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In Reply Refer To:
AESO/SE
22410-2011-F-0100
22410-2011-F-0112

December 23, 2011

Memorandum

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

From: Field Supervisor

Subject: Final Biological Opinion on the Operation of Glen Canyon Dam including High Flow Experiments and Non-Native Fish Control

Thank you for your request for formal consultation with the U.S. Fish and Wildlife Service (FWS) pursuant to section 7 of the Endangered Species Act of 1973 (16 U.S.C. 1531-1544), as amended (ESA). Your January 2011 request was supplemented with Biological Assessment (BA) dated July 13, 2011, and received by us on July 15, with supplements provided as described in the Consultation History section of this document. At issue are impacts that may result from the proposed 10-year continued operation of Glen Canyon Dam under the Modified Low Fluctuating Flows (MLFF) alternative along with High Flow Experimental (HFE) Releases and Non-Native Fish (NNFC) Control downstream from Glen Canyon Dam (GCD), Coconino County, Arizona.

The Bureau of Reclamation (Reclamation) concluded that the proposed action "may affect, and is likely to adversely affect" the humpback chub (*Gila cypha*) and its critical habitat, the razorback sucker (*Xyrauchen texanus*) and its critical habitat, and the Kanab ambersnail (*Oxyloma kanabensis haydenii).* You also concluded that the proposed action "may affect, but is not likely to adversely affect" the southwestern willow flycatcher (*Empidonax traillii extimus*). We concur with your determination on the flycatcher and provide our rationale in Appendix A.

This biological opinion (Opinion) replaces the 2008 Final Biological Opinion on the Operation of Glen Canyon Dam (USFWS 2008a, consultation number 22410-1993-F-R1 and the court ordered supplements to that opinion). This Opinion is based on information provided in Reclamation's January and July BAs biological assessments on HFE Releases and NNFC, the draft environmental assessment on HFE Releases and NNFC, telephone conversations and meetings between our staff, and other sources of information found in the administrative record supporting this Opinion. All other aspects of the proposed action remain the same as described in the Environmental Assessments (EA) and BAs. Literature cited in this biological opinion is not a complete bibliography of all literature available on the species of concern. A complete administrative record of this consultation is on file at this office. The proposed action is the continued operation of Glen Canyon Dam under MLFF with the inclusion of a protocol for high-flow experimental releases from Glen Canyon Dam and non-native fish control for the 10-year period, 2011 through 2020. It is the FWS's biological opinion that the action, as proposed, is not likely to jeopardize the continued existence of the humpback chub, razorback sucker, or Kanab ambersnail and is not likely to destroy or adversely modify designated critical habitat for razorback sucker or humpback chub. A Table of Contents is provided below.

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Consultation history

January 14, 2011

Reclamation submitted a BA and requested initiation of formal consultation on the Development and Implementation of a Protocol for High-Flow Experimental Releases from Glen Canyon Dam, Arizona, 2011-2020.

January 28, 2011

Reclamation submitted a BA, Draft EA, and requested informal consultation on implementation of Non-native Fish Control downstream from Glen Canyon Dam, Arizona, 2011-2020.

March 17, 2011

FWS submitted separate comments for the following: Draft EA for Development and Implementation of a Protocol for High-Flow Experimental Releases from Glen Canyon Dam (HFE Protocol), Arizona, 2011-2020; and Draft EA for Non-native Fish Control Downstream from Glen Canyon Dam (Non-native Fish Control). These reviews provided input on biological analysis and conservation needs for humpback chub, non-listed native species, and other fish and wildlife resources.

June 6, 2011

The FWS provided additional comments (email memorandum) for continuing issues to be addressed.

July 18, 2011

Reclamation submitted a Supplement to the BA responding to input received from, among others, FWS (as described above), and requested that the proposed action be modified to include:

1. A fuller description clarifying baseline operations that would form the basis for HFE implementation (the MLFF alternative as described in the 1995 Environmental Impact Statement and adopted in the 1996 ROD) for the 10-year period from 2011-2020.

2. Non-native fish control in the Little Colorado River (LCR) reach only when the number of adult humpback chub falls below 7,000.

3. A request that the proposed HFE protocol, non-native fish control (two separate BAs), and continued ROD operations (2011-2020) be evaluated in a single biological opinion. July 26, 2011 - FWS sent a memo to Reclamation acknowledging the request for the modified proposed action (re: non-native fish control), and the request for a single biological opinion and expedited consultation.

August 24, 2011 and
August 25, 2011

Informal meetings between Reclamation and the FWS in Phoenix, Arizona concerning the BAs for Non-native Control and High Flow Experiment. Notes compiled by Reclamation staff.

August 31, 2011

Conference call between Reclamation and FWS with notes by Reclamation staff.

September 2, 2011

Conference call between Reclamation, FWS, National Park Service (NPS), and Grand Canyon Monitoring and Research Center (GCMRC) to discuss the scientific merits of some potential changes to the proposed action.

September 6 - 8, 2011

FWS participated in the National Historic Preservation Act Section 106 Meeting in Phoenix along with Federal, State, Tribal, and private partners. FWS staffs discuss with meeting attendees the ongoing section 7 consultation.

October 4, 2011

Reclamation and FWS agree to general conservation measures for the draft biological opinion. Reclamation requests final Opinion by the end of November.

October 27, 2011

Reclamation sent revised Conservation Measures to FWS.

November 8, 2011 and
November 18, 2011

Conference calls with DOI, Reclamation, and FWS to review status of draft Opinion. Some revisions of conservation measures were provided.

November 25, 2011

FWS sent draft biological opinion to Reclamation for agency review.

November 30, 2011

Reclamation provides comments on the draft Opinion and requests review of a second draft.

December 6, 2011

Second revised draft Opinion provided to Reclamation for review.

December 8, 2011

Reclamation responded to second draft Opinion.

December 14, 2011
Third draft Opinion provided to Reclamation for review.

December 20, 2011
Conference call between FWS and Reclamation. Reclamation provides comments on the third draft document.

December 21, 2011 and
December 22, 2011
Reclamation and FWS discuss final draft biological opinion.

BIOLOGICAL OPINION

DESCRIPTION OF THE PROPOSED ACTION

The proposed action is the continued operation of Glen Canyon Dam under MLFF with the inclusion of a protocol for high-flow experimental releases from Glen Canyon Dam and non-native fish control for the 10-year period, 2011 through 2020. The 10-year period for the proposed action is based on the experimental development of the high-flow protocol, allowing a sufficient period of time to assess the long-term effects of repeated high-flow releases as a potential action to benefit downstream resources. The Department is also undertaking an Environmental Impact Statement (EIS) process to evaluate the Long-Term Experimental and Management Plan (LTEMP) which will be addressed as a separate Federal action.

HFEs

The proposed action is intended to meet the need for high-flow experimental releases during limited periods of the year when large amounts of sand from tributary inputs are likely to have accumulated in the channel of the Colorado River. HFEs restore sand bars in Grand Canyon which are thought to provide backwaters that are beneficial to humpback chub. Annual and monthly releases would follow prior decisions, including the MLFF flow regime adopted in the 1996 Record of Decision on Glen Canyon Dam Operations, and the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Reservoir Operations (Interim Guidelines). Fall steady flows as identified in the 2008 Opinion and the 2009 Supplemental Opinion[1] are also scheduled for September and October 2012 as part of the proposed action.

[1] On February 27, 2008, the Service issued to Reclamation a 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 Service to reevaluate the conclusion in the 2008 Opinion that the Modified Low Fluctuating Flow (MLFF) does not violate the Endangered Species Act (Case number CV-07-8164-PHX-DGC). The Court ordered the Service 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. The court noted that other portions of the biological opinion, the two components analyzing Reclamation's 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. The Service published a supplement to the 2008 Opinion (2009 Supplemental Opinion) in response to the Court Order. It provided a revised analysis of the effects of MLFF on endangered humpback chub and its critical habitat, and the endangered Kanab ambersnail. It also provides an explanation for why MLFF does not destroy or adversely modify humpback chub critical habitat and addressed whether MLFF will advance or impede chub recovery. On June 29,

The timing of HFE releases from Glen Canyon Dam would be March-April (spring) and October-November (fall); the magnitude would be between 31,500 cubic feet per second (cfs) and 45,000 cfs; and the duration would be from less than one hour to 96 hours. The precise number and sequence of HFEs over the 10-year experimental period cannot be predicted because of the uncertainty of water availability and sediment input, but one or two HFEs in a given year are possible.

A complete description of the proposed HFE protocol is provided in Reclamation's HFE Protocol EA (Reclamation 2011a) which we summarize here. Also, an expanded discussion of the past experimental actions regarding high flow testing is provided in the Environmental Baseline section below. With respect to the proposed action, the HFE protocol will consist of three components: (1) planning and budgeting, (2) modeling, and (3) decision and implementation. An annual report will assimilate and synthesize the information on the effects of HFEs, including the status and trends of key resources in the action area. This information will be used by the Department of the Interior to assist with the decision on whether to pursue one or more HFEs in any given year.

The HFE Protocol modeling component uses real-time sediment accounting/monitoring data to evaluate conditions of sediment in the Colorado River in Marble and Grand Canyons. Sediment is accounted for during two accounting periods. The fall accounting period is July 1 through November 30, and the spring accounting period is December 1 through June 30. Based on the amount of sand input during the accounting periods and analysis results of the three HFE Protocol components, HFEs may be scheduled in one of two release windows, March-April and October-November. HFE release volume and magnitude will be based on available information including model recommendations.

Because the hydrology and sediment conditions are unpredictable, the magnitude, duration, and frequency of HFEs will not be prescribed in advance. Sediment conditions depend on periodic and unpredictable tributary floods in the Paria River, and annual releases from GCD also vary considerably based on Colorado River inflows into Lake Powell. Colorado River inflows into Lake Powell can be modeled using Reclamation's Colorado River Simulation System (CRSS). The CRSS uses the last 100 years of Colorado River hydrology to establish dry conditions (10^{th} percentile of the last 100 years of annual river flows), moderate conditions (50^{th} percentile), and wet conditions (90^{th} percentile). Reclamation analyzed nine traces of hydrology and sediment conditions by combining three hydrology settings based on the CRSS (dry, moderate, and wet conditions of the Colorado River) with three sediment input settings from the Paria River: low sediment input (i.e. 1983, 862,000 metric tons), moderate sediment input (i.e. 1990, 1,334,000 metric tons), and high sediment input (1934, 1,649,000 metric tons). Using these nine possible combinations, the model simulates random sediment input and hydrology for a 10-year period. The simulation is not predictive of future events, but provides an example of how HFEs might be conducted under a maximum 10-year experimental period. The above-mentioned LTEMP is

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2010, the District Court issued an order remanding the 2009 Incidental Take Statement to the Service for further consideration. On March 30, 2011, the District Court issued a final order upholding the Service's court ordered revision to the 2009 Incidental Take Statement and terminating the case. On October 18, 2011, Plaintiff filed its opening appellate brief with the 9^{th} Circuit Court of Appeals. The portions of the 2008 Opinion and 2009 Supplemental Opinion that have been upheld by the District Court are incorporated by reference in this opinion.

anticipated to provide an updated analysis of flow and non-flow actions prior to the completion of the maximum 10-year experimental period for the HFE protocol.

Each of the nine traces was evaluated against 13 described HFEs to determine their possible occurrence in spring and fall for a hypothetical 10-year period. The type of HFE possible was determined by the volume of available sediment and water, as predicted through the modeling process. Based on these model simulations, an HFE could occur 56 percent of the time over the 10-year period. Of these HFEs, 91 percent had a peak magnitude of 45,000 cfs. Typically, HFEs occur in groups (consecutive HFEs); 80 percent of the HFEs had an HFE in the neighboring release window or accounting periods (i.e. 80 percent of HFEs were also consecutive).

Non-native fish control

The HFE proposes a program of high-flow releases that may increase the numbers of rainbow trout (*Oncorhynchus mykiss*) in the Lees Ferry reach (Wright and Kennedy 2011). An increase in trout population, as discussed in detail below, followed the 2008 HFE. The potential for increasing the numbers of trout by HFE's is an unintended consequence of the HFE. An increase in the trout population could result in greater downstream dispersal of trout into reaches of the Colorado River that are occupied by the humpback chub, where they prey upon and compete with this endangered species. Thus, Reclamation proposes to implement non-native fish control measures as described in the Non-native Fish Control Downstream from Glen Canyon Dam, 2011–2020 BA (Reclamation 2011b) and supplemental information provided by Reclamation staff. This portion of the proposed action could under limited circumstances remove trout from the LCR and tests the removal of rainbow trout in the Paria-Badger reach (PBR) to reduce the emigration of rainbow trout from Lees Ferry downstream to the LCR reach. The non-native fish control elements of the proposed action are designed to advance scientific understanding of non-native fish and the risks they pose to native fish in the Grand Canyon through targeted monitoring and research.

Boat-mounted electrofishing equipment will be used to remove non-native fish. The electrofishing equipment is not intended to result in mortality of any endangered fish species, although some small number of endangered fish may be injured or killed from being caught and handled. One to six removal passes would be conducted in each trip. Up to 10 PBR removal trips could be conducted in any one year for the ten-year period 2011-2020. Up to six non-native control trips could occur in the LCR reach in any one year, according to a defined trigger. Reclamation has committed to working with FWS to further define the triggering criteria over the life of the proposed action based on continuing research and related analyses. However, they may otherwise take action, such as moving to immediate removal of non-native fish in either the PBR or LCR reach, in the event of new information. For example, there is currently a very large cohort of rainbow trout in Lees Ferry, described in detail below, and should monitoring data indicate that these trout are moving downstream to the LCR, immediate control actions may be implemented.

The trigger to determine when LCR control would take place is as follows:
Removal of non-native fish at the LCR reach would only occur if 1) rainbow trout abundance estimates in the portion of the reach from RM 63.0-64.5 exceeds 760 fish, and 2) if the brown trout (*Salmo trutta*) abundance estimate for this reach exceeds 50 fish (evaluated each calendar year in January); and 3) the abundance of adult humpback chub declines below 7,000 adult fish

based on the Age-Structured Mark Recapture Model (ASMR) this model estimate will be conducted every 3 years, and each year the latest ASMR results will be evaluated with the other elements of the trigger (i.e. numbers of trout) each calendar year in January.

OR

The above conditions 1 and 2 for trout abundance are met, and all of the following three conditions are also met:

1. In any 3 of 5 years during the proposed action using data extending retrospectively to 2008, the abundance estimate of humpback chub in the LCR between 150-199 millimeters (mm) [5.9- 7.8 inches] total length within the 95 percent confidence interval drops below 910 fish (evaluated each calendar year in January); and

2. Temperatures in the mainstem Colorado River at the LCR confluence do not exceed 12 degrees Celsius (ºC) in two consecutive years (evaluated each calendar year in January); and

3. Annual survival of young humpback chub (40-99 mm total length (TL)) in the mainstem in the LCR Reach drops 25 percent from the preceding year (evaluated each calendar year in January)[2] .

One goal of the non-native fish control program will be to assess and mitigate the effects of the increased predation on and competition with humpback chub by reducing the numbers of trout in areas from which the trout may disperse and in reaches that they occupy together with humpback chub. Another goal of the non-native fish control program is to assess and mitigate the effects of the increased predation and competition, caused by implementation of the HFE protocol, by reducing the numbers of trout which may disperse into reaches occupied by humpback chub. An increase in trout population, as discussed in detail below, followed the 2008 HFE.

Predation and competition by rainbow trout and brown trout have been identified as sources of mortality for juvenile humpback chub (Valdez and Ryel 1995, Marsh and Douglas 1997, Yard et al. 2011). This added mortality reduces recruitment and possibly the overall size of the population of adult humpback chub (Coggins 2008a). Reclamation, in cooperation with the NPS, has also implemented a conservation measure to support the brown trout removal effort at Bright Angel Creek. Bright Angel Creek is a known source of brown trout to the LCR reach. Reclamation has committed to continuing and expanding this effort as discussed below.

All non-native fish will be removed alive, transported, and stocked into areas with approved stocking plans, or euthanized for future beneficial use. PBR reach removal is expected to be cost-efficient because boats used in the removal effort can travel to the Badger Creek confluence at River Mile (RM) 8 and return to Lees Ferry the same day and reduce program costs. Stocking

[2] As a result of the NSE study and other monitoring associated with the GCDAMP, we now have estimates of survival rates of y-o-y humpback chub in the LCR confluence area. The results are discussed in other sections of this opinion. These techniques were not available when the 2009 Opinion was prepared.

live trout removed from the Colorado River into other waters is not evaluated in this proposed action but stocking would only occur into areas with approved stocking plans. During the collection of non-native fishes, there is a potential for capture of listed fish. Reclamation has requested that any adverse effects to listed fish from implementation of non-native fish control and other aspects of the proposed actions be evaluated under their ESA section 10(a)(1)(A) recovery permit. This request will be addressed in a separate process.

Modified Low Fluctuating Flows

This portion of the proposed action includes the continuation of the MLFF alternative as described in the 1995 Environmental Impact Statement and adopted in the 1996 ROD on Glen Canyon Dam operations for the 10-year period for fiscal years 2011-2020. MLFF is also considered in the Environmental Baseline section of this opinion because MLFF has been in effect since 1996. Previously scheduled steady flows will continue in September and October 2012 as part of the proposed action that is subject of this consultation. Under the MLFF, daily flow releases are limited to a minimum of 5,000 cfs and maximum of 25,000 cfs (although this can be exceeded for emergencies or during extreme hydrological conditions). Minimum flow during the day from 7:00 am to 7:00 pm is further limited to 8,000 cfs. Daily fluctuation limit is 5,000 cfs for months with release volumes less than 0.6 million acre feet (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. Ramp rates must not exceed 4,000 cfs per hour ascending and 1,500 cfs per hour descending (Table 1). Operations under the MLFF are typically structured to generate hydropower in response to electricity demand, with higher monthly volume releases in the winter and summer months, and daily fluctuations in release volume.

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

Conservation Measures

As explained in the 2008 Opinion and 2009 Supplemental Opinion, we are confident that Reclamation will implement the following conservation measures because of their continued demonstration of effectiveness in implementing past and ongoing conservation measures. Essentially all of the ongoing conservation measures are currently being implemented by Reclamation. 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 when none of these elements were funded and implemented at that time, although some had been identified as potential actions. Based on new information, Reclamation in coordination with Glen Canyon Dam Adaptive Management Program (GCDAMP) has updated some of the conservation measures as described below.

Re-Evaluation Points – 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 meet at least once every 3 years to specifically review the need for reinitiation based on humpback chub status and other current and relevant information. Reclamation will undertake a review in 2014 of the first two years of implementation of the proposed action through a workshop with scientists to assess what has been learned, which will also serve as the first re-evaluation point. Reclamation will also produce a written report of each evaluation and either FWS or Reclamation may require reinitiation of formal consultation on the proposed action to reevaluate the effects of the action.

Humpback Chub Translocation – Reclamation will continue to assist the NPS and the GCDAMP in funding and implementation of translocating humpback chub in the LCR and into tributaries of the Colorado River in Marble and Grand canyons, and in monitoring the results of these translocations. Non-native fish control in these tributaries will be an essential element to translocation, so Reclamation will help fund control of both cold water and warm water non-native fish in tributaries, as well as efforts to translocate humpback chub into these tributaries. Havasu, Shinumo, and Bright Angel creeks will continue to be the focus of translocation efforts, although other tributaries may be considered.

Humpback Chub Nearshore Ecology Study – Through the Natal Origins Study, in coordination with other GCDAMP participants and through the GCDAMP, Reclamation will continue research efforts on nearshore ecology of the LCR reach to better understand the importance of mainstem nearshore habitats in humpback chub recruitment and the effect of non-native fish predation on humpback chub recruitment, and to monitor the trend in annual survival of young humpback chub in the mainstem for use in determining the need for non-native fish control.

Humpback Chub Refuge – Reclamation will continue to assist FWS in maintenance of a humpback chub refuge population at a Federal hatchery (Reclamation has assisted the FWS in creating a humpback chub refuge at Dexter National Fish Hatchery and Technology Center) (DNFHTC) or other appropriate facility by providing funding to assist in annual maintenance (including the collection of additional humpback chub from the Little Colorado River for this purpose). In the unlikely event 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.

Humpback Chub Monitoring and Mainstem Aggregation Monitoring – Reclamation will, through the GCDAMP, continue to conduct annual monitoring of humpback chub and, every 3 years, conduct the ASMR. Reclamation will also monitor the abundance of humpback chub and species composition at the eight mainstem aggregations of humpback chub in Marble and Grand Canyon annually.

Bright Angel Creek Brown Trout Control – Reclamation will continue to fund efforts of the NPS to remove brown trout from Bright Angel Creek and will work with GCMRC and NPS to expand this effort to be more effective at controlling brown trout in Grand Canyon. This issue has been prioritized based on emerging information on the particular risk that brown trout pose to native fish.

High Flow Experiment Assessments – Reclamation will conduct pre- and post-HFE assessments of existing data on humpback chub status and other factors to both determine if a HFE should be conducted and to inform decisions to conduct future HFEs. Consideration will be given to minimize effects to humpback chub in defining the timing, duration, and magnitude of each HFE conducted within the framework established by the HFE protocol.

Dexter National Fish Hatchery Genetic Study – Reclamation will fund an investigation of the genetic structure of the humpback chub refuge housed at the DNFHTC that will include: 1) a genotype of the refuge population using microsatellites; 2) an estimate of humpback chub effective population size; and 3) a calculation of pairwise relatedness of all individuals in the DNFHTC Refuge population.

Kanab Ambersnail – Reclamation implemented conservation measures for the HFEs conducted in 2004 and 2008 to protect habitat for the Kanab ambersnail at Vasey's Paradise. However, due to the pending taxonomic evaluation (discussed below), the FWS and Reclamation have agreed to forgo this conservation measure for future HFEs and to study the effect of the HFE Protocol on the population of Kanab ambersnail at Vasey's Paradise through continued monitoring. FWS has analyzed the effect of the potential loss of habitat over the life of the proposed action and concluded that the conservation measure is not necessary to maintain a healthy population of Kanab ambersnail at Vasey's Paradise because the amount of habitat and snails that will be unaffected by the proposed action is sufficient to maintain the population. Reclamation will continue, through the GCDAMP, to monitor the population on a periodic basis to assess the health of the population over the life of the proposed action.

Conservation of Mainstem Aggregations - Reclamation will also, as part of its proposed action, work within its authority through the GCDAMP to ensure that a stable or upward trend of humpback chub mainstem aggregations can be achieved. Ongoing and additional efforts will be coordinated to: 1) explore and potentially implement flow and non-flow measures to increase the amount of suitable humpback chub spawning habitat in the mainstem Colorado River (additional environmental compliance may be required); 2) secure numbers of humpback chub in a wider distribution in the mainstem Colorado River by supporting the number of young-of-year (y-o-y) recruiting to aggregations; 3) expand the role of tributaries and their ability to contribute to the growth and expansion of mainstem aggregations; and 4) develop and implement a protocol for "maintenance control" of rainbow trout through appropriate means to ensure low levels of trout in the LCR Reach, for example, by implementing PBR control every year, in coordination with the FWS and other partners.

Ongoing Research

The GCDAMP established in 1997 to implement the Grand Canyon Protection Act will continue. The Program provides a process for assessing the effects of current operations of Glen Canyon Dam on downstream resources and develops recommendations for modifying dam operations and other resource management actions, including monitoring listed species. Several of the conservation measures from the 2008 and 2009 Opinions have been completed such as the Monthly Transition Flow Study; other measures are ongoing such as supporting a refuge for humpback chub at DNFHTC, and translocation into Shinumo and Havasu Creeks, and above Chute Falls. Reclamation has also agreed to assist in implementing the Humpback Chub Comprehensive Plan.

Reclamation will undertake development, with stakeholder involvement, of additional non-native fish suppression options for implementation, and Reclamation will complete development of such options within the first two years of the proposed action to assist efforts to reduce recruitment of non-native rainbow trout at, and emigration of those fish from, Lees Ferry. Options will include both flow and non-flow non-native fish suppression experiments focused on the Lees Ferry reach, which would reduce the recruitment of trout in Lees Ferry, lowering emigration of trout. Additional environmental compliance may be necessary for implementation of these experiments. In full cooperation with the NPS, as co-lead for the LTEMP Process, Reclamation will assess whether and how the LTEMP may provide a mechanism for analysis and implementation of future experimental suppression flows.

The Natal Origins Study will also be a key research component to the proposed action. This new research effort is designed to determine the natal origins of rainbow trout in Marble Canyon and more specifically in the LCR reach. The study will also continue the mainstem juvenile humpback chub assessment conducted through the Nearshore Ecology Study described in the conservation measures and will provide information on rainbow trout emigration rates out of the Lees Ferry Reach.

Action Area

The action area for this proposed action is the Colorado River corridor from Glen Canyon Dam in Coconino County, Arizona, downstream to Pearce Ferry, Mohave County, Arizona including the confluence area of major tributaries in this reach: the Paria River, the LCR, Bright Angel Creek, Tapeats Creek, Kanab Creek, Shinumo Creek, and Havasu Creek. Below Pearce Ferry, ESA compliance is addressed within the Lower Colorado River Multi-Species Conservation Program (LCR MSCP 2005). The LCR MSCP addresses Section 7 and Section 9 responsibilities for areas up to and including the full-pool elevation of Lake Mead, and downstream areas along the Colorado River within the U.S.

STATUS OF THE SPECIES AND CRITICAL HABITAT

Humpback chub

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

The humpback chub is a medium-sized freshwater fish of the minnow family, Cyprinidae. The adults have a pronounced dorsal hump, a narrow flattened head, a fleshy snout with an inferior-subterminal mouth, and small eyes. It has silvery sides with a brown or olive-colored back. The humpback chub is endemic to the Colorado River Basin and is part of a native fish fauna traced to the Miocene epoch in fossil records (Miller 1955, Minckley et al. 1981). Humpback chub remains have been dated to about 4000 B.C., but the fish was not described as a species until the 1940s (Miller 1946), presumably because of its restricted distribution in remote whitewater canyons (USFWS 1990). Because of this, its original distribution is not known.

