had a detectable adverse affect on humpback chub and its critical habitat in the Little Colorado River, perhaps because these affects are diffuse over a wide area, and are distant from humpback chub and its critical habitat. A recently completed management plan for the Little Colorado River watershed (Valdez and Thomas 2009) provides many thorough recommendations to conserve humpback chub in light of these potential effects. The proposed action also includes a conservation measure for Reclamation's continued support of Little Colorado River watershed planning efforts.

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 action area is on Federal lands, any legal actions occurring in the future would likely 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. We have also incorporated the analysis requested in the Court Order from the District Court of Arizona (No. CV-07-8164-PHX-DGC, document 172, May 26, 2009, U.S. District Court of Arizona). In evaluating whether or not Reclamation's action results in adverse modification of critical habitat, we have evaluated whether or not the effects of Reclamation's action appreciably diminish the capability of critical habitat to provide for the recovery of the species (U.S. Fish and Wildlife Service and National Marine Fisheries Service 1998) as currently defined by the Humpback Chub Recovery Goals (U.S. Fish and Wildlife Service 2009).

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 Glen Canyon Dam March 2008 high flow test and the five-year implementation of the 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 1996 ROD) would jeopardize the continued existence of the species, and destroy or adversely modify its critical habitat. The Grand Canyon population, which was the population analyzed in the 1995 Opinion, appears to have recently improved to approximately 7,650 adult fish (age 4+) (an increase of 1,650 since the 2008 Opinion). This is similar to the number of adult fish thought to be present in Grand Canyon in 1995, and is nearing or has met the draft demographic recovery goal for this population (U.S. Fish and Wildlife Service 2009), although the status of the species overall is reduced from what it was in 1995 because of declines in populations of the upper basin as of September 2009, most notably in Yampa, Desolation and Gray canyons, due primarily to the proliferation of nonnative fishes that prey on and compete with humpback chub. Much of the scope of dam operations for the remaining years of Reclamation's five year proposed action will consist of MLFF, which in 1995 we determined would jeopardize the continued existence of the species and destroy or adversely modify its critical habitat. However, the most recent and best available estimates for the Grand Canyon humpback chub population trend (Coggins and Walters 2009) 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 in 2001. And the Grand Canyon population of humpback chub has increased in number during implementation of MLFF. This improvement in the population status and trend has been attributed in part to actions taken pursuant to MLFF, such as nonnative fish mechanical removal, and the 2000 low steady summer flow experiment, and other experimental flows and actions, as well as a serendipitous warming of Glen Canyon Dam releases due to lower reservoir elevations and inflow events (Andersen 2009). All of these actions suspected of benefiting the humpback chub population, with possible exception of warmer release water, will continue under the proposed action. Further, population modeling indicates the improvement in humpback chub status and trend was due to increased recruitment in the mid to late 1990s (Coggins and Walters 2009), 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. The increase in recruitment may have been due to the implementation of MLFF. Reclamation's proposed action, which continues actions believed beneficial to humpback chub, such as steady flows and high flows to improve nearshore habitats, and research to meet recovery needs, will likely be beneficial to humpback chub, and further increases in recruitment are expected based on recent catch rates of sub-adult humpback chub (Van Haverbeke and Stone 2009). The best available scientific information indicates that the implementation of MLFF (and the other aspects of Reclamation's action, including the GCDAMP) has not resulted in jeopardy to humpback chub or destruction or adverse modification of its critical habitat. In fact, Reclamation's implementation of MLFF, and more recently implemented conservation measures, has benefited humpback chub, and we believe is likely to continue to do so.

- The proposed action of MLFF will have adverse effects, predominantly to young-of-year and juvenile humpback chub. These effects will be primarily due to the reduction in quality of nearshore habitats for juvenile humpback chub. MLFF will result in a net cooling effect to the mainstem Colorado River and in destabilization of nearshore habitats by flow fluctuations. This will result in adverse effects to eggs and young fish from cold water temperatures, as well as increased energy expenditure and increased predation rate on young chub. However, these effects should be considered in light of the expected beneficial effects of Reclamation's proposed action from the monitoring and research aspects of the GCDAMP, the conservation measures (listed below), and from the 2008 high flow test and fall steady flow components, which will likely create or improve nearshore habitats, and create more persistent suitable habitat conditions that are warmer and more productive.

- Reclamation is committed to implementing a suite of conservation measures, through the GCDAMP, that will benefit humpback chub and its critical habitat. We are confident that Reclamation will implement these measures because of their continued demonstration of effectiveness in implementing past and ongoing conservations measures. Essentially all of these conservation measures are currently being implemented by Reclamation to some degree. These conservation measures further increase our confidence in our opinion that any and all adverse affects of the proposed action are reduced to the point that the action will not jeopardize the species or result in the destruction or adverse modification of critical habitat by precluding or compromising humpback chub recovery:

    - *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 2008), the population drops below 3,500 adult fish within the 95 percent confidence interval

    - *Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon* – Reclamation has been a primary contributor to the development of the GCDAMP's Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon. Reclamation will continue to work with GCDAMP cooperators to develop a comprehensive approach to management of humpback chub. The AMWG accepted the completed HBC Comprehensive Plan in August 2009, and Reclamation is currently implementing many aspects of the plan.

    - *Humpback Chub Translocation* – In coordination with other Department of the Interior (DOI) GCDAMP participants and through the GCDAMP, Reclamation

will assist NPS and the GCDAMP 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. Reclamation and the GCDAMP will also fund and implement translocation of up to 500 young humpback chub from the lower Little Colorado River to above Chute Falls per year if FWS determines that a translocation is warranted. Reclamation and the GCDAMP 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. This measure is currently being implemented; translocations above Chute Falls were conducted in 2008 and 2009, and a translocation into Shinumo Creek was conducted in 2009.

- *Nonnative Fish Control* – As first presented in the biological opinion on the Shortage Guidelines, Reclamation will, in coordination with other DOI GCDAMP participants and through the GCDAMP, continue efforts to assist NPS and the GCDAMP 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 GCDAMP, and may utilize other methods, to help to reduce this threat. GCMRC is preparing a nonnative fish control plan through the GCDAMP process that addresses both cold and warm-water species that will further guide implementation of this conservation measure. This measure is currently being implemented; a nonnative removal trip was conducted in 2009 and two trips are planned for 2010. GCMRC has also completed a draft Nonnative Fish Management Plan (Hilwig et al. 2009).

- *Humpback Chub Nearshore Ecology Study* – In coordination with other DOI GCDAMP participants and through the GCDAMP, 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. 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. The NSE began in 2008.

- *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. This study is now a part of the NSE, which began in 2008.

- *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. Development of these refuges began in 2008 and is ongoing; wild juvenile humpback chub were transferred to Dexter National Fish Hatchery and Technology Center in 2008, and were augmented with additional fish in 2009, all captured from the LCR near its mouth.

- *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. Reclamation recently completed a draft watershed plan for the LCR (Valdez and Thomas 2009) and continues to assist the Little Colorado River Watershed Coordinating Council in watershed planning efforts.

- We believe critical habitat in Reach 6, the LCR, will remain functional and continue to serve the intended conservation and recovery role for the humpback chub. MLFF should

have minimal effect on PCEs of this unit, and some PCEs of critical habitat will be improved by the proposed action and conservation measures. The W1 and W2 PCEs of Reach 6 will benefit from Reclamation's efforts to address watershed planning for the LCR, and projects in the HBC Comprehensive Plan provide protective measures for PCEs in Reach 6, such as watershed planning to protect flows, and spill prevention planning for the U.S. Highway 89 Cameron Bridge spanning the Little Colorado River. PCEs B2 and B3 of Reach 6 will benefit from efforts to control nonnative species, and perhaps from the cooling effect that MLFF has on the mainstem, which may suppress warm water nonnative species.

- The PCEs of Reach 7 will be directly affected by MLFF, but questions on the role of this reach of critical habitat will also be directly addressed by Reclamation's proposed action. The Recovery Goals include the need to identify the role of the mainstem Colorado River and its habitats in meeting the demographic goal of recovery, as well as the need to define humpback chub habitat use in the mainstem to best define and provide flow regimes that are necessary for all life stages of humpback chub to support a recovered Grand Canyon population. Reclamation is now operating the dam using adaptive management via the GCDAMP, and through the GCDAMP, the steady flow component of the proposed action, the NSE, and GCMRC's FSFP will directly address the recovery need of defining flow needs for Reach 7 to meet recovery, along with the suite of related ongoing monitoring and research by the GCDAMP (U.S. Bureau of Reclamation and U.S. Geological Survey 2009).

- The Recovery Goals also identify the need to determine the efficacy of a TCD in providing mainstem water temperatures that support recovery. The need to deliver cold water is now an essential consideration of such an assessment (U.S. Geological Survey 2008), especially given the potential effects of global climate change and serious threat of invasion and expansion of nonnative fish species that prey on and compete with humpback chub. Although the MLFF has adverse affects to PCEs of reach 7 of critical habitat in the mainstem Colorado River, in particular to the water and physical habitat PCEs by providing an unnatural hydrograph and colder water temperatures, as well as eroding sediment-formed habitats such as backwaters that are important nursery habitats, how this affects the status and trend of the Grand Canyon population is poorly understood. The status and trend of the Grand Canyon population has been improving since 2000, and recruitment has been improving since the mid to late 1990s, indicating MLFF may provide a sufficient flow for the maintenance of critical habitat PCEs in support of recovery, although the mechanisms involved are not well understood. Ongoing research efforts by Reclamation, GCMRC and the GCDAMP will serve to address the questions regarding the relationship between Glen Canyon Dam releases, humpback chub habitat, and humpback chub recruitment, and allow for further modification and testing of Glen Canyon Dam releases through adaptive management. MLFF may also provide a benefit to the biological environment PCEs in the cooling effect and displacement affect on nearshore habitats by disadvantaging nonnative fish species that prey on and compete with humpback chub.