Adult humpback chub occupy swift, deep, canyon reaches of river (Valdez and Clemmer 1982, Archer et al. 1985, Valdez and Ryel 1995), with microhabitat use varying among age-groups (Valdez et al. 1990). Within Grand Canyon, adults demonstrate high microsite fidelity and occupy main channel eddies, while subadults use nearshore habitats (Valdez and Ryel 1995, Robinson et al. 1998, Stone and Gorman 2006). Young humpback chub use shoreline talus, vegetation, and backwaters typically formed by eddy return current channels (Arizona Game and Fish Department (AGFD) 1996). These habitats are usually warmer than the main channel especially if they persist for a long time and are not inundated or desiccated by fluctuating flows (Stevens and Hoffnagle 1999). Subadults also use shallow, sheltered shoreline habitats but with greater depth and velocity (Valdez and Ryel 1995, Childs et al. 1998).

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

As young humpback chub grow, they exhibit an ontogenic shift toward deeper and swifter offshore habitats that usually begins at age 1 (about 100 mm [3.94 in] TL) and ends with maturity at age 4 (≥200 mm [7.87 in] TL; Valdez and Ryel 1995, 1997, Stone and Gorman 2006). Valdez and Ryel (1995, 1997) found that young humpback chub (21–74 mm [0.83-2.91 in] TL) remain along shallow shoreline habitats throughout their first summer, at low water velocities and depths less than 1 m (3.3 feet), and shift as they grow larger (75–259 mm [2.95-10.20 in] TL) by fall and winter into deeper habitat with higher water velocities and depths up to 1.5 m (4.9 ft). Stone and Gorman (2006) found similar results in the Little Colorado River, finding that humpback chub undergo an ontogenesis from diurnally active, vulnerable, nearshore-reliant y-o-y (30–90 mm [1.81-3.54 in] TL) into nocturnally active, large-bodied adults (180 mm [7.09 in] TL), that primarily reside in deep midchannel pools during the day, and move inshore at night.

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

The humpback chub is an obligate warm-water species that requires temperatures of about 16-22 °C (61-72 °F) for spawning, egg incubation, and optimal survival of young. Spawning is usually initiated at about 16 °C (61 °F) (Hamman 1982). Highest hatching success is at 19–20 °C (66-68 °F) with an incubation time of 3 days; and highest larval survival is slightly warmer at 21–22 °C (70-72 °F)(Marsh 1985). Hatching success under laboratory conditions was 12 percent, 62 percent, 84 percent, and 79 percent in 12–13 °C (54-54 °F), 16–17 °C (61-63 °F), 19–20 °C (66-

68 °F), and 21–22 °C (70-72 °F), respectively, whereas survival of larvae was 15 percent, 91 percent, 95 percent, and 99 percent, at the same respective temperatures (Hamman 1982). Time from fertilization to hatching ranged from 465 hours at 10 °C (50 °F) to 72 hours at 26 °C (79 °F), and time from hatching to swim-up varied from 372 hours at 15 °C (59 °F) to 72 hours at 21–22 °C (70-72 °F). The proportion of abnormal fry varied with temperature and was highest at 15 °C (59 °F) (33 percent) dropping to 17 percent at 25 °C (77 °F). Marsh (1995) also found total mortality of embryos at 5, 10, and 30 °C (41, 50, 86 °F). Bulkley et al. (1981) estimated a final thermal preference of 24ºC (75 °F) for humpback chub during their first year of life (80–120 mm [3.2-4.72 in]).

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

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

At hatching, larvae have nonfunctional mouths and small yolk sacs (Muth 1990). Robinson et al. (1998) found larvae drifting in the LCR from April through June, and evidence suggesting that larvae actively disperse to find suitable nearshore habitats. Robinson et al. (1998) quantified numbers of larval humpback chub that are transported by LCR flows into the mainstem, and Robinson et al. (1998) and Stone and Gorman (2006) suggested that daily fluctuations in the mainstem river may reduce the quality of nearshore habitat for y-o-y and juvenile humpback chub, which may be particularly important during the monsoon period (July to November) when storms cause floods in the LCR, displacing large numbers of young humpback chub into the mainstem (GCMRC unpublished data). Pre-dam annual peak Colorado River flows (April–July) ponded canyon-bound tributary mouths (Howard and Dolan 1981), including the LCR. Robinson et al. (1998) theorized that because ponding probably retained drifting larvae or slowed their passage, it probably allowed greater time for development in a warm, low-velocity environment. Without this ponding effect, presumably more y-o-y and juvenile humpback chub are likely transported into a now-harsher mainstem river while still at a size that is more vulnerable to thermal shock and predation.

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

Hendrickson (1993) aged humpback chub from the Little Colorado River and the mainstem Colorado River in Grand Canyon and showed a maximum of 23 annular rings. Based on polynomial regression of average number of annuli from otoliths and opercles, age-3 fish were 157 mm (6.18 in) TL and age-4 fish were 196 mm (7.72 in) TL. Valdez and Ryel (1995) recorded size at first observed maturity (based on expression of gametes, presence of spawning tubercles) of humpback chub in Grand Canyon at 202 mm (7.95 in) TL for males and 200 mm (7.87 in) TL for females; computed length of age-4 fish with a logarithmic growth curve was 201 mm (7.91 in) TL. A temperature dependent growth model has also been developed as described in Coggins and Walters (2010).

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

The decline of the humpback chub throughout its range and continued threats to its existence are due to habitat modification and streamflow regulation (including cold-water dam releases and habitat loss), competition with and predation by non-native fish species, parasitism, hybridization with other native *Gila*, and pesticides and pollutants (USFWS 2002a). Streamflow regulation, in general, eliminates flows and temperatures needed for spawning and successful recruitment, which is exacerbated by predation and competition from non-native fishes. In Grand Canyon, brown trout, channel catfish (*Ictalurus punctatus*), black bullhead (*Ameiurus melas*), and rainbow trout have been identified as principal predators of young humpback chub, with consumption estimates that suggest loss of complete year classes to predation (Marsh and Douglas 1997, Valdez and Ryel 1997). Valdez and Ryel (1997) also suggested that common carp could be a significant predator of incubating humpback chub eggs in the LCR. In the upper basin, channel catfish have been identified as the principal predator of humpback chub in Desolation/Gray Canyons (Chart and Lentsch 2000), and in Yampa Canyon (USFWS 2002a). Smallmouth bass (*Micropterus dolomieu*) have also become a significant predator in the Yampa River (T. Chart, FWS, pers. comm., 2007). Parasitism, hybridization with other native *Gila*, and pesticides and pollutants are also factors in the decline (USFWS 2002a).

There are six populations of humpback chub in the Colorado River basin; five in the upper basin, and one in the lower basin (basins divided by Glen Canyon Dam) (Figure 1). The upper basin 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. The lower basin population is found in the Colorado River and tributaries in Grand Canyon. In January 2011, the FWS signed the 5-Year Review on the Humpback Chub, which describes the significant decline noted from the first adult abundance estimate to the most recent estimate for the populations in Black Rocks, Westwater Canyon, and Desolation/Gray Canyons (FWS 2011a) as described below and shown in Figure 2. Populations in Yampa and Cataract Canyons are too small to monitor through mark-recapture analysis and some individuals have been brought into captivity to preserve their genetic uniqueness.

The Lower Basin currently hosts the largest population of humpback chub and is commonly referred to as the Grand Canyon population. Mark-recapture methods have been used since the late 1980s to assess trends in adult abundance and recruitment of the LCR aggregation, the primary aggregation constituting the Grand Canyon population. 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). 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, increased in 2006 to approximately 5,300-6,700, and further increased to 7,650 adults in 2008. Current methods for assessment of humpback chub abundance rely on the 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, the most important finding in their report is that the population trend in humpback chub is increasing. They also concluded 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) Grand Canyon population is approximately 7,650 fish (Coggins and Walters 2009).

Translocation of juvenile humpback chub from near the mouth of the LCR upstream to above Chute Falls was undertaken in 2008 - 2011 as a conservation measure of the 2008 Opinion. 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 every year since 2008. Monitoring of humpback chub in the mainstem Colorado River has documented the persistence of small aggregations, although no population estimates are available (W. Persons, USGS, written comm. 2011a). Young-of-year humpback chub were also translocated into Shinumo Creek and Havasu Creek in an effort to broaden the distribution of humpback chub in the action area. 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; USFWS 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 ESA, 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 ESA, 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 ESA 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). PCEs are provided by the final rule designating critical habitat and three supporting documents (USFWS 1994, Maddux et al. 1993a, 1993b. 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 considered, because, collectively, they represent the best available scientific information as to the recovery needs of the species.

Recovery for the humpback chub is defined by the FWS Humpback Chub Recovery Goals (Recovery Goals) (67 FR 55270) (FWS 2002a). In 2006, a U.S. District Court ruling set aside the Recovery Goals, 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, 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. In our 2009 Supplemental Opinion we referenced the draft 2009 revisions to the Recovery Goals document because that document provided updates on species biology and distribution, and represented the best available scientific information at that time. The draft 2009 revisions to the Recovery Goals included the same demographic criteria found in the 2002 Recovery Goals. Thus, we are using the demographic criteria found in both the 2002 Recovery Goals and 2009 draft recovery goals. The FWS' 2011 Humpback Chub 5-Year Review relies on the information provided in the recovery goals and provides supplemental information on the species' distribution and status. That supplemental information, as well as the demographic criteria found in the Recovery Goals have been considered in this biological opinion and are summarized here**.** The Recovery Goal demographic criteria for downlisting (endangered to threatened) are:

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 FWS, such that:

    a. the trend in adult (age 4+; ≥ 200 mm [7.9 inches] TL) point estimates does not decline significantly, and

    b. mean estimated recruitment of age-3 (150–199 mm [5.9-7.8 inches] 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 Minimum Viable Population (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 FWS, such that:

    a. the trend in adult (age 4+; ≥ 200 mm [7.9 inches] TL) point estimates does not decline significantly, and

    b. mean estimated recruitment of age-3 (150–199 mm [5.9-7.8 inches] 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:

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 FWS, such that:

    a. the trend in adult (age 4+; ≥ 200 mm [7.9 inches] TL) point estimates does not decline significantly, and

b. mean estimated recruitment of age-3 (150–199 mm [5.9-7.8 inches] 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

a. 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 FWS, such that:

b. the trend in adult (age 4+; ≥ 200 mm [7.9 inches] TL) point estimates does not decline significantly, and

c. mean estimated recruitment of age-3 (150–199 mm [5.9-7.8 inches] TL) naturally produced fish equals or exceeds mean annual adult mortality, and

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

The Recovery Goals consist of actions to improve habitat and minimize threats. The success of those actions is measured by the status and trend (i.e. the demographic criteria) of the population. We have evaluated the contribution of each critical habitat unit to recovery 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 criteria as defined in the Recovery Goals. In those cases, we rely on existing data to make an informed, evaluation of the PCEs in a critical habitat unit.

Primary Constituent Elements (PCEs)

In accordance with section 3(5)(A)(i) of the ESA 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 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 on FWS (1994), Maddux et al. (1993a), and Maddux et al. (1993b), and updated with the most current scientific information.

General PCEs of Critical Habitat

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 (FWS 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 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 non-native fish species.

The PCEs are all integrally related and must be considered together. For example, the quality and quantity of water (PCEs 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 non-native species. Even in systems like the Yampa River, where the water and physical PCEs are relatively unaltered, non-native 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 may depend on our ability to control non-native species, and manipulating the water and physical PCEs of critical habitat to disadvantage non-natives may play an important role.

Specific Critical Habitat Reaches and PCEs

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

The most northerly segment of humpback chub critical habitat is a 44-mile (70.8-km) 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 NPS, 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 non-native fish species (Finney 2006, USFWS 2011a).

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 the confluence (Roehm 2004, Muth et al. 2000). 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 that successful spawning continues to occur (Finney 2006). 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 non-native 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, Modde et al. 1999).

This reach of the Yampa also provides some areas of adequate physical habitat (FWS 1990, Karp and Tyus 1990, Finney 2006). Yampa Canyon within Dinosaur National Monument is typical of the deep canyon habitat preferred by the species (FWS 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, USFWS 1990). The Yampa reach of critical habitat remains relatively unaltered from pre-development times in terms of hydrology and geomorphology (Roehm 2004, Modde et al. 1999), 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 non-native fishes is probably the greatest alteration to the historical Yampa system. Non-native 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 Non-native Fish Control was developed for the Upper Colorado River Basin and implemented by the UCRRP in 1997 (Fuller 2009). The UCRRP identified smallmouth bass (*Micropterus dolomieu*) and channel catfish (*Ictalurus punctatus*) as the principal predators of humpback chub (USFWS 2009a). 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 despite non-native removal efforts, 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 native fish 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, which prevents this unit from providing for recovery at this time.

The Yampa illustrates that if non-native 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. 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 mid-2000s, cold high flows may have suppressed smallmouth bass production (along with removal efforts), and numbers of y-o-y 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 non-native fish species. Because of this relationship between the physical and biological PCEs, efforts focused on restoring physical attributes of critical habitat, in places such as the Grand Canyon could have the unintended consequence of benefiting non-native species, offsetting any gains from habitat improvement.

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

This unit is a 38-mile (61.2-km) 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 NPS 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 except for the abundance of non-native fishes. Only eight humpback chub were captured in Whirlpool Canyon from 2002 to 2004 (Bestgen et al. 2006), although young of year chub were collected from 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 2008 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, 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 non-native 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 - Green River - Desolation and Gray Canyons

The Green River in Desolation and Gray Canyons contains one of the five upper basin populations of humpback chub. The 73-mile (117.4 km) 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 (BLM), 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).

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). However, a significant decline has occurred recently; the first adult abundance estimate in Desolation/Gray Canyons in 2001, 1,254 fish declined to a low in 2007 of about 300 fish (Figure 2; USFWS 2011a). 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 non-native 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 - Colorado River - Black Rocks/Westwater Canyon

The Black Rocks and Westwater populations of humpback chub occur in this 30-mile (48.3-km) 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 BLM, 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, USFWS 2009a), 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 showed the Black Rocks population between about 1,000 and 2,000 adults in 2000 (age 4+) and the Westwater Canyon population between about 1,800 and 4,700 adults in 2003 (McAda 2006, Hudson and Jackson 2003, Eleverud 2007, Jackson 2010). But levels of both populations have declined as of the most recent estimates in 2008 to a few hundred in Black Rocks and approximately 1,500 in Westwater Canyon (Figure 2; USFWS 2011a). Levels of both populations appear to have declined further since that time, as evidenced by a few hundred reported by Francis and McAda (2011) in 2011. However, while the estimates are low, they fall within the confidence intervals of earlier abundance estimates, so we cannot conclude an additional decline.

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 (22.5-km) 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 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, and rapids, with strong turbulent currents. The quantity and quality of water in this reach (PCEs W1 and W2) are presently sufficient. This reach provides deep pools, eddies, and runs for feeding and movement corridors, and spawning and rearing habitat are 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 non-native fishes low (R. Valdez, pers. comm., 2009), and there currently is no non-native fish 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 non-native species; climate change and operations under the Interim Guidelines could lead to an increase in low water years and non-native fishes, challenging the ability of this unit to support recovery (Reclamation 2007, Rahel et al. 2008, R. Valdez, pers. comm., 2009).

Humpback Chub Critical Habitat Reach 5 - Colorado River - Cataract Canyon

A 13-mile (20.9 km) 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 NPS. 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 1980, 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 (R. Valdez, SWCA pers. comm., 2009).

The Cataract Canyon population of humpback chub has declined to approximately 100 individuals and currently is too small to monitor through mark-recapture analysis (USFWS 2011a). 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 (20.9 km) 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 (Badame 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.

Causes of the apparent current lack of recruitment of the population do not appear to be due to changes in the physical habitat PCEs. 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 non-native 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 (*Morone saxatilis*) were captured in past surveys (Valdez 1990). The water and physical PCEs appears to be met, but the presence of Lake Powell likely eliminated much of the historical habitat, and provides a robust population of non-native fish 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 high numbers of non-native species has resulted in the lack of the biological environment PCEs B2 and B3 and this is likely the reason this unit is not functioning currently in humpback chub recovery.

Humpback Chub Critical Habitat Reach 6 - Little Colorado River

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 NPS (Grand Canyon National Park). The Grand Canyon population of humpback chub occurs in both critical habitat reaches 6 and 7. 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, USFWS 2009a). 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[3] 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 (20.9 km) upstream from the mouth of the Colorado River.

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

The LCR above Blue Spring was once perennial, but is now intermittent throughout most of its 356-mile (572.9-km) length, flowing only during 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. Because of the reduced flow levels from Glen Canyon Dam, only the lower portion of the LCR is ponded by flows from the dam, where approximately 10 to 25% of the adult humpback chub are likely to occur (P. Sponholtz, FWS, pers. comm., 2011). The other adults will be in the mainstem Colorado River or in the upper reaches of the Little Colorado River in areas not affected by the operations of Glen Canyon Dam.

Flows in the LCR maintain acceptable habitat for all sizes and age classes of humpback chub. The historical 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 (0.40 km) 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, Van Haverbeke and Stone 2008, 2009). Thus PCEs W1 and W2 are present, although threats exist, as described 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 (USFWS 1990, Robinson et al. 1998). Adult humpback chub in the LCR utilize shoreline areas, pools and eddies, quiet waters under rock ledges, 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 y-o-y (30–90 mm, 1.2-3.5 inches TL) 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 (Van Haverbeke 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). Foods utilized in the Little 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 non-native fishes is unknown, but predation has been documented by rainbow trout, channel catfish, and black bullhead (Marsh and Douglas 1997). Numbers of non-native fish make up a small proportion of the fish community in the LCR, comprising only 7 percent of total catch in 2007 monitoring (Van Haverbeke and Stone 2008). While relatively small proportions of certain non-native species (e.g., channel catfish) could be problematic for humpback chub in the LCR, the most common non-native fish in 2010 was fathead minnow (Van Haverbeke et al. 2011). All of the PCEs are provided for in the Little Colorado Reach of critical habitat, although significant threats exist which are discussed in the Environmental Baseline.

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

The 173-mile (278.4-km) 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 NPS and 12.2 percent Tribal (Navajo Nation). As discussed above, Reaches 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 some movement of humpback chub between the aggregations (Paukert et al. 2006). All nine aggregations constitute what is considered a single reproducing population (Douglas and Douglas 2007). According to Paukert et al. 2006, approximately 85% (12,508 of 14,674) of the humpback chub were captured and recaptured in the LCR, whereas only 241 (1.6%) were captured and recaptured in the mainstem Colorado River within the LCR confluence area. In 2006, concurrent estimates of the LCR and LCR inflow population were determined and represented 14,526 fish (or 99.0% of the recaptures) demonstrating the species' disproportionate reliance on the LCR. There is, however, evidence of some fish travelling among and adding to the mainstem aggregations (Paukert et al. 2006, W. Persons, USGS, written communication, 2011b).

The eight other spawning aggregations are (per Valdez and Ryel 1995): 1) 30-mile (RM 29.8 to 31.3); 2) Lava to Hance (RM 65.7-76.3); 3) Bright Angel Creek Inflow (RM 83.8-93.2); 4) Shinumo Creek Inflow (RM 108.1-108.6); 5) Stephen Aisle (RM 114.9-120.1); 6) Middle Granite Gorge (RM 126.1-129.0); 7) Havasu Creek Inflow (RM 155.8-156.7); and 8) Pumpkin Spring (RM 212.5-213.2). As stated in the 2008 and 2009 Supplemental Opinions, 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 and Masslich1999). 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). The LCR aggregation has been expanded upstream of Chute Falls through translocation (Stone 2009, Van Haverbeke et al. 2011).

The abundances of the other humpback chub mainstem aggregations, other than the LCR inflow aggregation, are not precisely known, but catches of humpback chub in these other aggregations are consistently small compared to the LCR inflow aggregation. Young-of-year are consistently found throughout Grand Canyon, especially associated with aggregations at 30-mile, Middle Granite Gorge, Shinumo, and Randy's Rock, and recruitment may be occurring at low levels given that these aggregations continue to be documented over time (Figure 3) (Valdez and Ryel 1995, Trammel et al. 2002, Ackerman 2008). Monitoring continues to confirm the persistence of these aggregations (Trammell et al. 2002, W. Persons, USGS, written comm., 2011). In 2011, field surveys documented 2 or 3 year old fish in Havasu Creek just downstream of Beaver Falls (P. Sponholtz, FWS, pers. comm. 2011, Smith et. al. 2011). Eight untagged humpback chub were captured prior to humpback chub translocation in Havasu Creek (Smith et al. 2011). Humpback chub have also been caught infrequently downstream of Pumpkin Spring (Valdez 1994), an area warmed by mineral spring flows.

The Colorado River in Grand Canyon has a restricted channel with limited floodplain development. Channel widths vary from 180 to 390 feet (54.9-118.9 meters [m]) (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, and Bright Angel, Kanab, Shinumo, and Havasu creeks provide varying amounts of base flow to the river that create shallow water habitats for use by native fish with substrates that tend to be more rocky with fewer fine materials; and (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). Cobble is the most productive habitat for invertebrates (highest biomass and production), perhaps because sediment thickness is lowest there (T. Kennedy, USGS, written comm. 2011).

Water releases from Glen Canyon Dam vary between 5,000 and 25,000 cfs and will continue in this way as described by the MLFF regime adopted by the Secretary of the Interior in 1996. The dam blocks the primary sediment inflow to the river in the canyon, limiting the sediment load to the amount contributed by the tributaries. The HFE protocol is designed to maximize the tributary inputs by producing high flows to deposit sand on beaches and nearshore habitats. 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 the completion of Glen Canyon Dam and are cold (8.9 °C) year round when the reservoir is full (Reclamation files). Water temperatures downstream 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. Between 2003 and 2006 when Lake Powell levels were low, water temperatures were able to warm up to 17 º C, the warmest temperature recorded since Lake Powell filled in 1980 and near the minimum temperature at which successful humpback chub spawning is initiated (Hamman 1982). This along with increased sediment levels from Paria River and other tributaries and mechanical removal of non-native fish contributed to the creation of water temperatures and habitat parameters that allowed overwintering of young-of-year humpback chub (Andersen et al. 2010). Water years since 2006, and in particular in 2011, have also been unusually warm with water temperatures at Lees Ferry at 13.5 ºC and 14.5 ºC at the LCR (Figure 4; USGS unpublished data). As a result of the different water temperatures available to humpback chub, there can be great variability in growth rates of humpback chub depending on the amount of time fish spend in the mainstem versus time spent in the tributaries.

Non-native fish species, most notably rainbow trout, channel catfish, brown trout, and carp, are established in the river in Marble and Grand canyons (Maddux et al. 1993b, Valdez and Ryel 1995) and prey upon and compete with native fish. Of the native fish species that historically occurred in the Grand Canyon, two have been extirpated. Extirpated species include the bonytail and Colorado pikeminnow. 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 lower Grand Canyon but is very rare.

Flow fluctuations occur 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 in the mainstem is mostly found in backwaters, shoreline areas, and eddies, all areas of low-current velocity (Valdez and Ryel (1995). 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 existence of Glen Canyon Dam and its operations have had effects 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 caused by periodic changes in flow volume (Glen Canyon Dam Adaptive Management Program 2009). The physical habitat PCEs are at least partially met. In the 2008 and 2009 Supplemental Opinion, we concluded that the suitability of spawning and rearing habitats (PCEs P1 and P2) to fully function in meeting recovery needs was unknown. Converse et al. (1998) documented a preference for vegetated shorelines in subadult (< 200 mm TL [(7.9 inches]) humpback chub in the area below the LCR. The Near Shore Ecology (NSE) study has demonstrated that all PCEs appear to be met in the limited area of the mainstem where their study occurs 1,500 m (0.93 mile), downstream of the LCR confluence. Reclamation has committed to expand the information and understanding of mainstem aggregations through improved monitoring to support humpback chub distribution throughout the action area as a new conservation measure. Monitoring will be expanded beyond the small NSE study area to better understand the population dynamics of the mainstem aggregations of humpback chub, including yearly trips to try and generate population estimates for these aggregations.

Fish production in the mainstem Colorado River is supported by a small array of food resources of potentially limited availability, which may lead to strong competition for food among fishes, including competition with non-native fish species that may constrain production of the remaining native fishes in this river (Donner 2011). Food resources do not appear to be limiting in the reach for adult humpback chub, and in fact Hoffnagle et al. (2000) found that condition factor for humpback chub in the mainstem was better than that of adult fish in the LCR. However, humpback chub collected in the LCR during that same time may have been impacted by parasites (Hoffnagle et al. 2006.) Food resources in near shore areas and in relation to fluctuating flows continue to be an ongoing research question (U.S. Bureau of Reclamation and U.S. Geological Survey 2009) given the low diversity of aquatic insects currently present in the mainstem (T. Kennedy, written communication, USGS 2011).

There are fewer numbers of non-native fish species established in the Colorado River in Reach 7 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 (such as fathead minnows or smallmouth bass). As discussed earlier, providing warmer water through flow manipulations or dam modifications, or warmer water due to climate change and the Interim Guidelines, could improve the W1 PCE for humpback chub, but would need to be carefully monitored so as to not degrade the B2 and B3 PCEs of critical habitat by increasing predation and competition from non-native fish warm water 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 non-native fish predation and competition (B2 and B3); these are discussed in detail in the Environmental Baseline.

Previous consultations on humpback chub

Section 7 consultations on humpback chub have evaluated large-scale water-management activities. For the upper basin, UCRRP tracks the effects of such consultations on the species and provides conservation measures to offset the effects somewhat. Several consultations have occurred on the operations of Glen Canyon Dam, including one in 1995 that resulted in a jeopardy and adverse modification opinion. Subsequent consultations in 2008, 2009, and 2010 reached non-jeopardy/non adverse modification conclusions. Finally, a consultation on Sport Fish Restoration Funding evaluated the sport fish stocking program funded by the USFWS (USFWS 2011b). Biological opinions on actions potentially affecting humpback chub in Arizona may be found at our website www.fws.gov/southwest/es/arizona in the Section 7 Biological Opinion page of the Document Library.

Razorback Sucker and its Critical Habitat

The razorback sucker was first proposed for listing under the ESA on April 24, 1978, as a threatened species. The proposed rule was withdrawn on May 27, 1980, due to changes to the listing process included in the 1978 amendments to the ESA. In March 1989, the FWS was petitioned by a consortium of environmental groups to list the razorback sucker as an endangered species. A positive finding on the petition was published in the Federal Register on August 15, 1989. The finding stated that a status review was in progress and provided for submission of additional information through December 15, 1989. The proposed rule to list the species as endangered was published on May 22, 1990, and the final rule published on October 23, 1991, with an effective date of November 22, 1991. The Razorback Sucker Recovery Plan was released in 1998 (USFWS 1998). Recovery Goals were approved in 2002 (USFWS 2002b). Critical habitat was designated in 15 river reaches (Table 2) in the historical range of the razorback sucker on March 21, 1994, with an effective date of April 20, 1994 (USFWS 1994). Critical habitat included 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.

The following information is a summary of life history, habitat use, current distribution, threats, and conservation actions for the razorback sucker. This information was taken from the 2002 Recovery Goals (USFWS 2002b), and the Lower Colorado River Multi-Species Conservation Program Species Status documents (LCR MSCP 2005). Information in these documents is incorporated by reference.

The razorback sucker is the only representative of the genus *Xyrauchen* and was described from specimens taken from the "Colorado and New Rivers" (Abbott 1861) and Gila River (Kirsch 1889) in Arizona. This native sucker is distinguished from all others by the sharp-edged, bony keel that rises abruptly behind the head. The body is robust with a short and deep caudal peduncle (Bestgen 1990). The razorback sucker may reach lengths of 3.3 feet (1.0 m) and weigh 11 to 13 pounds (5.0 to 5.9 kilograms [km]) (Minckley 1973). Adult fish in Lake Mohave reached about half this maximum size and weight (Minckley 1983). Razorback suckers are long-lived, reaching the age of at least 40 years (McCarthy and Minckley 1987).

The razorback sucker is adapted to widely fluctuating physical environments characteristic of rivers in the pre-Euro-American-settlement Colorado River Basin. Adults can live 45-50 years and, once reaching maturity between two and seven years of age (Minckley 1983), apparently produce viable gametes even when quite old. The ability of razorback suckers to spawn in a variety of habitats, flows, and over a long season are also survival adaptations. In the event of several consecutive years with little or no recruitment, the demographics of the population might shift, but future reproduction would not be compromised. Average fecundity recorded in studies ranges from 46,740-100,800 eggs per female (Bestgen 1990). With a varying age of maturity and the fecundity of the species, it would be possible to quickly repopulate an area after a catastrophic loss of adults.

Spawning takes place in the late winter to early summer depending upon local water temperatures. Various studies have presented a range of water temperatures at which spawning occurs. In general, temperatures from 10° to 20° C are appropriate (summarized in Bestgen 1990). Adults typically spawn over cobble substrates near shore in water 3-10 feet (0.9 to 3.0 meters] deep (Minckley et al. 1991). There is an increased use of higher velocity waters in the spring, although this is countered by the movements into the warmer, shallower backwaters and inundated bottomlands in early summer (McAda and Wydoski 1980, Tyus and Karp 1989, Osmundson and Kaeding 1989). Spawning habitat is most commonly over mixed cobble and gravel bars on or adjacent to riffles (Minckley et al. 1991).

Razorback sucker diet varies depending on life stage, habitat, and food availability. Larvae feed mostly on phytoplankton and small zooplankton and, in riverine environments, on midge larvae. Diet of adults taken from riverine habitats consisted chiefly of immature mayflies, caddisflies, and midges, along with algae, detritus, and inorganic material (USFWS 1998).

Adult razorback suckers use most of the available riverine habitats, although there may be an avoidance of whitewater type habitats. Main channel habitats used tend to be low velocity ones such as pools, eddies, nearshore runs, and channels associated with sand or gravel bars (Bestgen 1990). Adjacent to the main channel, backwaters, oxbows, sloughs, and flooded bottomlands are also used by this species. From studies conducted in the upper Colorado River basin, habitat selection by adult razorback suckers changes seasonally. They move into pools and slow eddies from November through April, runs and pools from July through October, runs and backwaters during May, and backwaters, eddies, and flooded gravel pits during June. In early spring, adults move into flooded bottomlands. They use relatively shallow water (ca. three feet [0.9 m]) during spring and deeper water (five to six feet [1.5-1.8 m]) during winter (USFWS 2002b).

Data from radio-telemetered razorback suckers in the Verde River showed they used shallower depths and slower velocity waters than in the upper basin. They avoided depths <1.3 feet (0.4), but selected depths between 2.0 and 3.9 feet (0.6 to 1.2 m), which likely reflected a reduced availability of deeper waters compared to the larger upper basin rivers. However, use of slower velocities (mean = 0.1 foot/sec) may have been an influence of rearing in hatchery ponds. Similar to the upper basin, razorback suckers were found most often in pools or run over silt substrates, and avoided substrates of larger material (Clarkson et al. 1993).

Razorback suckers also use reservoir habitat, where the adults may survive for many years. In reservoirs, they use all habitat types, but prefer backwaters and the main impoundment (USFWS 1998). Much of the information on spawning behavior and habitat comes from fishes in reservoirs where observations can readily be made. Habitat needs of larval and juvenile razorback sucker are reasonably well known. In reservoirs, larvae are found in shallow backwater coves or inlets (USFWS 1998). In riverine habitats, captures have occurred in backwaters, creek mouths, and wetlands. These environments provide quiet, warm water where there is a potential for increased food availability. During higher flows, flooded bottomland and tributary mouths may provide these types of habitats.

Razorback suckers are somewhat sedentary; however, considerable movement over a year has been noted in several studies (USFWS 1998). Spawning migrations have been observed or inferred in several locales (Jordan 1891, Minckley 1973, Osmundson and Kaeding 1989, Bestgen 1990, Tyus and Karp 1990). During the spring spawning season, razorbacks may travel long distances in both lacustrine and riverine environments, and exhibit some fidelity to specific spawning areas (USFWS 1998). In the Verde River, radio-tagged and stocked razorback suckers tend to move downstream after release. Larger fish did not move as much from the stocking site as did smaller fish (Clarkson et al. 1993).

The razorback sucker was once abundant in the Colorado River and its major tributaries throughout the Basin, occupying 3,500 miles (5,633 km) of river in the United States and Mexico (Maddux et al. 1993b). Records from the late 1800s and early 1900s indicated the species was abundant in the lower Colorado and Gila river drainages (Kirsch 1889, Gilbert and Scofield 1898, Minckley 1983, Bestgen 1990). It now occurs in portions of the upper Colorado, Duchesne, Green, Gunnison, White, and Yampa rivers in the Upper Basin; and in the lower Colorado River from Grand Canyon down to Imperial Dam. The species is being reintroduced into the Verde River.

The range and abundance of razorback sucker has been severely impacted by water manipulations, habitat degradation, and importation and invasion of non-native species. Construction of dams, reservoirs, and diversions destroyed, altered, and fragmented habitats needed by the sucker. Channel modifications reduced habitat diversity, and degradation of riparian and upland areas altered stream morphology and hydrology. Finally, invasion of these degraded habitats by a host of non-native predacious and competitive species has created a hostile environment for razorback sucker larvae and juveniles. Although the suckers produce large spawns each year and produce viable young, the larvae are largely eaten by the non-native fish species (Minckley et al. 1991).

Populations in the upper Colorado Basin are being maintained through stocking (Nesler et al. 2003, Zelasko et al. 2010) and the lower basin populations are maintained through stocking and grow-out programs managed by the MSCP program (see http://www.lcrmscp.gov/fish/fish_res_mon.html for specific research projects and reports). In the San Juan River there is evidence of spawning and recruitment primarily at the inflow area to Lake Powell (D. Elverud, Utah Division of Wildlife, personal communication). The only known reproducing and recruiting populations in the Colorado River basin are in Lake Mead (where they are primarily found near inflow areas from the Colorado, Virgin, and Muddy rivers) and the Las Vegas Wash (Albrecht et al. 2008, Kegerries and Albrecht 2011). Stocking and other recovery efforts by the Upper Colorado River Basin and San Juan River Recovery Implementation Programs are ongoing and information on those actions is available at their websites (http://www.coloradoriverrecovery.org/index.html; http://www.fws.gov/southwest/sjrip/. The Lower Colorado River Multi-Species Conservation Program is also implementing conservation actions for the species that are described on their website (http://www.lcrmscp.gov/).

Since 1997, significant new information on recruitment to the wild razorback sucker population in Lake Mead has been developed (Albrecht et al. 2008, Kegerries and Albrecht 2011) that indicates some degree of successful recruitment is occurring at three locations in Lake Mead, and another spawning group was documented in 2010 at the Colorado River inflow area of the lake. This degree of recruitment has not been documented elsewhere in the species' remaining populations. As part of their ongoing commitment to conservation for this species, the AGFD is an active participant in implementation of the razorback sucker recovery plan. In the Lower Colorado River Basin, efforts to reintroduce the species to the Gila, Salt, and Verde rivers have not been successful in establishing self-sustaining populations. Reintroduction efforts continue in the Verde River. Very few razorback suckers were recaptured from these efforts (Jahrke and Clark 1999). The Horseshoe-Bartlett Habitat Conservation Plan (HCP) (SRP 2008) contains conservation actions to be implemented in the Verde River for the razorback sucker, including funding for continued stocking of the species.

Recovery for the razorback sucker is currently defined by the FWS Razorback Sucker Recovery Goals (USFWS 2002b). The Recovery Goals define recovery as specific demographic criteria that must be attained, and recovery factors that must be met to achieve downlisting and delisting of razorback sucker. The recovery factors were derived from the five listing threat factors under ESA section 4(a), and state the conditions under which threats are minimized or removed sufficient to achieve recovery; a list of site-specific management actions and tasks (e.g. the development and implementation of non-native fish control programs) is also provided. They include the need to identify, implement, evaluate, and revise (as necessary through adaptive management) flow regimes to benefit razorback sucker for all the rivers in which the species occurs. Essentially, the goals identify actions needed to maintain the habitat features (i.e. the physical and biological features of critical habitat) to accomplish recovery. But the measures 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 recovery actions, as well as the demographic Recovery Goals, are provided in USFWS (2002b). We summarize here the Recovery Goal demographic criteria for downlisting (there are no delisting criteria) as follows (population demographics in both recovery units must be met in order to achieve downlisting):

Upper basin recovery unit

Green River Subbasin

1. A self-sustaining population is maintained over a 5-year period, starting with the first point estimate acceptable to the FWS, such that:

    a. the trend in adult (age 4+; ≥ 400 mm [15.7 inches] TL) point estimates does not decline significantly, and

    b. mean estimated recruitment of age-3 (300-400 mm [11.8-15.7 inches]TL) naturally produced fish equals or exceeds adult mortality, and

    c. each population point estimate exceeds 5,800 adults (Note: 5,800 is the estimated MVP number).

Upper Colorado River and San Juan River Subbasins

1. A self-sustaining population is maintained in EITHER the upper Colorado River subbasin or the San Juan River subbasin over a 5-year period, starting with the first point estimate acceptable to the Service, such that for either population:

    a. the trend in adult (age 4+; ≥ 400 mm [15.7 inches] TL) point estimates does not decline significantly, and

    b. mean estimated recruitment of age-3 (300-400 mm [11.8-15.7 inches]TL) naturally produced fish equals or exceeds adult mortality, and

    c. each point estimate exceeds 5,800 adults (MVP).

Lower basin recovery unit

Lake Mohave

1. Genetic variability of razorback sucker in Lake Mohave is identified, and a genetic refuge is maintained over a 5-year period.

Rest of basin

1. Two self-sustaining populations (e.g., mainstem and/or tributaries) are maintained over a 5-year period, starting with the first point estimate acceptable to the FWS, such that for each population:

    a. the trend in adult (age 4+; ≥ 400 mm [15.7 inches] TL) point estimates does not decline significantly, and

    b. mean estimated recruitment of age-3 (300-400 mm [11.8-15.7 inches] TL) naturally produced fish equals or exceeds adult mortality, and

    c. each point estimate exceeds 5,800 adults (MVP).

General PCEs of Critical Habitat

Critical habitat was listed for the four big river fishes (Colorado pikeminnow, humpback chub, bonytail, and razorback sucker) concurrently in 1994, and the PCEs were defined for the four species as a group in two biological support documents and the final rule designating critical habitat (Maddux et al. 1993a, 1993b, USFWS 1994). The general PCEs are the same as these discussed previously for humpback chub and are not repeated here. 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.

Table 2. CRITICAL HABITAT UNITS FOR RAZORBACK SUCKER
(Range wide information by reach with conservation value and habitat issues at designation)

State	Reach Description/ River	Reach Description/ Segment	Conservation value	Important issues at time of designation
Arizona/Nevada	Colorado River	Paria River to Hoover Dam	Delisting	Flow alterations, non-native species
Arizona/Nevada	Colorado River	Hoover Dam to Davis Dam	Downlisting	Flow alterations, non-native species
Arizona/California	Colorado River	Parker Dam to Imperial Dam	Delisting	Flow alterations, non-native species
Arizona	Gila River	New Mexico state line to Coolidge Dam	Delisting	Flow alterations, non-native species
Arizona	Salt River	Bridge to Roosevelt Dam	Delisting	Flow alterations, non-native species

Arizona	Verde River	Perkinsville to Horseshoe Dam	Delisting	Flow alterations, non-native species
Colorado	Colorado River	Rifle to Westwater	Downlisting	Flow alterations
Colorado	Gunnison River	Uncompahgre River to Redlands Diversion	Delisting	Flow alterations, non-native species
Colorado	Yampa River	Lily Park to Green River	Downlisting	Non-native species
New Mexico/Utah	San Juan River	Hogback Diversion to Neskahai Canyon	Downlisting	Non-native species
Utah	Colorado River	Westwater to Dirty Devil	Delisting	Non-native species
	Duchesne River	Lower 2.5 miles (4.0 km)	Delisting	Flow alterations, non-native species
	Green River	Yampa River to Sand Wash	Downlisting	Flow alterations, non-native species
	Green River	Sand Wash to Colorado River	Delisting	Flow alterations, non-native species
	White River	Lower 18 miles (29.0 km)	Delisting	Flow alterations, non-native species

Previous consultations

Section 7 consultations on razorback sucker include consultations on large-scale water management activities. For the upper basin, the UCRRP addresses the effects of such consultations on the species and provides conservation measures to somewhat offset the effects of proposed actions. In the lower Colorado River, the Lower Colorado River MSCP addresses effects of water management and provides conservation to offset effects of water operations. Several Statewide consultations have occurred including the Land and Resource Management Program with the Forest Service and the IntraService consultation on Sport Fish Restoration Funding which evaluated the sport fish stocking program funded by the FWS (UFSWS 2011b). Smaller site-specific consultations addressing channelization, recreational development, and implementing recovery actions have also occurred. All prior consultations have reached non-jeopardy and non-adverse modification conclusions. Biological opinions on actions potentially affecting razorback sucker in Arizona may be found at our website www.fws.gov/southwest/es/arizona in the Section 7 Biological Opinion page of the Document Library.

Kanab ambersnail

The Kanab ambersnail was listed as endangered in 1992 (57 FR 13657) with a recovery plan completed in 1995 (USFWS 1995a). No critical habitat is designated for this species. 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. 2007).

Stevens et al. (1997) defined primary habitat at Vasey's Paradise as crimson monkey-flower (*Mimulus cardinalis*) and non-native watercress (*Nasturtium officinale*), and secondary, or marginal, habitat as patches of other species of riparian vegetation that are little or not used by Kanab ambersnail. The species occurs in Utah and at two populations in Grand Canyon National Park: one at Vasey's Paradise, a spring and hanging garden at the right bank at RM 31.8, and a translocated population at Upper Elves Chasm, at the left bank at RM 116.6 (Gloss et al. 2005). The Elves Chasm population is located above an elevation that could be inundated by HFEs of up to 45,000 cfs. Intensive searches at more than 150 springs and seeps in tributaries to the Colorado River between 1991 through 2000 found no additional Kanab ambersnail (Sorensen and Kubly 1997, Meretsky and Wegner 1999, Meretsky et al. 2000, Webb and Fridell 2000).

The Kanab ambersnail lives approximately 12–15 months and is hermaphroditic and capable of self-fertilization (Pilsbry 1948). Mature Kanab ambersnail mate and reproduce in May–August (Stevens et al. 1997, Nelson and Sorensen 2001). Fully mature snail shells are translucent amber with an elongated first whorl, and measure about 23 mm (0.9 inches) in shell size (J. Sorensen, AGFD, written communication, 2011). Adult mortality increases in late summer and autumn leaving the overwintering population dominated by subadults. Young snails enter dormancy in October–November and typically become active again in March–April. Over-winter mortality of Kanab ambersnail can range between 25 and 80 percent (USFWS 2011c, Stevens et al. 1997). Populations fluctuate widely throughout the year due to variation in reproduction, survival, and recruitment (Stevens et al. 1997). Current climate change science predicts decreases in precipitation and water resources in areas occupied by Kanab ambersnail. Because Kanab ambersnail populations are restricted to small wet vegetated habitat areas, we consider climate change and associated reduction in water resources a threat to Kanab ambersnail (USFWS 2011c).

The 5-year review on the Kanab ambersnail describes a draft report by Culver et al. (2007), which characterized mitochondrial diversity and AFLP marker diversity from 12 different southwestern *Oxyloma* populations (USFWS 2011c). The characterized populations included two Kanab ambersnail populations (Vasey's Paradise and Three Lakes) and 10 non-endangered ambersnail populations. Analysis detected some gene flow among the studied *Oxyloma* populations. The authors speculate that the measured gene flow demonstrates that all of the populations studied are members of the same interbreeding species (Culver et al. 2007). Thus, in contradiction to previous studies, they concluded that Kanab ambersnails are genetically the same as all other *Oxyloma haydeni (*Niobrara ambersnail*)* and subsequently Kanab ambersnails do not warrant subspecies status. A taxonomic change of Kanab ambersnail to Niobrara ambersnail could result in its downlisting or delisting. However, as of this writing, this report remains unpublished.

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.

Glen Canyon Dam has operated under MLFF since the Record of Decision was signed in 1996. Generally, the MLFF is a set of flow constraints that results in hourly, daily, and monthly variations in flow from Glen Canyon Dam. The MLFF is implemented by Reclamation through the GCDAMP as defined in the 1995 EIS and 1996 ROD (Reclamation 1995, 1996). The variations in flow resulting from MLFF affect many aspects of the ecosystem from Glen Canyon Dam 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, and adding to the complexity is the fact that few if any effects can be analyzed separately because they interact. The proposed action will continue the MLFF and add NNFC and HFE Releases.

HFE Releases will occur during limited times and periods of the year when large amounts of sand from tributary inputs are likely to have accumulated in the channel of the Colorado River. Annual releases would follow prior decisions, including the MLFF, Interim Guidelines for lower basin shortages and coordinated reservoir operations, and the steady flows as identified in the 2008 Opinion and the 2009 Supplemental Opinion. The 5-year experimental flow plan began in 2008 and will continue through calendar year 2012 under the proposed action.

Background - The history of scheduled experimental high-flow releases was as follows:

- 1996 Beach Habitat Building Flow (BHBF) 45,000 cfs for 7 days, March 26-April 2, 1996.
- 1997 Habitat Maintenance Flow (HMF), 31,000 cfs for 72 hours, November 5-7, 1997.

• 2000 HMF, 31,000 cfs for 72 hours, May 2-4, 2000.
• 2000 HMF, 31,000 cfs for 72 hours, September 4-6, 2000.
• 2004 HFE, 41,000 cfs for 60 hours, November 21–23, 2004.
• 2008 HFE, 41,500 cfs for 60 hours, March 5–7, 2008.

The first BHBF was held March 26 to April 7, 1996 and included pre- and post-release steady flows of 8,000 cfs for 4 days each and a 7-day steady release of 45,000 cfs. Dam releases were increased and decreased gradually relative to the peak release in order to minimize damage to resources. The coordinated effort of scientists to evaluate the effects of the 1996 BHBF on physical, biological, cultural, and socio-economic resources were documented by Webb et al. (1999). The 1996 experiment was conducted when the Colorado River was relatively sand depleted, especially in Marble Canyon, and, as a result, the primary sources of sand for building high-elevation sandbars were the low-elevation parts of the upstream sandbars and not the channel bed (Andrews 1991, Schmidt 1999, Hazel et al. 1999). During the 1996 experiment, the erosion of low-elevation sandbars actually resulted in a net reduction in overall sandbar size. Sandbars that eroded during the 1996 experiment did not recover their former sand volume during the late 1990s, in spite of above-average sand supplies and the implementation of the Record of Decision on operations. These results indicated that high-flow releases conducted under sand-depleted conditions, such as those that existed in 1996, will not successfully sustain sandbar area and volume. Scientists and managers used this information to focus their efforts on the need to strategically time high-flow releases to better take advantage of episodic tributary floods that supply new sand, particularly sand input by the Paria River, to the Colorado River downstream from Glen Canyon Dam.

The findings of the 1996 BHBF led to the decision to conduct the 2004 HFE when a sediment enrichment condition existed (Reclamation 2002). This experiment was held November 21–23, 2004, and included a 60-hour release of 41,000 cfs. The 2004 HFE was conducted shortly after a large amount of sediment was delivered by the Paria River and it helped test the hypothesis that maximum sediment conservation would occur with a high flow shortly after the sediment was deposited in the mainstem. Suspended sediment concentrations in the upper portion of Marble Canyon during the 2004 experiment were 60 to 240 percent greater than during the 1996 experiment, although there was less sediment in suspension below RM 42. The 2004 experiment resulted in an increase of total sandbar area and volume in the upper half of Marble Canyon, but further downstream, where sand was less abundant, a net transfer of sand out of eddies occurred that was similar to that observed during the 1996 experiment (Topping et al. 2006).

Following these findings with respect to effectiveness of the 2004 HFE trigger and implementation, a third planned high release was held March 5-7, 2008, and included a 60-hour release of 41,500 cfs. The 2008 HFE was timed to take advantage of the highest sediment deposits in a decade, and was designed to better assess the ability of these releases to rebuild sandbars and beaches that provide habitat for endangered wildlife and campsites for users of the Grand Canyon. The 2008 HFE was preceded by a sediment budget that was greater than the 2004 HFE and the net storage effect of the 2008 high-flow was positive. Although sandbar erosion occurred after the March 2008 HFE due to higher monthly water volumes, it was noted that the erosion rate slowed during the steady 8,000 cfs releases in September–October. Results of the 2008 HFE were summarized by Melis et al. (2010) and detailed in a number of USGS Open File Reports (Grams et al. 2010, Hilwig and Makinster et al. 2010, Korman et al. 2010, Rosi-Marshall et al. 2010, Topping et al. 2010, and others).

Three HMFs were held, including one in 1997 and two in 2000. Another HMF was scheduled in 2002 as a release that would coincide with a high Paria River inflow, but the conditions for conducting this HMF were never met. The 1997 release was held as a fall powerplant release of 31,000 cfs for 72 hours, November 5-7, 1997. The May 2-4 and September 4-6, 2000 HMFs were held in association with a low steady summer flows of 8,000 cfs from June 1 through September 4, 2000. The steady summer flows were designed to warm shoreline habitats for native and endangered fishes, especially humpback chub, and the HMFs were designed to maintain habitats, export invasive non-native fish, and evaluate ponding of tributary inflows. However, as noted in Ralston (2011), the variability of flow during this time may have hampered the effectiveness of studies to assess resource responses. Individual steady flows ranged from 4 days to 12 weeks. With respect to sediment, all flows export more sediment than they place into storage and past powerplant capacity flows have been less efficient at this than HFEs (Hazel et al. 2006).

Water stored in Lake Powell can be released through Glen Canyon Dam in three ways: (1) through eight penstocks that lead to hydroelectric generators (powerplant) with a combined authorized capacity of 31,500 cfs, (2) through the river outlet works or four bypass tubes with a combined capacity of 15,000 cfs, and (3) over the two spillways with a combined capacity of 208,000 cfs. Most releases are made through the powerplant. Spillway releases can only be made if the reservoir is sufficiently high to top the spillways. Hence, a high-flow release that exceeds the powerplant capacity would, in nearly all cases, invoke the bypass tubes to achieve the desired flow magnitude. Neither the bypass tubes nor the spillway are equipped with hydropower generating capability.

The Department of the Interior is currently undertaking an Environmental Impact Statement (EIS) process for the Long-Term Experimental and Management Plan (LTEMP), which will analyze and address flow and non-flow related options for future implementation as part of the Adaptive Management Program. Consultation on the LTEMP is anticipated to supersede the coverage provided by this biological opinion (76 FR 39435, 76 FR 64104).

A. STATUS OF THE SPECIES AND CRITICAL HABITAT WITHIN THE ACTION AREA

Humpback chub

The status of the humpback chub in the action area has improved since 2000 with increasing numbers of adult fish in the LCR Reach and evidence of y-o-y overwintering at 30-mile (Andersen et al. 2010, Yard et al. 2011). The Grand Canyon population consists primarily of adults residing in and near the LCR (the LCR Inflow aggregation), with eight other much smaller aggregations of the species scattered throughout approximately 180 river miles of the mainstem Colorado River as described above. Successful translocation of juvenile humpback chub into Havasu and Shinumo creeks is likely to increase the status of those aggregations and improve the species' status overall in the action area.

As stated in our 2008 and 2009 Supplemental Opinion, the population dynamics information for humpback chub is much improved since the 1995 opinion, with much more available information on humpback chub recruitment and abundance as a result of ongoing monitoring of the GCDAMP and the development of the ASMR (Coggins and Walters 2009). Coggins and Walters (2009) assessed the status and trend of the humpback chub in the LCR (the LCR Inflow aggregation) utilizing the ASMR model. As of 2008, the adult (age 4+) population of humpback chub was estimated to be about 7,650 fish, with a range between 6,000 and 10,000 fish. The ASMR indicates that a decline in the abundance of adult humpback chub occurred throughout the late 1980s and early 1990s, reached a low in the early 2000s, and has since trended upwards. This recent upward trend represents about a 50 percent increase in adult abundance since 2001 (Coggins 2008a, Coggins and Walters 2009) with the population size continuing to increase. The 2006 estimate was 5,300-6,700, an increase of about 50 percent since 2001 (Coggins 2008a, Coggins and Walters 2009). The change in status was due to an increase in recruitment that began before many actions predicted to improve the humpback chub status (such as mechanical removal of non-native 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). Notably, the largest increase in adult abundance occurred in 2007, when the 2003 brood-year matured to age-4 (Coggins and Walters 2009). This was the first year of non-native fish control, which coincided with warmer water releases from Glen Canyon Dam. This reinforces the findings of the 2008 Opinion in which we predicted those brood years would likely benefit from these changes to the mainstem critical habitat in Reach 7. According to C. Walters (2011, pers. comm., Anderson 2009, Coggins et al. 2011) and other sources current data are insufficient to support piscivory of non-native fish on humpback chub as the causal mechanism in the period of decline in humpback chub (approximately 1990-2000) because of the complexity of numerous factors and because the upward trend in adult humpback chub numbers appears to have started before warmer water and removal efforts to control non-native fishes began.