- The amount of scientific information available to assess the effects of MLFF is much greater than that available at the time of the 1995 Opinion. We now know that changes in hydrology and water quality variables, especially water temperature, can result in a rapid proliferation of nonnative fish species, which can lead to precipitous declines in humpback chub populations (Jackson and Hudson 2005, Finney 2006, Fuller 2008, Jackson et al. 2008, R. Valdez, pers. comm., 2009). We now have objective, measureable recovery criteria (U.S. Fish and Wildlife Service 2009). We now have improved information on humpback chub population dynamics (Coggins and Walters 2009) that indicates that MLFF may support sufficient levels of recruitment to achieve recovery (U.S. Fish and Wildlife Service 2009). We now have an adaptive management program in place that is implementing research needed in achieving recovery, as well conservation measures to benefit the species (U.S. Bureau of Reclamation and U.S. Geological Survey 2009). It is now evident that MLFF may have a beneficial effect to humpback chub by cooling the mainstem river, which suppresses nonnative fishes (Wright et al. 2008a, Valdez and Speas 2007), an effect which may become increasingly important in light of climate change (Rahel et al. 2008). All of this information leads us to conclude that Reclamation's proposed action represents a reasoned approach, utilizing adaptive management, to test experimental flows cautiously to determine appropriate long-term management of Glen Canyon Dam that supports humpback chub recovery. Implementing a more radical flow treatment could result in unnecessary harm to the species. The threat of nonnative fish species to humpback chub and the need control and suppress these species cannot be overemphasized. We believe Reclamation's action will provide valuable information without either compromising recovery or drastically altering the system irresponsibly.

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

- Although the MLFF will result in some loss of Kanab ambersnails and their habitat at Vaseys Paradise, we anticipate this loss will be small and not impair the long-term stability of the population because MLFF will only scour habitat at the highest flows during median and wet years, thus scouring would occur infrequently, and scouring would affect only a small proportion of overall habitat available, the habitat lost would be of low quality, and is expected to contain few snails. Kanab ambersnails have been subjected to such flows in the past under MLFF since 1991 and this occasional scouring effect of high MLFF releases appears to have had a negligible effect on the status and trend of the Vaseys Paradise population.

The conclusions of this biological opinion are based on full implementation of the project as described in the Description of the Proposed Action 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 MLFF is in the form of harm or mortality, resulting primarily from the cooling effect of the MLFF on mainstem and especially nearshore habitats and from the dewatering of nearshore habitats due to daily flow fluctuations; these effects can cause direct mortality from cold shock or stranding, as well as indirect mortality from increased predation rates by nonnative fish predators. These effects are not well understood, and the NSE, as part of Reclamation's action, will help inform how these effects impact humpback chub. GCMRC's FSFP will also help focus research efforts on how fluctuating flows affect humpback chub. However, even with these research efforts in place, humpback chub mortalities resulting from the MLFF will be difficult to detect, due to the small size of individuals likely to be affected and the size and remoteness of the action area. Our lack of understanding of the habitat needs of humpback chub in the mainstem also precludes establishing a quantifiable amount of habitat as a surrogate for take. 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 MLFF, the anticipated level of take of humpback chub is unquantifiable. 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 has also implemented a consultation trigger as a conservation measure. We will consider take to have been exceeded if the conditions of the trigger are met.

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 highest flows of the MLFF. The anticipated take is expected to be negligible to the Vaseys Paradise population and 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 350 ft^2 (32.5 m^2) of Kanab ambersnail habitat being removed at Vaseys Paradise and this loss is attributable to the MLFF.

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 below 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 the abundance of adult humpback chub in relation to the consultation trigger and report the findings to the FWS. Reclamation shall work in collaboration with the GCDAMP 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 GCDAMP 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 GCDAMP 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 GCDAMP 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, and continue to work with us on developing a recovery program for the Grand Canyon population of humpback chub.

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" (Sorensen and Nelson 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 (x233), Lesley Fitzpatrick (602) 242-0210 (x236), or me (x244). Please refer to consultation number (22410-1993-F-167R1) in future correspondence concerning this project.

/s/ Steven L. Spangle

cc: Regional Director, Fish and Wildlife Service, Albuquerque, NM
Assistant Field Supervisor, Fish and Wildlife Service, Flagstaff, AZ
Chief, Habitat Branch, Arizona Game and Fish Department, Phoenix, AZ
Director, Environmental Programs, Bureau of Indian Affairs, Phoenix, AZ
Chemehuevi Indian Tribe, Chemehuevi Valley, CA
Havasupai Tribe, Supai, AZ
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

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 emergencies 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 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

Table 3. Actual annual releases from Glen Canyon Dam under the proposed action for water years 2008 and 2009 (releases for August and September 2009 on are projected).

Water Year 2008 8.973 maf				**Water Year 2009 8.230 maf**			
Month	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**	**Month**	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**
Oct	9773	6613	12468	**Oct**	12103	11832	12326
Nov	10137	7114	12925	**Nov**	10250	7182	13176
Dec	13053	8939	16897	**Dec**	12986	8943	16963
Jan	13021	9021	16865	**Jan**	12986	8956	16869
Feb	10471	8342	14266	**Feb**	10812	7571	13581
Mar	13502	10209	16952	**Mar**	10205	7141	12957
Apr	11401	8298	14055	**Apr**	10142	6111	12259
May	12851	9077	15144	**May**	9473	7009	11151
Jun	13298	9746	15728	**Jun**	11211	7633	13435
Jul	14073	9754	17782	**Jul**	13052	8517	16481
Aug	14468	10058	17957	**Aug**	13010	8500	16500
Sep	12156	11991	12306	**Sep**	10000	10000	10000

Table 4. Humpback chub critical habitat reaches and primary constituent elements present in each unit (updated from Maddux et al. 1993a).

Critical Habitat Reach[1]	**Constituent Elements**[2]			**Humpback Chub Population**[3]	**Contributes to Recovery as of 2009?**[4]
	Water	**Physical**	**Biological**		
HBC 1	W1?, W2	P1, P2, P3, P4	B1	Yampa	No
HBC 2	W1, W2	P1, P2, P3, P4	B1		No
HBC 3	W1, W2	P1, P2, P3, P4	B1	Deso/Gray	No
HBC 4	W1, W2	P1, P2, P3, P4	B1, B2, B3	Westwater and Black Rocks	Yes
HBC 5	W1, W2	P1, P2, P3, P4	B1	Cataract	No
HBC 6	W1, W2	P1, P2, P3, P4	B1, B2, B3	Grand Canyon	Yes
HBC 7	W1?, W2	P1?,P2?, P3, P4	B1, B2?, B3?	Grand Canyon	Yes?

[1]See Status of the Species section for description of critical habitat reaches.

[2]The presence of a criterion code under the appropriate column in the table indicates that criterion is met within that reach: Water, W1=Quality, W2=Quantity; Physical Habitat, P1=Spawning Habitat; P2=Nursery Habitat; P3=Feeding Areas; P4=Movement Corridors; Biological Environment: B1=Food Supply; B2=Predation; B3=Competition.
The use of a question mark (?) behind a criterion code indicates insufficient data to determine with certainty if the criterion is met within that reach.

[3]The humpback chub population present in the critical habitat unit, from U.S. Fish and Wildlife Service 2009. HBC 2 does not appear to support a population, although isolated individuals have been found in past surveys.

[4]As of 2009, are all the PCEs of critical habitat functional to the extent that the critical habitat unit fully supports recovery.

Table 5. Recaptures of humpback chub collected throughout the Colorado River in Marble and Grand Canyons, Arizona, 1989–2002. Values along the diagonal (bold italics) indicate that the capture and recapture locations were the same (i.e., site fidelity). Values above the diagonal represent downstream movement, values below the diagonal upstream movement (From Paukert et al. 2006).

	Recapture location (RM) [1]									
Tag Location (RM)	**-15 - 58**	**62 (LCR)**[2]	**58-70**	**70-109**	**109-110**	**110-126**	**126-137**	**158 (Havasu Creek)**	**137-227**	**Total Recaptures**
-15-58	***26***	1								
62	1	***12,508***	868	5					4	
58-70		909	***241***	3		1	1			
70-109		2	1	1			1			
109-110		1			***8***					
110-126						***1***	1			
126-137						2	***77***			
158		1					1	***5***	1	
137-227									***2***	
										14,674

[1]River Mile
[2]Little Colorado River

Table 6. Spring 2008 captures of native and nonnative fishes in the lower Little Colorado River (LCR); hoop net sampling effort and total fishes captured in the Salt, Coyote, and Boulders' reaches, Arizona during spring 2008 monitoring trips. Nonnative fishes denoted with an asterisk (*) only includes unique individuals (i.e., no recaptures within a trip, from Stone 2008a).

Trip	April 1-10, 2008				April 29-May 8, 2008				Sp. 08
Reach	Salt	Coy.	Bould.	Total	Salt	Coy.	Bould.	Total	Total
Effort									
Hoop nets pulled	177	180	180	537	180	180	180	540	1,077
Total Hours	4,298	4,349	4,085	12,732	4,451	4,102	4,291	12,844	25,576
Mean hours/net ± SD	24.3 ± 2.3	24.2 ± 3.1	22.7 ± 1.6	23.7 ± 2.5	24.7 ± 3.8	22.8 ± 3.9	23.8 ± 3.0	23.8 ± 3.7	23.7 ± 3.2
Native fishes									
Catostomidae									
Catostomus discobolus (bluehead sucker)	48	162	180	390	776	898	760	2,434	2,824
C. latipinnis (flannelmouth sucker)	7	12	24	43	57	100	135	292	335
Cyprinidae									
Gila cypha (humpback chub)	96	136	200	432	1,015	923	760	2,698	3,130
Rhinichthys osculus (speckled dace)	16	21	27	64	781	189	610	1,580	1,644
Nonnative fishes									
Cyprinidae									
*Cyprinus carpio** (common carp)	-	-	1	1	-	-	-	-	1
Pimephales promelas (fathead minnow)	1	-	-	1	91	15	16	122	123
Cyprinodontidae									
Fundulus zebrinus (plains killifish)	-	-	-	-	1	-	-	1	1
Ictaluridae									
*Ameiurus melas** (black bullhead)	8	6	1	15	5	3	1	9	24
*Ictalurus punctatus** (channel catfish)	-	-	-	-	1	-	-	1	1

Table 7. Fall 2008 captures of native and nonnative fishes in the lower Little Colorado River (LCR); hoop net sampling effort and total fishes captured in the Salt, Coyote, and Boulders' reaches of the lower Little Colorado River (LCR), Arizona during fall 2008 monitoring trips. Nonnative fishes denoted with an asterisk (*) only includes unique individuals (i.e., no recaptures within a trip, from Stone 2008b).