A 4-year mechanical removal effort to reduce rainbow trout abundance in target reaches of the Grand Canyon began in January 2003 (Coggins 2008, Coggins et al. 2011). To aid the mechanical removal effort, an experimental "non-native fish suppression flow" (NFSF) regime from Glen Canyon Dam was implemented between January and March in 2003–2005. These flows were intended to reduce rainbow trout abundance in the Lees Ferry reach by increasing mortality rates on incubating life stages. As discussed below, the "non-native fish suppression flows" resulted in a total redd loss of approximately 23% in 2003 and 33% in 2004. However, because of increases in survival of rainbow trout at later life stages, this increased mortality did not lead to reductions in overall recruitment of rainbow trout due to density compensation of high survival of age 1 trout (Korman et al. 2005, Korman et al. 2011). The flow element of non-native removal was not repeated after 2005 although mechanical removal continued through 2006 and once in 2009.

In 2008, a large rainbow trout cohort spawned in Lees Ferry, apparently as a result of the 2008 HFE (Korman et al. 2010, 2011). Large downriver migration of this cohort, combined with local recruitment along downriver sections, likely led to a roughly 800 percent increase in rainbow trout densities in the vicinity of the Little Colorado River since 2006 (Makinster et al. 2010, Wright and Kennedy 2011. Preliminary estimates of the 2011 Natal Origins field work has estimated trout numbers at over 1 million age 0 fish in the Lees Ferry Reach, or 17 times higher than the previous estimate after the 2008 HFE (J. Korman, Ecometric, pers. comm. 2011). Although the fate of those age 0 fish cannot be reliably predicted, it is possible that a portion of this cohort will emigrate downstream and potentially interact with native fish. This increase in trout numbers may be due to high and steady dam releases in 2011 due to a wet water year and resulting equalization flows (from Lake Powell to Lake Mead) under the Interim Guidelines. Mainstem warming and mechanical removal effects both started in 2003 and could have begun affecting the abundance of age-2 humpback chub recruits in 2004 and later, (brood-years 2002 and later). But the increase in humpback chub recruitment appears to have begun in the mid-1990s before the population was exposed to warmer Colorado River water temperatures and reduced non-native fish 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 the largest of the humpback chub population range wide, and the only one with an increasing trend.

Other monitoring information developed through the GCDAMP also indicates humpback chub status has been improving over the past decade. FWS monitoring efforts in the LCR indicate that beginning in 2007 the abundance of adult humpback chub ≥ 200 mm (7.9 inches) in the LCR during the spring spawning season significantly increased compared to estimates obtained between 2001 and 2006 (Van Haverbeke et al. 2011), and have continued to trend upwards. Furthermore, all post-2006 spring abundance estimates of humpback chub ≥150 mm (5.0 inches) in the LCR do not differ statistically from the spring 1992 estimates obtained by Douglas and Marsh (1996). Finally, all post-2006 spring abundance estimates of humpback chub between 150 and 199 mm (5.0 and 7.8 inches) in the LCR (Van Haverbeke et al. 2011) appear to have equaled or exceeded the estimate of mean annual adult mortality provided in Coggins and Walters (2009). These findings are significant because the objective and measurable recovery criteria in the recovery goals (USFWS 2002a) require that the trend in adult abundance does not decline significantly, and that the mean estimated recruitment of age-3 (150-199 mm [5.0 and 7.8 inches]) naturally produced fish equals or exceeds mean annual adult mortality. It would appear that at least the portion of the LCR aggregation that enters the LCR to spawn each spring have returned to levels of abundance documented in the early 1990s.

Most of 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 Humpback Chub Comprehensive Plan in August 2009, and Reclamation is currently implementing many aspects of the plan (Glen Canyon Dam Adaptive Management Program 2009). For example, translocations above Chute Falls were conducted every year between 2008 and 2011. Working with NPS, translocations have also occurred into Havasu and Shinumo Creeks. A genetics management plan for humpback chub was also completed in 2010.

One LCR reach non-native removal trip was conducted in 2009. No trips were conducted in 2010 or 2011 because of Tribal concerns. In November 2010, at Reclamation's request, this office prepared a separate Biological Opinion on the continued Operations of Glen Canyon without Mechanical Removal for a 13-month period. In our November 9, 2010 biological opinion, we concluded that this action would result in incidental take of y-o-y, juvenile, and some adult humpback chub due to increased fish predation and competition, but that this would not jeopardize the species or adversely modify its critical habitat (USFWS 2010 Cancellation Opinion).

The Near Shore Ecology study began in 2008 and field work concluded in 2011. The NSE project was designed to estimate monthly survival estimates of juvenile humpback chub between 40-80 mm (1.57 and 3.15 inches) to assess population responses to experimental steady flows. The NSE project continues to develop approaches to estimate annual survival rates with these data in the NSE study reach downstream of the LCR. Reclamation has also instituted and completed a Monthly Flow Transition Study conservation measure as referenced in the 2008 Biological Opinion. Development of a refuge for humpback chub at DNFHTC began in 2008 and is ongoing, with 885 juvenile humpback chub being transferred to the station for this specific purpose. These humpback chub have all been captured from the wild in the lower 5.9 miles (9.5 km) of the LCR (300 fish in 2008, 200 fish in 2009, 185 fish in 2010, and 200 fish in 2011). Reclamation 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. To mitigate the adverse affects of the MLFF and the HFE Protocol, Reclamation has also committed to continue most of the conservation measures identified in previous biological opinions (USFWS 2008a, 2009) and as described in this opinion through 2020 as warranted, except for further non-native removal in the LCR reach which will only be conducted if certain triggers are met (Reclamation, Supplemental BA 2011).

As described earlier, translocation of humpback chub from the LCR to upstream of Chute Falls took place in between 2008 and 2011, as a conservation measure of the 2008 Opinion. Thus far, a total of 1,848 humpback chub have been translocated above Chute Falls. This upstream reach has been monitored since the first translocation in 2003, with annual mark-recapture methods being initiated in 2006. Humpback chub have consistently been found above the falls since then, a few adult chub have moved upstream on their own (thus the falls do not actually constitute an absolute barrier to humpback chub), and 156 humpback chub (120-344 mm [4.7-13.5 inches]) were captured above Chute Falls in monitoring in 2009 (Stone 2009). Between 2006 and 2009, population estimates of adult humpback chub (≥ 200 mm [7.9 inches]) above Chute Falls ranged from about 50 to 100 fish (Figure 5). However, in 2010 the abundance dropped to an estimate of only 2 fish. This decline is thought to be related to a protracted spring runoff event the LCR experienced during 2010 (Van Haverbeke et al. 2011).

The abundance of humpback chub in the lower reach immediately below Chute Falls in the Atomizer Falls complex increased dramatically in 2007, with hundreds of fish present, likely as a result of translocation efforts, although the humpback chub present were a mix of some translocated fish, some that had moved up from downstream areas of the LCR (upriver migrants), and fish of unknown origin that did not appear to have previously been tagged (Stone 2009, D. Stone, FWS, pers. comm. 2009). As with the severe decline of adult humpback chub above Chute Falls in 2010, the small reach of river immediately below Chute Falls also witnessed a dramatic decrease in 2010 (Figure 5).

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 (7.9 inches) fish in the Grand Canyon population is estimated to be 4 years old. Translocated fish may 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). At least 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 are 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 variable 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 high. However, most humpback chub have moved below Chute Falls, calling any range extension from the translocation effort somewhat into question (Van Haverbeke and Stone 2009).

In June 2009, Grand Canyon National Park and Grand Canyon Wildlands Council translocated 300 age-1 humpback chub into Shinumo Creek. Additional stocking occurred in 2010; and the third translocation of humpback chub into Shinumo Creek occurred on June 21, 2011, when three hundred young humpback chub averaging 89 mm (3.5 inches) were stocked (Healy et al. 2011). Supplemental translocations were also conducted in 2010 and 2011 (Healy et al. 2011). The 2011 field season documented 54 of the translocated humpback chub including 5 from the 2009 stocking season and 36 from the 2010 season (Healy et al. 2011).

In another 2008 Opinion conservation measure over 900 non-native rainbow trout were removed from Shinumo Creek in May and June 2009, in preparation for the humpback chub release. Fisheries biologists also removed 394 rainbow trout from Shinumo Creek during the 2011 field season (Healy et al. 2011). Native bluehead sucker and speckled dace were also documented, measured, and returned to the creek. Following the 2009 humpback chub 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 indicated high 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 were 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). The Shinumo aggregation is likely supporting a small mainstem spawning aggregation at Shinumo Creek, as captures of young fish indicates that successful spawning has occurred (Ackerman 2008, Grand Canyon Wildlands Council 2009).

In June 2011, 244 humpback chub approximately 95 mm TL (3.7 inches) were translocated to Havasu Creek in fulfillment of the translocation Conservation Measure of the 2008 Opinion. Native bluehead sucker (n=50), speckled dace (n=517), flannelmouth sucker (n=18), and unmarked humpback chub (7) were also documented in the creek, along with 22 rainbow trout (Smith et. al 2011). Reclamation has committed to continue support for translocation efforts as part of this biological opinion, which will help support expanding the range of humpback chub throughout its critical habitat in the action area.

Mainstem humpback chub spawning aggregations other than the LCR inflow were monitored in 2010 and 2011; however, preliminary data suggest that humpback chub abundance is either stable or increasing at most aggregations (W. Persons, USGS, written communication, 2011a).

Andersen et al. (2010) documented successful overwinter of y-o-y humpback chub at 30-mile. The 30-mile aggregation is the closest aggregation to the dam and thus water in this area would be warmed the least as it moves downstream. However, temperatures at the dam in 2005 were above the thermal minimum needed for successful humpback chub spawning, so it is conceivable that the 30-mile aggregation spawned. Monitoring of mainstem aggregations previously occurred every two years, but will now be conducted annually through the GCDAMP as a conservation measure of this biological opinion (described above).

Habitat Conditions

Water temperatures in the mainstem Colorado River below Glen Canyon Dam are an important factor of fishery habitat downstream. 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 when lake elevation is low); 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 (solar insolation directly warms water). Releases from Glen Canyon Dam affect downstream temperature primarily as a function of release temperature and release volume. Wright et al. (2008a) found that mainstem temperatures at the LCR 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 further downstream. Release temperature peaked in 2005 when Lake Powell reached its lowest point since filling in the 1980s of 3,555.1 feet (1083.6 m) elevation on April 8. Since the 2008 Opinion, Lake Powell elevation has ranged from 3,588.26 feet (1093.70 m) on March 11, 2008 to 3,642.29 feet (1110.17 m) on July 12, 2009. 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).

Water temperatures in the mainstem Colorado River have generally been elevated over the last decade (Figure 4). These temperatures are not optimal for humpback chub spawning and growth, but may provide some temporary benefit and contribute to the improving status of the species. 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, 2009, and 2011. Water temperature in the mainstem at Lees Ferry reached about 14 °C in 2008 (USGS 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 were 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. Water temperatures peaked at 11° in 2010 and 13.5° in 2011 (Figure 4; USGS unpublished data).

Nearshore habitats are important nursery habitats for humpback chub (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 (AGFD 1996, Behn et al. 2010). Behn et al. (2010) found that the water in Grand Canyon backwaters completely exchanges with the mainstem an average of 6.5 times per day when discharge fluctuates but just 2.3 times per day when discharge is stable. Hoffnagle (1996) found that the mean, minimum, maximum, and daily 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. Anderson and Wright (2007) also found that fluctuations have minimal effect on mainstem water temperatures but 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 main channel 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. However, they also noted that the extent of the effect was variable and depended on the timing of daily minimum and maximum flows, the difference between air and water temperatures, and the topography and orientation of the backwater relative to solar insolation. Nevertheless, when mainstem temperatures are cold (i.e., <12 ° C) backwaters may provide a thermal refuge for juvenile and adult humpback chub, and the thermal conditions in backwaters are generally more favorable for native fish when discharge is stable relative to fluctuating. Use of thermal refuges (i.e., small, discrete locations that represent a more favorable thermal environment than the main river) by fish have been documented in a variety of systems (e.g., Ebersole et al. 2001, Torgerson et al. 1999).

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. 2008b). HFEs do create sand bars and associated backwaters.

Although backwaters appear to be important habitat types of young humpback chub (AGFD 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 NSE, began in 2008. This study was designed to clarify the relationship between flows and mainstem habitat characteristics and habitat availability for young-of-year and juvenile humpback chub and other native and non-native fish species. The NSE has documented humpback use and available habitat in the small study area below the LCR between Heart Island and Lava Chuar rapid. Preliminary results suggest that backwater habitats in this reach were small and ephemeral with fluctuating flows because of the high shoreline gradients. When backwaters were present, these habitats were often submerged during higher water releases (>15,000). Additional preliminary NSE results suggest that during the NSE study period (July - October), humpback chub were most often found in talus slopes although positive selection for backwater habitats occurred when backwater habitats were available. However backwater habitats are clearly not required for humpback chub to persist in the NSE study reach because, while backwater habitats have been observed to be ephemeral in this study reach, juvenile humpback chub have been consistently collected and, as described below, exhibited juvenile survivorship between 12 NSE sampling trips (GCMRC unpublished data).

The NSE project has developed preliminary year-specific survival rates for humpback chub 40-99 mm (1.6- 3.9 inches) TL of 47% SE 3.5% (95% confidence interval [CI] 40-54%) in 2009 and 32% SE 6.1% (95% CI 21-45%) in 2010. For humpback chub 100-199 mm (3.9-7.8 inches) TL, year-specific annual survival rates were 52% SE 3.9% (95% CI 44% to 59%) in 2009 and 52% SE 7.5% (95% CI 37-66%) in 2010. The periods of these specific annual survival rates were selected based on the assumption that the majority of taggable y-o-y chub would begin entering the mainstem and encountering NSE gear (July 1). So the annual survival rate "2009" is the period from July 1, 2009 to June 30, 2010, and the "2010" survival rate is the period from July 1, 2010 to June 30, 2011. No information is available for humpback chub less than 40 mm (1.6 inches) because this size fish are too small to be marked and later identified (GCMRC unpublished data).

An important feature of the environmental baseline is climate change. Some studies predict continued drought in the southwestern United States, including the lower Colorado River basin due to climate change. Seager 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). 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 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, that 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 are not using their full allocations of Colorado River water 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 if it goes forward 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 (USFWS 2008).

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 warmer water aquatic non-native species by providing 31 percent more suitable habitat for aquatic non-native 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 warm water 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 non-native 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 warm water non-native species such as red shiner, common carp, mosquitofish (*Gambusia affinis*), and largemouth bass. 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 non-native 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 to have been underestimated by biologists of the time, given newer information available on the effects of non-native 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 (USFWS 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 non-native parasites. This may be an important threat to humpback chub. Optimal Asian tapeworm (*Bothriocephalus acheilognathi*) 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, which can weaken humpback chub and increase mortality rates.

Predation and Competition from Non-native Fish

As discussed in the 2008 Opinion and 2009 Supplement Opinion, predation and competition from non-native fish species constitute a serious threat to humpback chub (Minckley 1991, Mueller 1995), and the non-native fish control conservation measure of the 2008 Opinion was developed to reduce that threat. Over a three year period, the mechanical removal program of 2003-2006 reduced estimated numbers of trout by 90% from about 6,446 (in January 2003) to 617 (in February 2006). This removal took place at a time when the population of rainbow trout was undergoing a systemic decline of about 20% per year, presumably because of poor water quality from low levels in Lake Powell. The mechanical removal program in the LCR reach was successful primarily at reducing the abundance of rainbow trout. However, maintenance of low rainbow trout abundance was facilitated by reduced immigration rates during 2005-2006 and the systemic decline in trout abundance (Coggins 2009).

The abundance of non-native rainbow trout in the important LCR Reach has increased since the 2008 High Flow experiment (Makinster et al. 2009a, 2009b) and brown trout numbers in Reach

3 (RM 69.1-109) have increased every year beginning in 2006 (Makinster 2010). Mainstem fish monitoring detected increases in rainbow trout in the LCR inflow reach of the Colorado River in 2008, prompting a removal trip in May of 2009. During the 2009 removal trip, AGFD removed 1,873 rainbow trout. The 2010 catch per unit effort in reach 2 (RM 56-69) was similar to 2009, but catch per unit effort in 2011 was nearly twice that of 2009 (B. Stewart, AGFD, written comm. 2011). These estimates may indicate that rainbow trout are likely increasing throughout Marble Canyon. 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, Van Haverbeke et al. 2011).

The threat posed to humpback chub in Grand Canyon by non-native 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). Non-native crayfish have been found in Glen Canyon in the past, although they have not become established. 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, which could affect native fish populations. 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, AGFD, 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 non-native fishes and flow restoration in Fossil Creek, Arizona, crayfish abundance increased significantly, but this had no apparent effect on native roundtail chub (*Gila robusta*, another species closely related to humpback chub), which also increased in numbers significantly following removal of non-native fish. The threat posed to humpback chub in Grand Canyon by non-native crayfish is unclear, although climate change could result in their invasion in Marble and Grand Canyons due to warmer mainstem water temperatures (Valdez and Speas 2007, Rahel et al. 2008).

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. 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 (278-km) 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 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, USFWS 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.

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, 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 much of the LCR is now intermittent while it was perennial historically (Valdez and Thomas 2009). But data for the USGS Cameron gauge (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 throughout 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 (Gallert and Winter 2005). 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 from agricultural and residential use may enter water sources 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 significant 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 non-native 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, Van Haverbeke et al. 2011).

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 et al. (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 Asian tapeworm) in the LCR fish as opposed to greater food availability in the Colorado River. The NSE study also documented higher growth rates of juvenile humpback chub in the mainstem relative to growth rates of juvenile fish in the LCR in 2009 and 2010 (GCMRC unpublished data), but it is uncertain whether these growth differences are a function of food availability, habitat, temperature, parasites, or a combination of these and other as of yet unidentified factors).

The biological PCEs of predation (B2) and competition (B3) from non-native species are also met. Non-native fish species that prey on and compete with humpback chub are present, but in very low numbers relative to native fishes including humpback chub. 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 non-native 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). However, for the LCR, the primary indication that the biological PCE, as well as the other PCEs, are met in the LCR 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, Van Haverbeke et al. 2011).

The LCR reach of critical habitat plays an 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 criteria 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 (USFWS 2002a). As described earlier, in addition to the demographic criteria, 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. 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 criteria, and the secondary measure is the state of the recovery factors and the implementation of their associated management actions and tasks, such as flow management and non-native fish control.

The 2008 abundance of humpback chub in the LCR was estimated to be 7,650 adults (between 6,000-10,000, age 4+; ≥ 200 mm (7.9 inches 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 criteria 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 FWS, such that the trend in adult (age 4+; ≥ 200 mm [7.9 inches]) point estimates does not decline significantly, the mean estimated recruitment of age-3 (150–199 mm [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 Upper Basin (Region 6) has not yet determined that the demographic criteria for the Grand Canyon population have been met, but the best available science indicates that the demographic criteria are 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. Most of these are directed at improving and protecting humpback chub habitat including critical habitat and the PCEs of critical habitat. Those that relate to the LCR and Reach 6 are discussed below.

For Factor A, flows for the LCR that meet the needs necessary for all life stages of humpback chub to support a recovered Grand Canyon population appear 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 flows 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). They 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. This plan was developed in response to an element of the reasonable and prudent alternative of the 1995 Opinion (USFWS 1995b) which required that Reclamation be instrumental in developing a management plan for the LCR. LCR watershed planning was also a conservation measure of the 2008 Opinion and a project in the Humpback Chub Comprehensive Plan and will continue under this opinion (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 water uses 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.

Factor B, overutilization, may not be relevant to the status of critical habitat, although there have been some concerns raised about handling stress from field surveys. An estimated 50-200 are killed each year during field activities and collection for scientific purposes, although the number has reached as high as 1,000 humpback chub during one year (P. Sponholtz, FWS, pers. comm., 2011). However, despite this mortality from handling stress, humpback chub in the LCR (the primary location of research efforts) have continued to increase in number over the last decade, and research and monitoring efforts have provided important insights into the recovery needs of the species.

For Factor C, the focus is on controlling the proliferation and spread of non-native species that prey on, compete with, and parasitize humpback chub, such as rainbow trout, channel catfish, black bullhead, and common carp, as well as the non-native internal fish parasite Asian tapeworm. Current levels of control of non-native fish species appear adequate in the LCR as non-native fish in Reach 6 of critical habitat continue to be at low levels, although high numbers of trout occur in the mainstem confluence area adjacent to the tributary. Clearly such low levels should be maintained, but a specific target level as in the Recovery Goals has not been identified. Non-native fishes stocked into the area utilizing Federal funds have been evaluated, and are not anticipated to significantly affect humpback chub or its critical habitat; however, illegal stocking in the area could result in adverse effects to humpback chub (USFWS 2011b).

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. 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. In the 2010 spring sampling trip, *Lernaea* was observed on 67 of 3,264 humpback chub (2.0%); individual fish were carrying between 1 to 4 parasites each. *Lernaea* was also seen on one bluehead sucker, one flannelmouth sucker, and 5 speckled dace. During the fall sampling effort of 2010, *Lernaea* was observed on 181 humpback chub (6.2% of total humpback chub captures). The infected humpback chub on both trips appeared to be distributed between the confluence and the top of Salt reach. One flannelmouth sucker and one speckled dace were also observed carrying *Lernaea* each during the fall survey effort (Van Haverbeke et al. 2011). The New Zealand mud snail, *Potamopyrgus antipodarum*, was also detected in the Grand Canyon in 1995 and may be expanding. The Humpback Chub 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, 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, it appears as if flow needs for all life stages are met for humpback chub in Reach 6, a required task of the Recovery Goals, although Valdez and Thomas (2009) recommend that a model be developed that defines the instream flow needs of humpback chub to ensure continued support 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, Van Haverbeke et al. 2011) indicate that the current flow conditions in the LCR are adequate.

For Factor E, other natural or manmade factors, 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 Humpback Chub 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 Humpback Chub Comprehensive Plan and Reclamation has agreed to continue to implement this as part of the proposed action.

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. In the 2008 and 2009 Supplemental Opinions we stated that the importance of habitat in the mainstem to recovery is not known. However, we know that these “big river fish” use a variety of riverine habitats, with adults especially found in canyon areas with fast current, deep pools, and boulder habitat, and at least some of the PCEs are functional as demonstrated by the NSE study and the persistence of mainstem aggregations. Reach 7 provides an important role in support of the Grand Canyon population (the largest of the humpback chub populations) 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. Preliminary data from mainstem aggregation monitoring (Figure 3) show the distribution of catch rates of humpback chub in Reach 7. Catch of fish is not adjusted for effort, such as hours of netting, seine hauls, etc. Therefore, the number of humpback chub caught during different time periods does not represent density or relative abundance because effort and gear types are different during different time periods. Distribution of catches across river miles may also be somewhat biased by gear types used; however, a relatively wide distribution of humpback chub catches between river mile 25 and 250 has been documented. Longitudinal distribution has not decreased in the last decade and the data suggest a broader distribution of chub since 2000 compared to the 1990s as well as local increases in abundance (W. Persons, USGS, written communication, 2011b).

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 criteria 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 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. Flows since Reclamation's 1995 Environmental Impact Statement (EIS) and 1996 ROD have been limited to 5,000 to 25,000 cfs except during experimental flows such as in 1996, 2004, and 2008, when experimental high flows from 41,500 to 45,000 cfs were tested. Prior to the current MLFF period of flow releases, daily fluctuations were greater, from 1,000 to 31,500 with unrestricted ramping rates (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 flow 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, 6.6 ft or greater in some areas; pre-dam, diurnal stage change was seldom more than 1.0 ft (GCMRC unpublished data).

Since closure of the dam the river has usually been perennially cold because Glen Canyon Dam typically 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. Releases from 2003 to present have been warmer due to lower Lake Powell reservoir levels, and reached as high as 16 °C in the Lees Ferry reach in 2005, 13-14 °C in 2008, and about 13 °C in 2009 (Vernieu et al. 2005, USGS 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). However, the warmer flows may also have provided an advantage to warm water predators of and competitors with humpback chub, which include fathead minnows, plains killifish (*Fundulus zebrinus*). Those two species and even rainbow trout appear to benefit from warmer water or reduced fluctuations, or both (Ralston 2011). Other warm water fish present in the Colorado River such as smallmouth bass, channel catfish, black bullhead, and common carp are also likely to benefit from warmer water. Climatologists predict that the southwest will experience extended drought, so lower Lake Powell Reservoir elevations and warmer release temperatures may become the norm (Seager et al. 2007, U.S. Climate Change Science Program 2008a, b).

Water temperature also affects the food base available for fish, also a PCE of critical habitat for humpback chub. When water temperatures are higher, rates of algae and invertebrate production in the mainstem river likely increase (Yard 2003, Sutcliffe et al. 1981, Hauer and Benke 1987, Benke and others 1988, Pockl 1992, Huryn and Wallace 2000), and both algae and invertebrates represent important food resources for native and non-native fish (Donner 2011, Zahn-Seegert 2011, Cross et al. 2011, Valdez and Ryel 1995, McKinney et al. 2001). Warmer water temperatures also increase the survival and growth of other mainstem non-native fishes that compete with and prey on humpback chub, so warmer water temperatures present a tradeoff in a sense of providing more food and better growing conditions for humpback chub, but also more non-native fish predators and competitors (Peterson and Paukert 2005), some of which, (such as rainbow trout which are functioning below their optimum temperature preference), have high dietary overlap with humpback chub (Valdez and Ryel, 1995, Donner, 2011).

The complex relationship between temperature, physical habitat, and biological habitat PCEs for humpback chub may provide some explanation for why humpback chub have persisted in Grand Canyon, and even thrived over the past decade, despite co-occurring with non-native fish species such as rainbow trout and channel catfish. Although water temperatures may not reach the optimal of 16-24 °C for humpback chub spawning, rearing, and growth, temperatures of 12-16 °C, at which humpback chub can complete their life cycle but are not optimal, have occurred and in fact have been much more common in recent years. Temperatures in the 12-16 °C range have occurred every year since 2003 at the mouth of the LCR, although temperatures there have only exceeded 16 °C in one year, 2005 (P. Grams, USGS, oral communication, 2011).

The LCR aggregation of adult humpback chub has been steadily increasing in number since 2001 based on the ASMR through 2008 (Coggins and Walters 2009) and on closed population estimates in the Little Colorado River by the FWS through 2010 (Van Haverbeke et al. 2011). During this same period, other humpback chub aggregations in the mainstem Colorado River also appear to be increasing (R. Van Haverbeke, FWS, pers. comm., 2011, W. Persons, USGS, written communication, 2011b) although abundance estimates are not available. One possible explanation for this may be that although temperatures in the 12-16 °C range are not optimal for humpback chub survival and growth, the conditions provided for suitable PCEs of critical habitat in the mainstem necessary for humpback chub to survive and recruit. Another explanation is that the LCR population is stable and increasing and provides a significant source of fish to mainstem aggregations during passive and active egress out of the LCR. In this case, the LCR acts as "source" of fish to a "sink" population (a population that dies without reproduction or expansion) in the mainstem. Temperatures in this range may be high enough during certain critical periods to negate cold water shock of humpback chub moving from the LCR to the mainstem (Ward et al. 2002). These conditions allow for better growth of humpback chub in the mainstem (Hamman 1982, Marsh 1985, Valdez and Ryel 1995), promote better swimming ability, and may improve their ability to avoid predation (Ward and Bonar 2003, D. Ward, USGS, oral communication, 2011). Mainstem temperatures in this range may also provide for better food availability which may give humpback chub a competitive advantage over non-native fishes. Yet because these temperatures are also suboptimal for non-native fish predators and competitors, competition and predation from some non-native fishes (not including brown trout which do not appear to be affected at these temperature ranges), are somewhat kept in check, at least to the extent that humpback chub can survive and have some limited recruitment in the mainstem.

As described above, mainstem water temperatures have been warmer in recent years due to climate conditions/drought and lower Lake Powell elevation (USGS 2009b). The temperature of dam release temperatures peaked in 2005 when they exceeded 16° C and Lake Powell elevation dropped to 3535 feet (1077 m) elevation, its lowest since filling in 1980. 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). Releases in that 2000 experiment and releases since 2003 during low Lake Powell reservoir levels have resulted in temperatures exceeding 12 °C at the mouth of the Little Colorado River (Figure 6), and this may in part explain why humpback chub status has been steadily increasing during this period (Coggins and Walters 2009).

Cold water is also a factor in juvenile humpback chub vulnerability to predation by non-native 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). These movements may also occur during high spring flows (Robinson et al. 1998). Young humpback chub that are washed into the mainstem are subjected to a significant change in water temperature which can be as much as 10 °C or more. This results in thermal shock of young fish, and a reduction in swimming ability, which also increases their vulnerability to predation (Lupher and Clarkson 1994, Valdez and Ryel 1995, Marsh and Douglas 1997, Robinson et al. 1998, Clarkson and Childs 2000, Ward et al. 2002). Due to the effects of thermal shock, juvenile humpback chub exiting the warm LCR and entering the cold mainstem may be too lethargic to effectively avoid predation or swim to suitable nearshore habitats (Valdez and Ryel 1995, Robinson et al. 1998). Cold water by itself also results in mortality of eggs and larval fish (Hamman 1982, Marsh 1985). It is not known if the warmer mainstem temperatures observed since 2003 limited the effects of thermal shock versus conditions that occurred in the 1990s.

Glen Canyon Dam operations also modify the hydrograph (the timing of water delivery in the river). The MLFF produces a hydrograph with the highest flow volumes in the winter and summer months to meet increased demand for electricity. 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 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 non-native fish species under certain conditions and have been correlated with increased recruitment of humpback chub (Chart and Lentsch 1997). 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. During the colder months, the daily hydrograph is typically more bimodal, because electricity demand wanes in the afternoon and resumes in the evening to meet heating needs of residences in the evening. 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 (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 the changes in Reach 7 of critical habitat caused by the dam, humpback chub successfully spawn in the LCR, and likely move into other aggregations, such as 30-mile where they may have spawned and successfully overwintered as documented by Andersen et al. (2010). 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, restricted flows and warmer water releases from Glen Canyon Dam along with reduced numbers of rainbow trout contributed to conditions that accommodated mainstem overwintering of y-o-y humpback chub.

Evidence of recruitment to other mainstem aggregations is suggested by presence of juvenile fish, although recruitment of juveniles into adults has not been documented. The status of most aggregations has remained stable or increased over the last decade, indicating recruitment of fish to adult size (W. Persons, USGS, written communication, 2011b) although numbers are likely very low. Young-of-year and juvenile humpback chub (< 121 mm [4.8 inches] TL) outside the LCR aggregation were most often captured at RM 110-140 (Stephen Aisle and Middle Granite Gorge aggregations) and RM 160-200 (Johnstone and Lauretta 2004, 2007, Trammell et al. 2002, AGFD 1996, Ackerman 2008). Seine catches of all young-of-year humpback chub outside the nine aggregations were at their highest in 21 years during 2004 (Johnstone and Lauretta 2007). Four humpback chub were also collected at Separation Canyon (RM 239.5) in 2005 (Ackerman et al. 2006). Trammell et al. (2002) noted that the Middle Granite Gorge aggregation appeared to be stable or perhaps even increasing in size beginning in 1993, but that it may be sustained via immigration from the LCR aggregation, as well as local reproduction. Few humpback chub have been caught at the Havasu Inflow and Pumpkin Spring aggregations since 2000 (Ackerman 2008).

Valdez and Ryel (1995) provided mark-recapture estimates for PIT-tagged humpback chub adults (≥200 mm [7.9 in] TL) in five of the remaining eight aggregations, including 30-Mile (estimate, n-hat = 52), Shinumo Inflow (n-hat = 57), Middle Granite Gorge (n-hat = 98), Havasu Inflow (n-hat = 13), and Pumpkin Spring (n-hat = 5). Population estimates have not been made for other mainstream aggregations since 1993 (Trammell et al. 2002). Data collected through 2006 indicate that humpback chub may have spawned and recruited at 30-mile (Anderson 2009, Trammell et al. 2002). Information from monitoring mainstem aggregations over the past 10 years indicates that catch rates have increased (W. Persons, USGS, written communication, 2011a). Monitoring efforts in 2010 and 2011 have also indicated that these aggregations persist and the Shinumo aggregation appears to have been augmented by translocations of humpback chub to Shinumo Creek which subsequently entered the mainstem, which has the possibility of increasing the size of the aggregation (Healy et al. 2011).

The effect of Glen Canyon Dam release temperature on humpback chub and conservation has long been recognized (USFWS 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 (Reclamation 1999). The preferred alternative included a selective withdrawal structure, a single inlet, fixed elevation design with an estimated cost of $15,000,000. Sufficient concern was evidenced in the review of the EA (Mueller 1999) for the potential unintended negative effects, such as non-native fish proliferation in response to prolonged water warming, 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.

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. However, Reclamation 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 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 non-native 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 (temperatures for all of these species in Grand Canyon are currently below their optimum temperature preferences). Preliminary results also showed more suitable conditions for warm water 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 which adversely affect native species is significant.

Reclamation 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 non-native species and their predatory and competitive effects to humpback chub are potentially significant. In light of these concerns and with the recommendation of an independent scientist panel convened in April 2007 (USGS 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. Specifically, if the operational feasibility of a warm- and cold-water TCD is considered, detailed aquatic modeling is needed that will examine and show predictive outcomes for young and adult age classes of rainbow and brown trout, smallmouth bass, green and other sunfish species, bullheads and catfish, striped bass, carp (including Asian carp if accidentally introduced), crayfish, other invertebrates, and parasites and diseases on humpback chub and other native fish populations.

Another aspect of the changes in water quality in Grand Canyon that may affect humpback chub is turbidity. Pre-dam, turbidity was very high much of the year except during base flows. 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 non-native 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 non-native fishes (Ward and Bonar 2003, GCDAMP 2009). During the summer of 2000, high abundance of adult brown and rainbow trout in the mainstem and the high water clarity throughout the river corridor may have contributed to higher predation rates on native fish near the LCR (Ralston 2011). Reclamation completed a feasibility assessment for large-scale sediment augmentation in 2007. 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 and may benefit or be negatively affected by HFEs. 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). In fact, the 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. However, as stated earlier, the humpback chub condition in the LCR may have been limited by parasites (Hoffnagle et al. 2006). Studies completed by GCMRC and the University of Wyoming found a high degree of dietary overlap between humpback chub and rainbow trout (Donner et al. 2011). Both species rely on black flies and midges which are in short supply, so the degree of resource overlap is very high. In fact, consumption of invertebrate prey by the fish assemblage at all sites that were studied overlaps with independent estimates of invertebrate production. In other words, the fish assemblage appears to be consuming close to, or all of, the available midge and black fly production that occurs annually. This indicates the fish assemblage may be food-limited. The spatial overlap between humpback chub and rainbow trout is the highest at the LCR confluence.

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 Reclamation 2007). 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.

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 formed as water velocity in eddy return channels declines to near zero with falling river discharge, leaving an area of partially to completely non-flowing 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 (Reclamation 2007). 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). As discussed previously and in the Effects of the Proposed Action section below, the effects of high flows on the physical PCEs of critical habitat are quite variable.

The physical PCE for spawning (P1) does not appear to be met in most of the mainstem. All of the mainstem aggregations are small, although small fish have been captured (Johnston and Lauretta 2007), and overwintering of y-o-y have been documented at the 30-mile aggregation (Andersen et al. 2010) and the LCR Reach (GCMRC unpublished data). 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 (AGFD 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 feeding areas may be limiting for juvenile humpback chub due to the effect of fluctuations on nearshore habitats (AGFD 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 responded 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 inhibit the optimal suitability of nursery habitats (P2) and feeding areas (P3) for juvenile warm water fishes like humpback chub in most years. 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). However, recent investigations into the use of nearshore habitats in the mainstem just downstream of the LCR by 0-3 year old humpback chub (40-199 mm [1.6-7.8 inches] TL) indicate that the PCEs of critical habitat in the area immediately downstream of the LCR confluence appears to be functioning properly and may support recovery. Juvenile humpback chub used a variety of mainstem nearshore habitats, and survivorship and growth of fish in these habitats was documented (GCMRC unpublished data). Humpback chub in other aggregations in Marble and Grand canyons also appear to have persisted and possibly increased in size in recent years (W. Persons, USGS, written communication, 2011a); other native fish including flannelmouth sucker that have similar habitat needs have also increased in abundance in western Grand Canyon (Makinster et al. 2010). Thus, there are several lines of evidence indicating that the biological environment PCEs of critical habitat in Reach 7, although limited, may have improved in recent years which is important for recovery.

Non-native fish species that prey on and compete with humpback chub affect the PCEs (B2 and B3) of the biological environment aspect of critical habitat. Catfishes (channel catfish and black bullhead), trouts (rainbow and brown trout), and common carp are well established in the action area and will continue to function as predators or competitors of humpback chub. Minckley (1991) hypothesized that non-native fish predation and competition may be the single most important threat to native fishes 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 and, rainbow and brown trout annually. Small-bodied species such as fathead minnow, red shiner, plains killifish, 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. Marsh and Douglas (1997) suggested that entire year classes of humpback chub may be lost to predation by non-native 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. Yard et al. (2011) also concluded that even though predation levels were high (humpback chub comprised approximately 30% of the identifiable fish in trout stomachs), it is not evidence that there was a population-level effect on humpback chub.

Efforts by the GCDAMP to mechanically remove non-native fishes in the LCR inflow reach were successful in removing trout (Coggins 2008b). In total, between January 2003 and August 2006, it is estimated that approximately 36,500 fish from 15 species were removed from this stretch of river. However, due to a system-wide decrease in trout populations independent of the removal effort and warmer river temperatures, it is unclear whether removal of trout contributed to the increases seen in native fish populations. Yet stomach sample analyses, show that rainbow and brown trout predation on native fishes clearly occurs. During the first two years of removal, 2003 and 2004, it was estimated that over 30,000 fish (native and non-native species combined) were consumed by rainbow trout (21,641 fish) and brown trout (11,797 fish) (Yard et al. 2011). On average, 85% of the fish ingested were native fish species, in spite of the fact that native fish constituted less than 30% of the small fish available in the study area (Yard et al. 2011). According to Yard et al. (2011), even though rainbow trout had a large cumulative piscivory effect, the annual per capita consumption rate was low overall. On average, each rainbow trout consumed 4 fish/year (both native and non-native) in the upstream reach and 10 fish/year in the downstream reach. In contrast, per capita rates of fish consumption by brown trout were much higher: 90 fish/year in the upstream reach and 112 fish/year in the downstream reach, meaning that 200 brown trout could consume as much fish as 4,000 rainbow trout (Yard 2011). The majority of the humpback chub consumed by trout were young of the year and subadults (age < 3), and it is likely that the loss of so many young fish affects recruitment to the humpback chub population (Coggins and Walters 2009).

The level of non-native fish decreased over the next three years resulting in non-native fish comprising only 10% of the species composition in August 2006 (Coggins et al. 2011). Yet the efficacy of a similar effort today is questionable given current densities of trout and high immigration rates that may occur from the Lees Ferry Reach. Since immigration rates drive the level of effort necessary to effectively remove rainbow and brown trout from the LCR reach, it is unknown at this time what level of removal effort would be necessary to substantially reduce non-native trout at the LCR confluence. Reclamation will conduct two PBR test trips during FY 2012. This will provide useful information about emigration rates of rainbow trout out of the Lees Ferry Reach. These tests trips and the Natal Origins Study will provide the GCDAMP with additional information on trout movement and other needed field studies during the 10-year life of the project, which will provide important information for use in evaluating and potentially revising the trigger for implementation of LCR reach removal efforts, as well as other possible non-native fish control actions.

When the mechanical removal began in 2003 approximately 90% of the species composition was rainbow trout in the LCR Reach. Species composition and abundance of non-native fishes is dynamic and affected by natural conditions and other factors throughout the canyon, with colder water species dominating closer to the dam, and warm water species downstream. Common non-native 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 (GCMRC unpublished data). Immigration of non-native fishes from basins that feed into Grand and Marble canyons is also a source of non-native fish (Stone et al. 2007), and stocking of sport fish in these basins is an action that may contribute to source populations of non-native fish that invade the mainstem river, although the 2011 Sport Fish Opinion has concluded that this is not a significant factor. Lake Powell and Lake Mead are also sources of non-native species as evidenced by the presence of walleye (*Sander vitreus*) and green sunfish in Glen Canyon (AGFD 2008) that either were illegally stocked or came through Glen Canyon Dam, and striped bass, which likely move up from Lake Mead and are common in lower Grand Canyon.

However other mortality factors, such as disease, are not known. Just as the ultimate causes of the improved status of humpback chub is not known, a causal link between removal of non-native fish and humpback chub population parameters has not been established (Coggins 2008b). However, removal efforts are one suspected cause or contributor to recent increases in humpback chub recruitment (Andersen 2009).

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), and implementation of the Interim Guidelines, will result in 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 some warm water non-native species that may function as competitors or predators to humpback chub and other native fish (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 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 non-native fish 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 non-native fish species. Indeed, given climate change predictions, an increased capacity to deliver cold water for sustained periods seems more pressing. The relationship between warmer water temperatures and non-native 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 non-native fishes.

In the 2008 and 2009 Supplemental Opinions, we stated that the biological environment PCE for food base (B1) appears met for adult humpback chub, but may be limiting for juveniles. This was because available information indicated that adult humpback chub in the mainstem portion of the LCR reach had a higher condition factor compared to those in the LCR (Hoffnagle et al. 2006). We now question whether B1 is being met for adult humpback chub in all parts of Reach 7, given the small size of other mainstem aggregations. Based on some preliminary research on food base, it appears that in years when discharge is high over the winter, and light levels are low, primary production is very low (Yard 2003). Algae is readily consumed by aquatic invertebrates (i.e., midges and black flies; Stevens et al. 1997, Wellard Kelly 2010, T. Kennedy, USGS, written communication, 2011) that are important food items eaten by native and non-native fish in the system (Valdez and Ryel 1995, Donner 2011, Zahn-Seegert 2011), and native fish including humpback chub also directly consume algae (Valdez and Ryel 1995, Zahn-Seegert 2011, Donner 2011). As fish need to have sufficient food resource reserves (lipids) in order to produce eggs, humpback chub could get the lipids they need from direct consumption of algae or from consumption of invertebrates on the algae that are themselves rich in lipids. One possible reason for the near absence of documented spawning in the downstream reaches and small aggregation size may be the lack of food resources (lipids) over the winter months to prepare adult humpback chub to be able to mature eggs in spring. Some of the tributaries such as Havasu and Kanab creeks are warm enough to allow for spawning, and the discovery of untagged humpback chub in Havasu Creek in June 2011 (Smith et al. 2011, Sponholtz et al. 2011) suggests that the habitat and food resources are supportive of humpback chub using Havasu Creek for at least part of the year, where spawning may have occurred this year (P. Sponholtz, FWS, pers. comm., 2011). We believe that additional information is needed to evaluate overwintering conditions, and specifically whether the rates of primary production and food resources over the winter months are sufficient to prepare humpback chub to spawn/reproduce the following spring, especially in the western portion of Reach 7.

PCEs B2 (competition) and B3 (predation) continue to threaten the conservation of humpback chub, particularly 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 non-native fish competition and predation that needs more careful consideration before additional efforts to manipulate water temperature are attempted. Reclamation has committed to evaluating flow and non-flow non-native suppression experiments focused on the Lees Ferry reach to lower emigration of trout, which may be particularly informative in years like fiscal year 2012 when trout numbers are very high. Also, Reclamation will continue to support research on juvenile humpback chub use of Grand Canyon, which will help to better understand the degree to which predation and competition may be limiting recruitment.

Most of the Grand Canyon population relies on the LCR for spawning and 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 improved largely due to warmer water temperatures between 2004 and 2011 from low Lake Powell reservoir levels and/or warm water releases. The physical PCEs improved temporarily through high flow tests that have improved nearshore habitats, and the biological environment PCEs of predation and competition improved by removal of non-native fishes between 2003 and 2009. Considering the improvement in the status of humpback chub over this period, obtaining and maintaining high quality PCEs for humpback chub in this reach of critical habitat is likely essential to recovery of the species. As noted in the 2008 Opinion and 2009 Supplemental Opinion, conservation measures are an important aspect of Reclamation's proposed action. In collaboration with the GCDAMP and associated research efforts, literature and peer reviewed reports are regular products of the program providing updated information about native fishes throughout Grand Canyon.

As described in the Status of the Species section, demographic criteria 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 (USFWS 2009). As described earlier, in addition to the demographic criteria, 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.

As described earlier, the abundance of humpback chub in the LCR is estimated to be 7,650 adults (between 6,000-10,000, age 4+; ≥ 200 mm [7.9 inches] TL); 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 do not differ statistically from 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 (USFWS 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.

The improvement in humpback chub status is primarily in the LCR aggregation, but apparently also in some of the other mainstem aggregations downstream from Glen Canyon Dam (W. Persons, USGS, written communication 2011b). Since 2003, water temperature of dam releases has been above average below Glen Canyon Dam (>12 ^{o}C at the LCR), and for the variety of reasons discussed above, this may in part explain the improvement in the species over this period.

Nevertheless, 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. The recovery factor criteria and associated management actions and tasks that relate to this critical habitat unit are based on the five listing threat factors. These management actions and tasks are directed at research to determine the role of the mainstem Colorado River in providing for recovery of humpback chub. 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 conditions in the mainstem Colorado River through Grand Canyon (steady flows and flows that suppress non-native fish) 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 non-native fish (from Lees Ferry, Bright Angel, and other areas), as necessary for recovery, and develop and implement procedures for stocking sport fish to minimize escapement of non-native 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 are determined. The Colorado River through Grand Canyon must provide for adequate spawning, nursery, juvenile and adult habitat. Although a TCD will not be pursued at this time, other flow options could be developed through the GCDAMP to take advantage of years when above normal water temperatures are released from 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 (see earlier discussion on the history and current state of TCD investigations).

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 are still under investigation. The GCDAMP continues to provide 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, such as the Natal Origins study 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.

Factor B is not significant to humpback chub in the mainstem although there have been some concerns raised about handling stress from field surveys. As explained in other parts of the document, monitoring efforts that cause handling of humpback chub do cause some mortality. However, this mortality does not appear to have impacted the Grand Canyon population, and has resulted in important findings on the recovery needs of humpback chub.

For Factor C, the focus of the Recovery Goals in the mainstem Colorado River is on controlling the proliferation and spread of non-native 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 non-native fish species into the Colorado River and its tributaries through Grand Canyon. Stocking, both legal and illegal, throughout the LCR basin, has been suspected of resulting in non-native fish moving into the lower LCR (Stone et al. 2007), and likely into the mainstem Colorado River as well. As discussed below, the Sport Fish Opinion has evaluated impacts to humpback chub and its critical habitat in Arizona and concluded that given the distance from sport fish stocking sites in the upper LCR watershed, those stocking sites have only a minor effect to humpback chub populations and do not have a “meaningful role in affecting humpback chub recovery” (USFWS 2011b).

The Recovery Goals also identify the need to develop and implement levels of control for rainbow trout, brown trout, and warm water non-native fish species (USFWS 2002a). Non-native fish control has been a focus of the GCDAMP for some time. 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 warm water non-native fish species, so far with little success. Information on which non-native species should be removed during which times of the year continues to be a research question.

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. The Law of the River (which determines water delivery), coupled with the protection afforded by Grand Canyon National Park, may or may not 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. 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.

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 non-native fish control as necessary to support recovery. Reclamation's proposed action includes an active adaptive management program that is progressively testing different flow regimes. 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 Natal Origins Study, and various monitoring and research projects of the GCDAMP annual work plans (as discussed earlier in the Proposed Action). Reclamation has also included non-native fish control as a conservation measure. 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 criteria have been met, recent monitoring has documented an increase in humpback chub numbers and the native fish community.

Razorback sucker

Available information suggests that historically, the razorback sucker was not common in the canyon-bound reaches of Marble and Grand Canyons (Minckley et al. 1991, Valdez 1996). The Recovery Goals for razorback suckers in the Lower Basin includes two self-sustaining populations (e.g., mainstem and/or tributaries) maintained over a 5-year period, but does not specify the Grand Canyon or any other specific location (USFWS, Razorback Sucker Recovery Goals, 2002b). Ten records for razorback sucker were documented by 1995; one at Bright Angel Creek in 1944, one in the mainstem below the dam in 1963, a total of four in the Paria River in 1978 and 1979, one near Bass Canyon in 1986, three in Bright Angel Creek in 1987, and three in 1989 and 1990 at the mouth of the Little Colorado River. Hybrids between razorback sucker and flannelmouth sucker have also been reported several times near the Paria River and Little Colorado River (Valdez 1996).

Razorback suckers are currently known from Lake Mead outside of the action area and there are records of razorback suckers collected from Gregg Basin dating from 1978-1979 (McCall 1979). Razorback suckers are recruiting in three areas of Lake Mead outside the action area, most recently in 2008 (Shattuck et al. 2011). The population at the upper end of Lake Mead was re-documented in 2000-2001 through larval collections between Grand Wash Cliffs and Iceberg Canyon; although no adults were captured in net sets in 1999-2000 and 2002-2003 (Albrecht et al. 2008). AGFD captured an adult razorback sucker in Gregg Basin in 2008 (cited in Kegerries and Albrecht 2011). In 2010 and 2011, wild razorback suckers were captured in Gregg Basin and spawning locations were identified. These wild fish were aged at between 6 and 11 years old. It is unknown if these wild razorbacks are the result of recruitment at the Colorado River Inflow, or represent movements of wild razorback suckers from the known recruitment areas (two sites in the Overton Arm [the Virgin-Muddy River inflow and Echo Bay] and Las Vegas Wash) to the inflow area. In addition, nine razorback-flannelmouth sucker hybrids were captured and aged. These fish were between 6 and 10 years old, with four born in 2003 (Kegerries and Albrecht 2011). The radio-tagged stocked razorbacks from this study did not move upstream into Iceberg Canyon during the survey period, however, they did move between the more riverine and more lentic areas over the course of the monitoring, and were found with wild razorback suckers (Kegerries and Albrecht 2011).

At full-pool elevation (1229 ft [375 m] NGVD), Lake Mead impounds water up to Separation Canyon (RM 239.5); however, the effects of "ponding" of water (reduced velocity and increased sediment deposition) can extend upstream for several miles to Bridge Canyon (RM 235) as noted by Valdez (1994). Lake levels have declined since the late 1990s, reaching a low of 1081 feet (329 m) in November, 2010. This decrease in lake elevations increases the length of "riverine" habitat from Separation Canyon downstream and alters the structure of the habitat as the river downcuts through accumulated sediment and forms a channel with limited backwaters or shallow margins (Van Haverbeke et al. 2007). By 2011, the lake/river interface was in the upper portion of Gregg Basin (Kegerries and Albrecht 2011). How razorback suckers use the riverine portion versus the lentic portion of the Colorado River inflow area and how that changes with lake elevation is yet unclear.

Razorback Sucker Critical Habitat

Critical habitat for the razorback sucker extends from the mouth of the Paria River downstream to Hoover Dam, including Lake Mead to its full-pool elevation. Maddux et al. (1993) discussed how the PCEs for razorback sucker function in this reach; we summarize that discussion below.

In the riverine portion of the reach (Paria River to Separation Canyon), the PCEs for water, physical habitat, and biological environment have been altered by creation of Glen Canyon Dam as described earlier for the humpback chub. The suitability of the physical habitat conditions for razorback sucker in this reach were likely significantly less even before closure of the dam as razorback suckers are generally not found in whitewater habitats that are home to humpback chub (Bestgen 1990).