Trip	Sep. 16-25, 2008				Oct. 14-23, 2008				Fall. 08
Reach	Salt	Coy.	Bould.	Total	Salt	Coy.	Bould.	Total	Total
Effort									
Hoop nets pulled	180	180	180	540	180	180	180	540	1,080
Total Hours	4,367	4,224	4,104	12,696	4,371	4,306	4,308	12,984	25,680
Mean hours/net ± SD	24.3 ± 2.7	23.5 ± 2.5	22.8 ± 2.0	23.5 ± 2.5	24.3 ± 2.5	23.9 ± 3.3	23.9 ± 2.0	24.0 ± 2.7	23.8 ± 2.6
Native fishes									
Catostomidae									
Catostomus discobolus (bluehead sucker)	47	3	2	52	82	33	15	130	182
C. latipinnis (flannelmouth sucker)	6	18	30	54	19	70	78	167	221
Cyprinidae									
Gila cypha (humpback chub)	345	233	228	806	822	721	735	2,278	3,084
Rhinichthys osculus (speckled dace)	38	19	10	67	424	322	161	907	974
Nonnative fishes									
Cyprinidae									
*Cyprinella lutrensis** (red shiner)	-	-	-	-	-	2	-	2	2
*Cyprinus carpio** (common carp)	8	-	1	9	1	-	-	1	10
Pimephales promelas (fathead minnow)	-	1	-	1	111	47	23	181	182
Ictaluridae									
*Ameiurus melas** (black bullhead)	11	5	-	16	5	7	-	12	28
*Ictalurus punctatus** (channel catfish)	4	32	17	53	1	5	7	13	66
Salmonidae									
*Oncorhynchus mykiss** (rainbow trout)	-	-	-	-	2	-	-	2	2

Table 8. Dominant nonnative fish species distribution in the mainstem Colorado River downstream of Glen Canyon Dam using fish sampling reaches established by Walters and Korman (1999). The use of river miles (RM) is as defined in Stevens (1983). Table is from Hilwig et al. (2009), based on Makinster et al. (2009); Rogers et al. (2008), Ackerman (2008).

Reach	River Mile	Dominant Nonnative Species	Other Nonnative Species Captured
Lees Ferry	-15 - 0	Rainbow trout	Common carp, channel catfish, green sunfish, smallmouth bass, walleye
1	0–29.1	Rainbow trout	Common carp, brown trout
2	29.2–56.0	Rainbow trout	Common carp, brown trout
3	56.1–68.6	Common carp	Fathead minnow, red shiner, channel catfish, bullhead spp., rainbow trout, plains killifish
4	68.7–76.7	Common carp	Fathead minnow, red shiner, channel catfish, bullhead spp., rainbow trout, plains killifish
5	78.8–108.5	Brown trout	Common carp, rainbow trout
6	108.6–129.0	Brown trout	Common carp, rainbow trout
7	130.5–166.6	Common carp	Brown trout, rainbow trout
8	166.7–179.5	Common carp	Fathead minnow, channel catfish
9	179.8–200.0	Common carp	Fathead minnow, channel catfish, striped bass
10	200.1–220.0	Common carp	Fathead minnow, channel catfish, striped bass
11	220.1–236.0	Common carp	Red shiner, channel catfish, striped bass
12	236.1–256	Channel catfish	Red shiner, Western mosquitofish, striped bass
13	256.1–276	Channel catfish	Red shiner, Western mosquitofish, striped bass

FIGURES

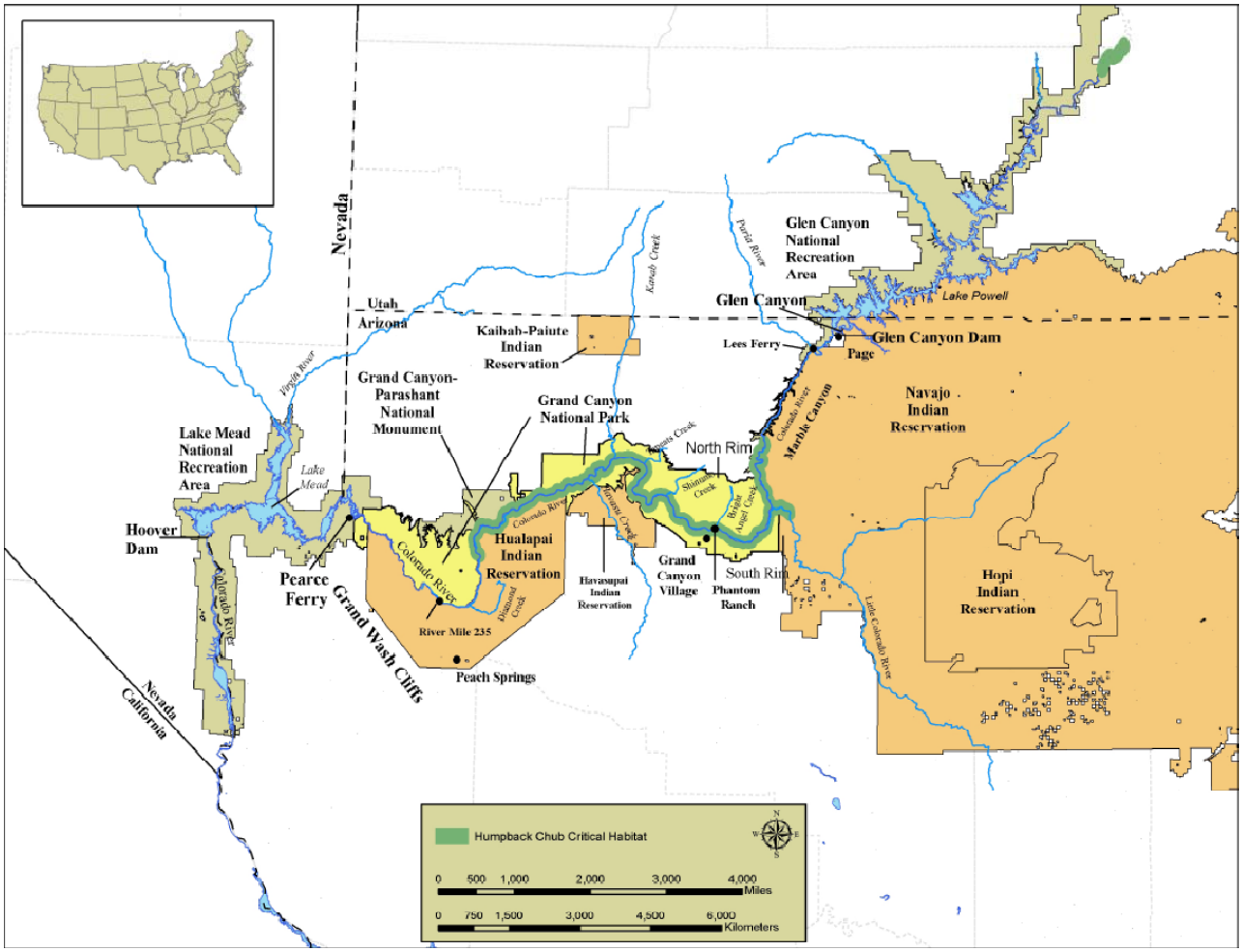

Figure 1. Map of Action Area and humpback chub (*Gila cypha*) critical habitat in the Colorado and Little Colorado Rivers.

Figure 2. Distribution of humpback chub (*Gila cypha*) from U.S. Fish and Wildlife Service (2009).

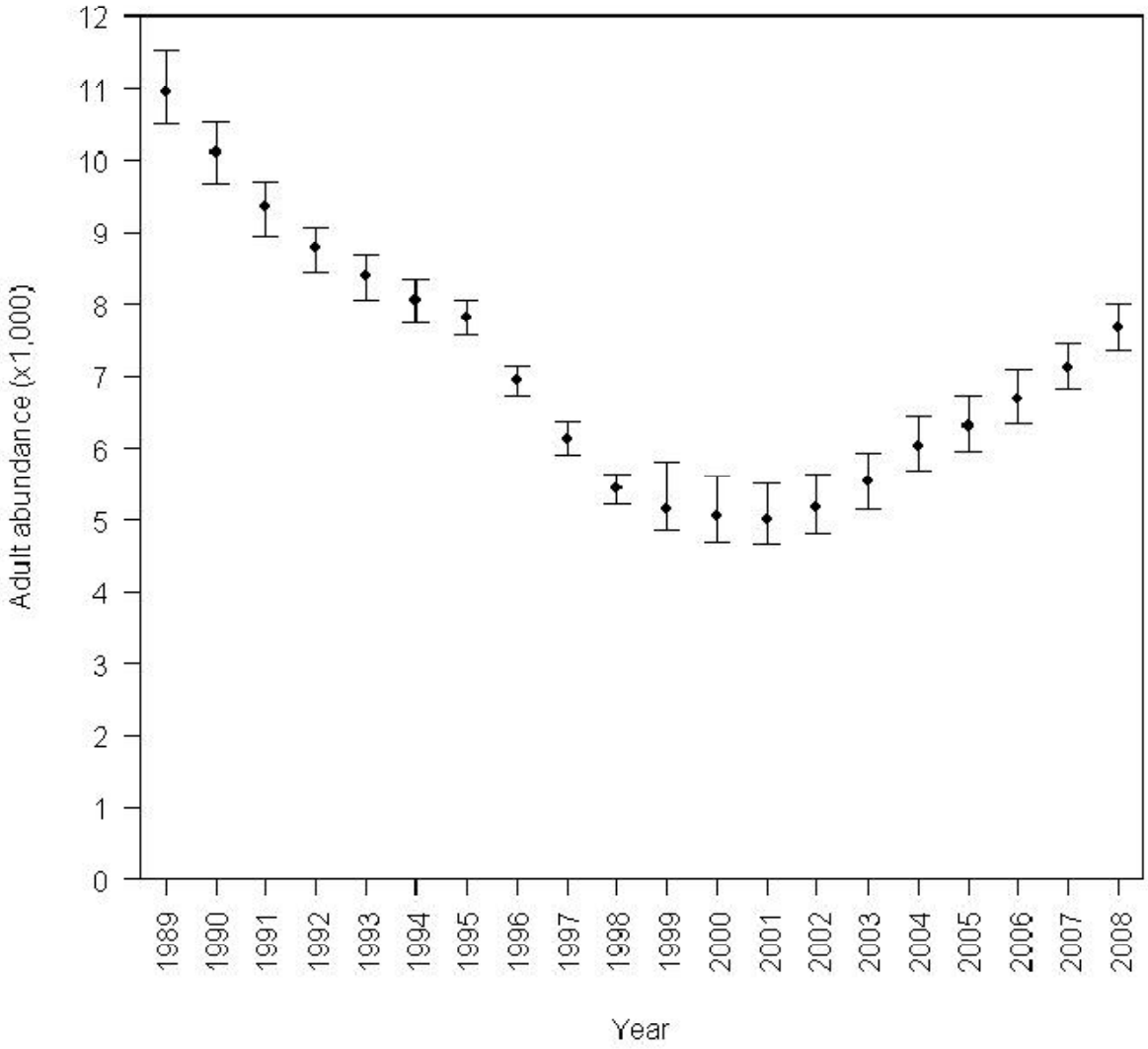

Figure 3. Estimated adult humpback chub abundance (age 4+) from ASMR, incorporating uncertainty in assignment of age. Point estimates are mean values among 1,000 Monte Carlo trials, and error bars represent maximum and minimum 95-percent profile confidence intervals among 1,000 Monte Carlo trials (from Coggins and Walters 2009).