Operations of Glen Canyon Dam changed the natural flow cycle of the Colorado River and altered water quality parameters as described for humpback chub. The distance downstream that fluctuating flows can be detected has changed as operations of the dam have changed. In 1992, Valdez (1994) measured a daily stage change of 60 cm (23.6 inches) at Spencer Creek (RM 246) and noted that stage changes were ameliorated by Lake Mead below Quartermaster Canyon (RM 259). In 1992, Lake Mead was between 1150 and 1175 feet (350 to 358 m) and the lake-river interface was downstream from Separation Canyon. With the implementation of interim operating criteria in 1991, it is uncertain if the stage changes reported in1992 were indicative of those resulting from previous operations. Under the MLFF, releases from Glen Canyon Dam are less extreme and effects to the river below Bridge Canyon (RM 235) from the fluctuating flows are considered insignificant.

There is information that indicates that at least some portions of the Colorado River through the canyon can provide the physical PCEs needed by razorback sucker. The most recent report is from a raft survey in 2009 (Speas and Trammel 2009) where the reach from Lava Falls to South Cove of Lake Mead (in Gregg Basin) was visually evaluated for habitat features that could support razorback sucker populations. Features evaluated included backwaters, islands/side channels, habitat types (runs, riffles, eddies, spawning cobble, shallow waters), and cover (turbidity or vegetation). Using these features, reaches of the river were determined have complex, less complex, or poor habitat quality for razorback suckers. Complex habitat extended from Lava Falls to Granite Park (RM 179-208), and Granite Spring to near 224 mile (RM 220-223). Less complex habitat was found from Granite Park to Trail Canyon (RM 209-219) and 224 mile to Last Chance Rapid (RM 224-253). Poor habitat extended from Last Chance Rapid to Pearce Ferry (RM 253-279). The poor habitat began 14 miles (22.5 km) below the full pool elevation of Lake Mead and was characterized as a straight, incised channel with little backwater areas and predominately swift run habitat. This condition extended further to the upper end of Gregg Basin where the river-lake interface was located in 2011 (Kegerries and Albrecht 2011).

The lower Grand Canyon fish fauna is affected by the non-native fish community moving upriver from Lake Mead (Valdez 1994, Ackerman et al. 2006, Van Haverbeke et al. 2007, Makinster et al. 2010) and large populations of non-native predators and competitors are present. Flannelmouth suckers, bluehead suckers, and speckled dace are the native species found. Razorback suckers, flannelmouth suckers and hybrids of the two species were found in Gregg Basin in 2011 (Kegerries and Albrecht 2011). Like other areas in Lake Mead with successful razorback sucker spawning and recruitment, the inflow area is highly turbid, and that may provide cover for young razorbacks.

Kanab ambersnail

The Kanab ambersnail status is discussed in the status of the species. During the early 2000s, Kanab ambersnails found in the zone that would be inundated during the high flow test and their habitat was temporarily removed, irrigated, and returned after the high flow because this saved potentially tens or hundreds of snails and approximately 15 percent (17 m2 [180 ft2]) of the Kanab ambersnail habitat that would have been flooded and scoured by the HFE. However, in a draft report, Culver et al. (2007) characterized mitochondrial diversity and AFLP marker diversity from 12 different southwestern *Oxyloma* populations. The characterized populations included two Kanab ambersnail (Vasey's Paradise and Three Lakes) and 10 non-endangered ambersnail populations. Analysis detected some gene flow among the studied *Oxyloma* populations. The authors speculate that the measured gene flow demonstrates that all of the populations studied are members of the same interbreeding species (Culver et al. 2007). Thus, in contradiction to previous studies, they concluded that Kanab ambersnails are genetically the same as all other *Oxyloma haydeni* and that Kanab ambersnails may not deserve subspecies status. The FWS discussed this in a recent 5-year review of Kanab ambersnail, and noted that if a taxonomic change occurs, the snail could subsequently be downlisted or delisted.

B. FACTORS AFFECTING SPECIES' ENVIRONMENT WITHIN THE ACTION AREA

Humpback chub

Successful humpback chub adult recruitment depends on spawning success, normal levels of predation on young of year and juveniles, habitat (water temperature), pathogens, adult maturation, food availability, and competition. Flow conditions can vary significantly from year to year. The average unregulated inflow to Lake Powell from 2005 through 2011 was 11.2 maf which is slightly below the official average of 12.0 maf (based on the period from 1971 through 2000). The annual variability from 2005-2011 has varied from a low water year unregulated inflow slightly below average in 2005, 8.4 maf (70% of average) in water year 2006, to a high of over 17.0 maf (141% of average) into Lake Powell in 2011 (R. Clayton, Reclamation, written communication, 2011). The 2011 water year release volume from Glen Canyon Dam was 12.52 maf and this was the largest water year release volume made from Glen Canyon Dam since water year 1998 (R. Clayton, Reclamation, written communication, 2011).

The Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Mead and Lake Powell will govern releases from Glen Canyon Dam through September 2026. Flows were developed in the 1996 Record of Decision on the Operations of Glen Canyon Dam, and currently follow the MLFF 5-Year Plan. A full description of the operation strategies is discussed in the 2007 Shortage Opinion (USFWS 2007). 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 for 60 hours. As a result of the high flow test, the elevation of Lake Powell dropped by approximately 2.3 feet (0.7 m). 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 (1,108 m) (the equalization level for water year 2008), based on the April 1st final inflow forecast.

The Arizona statewide sport fishing program as funded by the Federal Wildlife and Sport Fish Restoration Program was evaluated in a 2011 Opinion on Sport Fish Restoration. The Opinion evaluated stocking of non-native sport fish species, and analyzed the distance and availability of surface water, flood events, and fish movement to determine the degree of connectivity and subsequent exposure to humpback chub and critical habitat with a focus on three areas: Havasu Creek, Canyon Diablo, and the White Mountain area. Although the risk is low, there is opportunity for stocked non-native fishes to move downstream into the action area during flood events, although this is likely to be an infrequent occurrence.

For the Havasu Creek stocking sites, the FWS concluded that any individuals of the stocked species, particularly channel catfish, could access the humpback chub habitats alive after being transported by flood waters. However, the spill potential from the stocking sites, the distances involved, and the physical conditions encountered, when considered together, leads to a very low risk of exposure of humpback chub to these fish. This low potential for exposure also leads to our determination that PCEs B2 and B3 would not be affected to the extent that the conservation value of the Colorado River Marble and Grand Canyon critical habitat reach would be diminished.

For the Canyon Diablo stocking sites, we concluded that any individuals of the stocked species, particularly channel catfish, could access the humpback chub habitats alive after being transported by flood waters. The spill potential from the stocking sites, the distances involved, and the physical conditions encountered, when considered together, leads to a very low risk of exposure of humpback chub to these fish.

For the White Mountain stocking sites we concluded that individuals of the stocked species, particularly channel catfish, could access the humpback chub habitats alive after being transported by flood waters. There is connectivity between the Little Mormon Lake stocking site and the LCR through White Mountain Lake for channel catfish if reproduction occurs in Little Mormon Lake; the grate on the outflow would prevent stocked adult channel catfish from escaping but not juvenile catfish which would only be present if reproduction occurs at this site (reproduction has never been documented at this site). Channel catfish maintain a reproducing population in White Mountain Lake, and any channel catfish exiting the lake to Silver Creek would most likely come from that population and not the stocking sites. However, the tributaries and mainstem LCR independently support wild populations of channel catfish that are not reliant on escapees from White Mountain Lake to maintain their populations.

Channel catfish can be a significant predator on young humpback chub, and the connectivity from the White Mountain stocking sites is directly into the area above Chute Falls where translocations of small humpback chub have occurred. The numbers of channel catfish in that reach of the LCR is not known; however, augmentation of those numbers is likely to be deleterious to the chub. However, we concluded that stocking channel catfish into Little Mormon and Whipple lakes has no measurable effect on existing channel catfish populations in this drainage or in the LCR because of the very low likelihood that they could survive transport to the lower LCR area.

Non-native fishes, including channel catfish, are an identified concern for PCEs B2 and B3 for humpback chub critical habitat. Based on our analyses, we concluded that the channel catfish associated with stocking events have, at most, an extremely minor effect to recovery values in the LCR since their ability to reach the critical habitat is very limited. Also, neither stocked channel catfish nor their progeny are supporting the currently established populations of that species in Lyman Lake, lower Chevelon Creek, and Clear Creek Reservoir or washes draining into the LCR from the north. It is far more likely that individuals from those self-sustaining populations would access the LCR below Grand Falls as described by Stone et al. (2007). The Sport Fish Stocking Opinion concluded that that the stocking events covered did not have any meaningful role in affecting humpback chub recovery in the Little Colorado River critical habitat unit or Havasu Creek, and are not likely to contribute additional non-native predators to the existing populations in the mainstem Colorado River. Non-native rainbow and brown trout in the LCR itself do not appear to be problematic because seasonal warm temperatures and high salinity levels limit the suitability of LCR habitats to support these species. Thus, changes to PCEs B2 and B3 are not anticipated, so the conservation value of the critical habitat is not impaired by federally funded sport fish stocking.

The act of stocking fish obtained from AGFD hatcheries or other sources has the potential to introduce unwanted aquatic organisms to the receiving water, although the use of hatchery and operational protocols for the movement of stocked species is designed to reduce the opportunity for the transmission of other non-native fish species, parasites, or diseases via stocking actions. Illegal or inadvertent movement of unwanted aquatic organisms between waters in Arizona may also occur. Disease and parasites are additional threats to humpback chub populations. Parasites may be introduced incidentally with the spread of non-native species. Transmission may occur via introduced fish species, and bait species used for angling such as crayfish and waterdogs (tiger salamanders). Asian tapeworm from grass carp introductions was first documented in the Virgin River basin in 1979 (Heckmann et al. 1986), probably carried there by red shiner. It later appeared in the Little Colorado River in Grand Canyon in 1990 (Clarkson et al. 1997).

As a result of the 2011 Opinion on the Sport Fish Restoration Funding of AGFD's Statewide and Urban Stocking program, the AGFD has committed to incorporating some aspects of the Integrated Fisheries Management Plan for the Little Colorado River (Young et al. 2001). The LCR drainage above Grand Falls has been identified as a source of non-native fish species (particularly channel catfish) into occupied humpback chub habitat in the lower LCR (Stone et al. 2007). In the 2011 Opinion on Sport Fish Restoration Funding, we concluded that there is very limited potential for connectivity between the stocking sites in the Little Colorado River. No incidental take was anticipated in r the Sport Fish Restoration Funding Opinion (USFWS 2011b). However, a conservation measure was included in the proposed action to assess native and non-native fisheries management in the Little Colorado River basin which will assist in evaluating any future risks to humpback chub in the LCR.

As part of the humpback chub annual monitoring, some are killed each year during field activities (P. Sponholtz, FWS, pers. comm., 2011). Agencies must report such incidents to the results of info to the FWS as part of their 10(a)(1)(A) collecting permit. The numbers of injuries and delayed mortalities are not known and much more difficult to track. However, we know that when bonytail chub and razorback suckers are collected in trammel nets in temperatures that exceed 20 ºC, mortality associated with handling stress increases significantly (Hunt 2009). Despite inevitable take of humpback chub from monitoring and research activities, as described earlier, the status of the species has improved over about the last decade, and research and monitoring efforts have provided invaluable information to humpback chub recovery.

Razorback sucker

The razorback sucker has not been reported upstream from about Pearce Ferry since 1990 and only 10 adults were reported between 1944 and 1995 (Valdez 1996, Gloss et al. 2005). Carothers et al. (1981) reported four adults from the Paria River in 1978–1979. Maddux et al. (1987) reported one blind female razorback sucker at Upper Bass Camp (RM 107.5) in 1984, and Minckley (1991) reported five adults in the lower LCR from 1989–1990. A full complement of habitat types (large nursery floodplains, broad alluvial reaches for feeding and resting, and rocky canyons for spawning), as used by razorback suckers in the Upper Colorado River Basin (USFWS 2002b), does not appear to be fully available between Glen Canyon Dam and Pearce Ferry; however, alluvial gravel bars off tributary mouths and side canyons are available for spawning, a few backwaters are available for nursing by young, and alluvial reaches are present for resting and feeding. For the first time in many years in 2011, BioWest documented wild razorback suckers in the Lake Mead Colorado River Inflow area, including larval razorback suckers providing evidence that razorback sucker spawned below the action area (Kegerries and Albrecht 2011). If razorback suckers use lower Grand Canyon, it most likely involves fish that spend at least part of their life cycle in the more complex, warmer habitat offered by the Lake Mead inflow area currently located downstream from Pearce Ferry. Changes in Lake Mead water levels will alter the location of the river/lake interface as the inflow and alter the location of suitable habitat.

<u>Kanab Ambersnail</u>

There has likely been some loss of snails and habitat from the highest MLFF flows, although this has been 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 exceeded this level in 2011. 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 significantly affected (Patch 12), and a second patch is impacted 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). Surveys in 2008 and 2009 indicated that overall, habitat at Vasey's Paradise is in good condition, and the species is in numbers that are comparable to recent years, although their numbers are lower than levels during 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).

Kanab ambersnail are pulmonate or air-breathing mollusks, but are able to survive underwater for up to 32 hours in cold, highly oxygenated water (Pilsbry 1948). In previous Biological Opinions on the operations of Glen Canyon Dam operations, we concluded that up to 350 ft^2 (32.5 m^2) of the habitat and resident ambersnails would be lost by the highest flows from Glen Canyon Dam during MLFF (25,000 cfs), and that up to 117 m^2 (1259 ft^2) would be lost during the largest HFE (45,000 cfs). We anticipate the same level of habitat and snail loss during the 10-year life of the project.

The translocated population at Elves Chasm is not affected by dam operations and 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. The habitat at Vasey's Paradise remains somewhat stable from year to year but is easily scoured by high floods and likely is affected by microclimatic conditions such as higher humidity and lower air temperatures. The surrounding environments and high vegetative cover may be important habitat features related to Kanab ambersnail survival (Sorenson and Nelson 2002).

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

As discussed in the 2008 Opinion and 2009 Supplemental Opinion, the operation of Glen Canyon Dam has adverse affects to humpback chub (USFWS 1995b, 2008, and 2009 Supplement). The 2008 Opinion and 2009 Supplemental Opinions provide thorough analyses of these effects and the parts of those opinions that were not challenged are incorporated here by reference. The MLFF will continue as described in the 1995 EIS and 1996 ROD. The MLFF as defined in the 1995 EIS (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. This approach utilizes 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. Many of the effects documented during the first years of MLFF are expected to be seen during this 10-year project as discussed in detail in the 2008 and 2009 Supplemental Opinion; those discussions are incorporated by reference.

Reclamation's action of fluctuating daily volume to meet power demand will continue to have direct and indirect effects to humpback chub. We acknowledge many improvements to the understanding and status of humpback chub during the past implementation of the MLFF. However, as a result of the existence and operations of Glen Canyon Dam, this endangered species will continue to experience altered water temperatures, flow regimes, and sediment loads. Pending experimental results from the HFE Protocol, it is not known if the managed sediment transport under the HFE Protocol will benefit or reduce the formation of nursery habitats downstream throughout Marble Canyon. Juvenile humpback chub prefer nearshore habitats in association with vegetation and talus slopes, where the effects of fluctuating daily volumes are concentrated (Valdez and Ryel 1995, Robinson et al. 1998, Stone and Gorman 2006, Korman and Campana 2009). Because of this preference y-o-y and juveniles are likely to be most affected by the fluctuating flows associated with continuation of the MLFF. However, the MLFF may also have a key beneficial effect, because it disadvantages non-native warm water fish that prey on and compete with humpback chub. Also, humpback chub recruitment appears to have improved during a period when the only known change to the system was from the MLFF (Coggins and Walters 2009). Thus, as discussed in other parts of this document, MLFF and other changes to the system, in particular changes that have led to warmer water temperatures may have improved conditions to support the humpback chub's ability to recover. Further the humpback chub is a long-lived and fecund species, living 30 years or more and producing about 2,500 eggs per female per year (Hamman 1982). This type of evolutionary adaptation is typical for a species that provides little parental care (humpback chub use broadcast spawning and do not protect young or use a nest) and are subjected to hostile environmental conditions that seldom provide adequate habitat for the survival of young, which are numerous due to normal losses from predation and the environment. This evolutionary strategy enables survival despite sporadic and poor recruitment in most years (Minckley and Deacon 1991, Jakobsen 2009). To summarize, the information available today indicates that although MLFF may have adverse effects, it also may provide sufficient habitat for humpback chub to survive and recover, and we do not find that MLFF will have result in adverse modification to critical habitat for this reason.

The operation of Glen Canyon Dam is directly linked to survival rates and production of rainbow trout downstream of the dam (Korman and Melis 2011). Preliminary information indicates that high steady flows in 2011 have resulted in a significant increase in rainbow trout reproduction at Lees Ferry (J. Korman, Ecometric, written communication, 2011). High steady flows are also likely to occur in 2012 to fulfill equalization requirements. However, it is not known if and/or when high numbers of rainbow trout will move out of the Lees Ferry Reach into the LCR Reach. The Natal Origins and other mainstem monitoring work will provide some additional assessment, but overall we anticipate a significant adverse effect to the biological elements of humpback chub critical habitat: food supply (B1), predation (B2), and competition (B3) in Reach 7. However, we do not anticipate adverse modification to critical habitat from this effect because under this Opinion Reclamation will institute non-native fish control based on a series of data-driven triggers and re-evaluate project implementation every three years which will provide sufficient opportunities to re-direct management through the GCDAMP.

The majority of the humpback chub are distributed throughout the LCR. Rainbow trout, although prominent in the mainstem, are rare in the LCR. Most humpback chub spawning takes place in the LCR, and some adults may never leave the LCR. Douglas and Marsh (1996) hypothesized that there was a contingent of resident adult fish that never leave the LCR, and another contingent that migrated into the LCR to spawn. Since many humpback chub inhabit the upper reaches of the LCR, they are not affected by the operations of Glen Canyon Dam, at least while they are in the LCR. Most of the humpback chub in the LCR are not impacted by the daily operations of Glen Canyon Dam except when these fish enter the mainstem. However, the species has had few opportunities to expand into the mainstem aggregation because of cold water, the loss of seasonal flows, daily fluctuating flows, and the presence of predators and competitors. However, as discussed throughout the document, new information from the NSE study indicates that young humpback chub may be able to survive in mainstem habitats.

With the continuation of MLFF, outside of equalization flows, the highest monthly flow releases will likely continue to occur in the winter and summer when power demands are highest. This is in contrast to historical pre-dam hydrograph patterns when the spring months delivered the highest flows, followed by low summer flows which allowed the water to warm sufficiently and accommodate mainstem reproduction and recruitment of humpback chub. Low summer flows to benefit young of year humpback chub that are displaced into the mainstem via monsoon flows from tributaries such as the LCR will not occur in a manner that resembles the pre-dam conditions to which humpback chub are adapted. However, preliminary estimates that show apparent good survival rates of young of year humpback chub in the mainstem near the LCR have been documented between 2009 and 2011 when water temperatures were relatively warm, and this may continue during years of above average water temperature (S. VanderKooi, USGS, oral communication, 2011).

During years when water levels in Lake Powell are high, water temperature of Glen Canyon Dam releases are typically cold, averaging between 8 and 10 ºC. This effect is seen clearly in Figure 6, which illustrates that water temperatures at the LCR failed to reach 12 ºC every year from 1990 to 2003 with the exception of the low summer steady flow experiment conducted in 2000. If Lake Powell elevations rise to full pool levels again during the proposed action, humpback chub in the mainstem would experience water temperatures not conducive to successful mainstem spawning, egg incubation and optimal survival of young. As such, river conditions would limit humpback chub spawning and rearing in a significant portion of the action area. However, juvenile and adult life stages will persist throughout the action area, primarily in association with small aggregations near tributary mouths or small, warm springs.

During years when Lake Powell elevations are lower, water temperatures are more likely to be above average (Figure 6, years 2003 to present). The ability of humpback chub to effectively avoid some predators may increase with temperature, especially when temperatures are closer to 20 ºC as preliminary data for rainbow trout indicates (D. Ward, USGS, written communication, 2011). Modeling predictions and the regional projections relative to climate change predictions for the southwestern United States all tend to indicate that the river may continue to be warm, at least relative to conditions downstream from Glen Canyon Dam since the dam was completed and filled in 1980.

Reclamation also predicted that Lake Powell elevations would be lower on average, and water temperatures of Glen Canyon Dam releases higher on average, under operations of Glen Canyon Dam defined by the Interim Guidelines which will be in effect through 2026 (G. Knowles, Reclamation, written communication 2011).

A more natural hydrograph including low steady flows in the summer months has long been supported by some researchers. In some years, when equalization flows occur between lakes Powell and Mead, such as in water year 2011, flows will tend to be steady. The steady flows may occur later in the year such as in November 2011, when releases were steady near 15,500 cfs due to ongoing maintenance work at Glen Canyon Dam. Projections for steady flows are likely to continue at approximately 22,600 cfs through the end of the 2011 calendar year (R. Clayton, Reclamation, written communication, 2011).

The use of steady flows to accommodate downstream and nearshore warming also requires elevated air temperatures, so low steady flows in the late fall (that is, past about mid-October) are not expected to increase water temperature. This is supported by the fact that mainstem monitoring in the LCR Reach in 2009 and 2010 did not document any benefit to humpback chub in this portion of in Reach 7 (GCMRC unpublished data). Steady flows were discussed at the 2007 Long Term Experimental Plan (LTEP) Workshop (GCMRC 2008). Researchers at the workshop concluded that if the primary goal is to promote humpback chub spawning and increase larval survival in the mainstem, then efforts to increase mainstem temperatures through the use of steady flows should be initiated in June. If the goal is limited to promoting survival and growth of fish produced in the LCR that are transported into the mainstem of the Colorado River by late summer monsoon rain events, then efforts to increase mainstem temperatures should be initiated in August (GCMRC 2008). The use of steady flows to accommodate downstream and nearshore warming also requires elevated air temperatures, so low steady flows in late fall (that is, past about mid-October) are not expected to increase water temperature. In addition, little to no benefit has been documented for humpback chub in the LCR Reach from the

September-October steady flow experiment (GCMRC unpublished data). In fact, during the 2011 Knowledge Assessment Workshop, some researchers hypothesized that steady flows would benefit rainbow trout and other non-natives more than humpback chub. However, Ralston (2011) concluded that "When reservoir elevations allow discharge temperatures to exceed 13ºC, it may be informative to implement steady discharges to see how YOY [fish at the LCR respond to warmer temperatures and steady discharges. The results can be compared with data collected [from] 2003–6 during fluctuating discharges and possibly different predator loads, provided sufficient long-term monitoring is in place." As stated previously, the high steady flows associated with equalization may be providing a large benefit to rainbow trout by providing additional habitat in the Lees Ferry Reach. Without suppression flows or non-native removal, this may have significant effects on the humpback chub and its critical habitat. Ongoing monitoring and information gathered from the Natal Origins study will provide additional information.

Humpback chub and other native fish (flannelmouth and bluehead sucker) known to use tributaries for spawning appear to be persisting in stronger numbers in recent years (Van Haverbeke et al. 2011). Additional mainstem translocations of humpback chub and exploratory efforts for razorback sucker may result in positive effects for both species. Reclamation's commitment to continue working with the NPS and other partners to support translocation of humpback chub will further conserve the species. If humpback chub populations can be secured in tributaries other than the LCR, adult chub can be expected to move into the mainstem aggregations and other areas of the mainstem river and augment the distribution of humpback chub throughout the action area.

Several researchers have reported that transport of young humpback chub from the LCR to the mainstem occurs primarily with monsoonal rainstorm floods during July and August (Valdez and Ryel 1995, Douglas and Marsh 1996, Gorman and Stone 1999) and this will continue during the life of the project. As they enter the mainstem Colorado River, these fish will experience slower growth rates, predation, and effects from flow fluctuations, possible cold-water shock, diseases, and other factors (USFWS 2002a). Depending on the strength of the year-class, impacts from humpback chub escapement can vary (Valdez and Ryel 1995), with age-0 and age-1 humpback chub groups expected to be most impacted during the 10-year life of the project.

Under the proposed action, we anticipate that the majority of humpback chub will spend most if not all of their life in a very small portion of the action area. This is because the largest aggregation of humpback chub in the Grand Canyon (the LCR aggregation), occupies only a few miles of river in Grand Canyon. Many subadult and adult humpback chub (approximately 200 mm and larger) leave the LCR once they reach a certain size to spend non-spawning periods in the mainstem (Gorman and Stone 1999). These larger size classes are more likely to withstand cold water temperatures and avoid most predators. While this movement is part of their life history, some scientists believe that these fish move into mainstem habitats because of density dependent factors in the LCR. That is, food resources in the LCR are limited and competition is high so the larger individuals move into the mainstem in search of food. Thus, as stated in our 2008 Opinion, it is possible that the recovery 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. We conclude that prospects for recovery would improve by providing for all the PCEs in Reach 7, which would add resiliency to the overall population by maintaining some recruitment from the mainstem aggregations.

Reclamation has committed to work through the GCDAMP to monitor the abundance of humpback chub and species composition at the eight mainstem aggregations of humpback chub in Marble and Grand Canyon annually. This monitoring will provide additional information to determine the level at which the PCEs in the mainstem Colorado River are functioning.

If the spring 2008 HFE conditions are repeated between 2010 and 2020, we can expect rainbow trout cohorts that hatch after April 15 to have high early survival rates particularly since redds would not be subject to scour and burial, and hatchlings would be less susceptible to displacement from the high flows associated with HFE. Instead, these cohorts will likely emerge into a benthic invertebrate community that was enhanced by the flood event, with some portion of the trout likely moving downstream into humpback chub habitat. In future spring HFEs, number of non-native fish is likely to be limited when additional mortality can be applied to older life stages after the majority of density-dependent mortality has occurred (Korman et al. 2011).

The increase in brown trout may continue with or without HFEs, and their high piscivory rates appear to be unaffected by temperature, turbidity levels, or flows. However, Reclamation's commitment to continued coordination with NPS for brown trout control may ameliorate the situation somewhat. A complete understanding of the effect of increases in trout numbers on humpback chub survival and recruitment will take many years to achieve. This is because it will take time for these newly hatched trout to grow and disperse. In addition, it takes at least 4 years for humpback chub to reach maturity and be counted as an adult, as determined by the ASMR (Coggins et al. 2006, Coggins and Walters 2009).

The overall effect of fall HFEs on rainbow trout abundance is unclear. As discussed above, the 2008 HFE resulted in an 800 percent increase in rainbow trout in the LCR reach as a likely result of improved habitat conditions in Glen Canyon and subsequent emigration downstream (Makinster et al. 2010, Korman et al. 2011, Wright and Kennedy 2011). Although there are fewer data from the 2004 fall HFE, some effects appeared to have occurred to rainbow trout as well. During a three-week period that spanned the November 2004 HFE, abundance of age-0 trout, estimated to be approximately 7 months old at that time, underwent a three-fold decline (Korman et al. 2010). The decline may have been due to either increased mortality or displacement/disbursal as a result of the higher flow of the HFE (Korman et al. 2010). However, long-term trout monitoring data indicated that trout started to decline system-wide in 2001-2002, declined through the period of the 2004 HFE, and only began to recover in about 2007 (Makinster 2009b). Also, key monitoring programs to detect ecosystem pathways that affect rainbow trout in Lees Ferry were not in place at the time of the 2004 HFE (Wright and Kennedy 2011). Higher water temperatures and lower dissolved oxygen in fall 2005 also may have increased mortality and reduced 2006 spawning activity (Korman et al. 2010).

Impacts to food resources are expected to occur during the life of this project. As stated in the 2008 and 2009 Supplemental Opinions, 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 (water current) on the descending limb of the diurnal hydrograph, and McKinney et al. (1999) documented a similar response for *G. lacustris*. Chironomids and simuliids 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 the 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).

Field studies have documented a reduction in primary productivity during high steady flows in the winter months such as occurred during equalization flows of FY 2011. These equalization flows, which are expected to continue into 2012, will likely preclude enough light from reaching the river bottom to support algae growth thereby reducing algae production to just the edges of the river (Yard 2003, T. Kennedy, USGS, oral communication, 2011). It is not known if these flows will have a long-term affect. Invertebrate biomass and production on cobble is significantly higher than other habitat types (i.e., talus, cliff, backwaters) likely because cobble also has the highest algae biomass of any habitat (Stevens et al. 1997, T. Kennedy, USGS, oral communication, 2011). During spring HFEs, a switch from diatoms to filamentous algae may dominate the aquatic community, as was documented after the 2008 spring HFE. Both midges and black flies in Lees Ferry benefitted from this disturbance (Kennedy et al. 2011). Although production of black flies and midges was unaffected by the 2008 HFE at downstream sites, production of these taxa did increase in Lees Ferry and drove the significant increase in juvenile rainbow trout survival rates (Korman et al. 2011). This increase in food resources in the Lees Ferry Reach likely benefits rainbow trout but no benefit is expected to downstream food resources. Thus, it stands to reason that future spring HFEs are unlikely to be detrimental to key food items at downstream locations where humpback chub occur. The effect of future winter timed HFEs is highly uncertain but could be detrimental to the aquatic community downstream. Additional research is needed to determine the extent to which October - November HFEs and other high winter flows affect humpback chub.

Reclamation has committed to periodic "re-evaluations" of the proposed action with the FWS beginning in 2014. The purpose of this first evaluation is to undertake a review of the first two years of implementation of the proposed actions through a workshop with scientists to assess what has been learned; a written report will be prepared. Subsequent re-evaluations will occur every 3 years.

Non-Native Fish Control

As part of the proposed action, Reclamation will be conducting some non-native fish control efforts. Allowing trout populations to increase without an effective strategy for reduction poses a risk to the humpback chub population. Several techniques have been considered by Reclamation. In addition to mechanical removal of non-native fish in the PBR and the LCR Reaches, it may be possible that the increase in rainbow trout reproduction could be mitigated by suppression flows, although the subsequent density dependent offsets are unknown and may actually increase the survival of rainbow trout at latter life stages (i.e. age 1) because of lower trout densities overall, as documented by Korman et al. (2011). Increased flow fluctuations during summer may be effective at reducing trout numbers, because these fluctuations negatively affect fry growth and habitat use.

It is hypothesized that the trout population in the mainstem Colorado River near the LCR is not self-sustaining but is maintained by rainbow trout immigration into the reach (Makinster et al. 2010) likely by trout from the Lees Ferry, although rainbow trout may also reproduce in Marble Canyon (Coggins and Yard 2010, Coggins et al. 2011). Korman et al. (2011) noted that y-o-y trout numbers decline over the summer in the Lees Ferry Reach, especially when abundance is high, such as following the 2008 HFE, and speculated that this is likely due to either density-dependent mortality or emigration. Thus, when trout numbers are high in Lees Ferry, emigration may increase as a result of increased density. Recent monitoring in November 2011 indicate that numbers of y-o-y rainbow trout in Lees Ferry are very high, likely due to good spawning and nursery conditions caused by the wet hydrologic year and corresponding high steady equalization releases in 2011 under the Interim Guidelines, and numbers of rainbow trout in the Lees Ferry Reach are currently estimated to be over 1 million (J. Korman, Ecometric, pers. comm., 2011). This set of circumstances could lead to increases in numbers of rainbow trout in the LCR reach in 2012, adding to already high numbers of rainbow trout, and increasing potential losses of y-o-y and juvenile humpback chub to predation and competition.

Although humpback chub are generally a small component of the rainbow trout diet (Yard et al. 2011), in years such as 2011 when rainbow trout densities throughout Marble Canyon are high, their predatory impact on humpback chub could be very large. During the 2003-2004 study periods, rainbow trout consumed 65% of the total fish even though they are less piscivorous than brown trout. But because of their abundance (rainbow trout constituted 98% of salmonids in the catch initially), rainbow trout had a greater cumulative piscivory effect (Yard et al. 2011). In the 2010 Opinion, the efficiency rate of non-native mechanical removal was estimated. With a low electrofishing efficiency rate, it was estimated that predation on humpback chub would be reduced by 10-14%. If mechanical removal rates experienced an average efficiency rate, predation on humpback chub would be reduced by 41-70%, and if high efficiency field efforts were to occur, predation rates could be reduced by 49-85%. Based on GCMRC data, the canceling of two non-native removal efforts in 2009 resulted in the estimated loss of 1,000 to 24,000 mostly y-o-y and age 1- humpback chub. The average loss of humpback chub across variable predation and immigration rates was estimated at 10,817 juvenile and y-o-y fish. Based on the numbers of fish eaten during the 2003 and 2004 field season (Yard et al. 2011), we estimate that similar numbers of fish will be lost in each year when trout numbers are above 1,200 in the LCR Reach when (approximately 30,000 fish [native and non-native species combined] were consumed by rainbow trout [21,641 fish] and brown trout [11,797 fish] including 9,326 humpback chub). Additional modeling data by Yard et al. (2011) estimated predation rates in 2009 at 16,215 fish, which is still within the anticipated range of take of 1,000 to 24,000 fish. Given the high piscivory rate of brown trout, the losses of humpback chub could be much higher. However, as stated in the Description of the Proposed Action, Reclamation has committed to working with NPS to expand the brown trout removal efforts both in Bright Angel Creek and the mainstem Colorado River.

Semi-annual or quarterly monitoring trips will be conducted throughout the year to estimate both juvenile humpback chub and rainbow and brown trout abundance in the mainstem at the LCR confluence. These efforts will use mark-recapture abundance estimation techniques for trout and humpback chub focused at estimating rainbow trout abundance below the LCR confluence. This sampling effort would be scheduled around and throughout the water year. The resulting analysis and reporting will occur in January to allow for sufficient time to plan and schedule mechanical removal in the following year. The trout abundance trigger for mechanical removal is based on prior efforts (Coggins et al. 2011). The trigger would be reached if population estimates exceed average monthly abundance estimates of 760 rainbow trout, 50 brown trout, and the number of adult humpback chub drops below 7,000 adults. These estimates will also serve as trigger for ceasing removal.

We believe that reducing the production of rainbow trout in the Lees Ferry reach could help to negate the long-term need for mechanical removal in the LCR reach because it will reduce the number of fish available to emigrate into the LCR reach from upstream areas. These efforts are predicated on the assumption that non-native fish have a negative population level impact on native fish. The LCR reach non-native removal program (as in 2003-2006, 2009) demonstrated our ability to remove non-native fish and this program could be successfully re-implemented if necessary to reduce the numbers of non-natives in the LCR reach. Removal of non-native fish represents a major concern to Tribes in the LCR reach, plus uncertainty persists as to whether action is required at this time because a link between predation by trout and humpback chub population levels at the LCR has not been established. As discussed throughout this document and in Coggins et al. (2011), earlier removal efforts were successful at removing non-native fish and concurrent with this time period humpback chub populations were showing increased recruitment and increasing abundance. However, they further point out that this non-native fish removal occurred during a period of system-wide declines in rainbow trout associated with warming water in the Colorado River, which may also have increased humpback chub recruitment rates and abundance. The removal experiment was therefore confounded by increasing riverine water temperatures due to drought. Coggins et al. (2011) concluded that "…these early signs of [humpback chub] increasing survival and recruitment are encouraging, [but] they are not adequate to infer the success of the non-native removal policy primarily because of the nearly perfect correlation between the unplanned increases in release water temperature and the magnitude of the non-native fish reduction." Additionally, other assessments (Coggins and Walters 2009) suggest that increases in humpback chub may have begun prior to the 2003 mechanical removal effort. Thus uncertainty persists in whether non-native fish, through direct or indirect interactions with humpback chub, are increasing the risk of extinction or delaying recovery time for this species.

Similarly, Reclamation-proposed reductions in juvenile and adult brown trout numbers at their source in Bright Angel Creek could reduce the numbers of fish emigrating to the LCR reach, but this still has not been effectively demonstrated. Currently, brown trout in the mainstem Colorado River are primarily limited to the reach near the mouth of Bright Angel Creek (Makinster et al. 2010). Based on catch rates, preliminary abundance estimates of brown trout near Bright Angel (RM 87.4-89.9) were 621 ± 154 (95% confidence) (B. Stewart, AGFD, pers. comm., 2011). Reclamation has committed to working with NPS on an expansion of the brown trout removal effort through the GCDAMP. However, brown trout control may require an ecosystem or watershed level approach to be effective overall.

In addition to effects from predation, the high number of trout may also impact the humpback chub in the LCR reach through competition. All fish species compete for food resources and living space where ever they occur. Rainbow trout and adult humpback chub are both mid-water swimming fish, often found occupying the same habitat in the LCR reach, and are presumably competing for food and space. Reducing the production of trout in the Lees Ferry reach will not substantially reduce the abundance of trout in the LCR reach in the near-term because of the presence of trout that have already migrated into the LCR reach (Wright and Kennedy 2011). Further, it may take up to 5 years to significantly reduce the abundance of trout in the LCR reach depending on movement rates of rainbow trout from the Lees Ferry Reach (Coggins et al. 2011). On the other hand, significant reductions in the abundance in trout numbers were clearly made with only 1 year of mechanical removal efforts at the LCR Reach (Coggins et al. 2011).

If, as currently proposed by Reclamation, future removal efforts are directed at upstream areas such as PBR to intercept rainbow trout as they migrate downstream, it may take several years before the effects of intercepting rainbow trout in the PBR reach reduces rainbow trout populations in the LCR reach. This is because prior removal efforts targeted the non-native fish in the LCR reach directly (Coggins et al. 2011), while the PBR removal effort would only affect trout abundance in the LCR reach indirectly by intercepting the fish upstream while waiting for the LCR reach population of non-native fish to die of natural causes. Additionally, the PBR removal effort target a much larger number of rainbow trout. To accelerate the reduction in the biomass of rainbow trout in the LCR reach, further, mechanical removal may be necessary in the short-term to reduce the existing rainbow trout population biomass in the LCR as the PBR removal program reduces the new emigrants into this population from upstream.

Reclamation has committed to removing non-native fishes at the LCR reach only if 1) rainbow trout abundance estimates in the portion of the reach from RM 63.0-64.5 exceeds 760 fish, and 2) if the brown trout abundance estimate for this reach exceeds 50 fish (evaluated each calendar year in January); and 3) the abundance of adult humpback chub declines below 7,000 adult fish based on the ASMR. This model estimate will be conducted every 3 years, and each year the latest ASMR results will be evaluated with the other elements of the trigger (i.e. numbers of trout) each calendar year in January.

OR

The above conditions 1 and 2 for trout abundance are met, and all of the following three conditions are also met:

1. In any 3 of 5 years during the proposed action using data extending retrospectively to 2008, the abundance estimate of humpback chub in the LCR between 150-199 mm TL (5.9- 7.8 inches) within the 95 percent confidence interval drops below 910 fish (evaluated each calendar year in January); and

2. Temperatures in the mainstem Colorado River at the LCR confluence do not exceed 12 ºC in two consecutive years (evaluated each calendar year in January); and

3. Annual survival of young humpback chub (40-99 mm [1.6-3.9] TL) in the mainstem in the LCR Reach drops 25 percent from the preceding year (evaluated each calendar year in January).

Based on the fact that high trout numbers existed in the LCR Reach before the 2003-2006 non-native mechanical removal effort, and high numbers returned to 2003 levels after only a 2-year hiatus of mechanical removal, we conclude that a mechanical removal program in the LCR reach would, on its own, be inefficient at maintaining low densities of trout in the LCR reach for extended periods of time. If the PBR removal effort is ineffective, trout production in Lees Ferry would likely out-pace the removal efforts in the LCR reach and could result in an extended and expensive, but perhaps ineffective, mechanical removal program.

We know that the majority of the humpback chub consumed by trout are y-o-y and subadults (age < 3), and this is expected to continue during the life of this project. The loss of so many young fish will affect recruitment to the humpback chub population. However, Yard et al. (2011) stated that "Our findings show that humpback chub are vulnerable to trout predation at an individual level, but it is uncertain whether or not trout piscivory has had a population-level effect on this endangered species." This idea is further validated by the fact that the number of adult fish has increased in recent years both with and without removal of trout. This increase occurred in the presence of warmer water; future years of cold water and high trout numbers may have less favorable results. Reclamation's proposed action will both provide more information about the effect of predation and competition from non-native fish on humpback chub, and implement strategies to protect humpback chub if predation and competition are found to affect humpback chub status.

We believe that the increase in rainbow trout reproduction could be mitigated by suppression flows particularly in summer which could reduce rainbow trout survival in the Lees Ferry Reach. From 2003-2005 "Nonnative Fish Suppression Flows" were tested. These flows consisted of fluctuating dam releases daily from 5,000 to 25,000 cfs, from January 1 to approximately April 1, to evaluate their ability in controlling the trout population in the Lees Ferry reach. Although the "non-native fish suppression flows" did result in a total redd loss estimate of 23% in 2003 and 33% in 2004, this increased mortality did not lead to reductions in overall recruitment due to increases in survival of rainbow trout at later life stages (Korman et al. 2005, Korman et al. 2011). It has been suggested that such flows, if tested in the future, be referred to as "fishery management flows" since reducing the overall population of rainbow trout in Lees Ferry would theoretically benefit the Glen Canyon population of rainbow trout by reducing intra-species competition among trout in that reach, and benefit native fishes downstream through reduced emigration of trout from Glen Canyon to areas downstream, therefore reducing predation and competition from rainbow trout on native fishes. Reclamation has committed to study the use of suppression flows during the first two years of the proposed action. These studies would include some of the concepts addressed in the Saguaro Ranch workshop (discussed below) (Valdez et al. 2010), particularly the strategies to increase the daily down ramp rate, or high flows followed by low flows to strand or displace age 0 trout.

Rainbow trout are sensitive to Glen Canyon dam operations because habitat conditions are directly tied to flow conditions and are significant in determining the number of juveniles recruiting to the mainstem. Yet trout response to the low steady summer flows (LSSF) in 2000 was uncertain both in magnitude of response but also the extent of the outmigration after the LSSF was concluded (Ralston 2011). Increased flow fluctuations during summer may also be effective at reducing trout numbers, because these fluctuations negatively affect fry growth and habitat use. If the production of rainbow trout in the Lees Ferry reach could be reduced, the long-term need for mechanical removal in the LCR reach may diminish. However, there are currently so many trout in the LCR Reach that additional measures may be needed in the short-term, especially if water temperatures decrease, which could cause humpback chub to become more vulnerable to predation by rainbow trout (S. VanderKooi, GCMRC, pers. comm., 2011).

Reclamation has committed to a comprehensive program review in 2014, and this short-term measure will be re-evaluated at that time.

The prey base (mostly chironomids, simuliids, and plant material) for fish in the Colorado River below Glen Canyon Dam will persist under MLFF, but because invertebrate diversity and production is low, competition for these limited food resources is likely at locations where native and non-native fishes overlap. As stated previously, studies completed by GCMRC and the University of Wyoming have found a high degree of dietary overlap between humpback chub and rainbow trout (Donner et al. 2011). In fact, consumption of invertebrate prey by the fish assemblage at all sites that were studied overlaps with independent estimates of invertebrate production. In other words, the fish assemblage appears to be consuming close to, or all of, the available midge and black fly production that occurs annually. This indicates that the fish assemblage may be food-limited. The spatial overlap between humpback chub and rainbow trout is the highest at the LCR confluence. Fish production in the mainstem Colorado River is supported by a small array of food resources of potentially limited availability, which may lead to strong competition for food among fishes, including competition with non-native species that may constrain production of the remaining native fishes in this river (Donner 2011). Competition between these species includes y-o-y and age 1 humpback chub when they enter the mainstem through adulthood, which may result in a much larger concern than just predation alone and may be compounded given the high numbers of trout predicted to be near the LCR confluence area now and in the future after spring HFEs.

In April 2010, a group of independent scientists, during a meeting at Saguaro Lake, developed a Discussion Paper to assimilate some of the many discussions among scientists and managers faced with the challenge of balancing non-native fish populations in Grand Canyon with conservation of native and endangered fish species. As stated above, we believe that paper summarizes the appropriate objectives of the mechanical removal effort and provides a framework for understanding the degree to which rainbow trout emigrating from the Lees Ferry reach result in increased trout abundance in the LCR reach; and will help evaluate the efficacy of removing rainbow trout in the PBR Reach. The April 2010 paper identifies several alternatives for meeting the objectives described below. These were also considered in the structured decision making report that helped develop Reclamation's proposed action (Runge et al. 2011):

1. Reduce annual production rates of rainbow trout in the Lees Ferry reach,
2. Sustain a healthy Lees Ferry trout population with a balanced age-structure,
3. Reduce emigration rates of rainbow trout from Lees Ferry to downstream reaches occupied by humpback chub, and
4. Reduce numbers of brown trout in Bright Angel Creek and thus emigration rates to the LCR reach.

The effectiveness of rainbow trout removal in the PBR is not known, and is proposed to occur only as a test phase during fiscal year 2012. Testing trout removal in the PBR is expected to inform decisions on the further use of this portion of the proposed action. Some scientists have stated that PBR trout removal is not likely to affect the number of trout in the LCR reach (C. Walters, pers. comm. 2011). Depending on the number of trips per year, we believe that the PBR effort may result in a decline of rainbow trout available to move down into the LCR Reach, based on the estimates of the number of trout that may be removed from the PBR Reach. We believe that PBR may be effective, especially if tested in conjunction with flows or environmental conditions that limit rainbow trout recruitment.

To summarize, Reclamation anticipates removing rainbow trout from the PBR reach with up to 10 trips per year. However, for 2012, only two trips are planned as an experimental test of this concept. There is also a commitment to remove non-native fishes from the LCR reach based on the estimates of adult humpback chub provided by the ASMR and the number of trout in the LCR confluence and other triggers as described above. Reclamation has also committed to examine further the potential to use flows and other non-flow actions to improve the effectiveness of non-native fish control, including testing various flows as recommended at the Saguaro Ranch science workshop.

In conclusion, humpback chub status has improved in the Grand Canyon, in the LCR aggregation in particular, but apparently also in some of the other mainstem aggregations downstream from Glen Canyon Dam. These improvements coincided with management under MLFF. Recovery of a species is based on reduction or removal of threats and improvement of the status of a species during the period in which it is listed. Competition and predation by non-native fishes, including rainbow trout and brown trout, will continue to reduce the survival and recruitment of young humpback chub in the mainstem, which could threaten the potential recovery of the species. As discussed, the ultimate effect of predation and competition on humpback chub is still in question. Reclamation has designed a proposed action to both help answer this question and provide contingency for large-scale removal of non-native fishes if significant population-level effects are detected.

Near term modeling predictions through 2012, longer term predictions of the implementation of the Shortage Guidelines through 2026, and the regional projections relative to climate change predictions for the southwestern United States all tend to indicate that the river may continue to be warm, at least relative to conditions downstream from Glen Canyon Dam since the dam was completed and filled in 1980. Although these warmer water temperatures may still be too cold to provide optimal conditions for humpback chub, they will likely periodically provide sufficient conditions that support survival and recruitment of the Grand Canyon population because, as described earlier, the warmer water may provide sufficient temperatures for humpback chub spawning, survival of young, and growth.

Effects to Humpback Chub Critical Habitat

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, USFWS 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 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 physical and biological features of those units, to determine the overall ability of all designated critical habitat to support recovery. Further, the functional role of each of the affected critical habitat units in recovery must also be defined.

The water and physical habitat PCEs of critical habitat of the LCR reach (Reach 6) 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, (about three percent 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 in a manner that differs from pre-dam conditions, 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.

In Reach 7, HFEs are likely to affect the following non-biological primary constituent elements: water (W1) water quality (W2), and physical habitat (nursery (P2) and feeding habitat (P3)). One of the desired outcomes of HFE protocol implementation is frequent rebuilding of sandbars and beaches through re-suspension and deposition of channel sediment deposits at higher elevations. HFEs may provide some rearranging of sand deposits in recirculating eddies, but that is expected to be quickly lost with a return to daily fluctuations. Reclamation's BA on HFEs noted that the immediate physical impacts of high flow tests (1996, 2004, and 2008) on backwater habitats were positive and included increased relief of bed topography, increased elevation of reattachment bars, and deepened return current channels. However, the return to fluctuating flows may make these habitats temporal, as documented in the months following the 2008 HFE, when erosion of sandbars and deposition in eddy return-current channels caused reductions of backwater area and volume. A temporary decline in benthic invertebrate numbers and fine particulate organic matter were documented after the 1996 high flow, but levels rebounded quickly and were available as food for y-o-y humpback chub the same year (Brouder et al. 1999). Overall, HFEs are likely to have a benefit to backwaters. As discussed previously, the MLFF directly affects water temperature, part of PCE W1 of Reach 7, by cooling mainstem water temperatures. However, overwintering and recruitment are expected to continue at 30-mile and other mainstem aggregations, particularly during years when water temperatures are above average and flows trend toward less daily fluctuations, although daily fluctuations may not be as significant limiting factor when water temperatures are warm. An increase in warmer water will likely result in increased growth rates of humpback chub but may be a tradeoff for improved conditions for brown trout, fathead minnows, and other warm water species that prey on or compete with humpback chub. As described earlier, water temperatures for about the last decade have consistently exceeded 12 °C, which may represent the threshold temperature for humpback chub given the improvement in the species status over this period.

The PCEs associated with the biological environment including food supply (B1), and predation from non-native fish species (B2), are expected to be adversely affected with HFEs. Food supply is a function of nutrient supply, productivity, and availability of food to each life stage of the species. Based on the currently available information, negative effects to the benthic community are not expected for HFEs below 31,500 cfs. However, the aquatic food base is expected to be scoured by spring HFEs between 41,000 and 45,000 cfs. The effect will decrease with downstream distance away from the dam, and recovery will be shorter in the downstream reaches, as was reported after the 2008 HFE (Rosi-Marshall et al. 2010). More information is needed on the effect of fall HFEs; however, in Reclamation's BA on HFEs, it is predicted that a fall HFE followed by a spring HFE could cause long-term damage to the food base. Since only 4 or 5 months would separate the two events, this is insufficient time to allow for complete recovery of most benthic invertebrate assemblages, although chironomids may recover within 3 months (Brouder et al. 1999.) In years when the food base recovery from a fall HFE is delayed until the following spring because of reduced photosynthetic activity over the winter months, a subsequent spring HFE could scour the remaining food resources and further delay recovery of the food base. Whenever two HFEs are conducted in a 12-month period, we anticipate adverse effects to the humpback chub food supply.

Predation and competition are normal components of the ecosystem, but are out of balance due to introduced fish species within critical habitat unit Reach 7, and are likely to remain sub-optimal with or without HFEs. The incidence of piscivory on humpback chub could be reduced during HFEs by periods of high turbidity. HFEs will redistribute sediment and will create periods of high turbidity during March-April and October-November, when sediment levels warrant a HFE. Since rainbow trout are visual feeders, their ability to prey on humpback chub should be limited during periods of HFEs. However, the opposite was documented in 2003 and 2004. Yard et al. (2011) documented higher piscivory rates of rainbow and brown trout during periods when the waters were consistently turbid downstream of the LCR. The cause of the increase in predation is not known and may be due to an increase in prey availability (i.e. small humpback chub moving passively out of the LCR with sediment), fish behavior, or other factors (Yard et al. 2011). Brown trout piscivory levels in the Colorado River have not been shown to be affected by turbidly and may cause substantial losses of to humpback chub.

Reclamation has also included in its proposed action several projects to monitor and evaluate the functioning of the critical habitat in Reach 7. Further, Reclamation will continue to work through the GCDAMP to monitor and analyze the effectiveness of experimental high flow releases in achieving specific resource goals downstream of Glen Canyon Dam. Information obtained from this monitoring and analysis will be collected in annual progress reports and incorporated into the decision making component of the HFE Protocol to better inform future decision making regarding dam operations and other related management actions.

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

The LCR reach of critical habitat plays an important role in the recovery of the species because this is the primary spawning and rearing area for the Grand Canyon population, which constitutes the lower Colorado River Recovery Unit. As described in the Status of the Species section, demographic criteria 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 (USFWS 2002a). The demographic criteria 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 demographic criteria, 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. 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 criteria, and the secondary measures are the state of the recovery factors and implementation of their associated management actions and tasks.