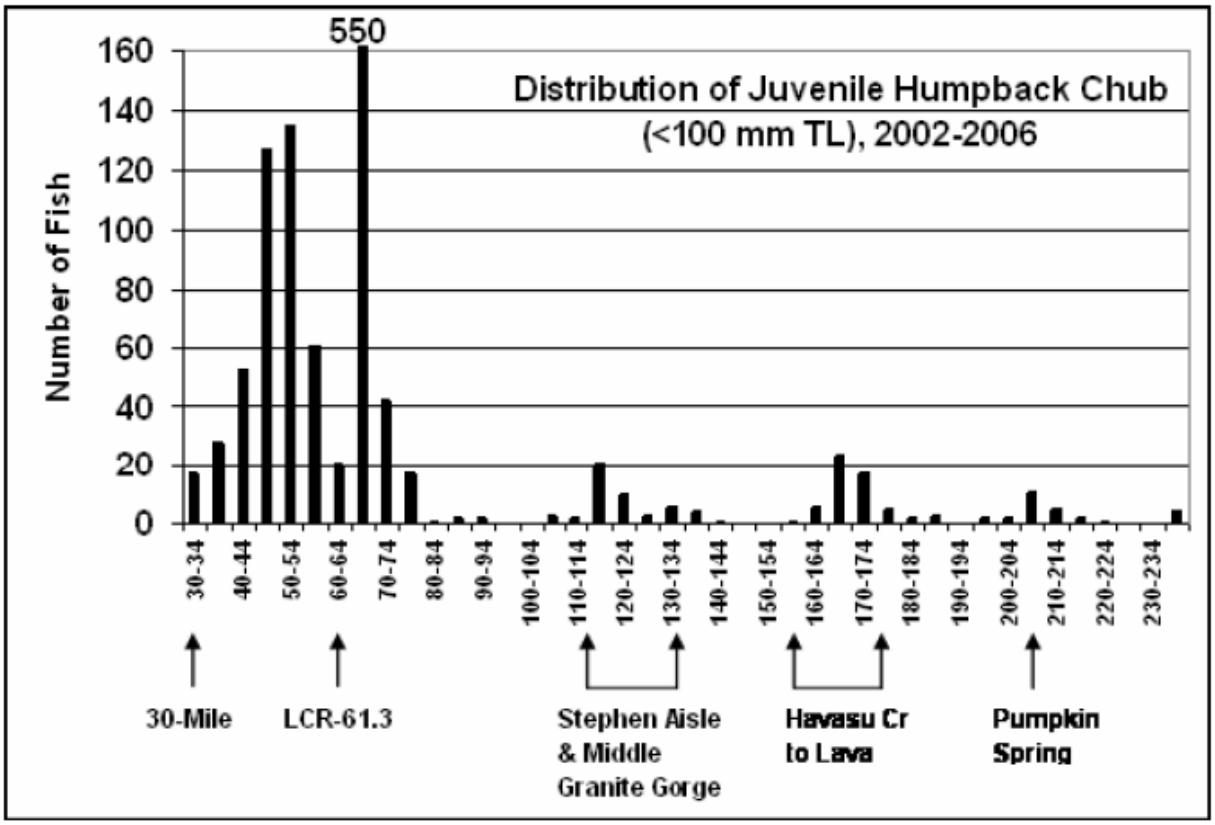

Figure 4. Distribution of juvenile humpback chub (<100 mm TL) in the Colorado River in the Action Area during 2002-2006 by 5-mile increments, from RM 30 to RM 230 (from U.S. Bureau of Reclamation 2007a, data from Ackerman 2008).

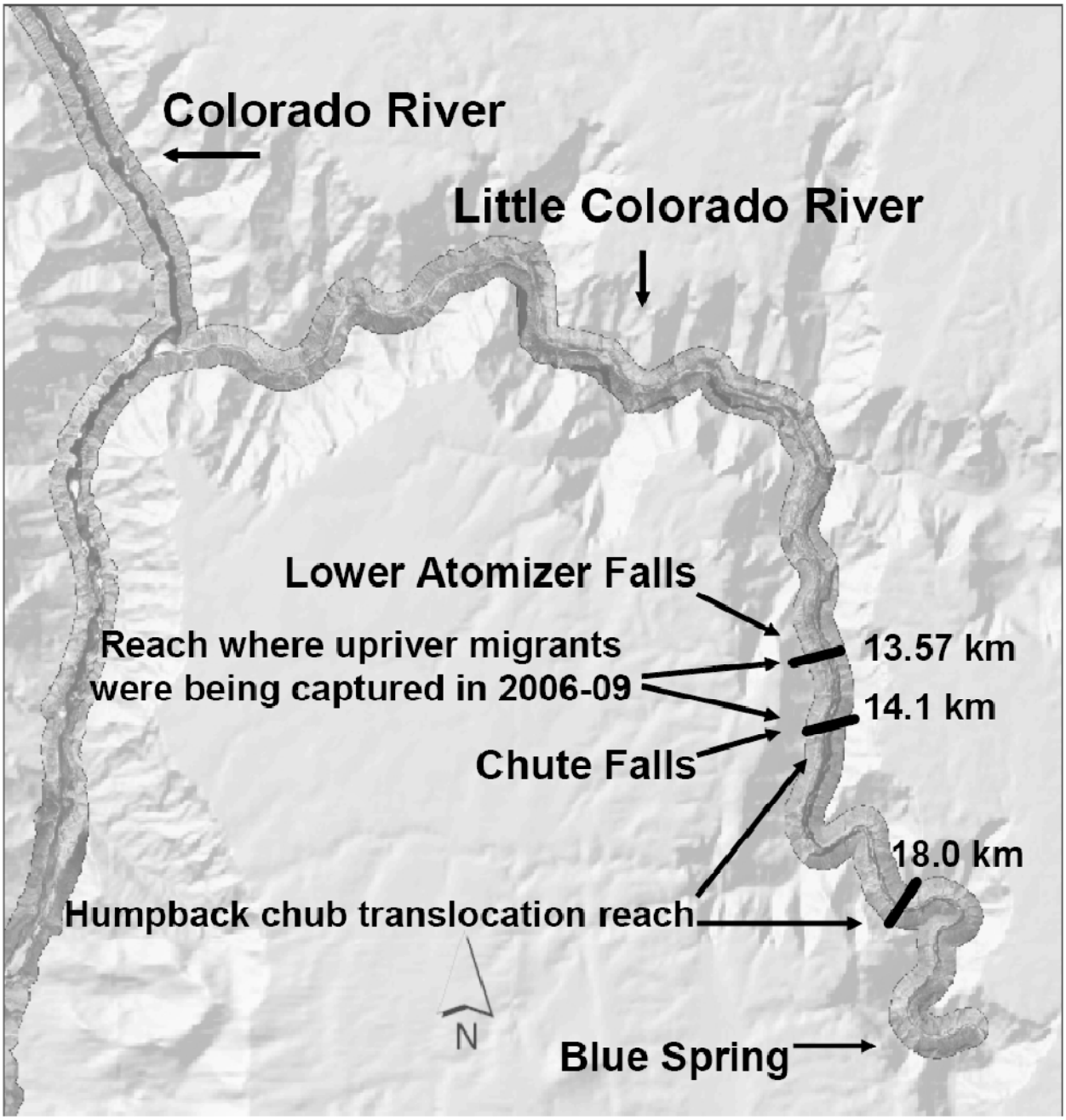

Figure 5. Map of reaches of the Little Colorado River, Arizona, where humpback chub have been captured in monitoring of translocation efforts. The lower reach includes the river corridor from the top of Lower Atomizer Falls (13.57 km [8.43 miles]) to below Chute Falls (14.11 km [8.77 miles]) and the upper reach includes the corridor from the top of Chute Falls to ~17.89 km (11.11 miles) (from from D. Stone, U.S. Fish and Wildlife Service, pers. comm., 2009).

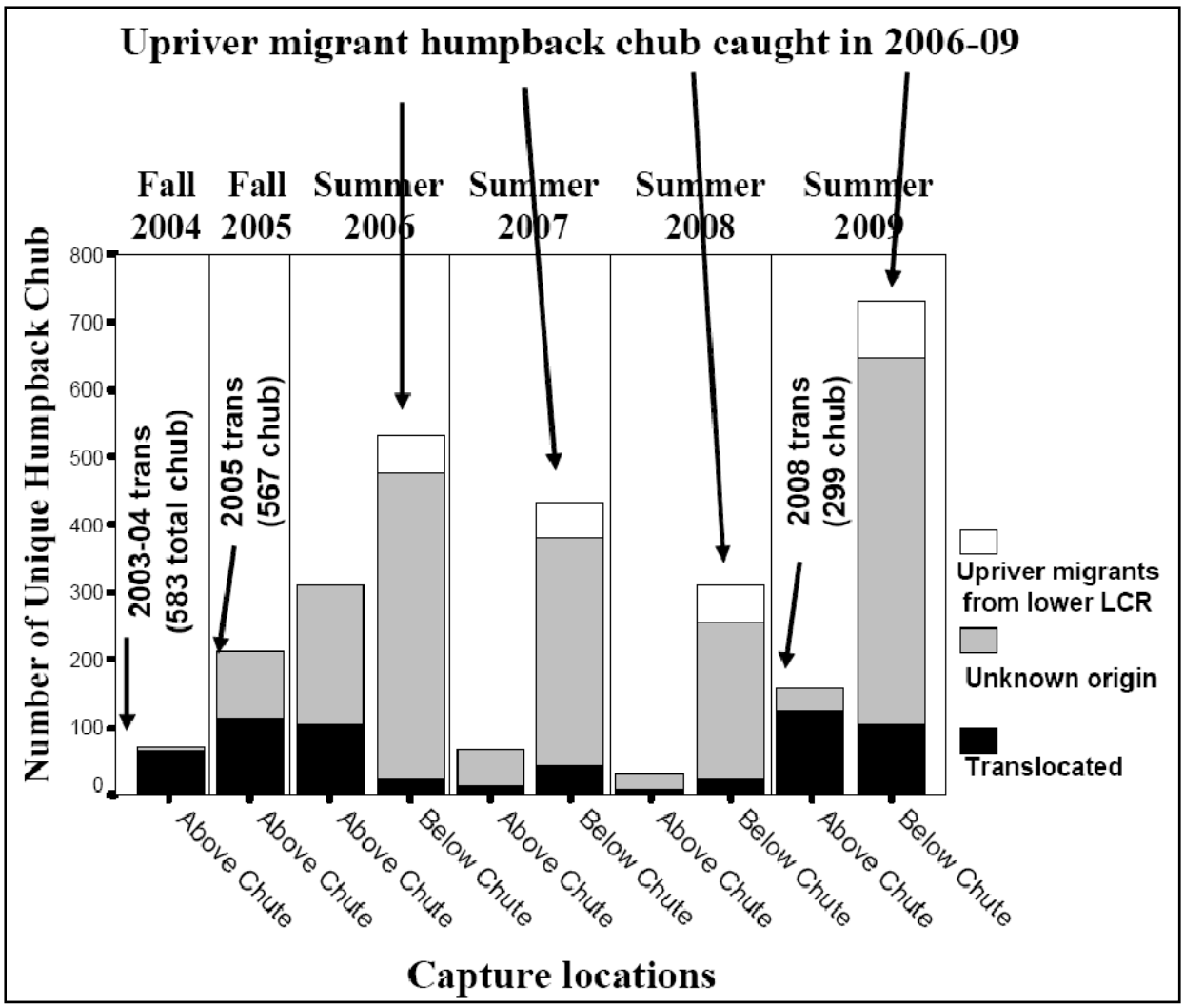

Figure 6. Upriver migrant humpback chub that were captured between Lower Atomizer and Chute Falls (13.57-14.11 km [8.43-8.77 miles]) in the Little Colorado River, Arizona, during the summers of 2006-09. A total of 53, 31, 32, and 48 new upriver migrants were caught in this reach during 2006-09 sampling trips, respectively, some of which have been repeatedly recaptured over subsequent years (from D. Stone, U.S. Fish and Wildlife Service, pers. comm., 2009).

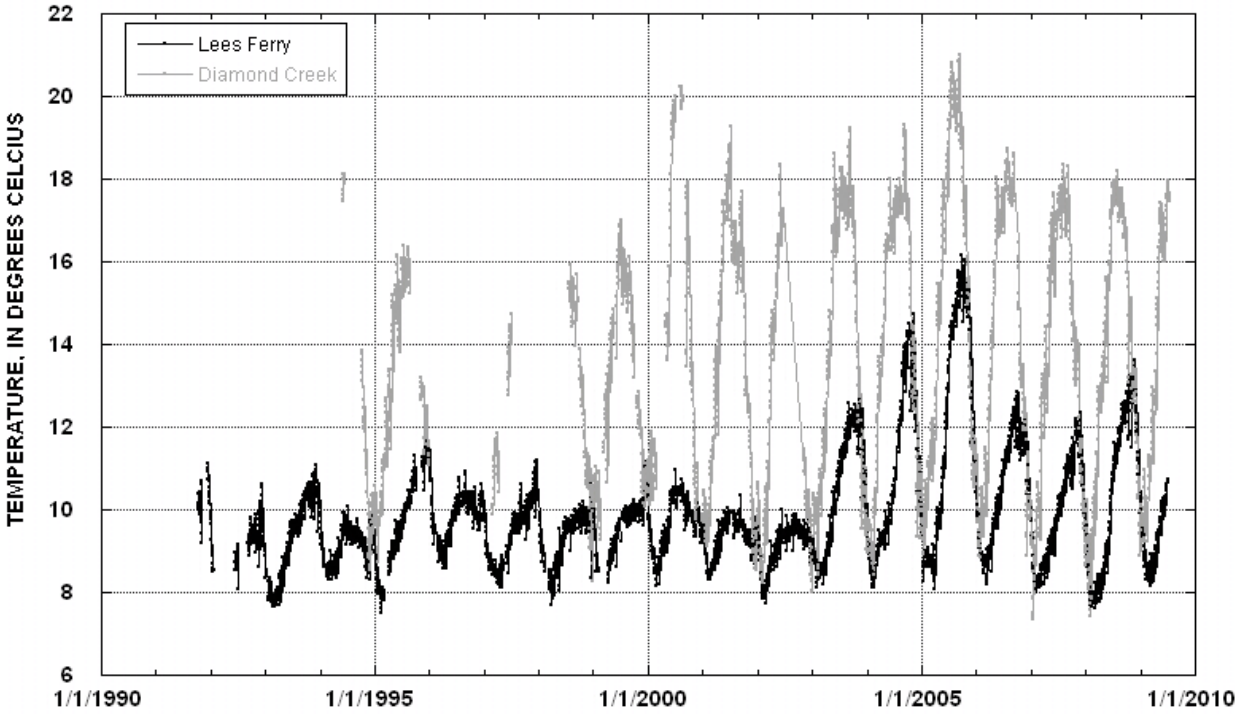

Figure 7. Mainstem Colorado River water temperatures at Lees Ferry and Diamond Creek, 1991-2009.

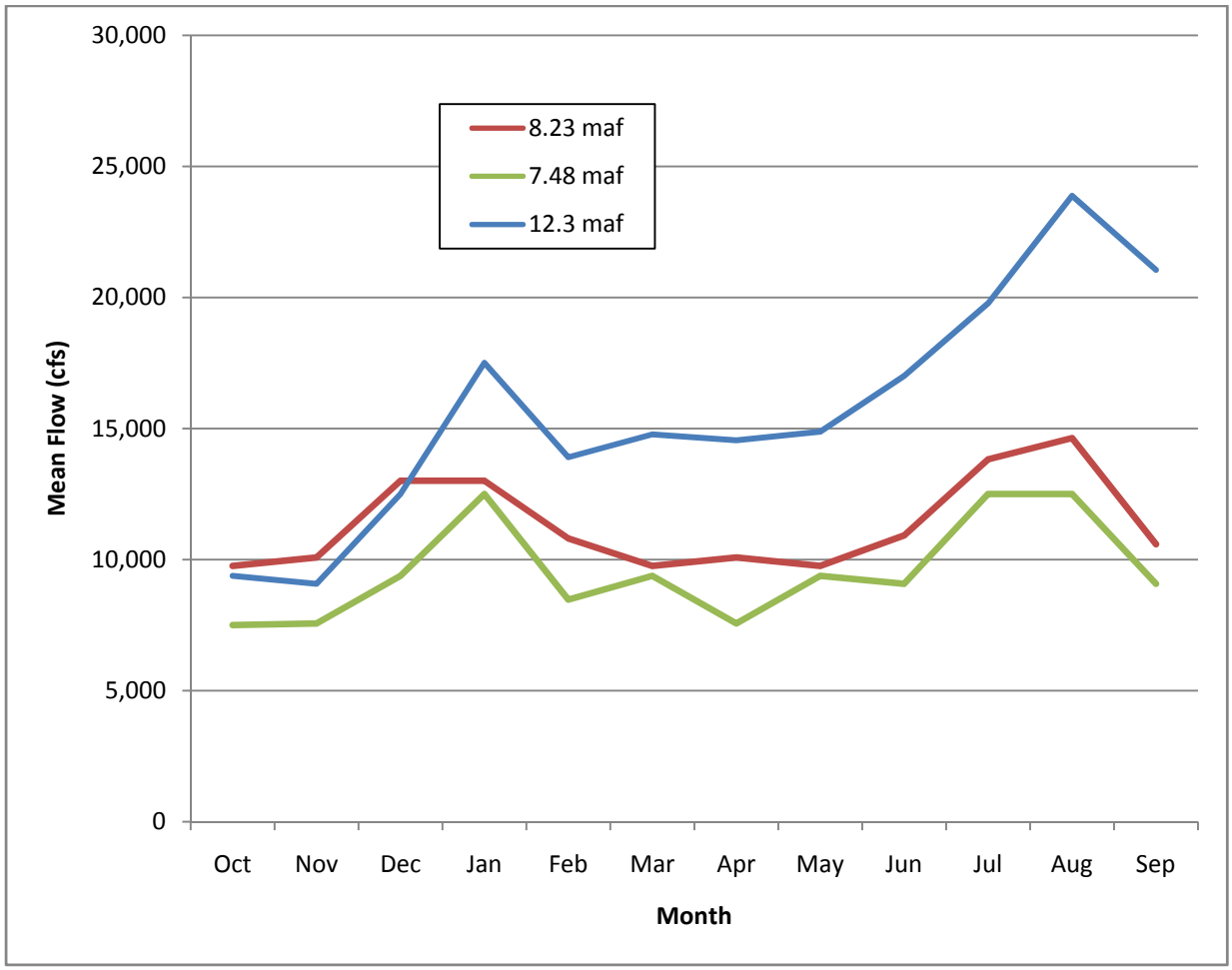

Figure 8. Average monthly (mean) flow in cubic feet per second of Glen Canyon Dam releases during a 7.48 million acre foot (maf), 8.23 maf, and a 12.3 maf release year, based on U.S. Bureau of Reclamation projected releases (see Table 2).

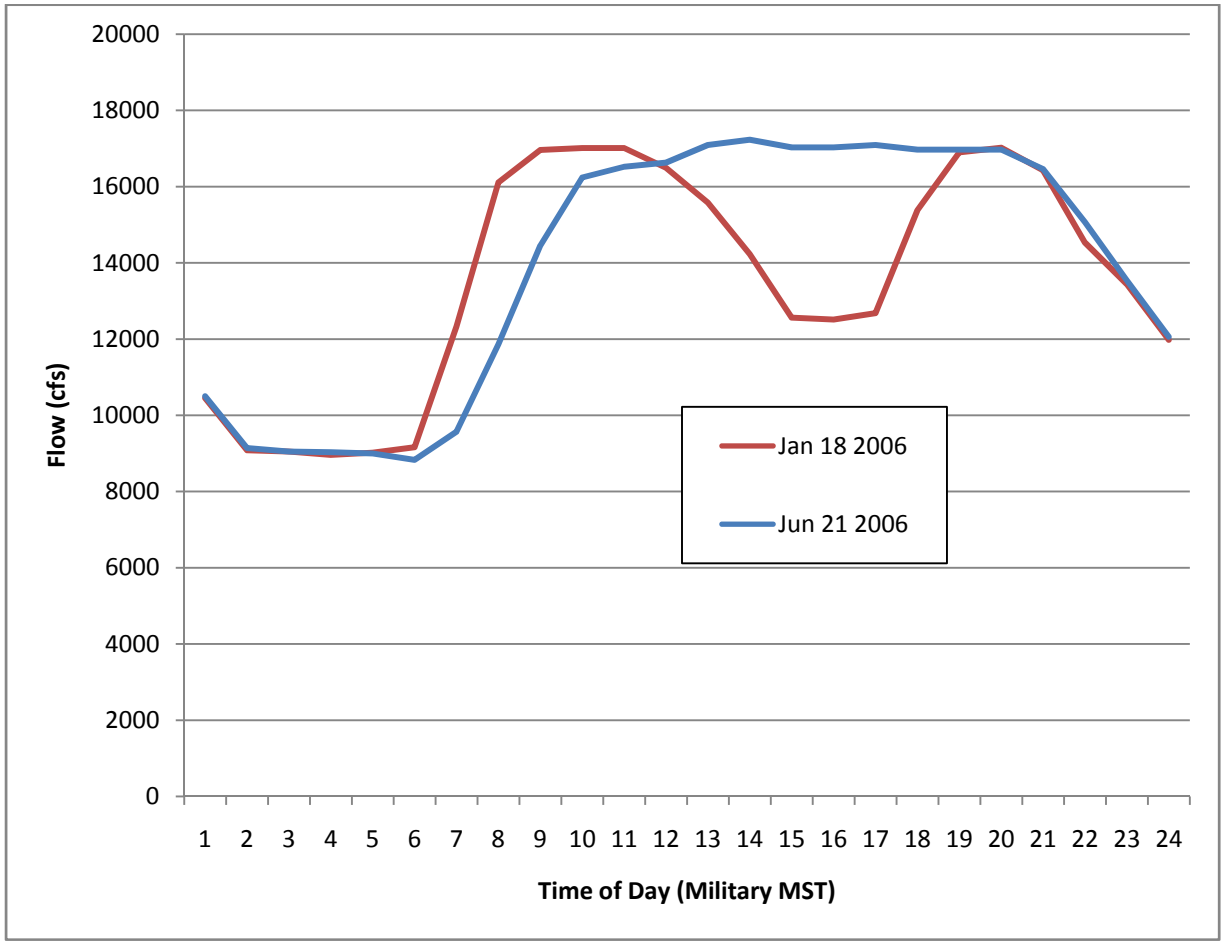

Figure 9. Actual daily flow in cubic feet per second of Glen Canyon Dam releases for Wednesday January 18, 2006, and Wednesday June 21, 2006, illustrating daily flow fluctuation in response to changing electricity demand.

APPENDICES

APPENDIX A: CONCURRENCES

Concurrence for the Supplemental Biological Opinion for Glen Canyon Dam Operations for the Period 2008-2012

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

Proposed Project

This appendix contains the FWS updated concurrences 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) and in response to the Court Order to further evaluate the proposed action with regard to the MLFF (U.S. District Court 2009). We have supplemented the concurrences in the 2008 Opinion with this additional information analyzing the effects of MLFF on these species. We refer to the original 2008 Opinion for information on our concurrence relative to other aspects of Reclamation's proposed action. The proposed Federal action is described in the Proposed Action section of the attached biological opinion and of the FWS biological opinion on the operation of Glen Canyon Dam (2008 Opinion) (U.S. Fish and Wildlife Service 2008a). 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. No critical habitat for the southwestern willow flycatcher occurs in the action area, thus none will be affected. 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 2002c). 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, flat-water 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). The general PCEs for razorback sucker are the same as for the humpback chub. These consist of: water, of an adequate quantity of water (W2), and water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, turbidity, etc.)(W1) that is delivered to a specific location in accordance with a hydrologic regime that is required for the particular life stage for the species; physical habitat, that includes areas of the Colorado River system that are inhabited by fish or potentially habitable for use in spawning (P1), nursery (P2), feeding (P3), and rearing (P4), or corridors between these areas; and biological environment, food supply (B1), predation (B2), and competition (B3). Food supply is a function of nutrient supply, productivity, and availability to each life stage of the species. Predation, although considered a normal component of this environment, is out of balance due to introduced fish species in some areas. This is also true of competition from nonnative fish species.

The MLFF affects razorback sucker critical habitat in Grand and Marble canyons in the same ways it affects humpback chub critical habitat, primarily by cooling water temperatures and a displacement and dewatering effect on nearshore habitats from daily fluctuations in flow. But razorback suckers have always been rare in the action area, and the ability of the Colorado River in the action area to fully provide the PCEs is uncertain, even historically. It is unclear if the necessary PCEs of critical habitat are present in Grand Canyon, or even if they were historically. Information on razorback sucker use of riverine habitat available from the Upper Basin indicates the species has variable habitat requirements, with adults in rivers using deep runs, eddies, backwaters, and flooded off-channel environments in spring; runs and pools often in shallow water associated with submerged sandbars in summer; and low-velocity runs, pools, and eddies in winter (U.S. Fish and Wildlife Service 2002c). Razorback suckers historically migrated as adults to spawn, often over long-distances, thus their historical presence in Grand Canyon may have been as a movement corridor.

Spawning in rivers occurs over bars of cobble, gravel, and sand substrates during spring runoff at widely ranging flows and water temperatures and spawning in reservoirs takes place over rocky shoals and shorelines. Spawning habitat may be available for razorback suckers in Grand Canyon. Spawning of razorback sucker in Grand Canyon has never been documented, but cool temperatures could limit spawning. Young razorback suckers require nursery environments with quiet, warm, shallow water such as tributary mouths, backwaters, or inundated floodplains in rivers, and coves or shorelines in reservoirs (Valdez 1996, U.S. Fish and Wildlife Service 2002c). These habitats are very rare in Grand Canyon, and although they may have been historically more common following large flood events, the geology of the area, especially in steep canyon-bound reaches, would limit their development. The lack of suitable rearing habitats may be responsible for the low numbers of historical captures. A small but reproducing

population of razorback sucker occurs in Lake Mead, and this may be due to the presence of low-velocity marsh-like habitats on the shoreline at inflow areas of Lake Mead that are essential as nursery habitat.

Razorback sucker is very rare in Grand Canyon, and the area may not provide all of the PCEs of critical habitat, and it is not clear if the PCEs occurred historically. While the MLFF affects the PCEs of razorback sucker critical habitat in similar ways as it does humpback chub critical habitat, the PCEs may not be provided sufficiently regardless of the Glen Canyon Dam flow regime. Based on the rarity of razorback suckers in the action area, and the apparent lack of suitable habitat, MLFF is not expected to adversely affect razorback sucker critical habitat or diminish its function in recovery.

As part of their proposed action for the Shortage Guidelines, Reclamation has committed to investigating the potential for habitats in the action area to support razorback sucker, and to work to improve the status of razorback sucker in the action area, if appropriate. In collaboration with other agencies, programs, and stakeholders, Reclamation will commit funding to evaluating potential habitat within the GCDAMP 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

This species is very rare or absent in the action area, thus the probability of an adverse or beneficial effect from MLFF 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 began an effort to examine the potential of habitat in Grand Canyon for the species, and will institute an augmentation program in collaboration with FWS and the MSCP, 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. There is no critical habitat in the action area, thus none will be affected. A final recovery plan for the southwestern willow flycatcher was completed in 2002 (U.S. Fish and Wildlife Service 2002d).

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 (Holmes 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 (Holmes et al. 2005, James 2005). 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 (Holmes 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 (Christensen 2007, McLeod and Koronkiewicz 2008). The lack of flycatchers recently in Grand Canyon is likely more a function of decreasing numbers in more important areas nearby, like Lake Mead, than from changes in habitats in Grand Canyon. Nonnative tamarisk beetles have recently been found at Navajo Bridge and Brown's Inscription (RM 4 and RM 12). It is likely the beetle will spread through Grand Canyon, which may adversely affect much of the flycatcher habitat in the action area (G. Beatty, U.S. Fish and Wildlife Service, pers. comm., 2009).

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. However, willow flycatcher nests in Grand Canyon are typically above the 45,000 cfs stage, and thus would not be affected by the highest Glen Canyon Dam releases (Holmes et al. 2005). Flycatchers nest primarily in tamarisk shrub in the lower Grand Canyon (Sogge et al. 1997), which is quite common, and can tolerate very dry and saline soil conditions, and thus is capable of surviving lowered water levels (Glenn and Nagler 2005). Therefore, maximum flows of the MLFF of 25,000 cfs and minimum flows of 5,000 cfs are neither expected to scour or

significantly dewater habitats enough to kill or remove tamarisk, and no loss of southwestern willow flycatcher nesting habitat from flooding or desiccation is anticipated.

An important element of flycatcher nesting habitat is the presence of moist surface soil conditions (U.S. Fish and Wildlife Service 2002d). Moist surface soil conditions are maintained by overbank flow or high groundwater elevations supported by river stage, and provide nesting habitat of riparian trees, and habitat for insects that contribute to the food base for flycatchers. The MLFF flows have been implemented since 1991, and given the typical range of daily fluctuations, groundwater elevations adjacent to the channel are not expected to decline enough to significantly desiccate nesting habitat. 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 flows within the limits of the MLFF;
- The flow limits of the MLFF are not expected to desiccate flycatcher habitat to the point that food base for willow flycatcher is affected.

APPENDIX B: RECOVERY CRITERIA

Recovery Criteria from the draft Humpback Chub (*Gila cypha*)

Recovery Goals 2009 Revisions (U.S. Fish and Wildlife Service 2009)

5.2 Site-Specific Management Actions and Tasks by Recovery Factor

5.2.1 Upper basin recovery unit

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

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

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

Task A-1.2.—Provide flow regimes (as determined under Task A-1.1) that are necessary for all life stages of humpback chub to support recovered populations in Black Rocks, Westwater Canyon, Yampa Canyon, Desolation/Gray Canyons, and Cataract Canyon.

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

Management Action B-1.—Protect humpback chub populations from overutilization for commercial, recreational, scientific, or educational purposes (see section 4.2).

Task B-1.1.—Reevaluate and, if necessary, identify actions to ensure adequate protection from overutilization of humpback chub; not currently identified as an existing threat.

Task B-1.2.—Implement identified actions (as determined under Task B-1.1) to ensure adequate protection for humpback chub populations from overutilization.

5.2.1.3 Factor C.—Adequate protection from diseases and predation

Management Action C-1.—Minimize adverse effects of diseases and parasites on humpback chub populations (see sections 4.3.1 and A.12 for discussion of diseases and parasites).

Task C-1.1.—Reevaluate and, if necessary, identify actions to minimize adverse

effects of diseases and parasites on humpback chub populations; not currently identified as an existing threat in the upper basin.

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

Management Action C-2.—Regulate nonnative fish releases and escapement into the mainstem, floodplain, and tributaries (see sections 4.3.2 and A.8 for discussion of effects of nonnative fishes).

Task C-2.1.—Develop, implement, evaluate, and revise (as necessary through adaptive management) procedures for stocking nonnative fish species in the Upper Colorado River Basin to minimize negative interactions between nonnative fishes and humpback chub.

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

Management Action C-3.—Control problematic nonnative fishes as needed (see sections 4.3.2 and A.8 for discussion of effects of nonnative fishes).

Task C-3.1.—Develop channel catfish control programs in Yampa Canyon and Desolation/Gray Canyons to identify levels of control that will minimize negative interactions on humpback chub.

Task C-3.2.—Implement identified levels (as determined under Task C-3.1) of channel catfish control..

Task C-3.3.—Develop centrarchid control programs (e.g., smallmouth bass, largemouth bass, green sunfish, etc.) in Yampa Canyon and Desolation/Gray Canyons to identify levels of control that will minimize negative interactions on humpback chub.

Task C-3.4.—Implement identified levels (as determined under Task C-3.3) of smallmouth bass control.

5.2.1.4 Factor D.—Adequate existing regulatory mechanisms

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

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

Task D-1.2.—Implement mechanisms for legal protection of habitat (as determined under Task D-1.1).

Management Action D-2.—Provide for the long-term management and protection of humpback chub populations and their habitats after delisting.

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

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

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

Management Action E-1.—Minimize the threat of hybridization among *Gila* species in river reaches occupied by humpback chub (see sections 4.5.1 and A.3 for discussion of hybridization).

Task E-1.1.—Provide flow regimes that reflect inter-annual variability in hydrologic conditions in order to maintain natural proportions of *Gila* species and intergrades in Black Rocks, Westwater Canyon, Yampa Canyon, Desolation/Gray Canyons, and Cataract Canyon.

Management Action E-2.—Minimize the risk of hazardous-materials spills in critical habitat (see section 4.5.2 for discussion of hazardous-materials spills).

Task E-2.1.—Review and recommend modifications to State and Federal hazardous-materials spills emergency-response plans to ensure adequate protection for humpback chub populations from hazardous-materials spills, including prevention and quick response to hazardous-materials spills.

Task E-2.2.—Implement State and Federal emergency-response plans that contain the necessary preventive measures (as determined under Task E-2.1).

Task E-2.3.—Identify measures to minimize the risk of hazardous-materials spills in Black Rocks and Westwater Canyon from transport of materials along the

adjacent railway.

Task E-2.4.—Implement measures (as determined under Task E-2.3) to minimize the risk of hazardous-materials spills.

Task E-2.5.—Identify locations of all petroleum-product pipelines within the 100-year floodplain of critical habitat and assess the need for emergency shut-off valves to minimize the potential for spills.

Task E-2.6.—Install emergency shut-off valves (as determined under Task E-2.5) on problematic petroleum-product pipelines.

5.2.2 Lower basin recovery unit

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

Management Action A-1.—Investigate the role of the mainstem Colorado River in maintaining the Grand Canyon humpback chub population and provide appropriate habitats in the mainstem as necessary for recovery.

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

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

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

Task A-2.1.—As determined necessary and feasible, continue to operate Glen Canyon Dam water releases under adaptive management to benefit humpback chub in the mainstem Colorado River through Grand Canyon (see section 4.1 for discussion of existing releases from Glen Canyon Dam and for discussion of humpback chub flow-habitat requirements; see Appendix A for synopsis of humpback chub life history).

Task A-2.2.—Identify, implement, evaluate, and revise (as necessary through adaptive management) a flow regime in the Little Colorado River to benefit humpback chub.

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

Management Action A-3.—Investigate the anticipated effects of and options for providing suitable water temperatures in the mainstem Colorado River through Grand

Canyon that would allow for range expansion of the Grand Canyon humpback chub population and provide appropriate water temperatures if determined feasible and necessary for recovery.

Task A-3.1.—Determine the effects and feasibility of a temperature control device for Glen Canyon Dam to provide suitable water temperatures in the mainstem Colorado River through Grand Canyon that would allow for range expansion of humpback chub.

Task A-3.2.—Implement a temperature control device for Glen Canyon Dam if determined feasible and necessary for recovery of humpback chub.

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

Management Action B-1.—Protect humpback chub populations from overutilization for commercial, recreational, scientific, or educational purposes (see section 4.2).

Task B-1.1.—Reevaluate and, if necessary, identify actions to ensure adequate protection from overutilization of humpback chub for commercial, recreational, scientific, or educational purposes; not currently identified as an existing threat.

Task B-1.2.—Implement identified actions (as determined under Task B-1.1) to ensure adequate protection for humpback chub populations from overutilization.

5.2.2.3 Factor C.—Adequate protection from diseases and predation

Management Action C-1.—Control Asian tapeworm as needed (see sections 4.3.1 and A.12 for discussion of diseases and parasites).

Task C-1.1.—Develop an Asian tapeworm control program in the Little Colorado River to identify the levels of control that will minimize the negative effects of parasitism on the humpback chub population.

Task C-1.2.—Implement identified levels (as determined under Task C-1.1) of Asian tapeworm control in the Little Colorado River.

Management Action C-2.—Regulate nonnative fish releases and escapement into the mainstem, floodplain, and tributaries (see sections 4.3.2 and A.8 for discussion of effects of nonnative fishes).

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

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

Management Action C-3.—Control problematic nonnative fishes as needed (see sections 4.3.2 and A.8 for discussion of effects of nonnative fishes).

Task C-3.1.—Develop rainbow trout, channel catfish, black bullhead, and common carp control programs in the Little Colorado River to identify levels of control that will minimize negative interactions on humpback chub.

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

Task C-3.3.—Develop brown trout and rainbow trout control programs in the Colorado River through Grand Canyon to identify levels of control that will minimize negative interactions on humpback chub.

Task C-3.4.—Implement identified levels (as determined under Task C-3.3) of brown trout and rainbow trout control in the Colorado River through Grand Canyon.

Task C-3.5.—Develop control programs for warmwater nonnative fishes in the Colorado River through Grand Canyon to identify levels of control that will minimize negative interactions on humpback chub.

Task C-3.6.—Implement identified levels (as determined under Task C-3.3) of warmwater nonnative fish control in the Colorado River through Grand Canyon.

5.2.2.4 Factor D.—Adequate existing regulatory mechanisms

Management Action D-1.—Legally protect habitat (see definition of habitat in section 5.1.2) necessary to provide adequate habitat and sufficient range for all life stages of humpback chub to support a recovered Grand Canyon population, based on demographic criteria (see section 4.4 for discussion of regulatory mechanisms).

Task D-1.1.—Determine mechanisms for legal protection of adequate habitat in the mainstem Colorado River through Grand Canyon and the Little Colorado River through instream-flow rights, contracts, agreements, or other means.

Task D-1.2.—Implement mechanisms for legal protection of habitat in the mainstem Colorado River and the Little Colorado River (as determined under Task D-1.1) that are necessary to provide adequate habitat and sufficient range for all life stages of humpback chub to support a recovered Grand Canyon population.

Management Action D-2.—Provide for the long-term management and protection of humpback chub populations and their habitats after delisting.

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

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

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

Management Action E-1.—Minimize the risk of hazardous-materials spills in critical habitat (see section 4.5.2 for discussion of hazardous-materials spills).

Task E-1.1.—Review and recommend modifications to State and Federal hazardous-materials spills emergency-response plans to ensure adequate protection for humpback chub populations from hazardous-materials spills, including prevention and quick response to hazardous-materials spills.

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

Task E-1.3.—Identify measures to minimize the risk of hazardous-materials spills from transport of materials along U.S. Highway 89 at and near the Cameron Bridge spanning the Little Colorado River.

Task E-1.4.—Implement measures (as determined under Task E-1.3) to minimize risk of hazardous-materials spills from transport of materials along U.S. Highway 89 at and near the Cameron Bridge.

5.3.1 Downlist criteria

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

5.3.1.1.1 Upper basin recovery unit

1. Each of the five self-sustaining populations is maintained over a 5-year period, starting with the first point estimate acceptable to the Service, such that:

    a. the trend in adult (age 4+; ≥ 200 mm TL) point estimates does not decline significantly, and

    b. mean estimated recruitment of age-3 (150–199 mm TL) naturally produced fish equals or exceeds mean annual adult mortality, and

2. One of the five populations (e.g., Black Rocks/Westwater Canyon or Desolation/Grey Canyons) is maintained as a core population such that each point estimate exceeds 2,100 adults (Note: 2,100 is the estimated MVP number; see section 3.3.2).

5.3.1.1.2 Lower basin recovery unit

1. The Grand Canyon population is maintained as a core over a 5-year period, starting with the first point estimate acceptable to the Service, such that:

    a. the trend in adult (age 4+; ≥ 200 mm TL) point estimates does not decline significantly, and

    b. mean estimated recruitment of age-3 (150–199 mm TL) naturally produced fish equals or exceeds mean annual adult mortality, and

    c. each core population point estimate exceeds 2,100 adults (MVP).

5.3.1.2 Recovery factor criteria for downlisting (recovery factor criteria in both recovery units must be met in order to achieve downlisting)

5.3.1.2.1 Upper basin recovery unit

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

1. Flow regimes to benefit humpback chub populations in the upper Colorado, Green, and Yampa rivers identified, implemented, evaluated, and revised (Task A-1.1), such that:

    a. Adequate spawning habitat and appropriate spawning cues (e.g., flow patterns and water temperatures) are available to maintain self-sustaining populations, as reflected by downlisting demographic criteria in section 5.3.1.1.1.

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

section 5.3.1.1.1.

c. Adequate juvenile and adult habitat (e.g., cover, resting, and feeding areas) is available to maintain self-sustaining populations, as reflected by downlisting demographic criteria in section 5.3.1.1.1.

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

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

Factor C.—Adequate protection from diseases and predation.

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

4. Procedures developed, implemented, evaluated, and revised for stocking nonnative fish species in the Upper Colorado River Basin to minimize negative interactions between nonnative fishes and humpback chub (Task C-2.1).

5. Channel catfish control programs developed and implemented to identify levels of control that will minimize negative interactions on humpback chub in Yampa Canyon and Desolation/Gray Canyons (Task C-3.1).

6. Centrarchid control programs (e.g., smallmouth bass, largemouth bass, green sunfish, etc.) developed and implemented to identify levels of control that will minimize negative interactions on humpback chub in Yampa Canyon and Desolation/Gray Canyons (Task C-3.3).

Factor D.—Adequate existing regulatory mechanisms.

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

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

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

9. Flow regimes identified that reflect inter-annual variability in hydrologic

conditions in order to maintain natural proportions of *Gila* species and intergrades in Black Rocks, Westwater Canyon, Yampa Canyon, Desolation/Gray Canyons, and Cataract Canyon (Task E-1.1).

10. State and Federal hazardous-materials spills emergency-response plans reviewed and modified to ensure adequate protection for humpback chub populations from hazardous-materials spills (Task E-2.1).
11. Measures identified to minimize the risk of hazardous-materials spills in Black Rocks and Westwater Canyon from transport of materials along the adjacent railway (Tasks E-2.3).

12. Locations of all petroleum-product pipelines within the 100-year floodplain of critical habitat identified and the need for emergency shut-off valves assessed (Task E-2.5).

5.3.1.2.2 Lower basin recovery unit

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

1. Life stages and habitats of humpback chub in the mainstem Colorado River identified and the relationship between individuals in the mainstem and the Little Colorado River determined (Task A-1.1).

2. Operations of Glen Canyon Dam to benefit humpback chub in the Colorado River through Grand Canyon continued (Task A-2.1) and a flow regime to benefit humpback chub in the Little Colorado River identified, implemented, evaluated, and revised (Task A-2.2), such that:

    a. Adequate spawning habitat and appropriate spawning cues (e.g., flow patterns and water temperatures) are available to maintain a self-sustaining population, as reflected by downlisting demographic criteria in section 5.3.1.1.2.

    b. Adequate nursery habitat is available to maintain a self-sustaining population, as reflected by downlisting demographic criteria in section 5.3.1.1.2.

    c. Adequate juvenile and adult habitat (e.g., cover, resting, and feeding areas) is available to maintain a self-sustaining population, as reflected by downlisting demographic criteria in section 5.3.1.1.2.

3. Effects and feasibility of a temperature control device for Glen Canyon Dam to provide suitable water temperatures in the mainstem Colorado River through Grand Canyon that would allow for range expansion of humpback chub determined (Task A-3.1).

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

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

Factor C.—Adequate protection from diseases and predation.

5. Asian tapeworm control program developed and implemented in the Little Colorado River to identify levels of control that will minimize the negative effects of parasitism on the humpback chub population (Task C-1.1).

6. Procedures developed, implemented, evaluated, and revised for stocking and to minimize escapement of nonnative fish species into the Colorado River and its tributaries through Grand Canyon to minimize negative interactions between nonnative fishes and humpback chub (Task C-2.1).

7. Rainbow trout, channel catfish, black bullhead, and common carp control programs developed and implemented to identify levels of control that will minimize negative interactions on humpback chub in the Little Colorado River (Task C-3.1).

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

9. Warmwater nonnative fishes control programs developed and implemented to identify levels of control that will minimize negative interactions on humpback chub in the Colorado River through Grand Canyon (Task C-3.5).

Factor D.—Adequate existing regulatory mechanisms.

10. Mechanisms determined for legal protection of adequate habitat in the mainstem Colorado River through Grand Canyon and the Little Colorado River (Task D-1.1).

11. Elements of conservation plans identified that are necessary to provide for the long-term management and protection of humpback chub populations after delisting (Task D-2.1).

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

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

13. Measures identified to minimize the risk of hazardous-materials spills from transport of materials along U.S. Highway 89 at and near the Cameron Bridge spanning the Little Colorado River (Task E-1.3).

5.3.2 Delist criteria

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

5.3.2.1.1 Upper basin recovery unit

1. Each of the five self-sustaining populations is maintained over a 3-year period beyond downlisting, starting with the first point estimate acceptable to the Service, such that:

    a. the trend in adult (age 4+; ≥ 200 mm TL) point estimates does not decline significantly, and

    b. mean estimated recruitment of age-3 (150–199 mm TL) naturally produced fish equals or exceeds mean annual adult mortality, and

2. Two of the five populations (e.g., Black Rocks/Westwater Canyon and Desolation/Grey Canyons) are maintained as core populations such that each point estimate exceeds 2,100 adults (MVP).

5.3.2.1.2 Lower basin recovery unit

1. The Grand Canyon population is maintained as a core over a 3-year period beyond downlisting, starting with the first point estimate acceptable to the Service, such that:

    a. the trend in adult (age 4+; ≥ 200 mm TL) point estimates does not decline significantly, and

    b. mean estimated recruitment of age-3 (150–199 mm TL) naturally produced fish equals or exceeds mean annual adult mortality, and

    c. each core population point estimate exceeds 2,100 adults (MVP).

5.3.2.2 Recovery factor criteria for delisting (recovery factor criteria in both recovery units must be met in order to achieve delisting)

5.3.2.2.1 Upper basin recovery unit

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

1. Flow regimes provided that are necessary for all life stages of humpback chub to support recovered populations in Black Rocks, Westwater Canyon, Yampa Canyon, Desolation/Gray Canyons, and Cataract Canyon (Task A-1.2), such that:

    a. Adequate spawning habitat and appropriate spawning cues (e.g., flow patterns and water temperatures) are available to maintain self-sustaining populations, as reflected by delisting demographic criteria in section 5.3.2.1.1.

    b. Adequate nursery habitat is available to maintain self-sustaining populations, as reflected by delisting demographic criteria in section 5.3.2.1.1.

    c. Adequate juvenile and adult habitat (e.g., cover, resting, and feeding areas) is available to maintain self-sustaining populations, as reflected by delisting demographic criteria in section 5.3.2.1.1.

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

2. Adequate protection of humpback chub populations from overutilization for commercial, recreational, scientific, or educational purposes attained (Task B-1.2).

Factor C.—Adequate protection from diseases and predation.

3. Adequate protection of humpback chub populations from deleterious diseases and parasites attained (Task C-1.2).

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

5. Identified levels of channel catfish control to minimize negative interactions on humpback chub attained in Yampa Canyon and Desolation/Gray Canyons (Task C-3.2).

6. Identified levels of smallmouth bass control to minimize negative interactions on humpback chub attained in Yampa Canyon and Desolation/Gray Canyons (Task C-3.4).

Factor D.—Adequate existing regulatory mechanisms.

7. Habitat necessary to provide adequate habitat and sufficient range for all

life stages of humpback chub to support recovered populations in Black Rocks, Westwater Canyon, Yampa Canyon, Desolation/Gray Canyons, and Cataract Canyon is legally protected in perpetuity (Task D-1.2).

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

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

9. Flow regimes provided that reflect inter-annual variability in hydrologic conditions in order to maintain natural proportions of *Gila* species and intergrades in Black Rocks, Westwater Canyon, Yampa Canyon, Desolation/Gray Canyons, and Cataract Canyon (Task E-1.1).

10. State and Federal emergency-response plans implemented that contain the necessary preventive measures for hazardous-materials spills (Task E-2.2).

11. Measures finalized and implemented to minimize the risk of hazardous-materials spills in Black Rocks and Westwater Canyon from transport of materials along the adjacent railway (Task E-2.4).

12. Emergency shut-off valves installed on all problematic petroleum-product pipelines within the 100-year floodplain of critical habitat (Task E-2.6).

5.3.2.2.2 Lower basin recovery unit

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

1. Appropriate habitats for humpback chub in the mainstem Colorado River provided (Task A-1.2).

2. Flow regimes provided in the mainstem Colorado River and the Little Colorado River (Task A-2.3) that are necessary for all life stages of humpback chub to support a recovered Grand Canyon population, such that:

    a. Adequate spawning habitat and appropriate spawning cues (e.g., flow patterns and water temperatures) are available to maintain self-sustaining populations, as reflected by delisting demographic criteria in section 5.3.2.1.2.

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

section 5.3.2.1.2.

c. Adequate juvenile and adult habitat (e.g., cover, resting, and feeding areas) is available to maintain self-sustaining populations, as reflected by delisting demographic criteria in section 5.3.2.1.2.

3. Temperature control device for Glen Canyon Dam implemented, if determined feasible and necessary for recovery of humpback chub (Task A-3.2).

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

4. Adequate protection of humpback chub populations from overutilization for commercial, recreational, scientific, or educational purposes attained (Task B-1.2).

Factor C.—Adequate protection from diseases and predation.

5. Identified levels of Asian tapeworm control to minimize the negative effects of parasitism on the humpback chub population attained in the Little Colorado River (Task C-1.2).

6. Procedures finalized and implemented for stocking and to minimize escapement of nonnative fish species into the Colorado River and its tributaries through Grand Canyon to minimize negative interactions between nonnative fishes and humpback chub (Task C-2.2).

7. Identified levels of rainbow trout, channel catfish, black bullhead, and common carp control to minimize negative interactions on humpback chub attained in the Little Colorado River (Task C-3.2).

8. Identified levels of brown trout and rainbow trout control to minimize negative interactions on humpback chub attained in the Colorado River through Grand Canyon (Task C-3.4).

9. Identified levels of warmwater nonnative fishes control to minimize negative interactions on humpback chub attained in the Colorado River through Grand Canyon (Task C-3.6).

Factor D.—Adequate existing regulatory mechanisms.

10. Habitat necessary to provide adequate habitat and sufficient range for all life stages of humpback chub to support a recovered Grand Canyon population is legally protected in perpetuity (Task D-1.2).

11. Conservation plans developed and implemented and agreements among

State agencies, Federal agencies, American Indian Tribes, and other interested parties executed to provide reasonable assurances that conditions needed for the recovered Grand Canyon humpback chub population will be maintained after delisting (Task D-2.2).

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

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

13. Measures finalized and implemented to minimize the risk of hazardous-materials spills from transport of materials along U.S. Highway 89 at and near the Cameron Bridge spanning the Little Colorado River (Task E-1.4).

APPENDIX C: LIST OF ACRONYMS

Act	Endangered Species Act of 1973
ASMR	Age Structured Mark Recapture Model
AOP	Annual Operating Plan
cfs	cubic feet per second
C	degrees Centigrade
CRBPA	Colorado River Basin Project Act of 1968
EIS	Environmental Impact Statement
FSFP	Fall Steady Flow Plan
FWS	U.S. Fish and Wildlife Service
GCDAMP	Glen Canyon Dam Adaptive Management Program
GCMRC	Grand Canyon Monitoring and Research Center
LROC	Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs
maf	million acre feet
mm	millimeter
MLFF	Modified Low Fluctuating Flow
MSCP	Lower Colorado River Multi-Species Conservation Program
NSE	Nearshore Ecology Study
PIT	Passive Integrated Transponder
PCE	Primary Constituent Element
RM	River Mile
Reclamation	U.S. Bureau of Reclamation
ROD	Record of Decision
SASF	Seasonally Adjusted Steady Flow
TL	total length
UCRRP	Upper Colorado River Endangered Fish Recovery Program
USGS	U.S. Geological Survey