As stated in the 2008 an 2009 Supplemental Opinions, 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 [7.8 inches] 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). 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 criteria 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. Most of these are directed at improving and protecting humpback chub habitat including critical habitat and the PCEs. For Factor A, an adequate flow 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 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 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 in the LCR that is impacted by MLFF or HFEs, 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 (USFWS 1994). That reasonable and prudent alternative required that Reclamation be instrumental in developing a management plan for the LCR (USFWS 1995). The 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 Humpback Chub Comprehensive Plan (Glen Canyon Dam Adaptive Management Program 2009). Reclamation's assistance in this regard will help protect critical habitat in the LCR to the extent consistent with Reclamation's legal authority.

Factor B, overutilization, may not be relevant to the status of critical habitat, although there have been some concerns raised about handling stress in Reach 6 and 7. The highest estimated mortality rate of humpback chub associated with scientific collection during field activities is about 1,000, but most years the numbers are much lower (200 or less) (P. Sponholtz, FWS pers. comm., 2011). Despite the effects of handling stress on the species from repeated monitoring, the Grand Canyon population of humpback chub has improved in the last decade, and the results of research and monitoring activities have provided invaluable insight into the conservation needs of this endangered fish.

For Factor C, the focus of the Recovery Goals is on controlling the proliferation and spread of non-native fish species that prey on, compete with, and parasitize humpback chub. For the non-native fish species, current levels of control appear adequate. Non-native 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 Humpback Chub 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 Humpback Chub Comprehensive Plan, which will assist with this aspect of recovery.

However, recently FWS completed consultation on the Arizona Statewide Sport Fish Stocking Program, and concluded that stocking would have minimal effect on the Grand Canyon population of humpback chub. Thus, at least with regard to legal stocking in Arizona, this aspect of the recovery goals has at least partially been addressed.

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 the 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 MLFF results in net cooling effect to the mainstem and nearshore habitats of the mainstem, MLFF contributes to the suppression of both non-native fish species and Asian tapeworm.

For Factor D, 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 of the LCR 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, 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 Humpback Chub 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 Humpback Chub 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 Humpback Chub Comprehensive Plan as a conservation measure of the 2008 Opinion, which will serve to address this recovery need in Reach 6.

In summary, non-native fish in Reach 6 of critical habitat are expected to continue to be at low levels. As a conservation measure of the 2008 biological opinion, Reclamation will continue to support the implementation of the Humpback Chub Comprehensive Plan. Because MLFF results in net cooling effect to the mainstem and nearshore habitats of the mainstem, MLFF contributes to the suppression of both non-native fish species and Asian tapeworm. Non-native fish control efforts in the mainstem Colorado River may also provide some benefit to the PCEs in Reach 6 because warm water non-native fish will also be removed, preventing these fish from moving into the LCR and preying upon or competing with humpback chub. HFEs may result in short-term reductions in near shore habitat in the vicinity of the LCR confluence. However, sand re-deposition that rebuilds and maintains near shore and backwater habitats in the LCR confluence will benefit the functionality of the PCEs in this portion of critical habitat.

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

The MLFF will continue to affect the PCEs of humpback chub critical habitat in Reach 7 by manipulating flow releases on an hourly, daily, and monthly basis, affecting the timing and volume of delivery of water, water quality (W1, W2), the formation and quality of nearshore habitats (P2, P3), the composition of the food base, and the abundance and distribution of native and non-native fishes (B1, B2, and B3). 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 and 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 non-native fish species, as necessary to meet the demographic criteria 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 criteria 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 (USFWS 2002a). 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 [7.8 inches] 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 criteria for the Grand Canyon population for downlisting includes the humpback chub population maintained as a core over a 5-year period, starting with the first point estimate acceptable to the FWS, such that the trend in adult (age 4+; ≥ 200 mm [7.8 inches] TL) point estimates does not decline significantly, the mean estimated recruitment of age-3 (150–199 mm [5.9- 7.8 inches] 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 criteria for the Grand Canyon population has been met, but the best available science indicates that the PCEs in Critical Habitat Unit 7 are contributing to recovery because the demographic criteria are near to being met and the status of the species continues to improve in portions of the mainstem Colorado River. The Recovery Goals identify the need to determine the role of habitats in the mainstem in meeting the demographic criteria 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, 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 criteria for the species. The steady flow experiment in September and October from 2008 - 2012, the 2008 high flow test, the NSE, and other research, monitoring, and management actions, tested 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, the NSE, will be continued by Reclamation as part of the Natal Origins Study, and evaluate the response of fish and other variables in nearshore habitats such as backwaters under different flows to help clarify the relationship between flows and mainstem habitat characteristics, and the availability of nursery habitat for y-o-y and juvenile humpback chub, and the degree to which humpback chub are effected by competition and predation in these nearshore habitats.

Ongoing 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 determine the relationship of habitats in the mainstem and the LCR, thus defining appropriate operations of Glen Canyon Dam to achieve humpback chub recovery, as required by the Recovery Goals. The Recovery Goals require that procedures for stocking sport fish be updated to minimize escapement of non-native fish species into the Colorado River and its tributaries through Grand Canyon to minimize negative interactions between non-native fishes and humpback chub. Information provided in the FWS Sport Fish Opinion has provided updated information on the threat of sport fish stocking and AGFD has committed to implement the Conservation and Mitigation Program (CAMP) which uses a suite of tools to provide on-the-ground conservation benefits to the native aquatic species and, where appropriate, to riparian or terrestrial species indirectly affected by anglers. Reclamation has also included as a conservation measure in the 2008 and 2009 Supplemental Opinions continued support for the implementation of the Humpback Chub 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 non-native fish species. As a conservation measure of the proposed action, Reclamation has also committed to continue implementation of non-native fish control efforts. As discussed above, the GCDAMP has demonstrated that successful removal of non-native 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. (2011) found that the 2003-2006 removal of rainbow and brown trout contributed significantly to reduce predation losses of juvenile humpback chub. Non-native removal has been identified by several authors as a possible cause of improved status of humpback chub (Andersen 2009, Coggins and Walters 2009, Van Haverbeke and Stone 2009). Reclamation’s proposed action also includes evaluation of various non-native fish control techniques which will continue to refine methods of controlling non-native fish species. Reclamation’s effort to control non-native fish species directly addresses this recovery need for the B2 and B3 PCEs of Reach 7.

Temperature is also likely key in the increasing numbers of humpback chub. Temperature analysis has revealed that there may be a minimum temperature at which survivorship of young humpback chub in the mainstem Colorado River near the LCR improves. Preliminary results from recently conducted research on the predation of trout on humpback chub has revealed that humpback chub appear better able to avoid predation by rainbow trout as temperatures increase (D. Ward, USGS, oral comm., 2011). Also, hatching success, growth, and survival of larval and y-o-y humpback chub all increase with temperature up to about 20 °C. Interestingly, humpback chub status has increased since about 2000 (Coggins and Walters 2009) and temperatures since that time have consistently been above 12 °C in the mainstem (P. Grams, USGS, oral comm., 2011). Therefore, LCR reach removal will also be triggered based on temperature of the mainstem at the LCR confluence. If in any two consecutive years temperature in the mainstem does not exceed 12 °C, this trigger will be reached. This trigger will be evaluated every January for the prior two years of temperature data. Further, Reclamation predicts that water temperatures in the future are likely to be higher as a result of the Interim Guidelines and global climate change. Thus, although not entirely as result of Reclamation's action, this PCE may also improve over the life of the project.

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 non-native 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, and taking corrective actions based on the status of the humpback chub and its habitat. Reclamation has also included in its proposed action several projects to continue to monitor and evaluate the effect of flows and other actions on the PCEs of critical habitat in this reach. During the life of the proposed action, Reclamation will implement Non-native Fish Control when necessary, and is actively working to refine methods to remove and control the spread of non-native 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 criteria have been met, as stated in the 2009 Supplemental Opinion, recent monitoring and modeling suggests that it has (Coggins and Walters 2009, Van Haverbeke and Stone 2009).

Razorback Sucker and its Critical Habitat

Because the species is very rare in the action area (limited to the very lower portion of Grand Canyon), the possibility of adverse affects to individuals is low through most of the action area. In the inflow area to Lake Mead, razorback suckers may use portions of the river upstream of Pearce Ferry; however the extent of such use is uncertain due to limited habitat available. Normal MLFF flows have little to no effect to the area likely occupied by razorback sucker as the fluctuations have attenuated to the point that significant stage change is unlikely to occur.

The known razorback sucker spawning area in Gregg Basin could be affected by HFEs, particularly in the spring (March-April) when razorbacks are documented to be spawning (Kegerries and Albrecht 2011). The increased amount of water moving from the river to the lake will raise water levels at the inflow and possibly increase turbidity with additional sedimentation once the water slows down in the upper lake. Razorback suckers spawn on gravel and cobble bars, and if eggs are present, any sediment deposition could result in damage or mortality to eggs. Depending on the change in water temperature from the HFE flows, development of eggs and the health of larval razorback suckers may be affected. Razorback sucker larvae may also be displaced from nursery areas and moved into unsuitable habitats as the water deepens with passage of the HFE. Our knowledge of the inflow razorback sucker population is limited, and factors controlling recruitment at this location are unknown. A project initiated by Reclamation in September 2010 is designed to evaluate habitat potential of razorback sucker in lower Grand Canyon and to identify possible and existing linkages with the reproducing population in Lake Mead.

Spawning of razorback suckers in Grand Canyon proper has never been documented and post-dam cool water temperatures likely limit spawning throughout most of the river. Although cold water is anticipated for the near future, warmer water is likely in the long-term. The warmer water should benefit razorback sucker but may also result in the expansion on non-native fishes and Asian tapeworm. The proposed action will continue to affect sediment transport and flow levels. The sediment transport may affect the availability of fine sediment and, therefore, the availability of backwaters in areas above Separation Canyon. Without aggressive management (i.e. movement of adult razorback suckers into secluded areas and removal of non-native species) high numbers of non-native fishes will continue to occupy the same backwaters that are very important for young razorback sucker throughout the action area.

The proposed actions will affect razorback sucker critical habitat in Grand and Marble Canyons in the same ways it affects humpback chub critical habitat, primarily by cooling water temperatures, providing for the presence of high numbers of cold-water predators, and dewatering effects on nearshore habitats from daily fluctuations in flow. Razorback suckers have always been rare in the action area, and the ability of the Glen and Grand Canyon reaches of the Colorado River to fully provide the PCEs is uncertain, although events (i.e. stocking of adults, collection of larvae) in the lower portion of the action area may be promising. 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.

The largest HFE (45,000 cfs for 96 hours) could increase the level in Lake Mead by 1 or 2 feet (0.3 to 0.6 m) (Reclamation, BA on HFE, 2011). It is not known if this will encourage or discourage spawning by razorback suckers. However, HFEs may improve food availability (B1) by creating a boost in the amount of organic matter into the Lake Mead area and inundating areas available for spawning. There may be an increase in the number of predators and non-native fish moving into the Lake Mead inflow area (B2) but given the large numbers of carp, channel catfish, and other non-natives already in the lake, it is not known whether this change will be measurable. Based on the rarity of razorback suckers in the action area, and the apparent lack of suitable habitat, the proposed action is not expected to further diminish the conservation contribution from this stretch of river and critical habitat.

Kanab ambersnail

Kanab ambersnail habitat will be adversely affected by scouring at Colorado River flows exceeding 17,000 cfs. In general, MLFF will scour Kanab ambersnail habitat, actually removing habitat and snails above 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. Most of the HFE flows are expected to be at 45,000 cfs and may occur more than once a year and in consecutive years. As a result, some loss of habitat and snails will occur as these flows scour the vegetation and carry the snails downstream. If conducted frequently enough, HFEs may result in some permanent loss of habitat. Meretsky and Wegner (2000) noted that at flows from 20,000 to 25,000 cfs, only one patch of snail habitat was much affected (Patch 12), and a second patch to a lesser extent at flows above 23,000 cfs (Patch 11). According to estimates in 2000, flows of 31,500 to 33,000 cfs are expected to scour and cover with sediment between 10 and 17 percent of the Kanab ambersnail primary habitat at Vasey's Paradise (Reclamation 2002).

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, the patches expected to be affected by MLFF (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). 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 limited effect on the overall population of Kanab ambersnail at Vasey's Paradise and scouring would occur in habitat low quality.

During the 2004 HFE, approximately 25 – 40 percent (29m^2 to 47m^2; [312 ft^2 to 506 ft^2]) of habitat that would have been lost due to scour effects from the high flow test was temporarily removed prior to the test flow and replaced afterwards; 55 live Kanab ambersnails were also found and moved above the 41,500 cfs flow line, and essentially all of the habitat had recovered six months later (Sorensen 2005). This conservation measure was also conducted during the 2008 HFE. As discussed previously, Reclamation will not carry out this conservation measure for the proposed action because FWS and Reclamation have determined that this is no longer necessary. Instead, Reclamation will, through the GCDAMP, monitor the population on a periodic basis. It is worth noting that the median pre-dam high discharge was 51,200 cfs (Topping et al. 2003), thus historically, Kanab ambersnails were subjected to flows in excess of those proposed under the HFE Protocol on an annual basis, and it is likely that none of the habitat that will be affected by the proposed action existed historically.

Kanab ambersnails are pulmonate or air-breathing mollusks, but are able to survive underwater for up to 32 hours in cold, highly oxygenated water (Pilsbry 1948). In previous biological opinions on the operations of Glen Canyon Dam, we concluded that up to 350 ft^2 (32.5 m^2) of the habitat and resident ambersnails would be lost by the highest flows from Glen Canyon Dam during MLFF (25,000 cfs), and that up to 117 m^2 (1259 ft^2) would be lost during the largest HFE (45,000 cfs). We anticipate the same level of habitat and snail loss during the 10-year life of the project.

The proposed action will have no effect on the water flow from the side canyon spring that maintains wetland and aquatic habitat at Vasey's Paradise. Kanab ambersnail at Elves Chasm would also 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.

Climate Considerations for Effects to Humpback Chub

Climatologists predict that the southwest will experience extended drought, so lower Lake Powell Reservoir elevations and warmer release temperatures may be more common over the life the proposed action when compared to historical conditions (Seager et al. 2007, U.S. Climate Change Science Program 2008a, b). Modeling conducted by Reclamation to evaluate the effects of the Interim Guidelines provided predictions of water temperatures below Glen Canyon Dam through 2026. Reclamation utilized 100 years of Colorado River flow data to portray the potential effects of operational changes in wet (90^{th} percentile, i.e. only 10 percent of the 100 years were above the 90^{th} percentile of runoff), average (the 50^{th} percentile), and dry (the 10^{th} percentile). At the confluence of the LCR, during 10th percentile years, the average water temperature near the LCR was predicted to be slightly warmer (less than 0.8ºF [17 ºC]) under the Interim Guidelines in most months. During 50th percentile years, average water temperature near the LCR would also be slightly warmer from April through August. Overall, the predictions were that water temperatures downstream from Glen Canyon Dam would be warmer under the implementation of the Interim Guidelines (Reclamation 2007).

Reclamation has also completed finer-resolution modeling based on hydrological modeling for its October 24-Month Study forecast for Colorado River reservoir operations (Figure 7). Model predicted release temperatures from Glen Canyon Dam were computed based on model inputs from analogous years as determined by a comparison of forecasted Lake Powell hydrology with historic hydrology between the years 1990 and 2010. The forecast is provided as a range based on minimum, maximum, and most probable inflow volumes to Lake Powell. The forecasted Glen Canyon Dam release temperatures for the period through September 29, 2013 are expected to be relatively cooler compared with the period since 2003, but warmer than the historical period of 1978-2000 (Figure 6). Perhaps more importantly, the most probable scenarios predict release temperatures would exceed 12 °C in 2012. Thus 2012 is likely to continue the period since 2003 of 12+ °C temperatures at the LCR confluence, which as described above, may be at least partly responsible for the improvement in status of humpback chub over this period. Although these warmer water temperatures may not be optimal for humpback chub, they appear to provide, and may continue to provide, conditions that support survival and recruitment of the Grand Canyon population.

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. 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 ESA.

Cumulative effects to the humpback chub and its critical habitat stem from Native American actions, and State, 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 NPS, although on a much smaller scale thus far, and thus are projected to have minimal effects to humpback chub and its critical habitat.

Stone et al. (2007) describes the potential for non-native fishes, including those hosting parasites, to invade the lower LCR from upriver sources 155 miles (250 km) away during certain flood events travelling through the intermittent river segments. Non-native fishes stocked into the area in Arizona utilizing Federal funds have been evaluated, as described above, and are not anticipated to significantly affect humpback chub or its critical habitat; however, illegal stocking in the area could result in adverse effects to humpback chub.

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 LCR drainage are extensive, but as discussed in the Environmental Baseline section, these effects have thus far not had a detectable adverse effect on humpback chub and its critical habitat in the LCR, perhaps because these effects are diffuse over a wide area, and are distant from humpback chub and its critical habitat. The draft management plan for the LCR watershed (Valdez and Thomas 2009) provides recommendations to conserve humpback chub in light of these potential effects.

Razorback sucker critical habitat will be affected through the same activities as humpback chub critical habitat. Ongoing land uses around the non-Federal properties are not expected to change during the 10-year period covered by the proposed action, with agricultural uses, urban/suburban development, and recreational uses continuing.

Kanab ambersnail occurrence in the action area is entirely on Federal lands managed by 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 supplies these springs. We are currently unaware of any possible future non-Federal actions that affect the aquifers that create Kanab ambersnail habitat.

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 ESA. 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. All activities will occur with the uncertainty surrounding the effects of climate change. The potential for alteration of flows in the basin as a result of climate change could have large impacts on the basin's aquatic ecosystem, including changes in the timing of peak flows from an earlier snowmelt; lower runoff peaks because of reduced snow packs; and higher water temperatures from increased air temperature. Not only would climate change affect the ecology of the species, it also could greatly affect the management of the programs through changes in politics and economics, such as a greater evaporation losses in the larger reservoirs that may reduce flexibility of operations; and drier conditions in the basin that may cause irrigators to call on their water rights more often or request more water rights.

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 ESA 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."

After reviewing the current status of the humpback chub, razorback sucker, and Kanab ambersnail, the environmental baseline for the action area, the effects of the proposed actions, and the cumulative effects, it is the FWS's biological opinion that the actions, as proposed, are not likely to jeopardize the continued existence of the humpback chub, razorback sucker, or Kanab ambersnail and are not likely to destroy or adversely modify designated critical habitat for razorback sucker or humpback chub for the following reasons.

Humpback chub

As stated in the 2008 and 2009 Supplemental Opinions and re-affirmed in 2011, the Grand Canyon population appears to have improved to approximately 7,650 adult fish (age 4+) (an increase of 1,650 since the 2008 Opinion). This estimate is similar to the number of adult fish thought to be present in Grand Canyon in 1995, and is nearing or has met the demographic criteria for this population (USFWS 2002). 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 non-native fishes that prey on and compete with humpback chub. 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 non-native 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). However, 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 non-native 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 conservation measures and ongoing research will likely be beneficial to humpback chub and its critical habitat.

Population modeling indicates an upward trend in the number of adult humpback chub which continues to be the largest population range wide. This is in part due to the security of humpback chub in the LCR which are largely unaffected by dam operations or other factors.

The proposed action includes several projects to monitor and evaluate the effect of the proposed action including various monitoring and research projects of the GCDAMP annual work plans, which will provide timely information if the upward trend in humpback chub were to change .

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 conservation measures. 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. The proposed action includes a number of actions to benefit the species. Conservation measures and ongoing research that will likely be beneficial to both the humpback chub and its critical habitat. The following is a summary of past efforts that demonstrate Reclamation's commitment to implementing these conservation measures to benefit humpback chub, and future conservation measures that will be implemented as part of the proposed action.

Fish Research and Monitoring

- As discussed in the 2008 and 2009 Supplemental Opinions, 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 plans to utilize this plan in cooperation with the USFWS and other GCDAMP members to determine what actions remain to be accomplished, and find additional funding sources that will be provided by other willing partners to help achieve recovery of the humpback chub.

- Reclamation continues to support fish research and monitoring efforts in Grand Canyon that will help to better determine effects of the proposed action on the endangered species. These efforts include continued population estimates of humpback chub in the LCR, ongoing monitoring of fish in the mainstem Colorado River, and monitoring of the abundance of humpback chub and species composition at the eight mainstem aggregations of humpback chub in Marble and Grand Canyon annually.

- Reclamation will, through the Natal Origins Study, continue research efforts on nearshore ecology of the LCR reach to better understand the importance of mainstem nearshore habitats in humpback chub recruitment and the effect of non-native fish predation on humpback chub recruitment, and to monitor the trend in annual survival of young humpback chub in the mainstem for use in determining the need for non-native fish control.

Non-native Fish Control

- In the past decade, Reclamation has provided financial and/or technical support to control non-native fish species in the Colorado River and its tributaries as a way to minimize effects of predation and competition on native fish species. These activities include ongoing non-native fish control planning, non-native fish control methods pilot testing, removal of rainbow trout from the LCR reach of the Colorado River, increased fluctuating flows during the months of January through March to increase mortality of young rainbow trout, and mechanical removal of brown trout through weir operations at Bright Angel Creek.

- Reclamation has also funded and helped to conduct a non-native fish workshop and meetings with American Indian Tribe representatives to address concerns about mechanical removal of non-native fish in the LCR inflow reach. Reclamation recently conducted a structured decision-making workshop to help identify science-based alternatives for non-native fish control downstream of Glen Canyon Dam, and Reclamation's Lower Colorado Regional Office has provided $20,000 to support an international symposium on the use and development of genetic biocontrol of non-native invasive aquatic species.

- Reclamation will conduct further analysis on the effects from non-native fish removal and analysis of incidental take through the proposed action. The analysis will be directed at further refinement of targets for non-native fish control to determine a level of effort that would effectively reduce non-native numbers to benefit humpback chub, and better understand the link between non-native fish control and status and trend of humpback chub. The action on non-native fish control would help to mitigate the unintended consequences of an increased rainbow trout population that is likely to result from the HFE protocol.

- As an additional mitigating measure, Reclamation will continue to work with the NPS to implement removal of non-native rainbow trout in Shinumo Creek as part of the humpback chub translocation project and will help support such control measures in Havasu and Bright Angel creeks in advance of future humpback chub translocations in those systems.

Humpback Chub Translocation and Refuge

- Reclamation has supported translocation of humpback chub to the LCR above Chute Falls since 2003 and has been involved with the NPS translocation plan and logistics coordination for Shinumo Creek since late summer 2007. As stated in our 2009 Supplemental Opinion, during July 2008 and 2009 humpback chub were translocated to areas above Chute Falls, and additional fish were collected for the purposes of establishing a hatchery refuge population and translocation to Shinumo Creek during both years. Reclamation has funded additional translocations of humpback chub into Shinumo and Havasu Creeks since that time. Reclamation assisted the USFWS with development and funding of a broodstock management plan and creation and maintenance of the refuge population at the DNFHTC. These translocations and the refuge population help to offset losses of young humpback chub due to predation and displacement of young by HFEs. This effort will continue as described in the Description of the Proposed Action in this document.

- Reclamation will also, as a conservation measure of the proposed action, fund an investigation of the genetic structure of the humpback chub refuge housed at DNFHTC that will include: 1) a genotype of the refuge population at DNFHTC using microsatellites; 2) an estimate of humpback chub effective population size; 3) a calculation of pairwise relatedness of all individuals in the DNFHTC Refuge population.

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Re-Evaluation Points

- Reclamation and FWS agree to meet at least once every 3 years to specifically review the need for reinitiation of consultation based on humpback chub status and other current and relevant information. Reclamation will undertake a review in 2014 of the first two years of implementation of the proposed action through a workshop with scientists to assess what has been learned, which will also serve as the first re-evaluation point. Reclamation will also produce a written report of each evaluation and either FWS or Reclamation may require reinitiation of formal consultation on the proposed action to reevaluate the effects of the action if warranted.

Parasite Monitoring

- A considerable amount of research has been done on parasites of the humpback chub in Grand Canyon (e.g., Clarkson et al. 1997, Choudhoury et al. 2001, Cole et al. 2002, Hoffnagle et al. 2006). In coordination with the GCDAMP Reclamation will continue to support research on the effects of parasites such as the Asian tapeworm on humpback chub and potential methods of controlling these parasites.

Sediment Research

Reclamation has modified releases from Glen Canyon Dam and supported studies on the effects of sediment transport on humpback chub habitats. Substantial progress has been made toward these efforts. High Flow Experiments conducted in 1996, 2004, and 2008 have enhanced our knowledge of sediment transport and its effects on humpback chub habitat. Extensive data collection and documentation have resulted from these tests (Hazel et al. 1999, Schmidt 1999, Topping et al. 2000a, 2000b, 2006, Rubin et al. 2002, Schmidt et al. 2004, Wright et al. 2005, Melis et al. 2010, Melis 2011). In coordination with other DOI GCDAMP participants and through the GCDAMP, Reclamation will continue to support monitoring of the effect of sediment transport on humpback chub habitat. This sediment research will also help to quantify the amount of sediment available for an HFE, and could help to determine the proportion of the inorganic sand component and the finer organic component that is important to the aquatic ecosystem in Grand Canyon.

Little Colorado River Watershed Planning

- Reclamation will continue its efforts to help other stakeholders in the LCR watershed with development planning efforts, with consideration for watershed level effects to the humpback chub in Grand Canyon. Under contract with Reclamation, SWCA, Inc. has developed a draft LCR Management Plan that has identified some of the primary water development risks to sustainable humpback chub critical habitat, as well as steps toward effective risk management, and key players in the implementation of the management plan (Valdez and Thomas 2009).

Humpback Chub Critical Habitat

- We believe humpback chub 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 protected by the proposed action.

- The W1 and W2 PCEs of critical habitat in Reach 6 will benefit from Reclamation's efforts to address watershed planning for the LCR, and projects in the Humpback Chub 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 non-native species, and perhaps from the cooling effect that MLFF has on the mainstem, which may suppress warm water non-native species.

- In summary, we find that the proposed action will not result in jeopardy to humpback chub or adverse modification of its critical habitat. The MLFF, periodic HFEs, and non-native fish control will have adverse effects to humpback chub, most notably due to changes in the river flows and their effect on near shore habitats for young humpback chub. However, the best available information indicates that the species' status began to improve for during implementation of MLFF and, new information indicates that while water temperatures have not been optimal for the species, they periodically occur at a level that allows for survival and recovery. HFEs may have adverse effects to humpback chub due to displacement and beneficial effects to rainbow trout, but also may improve habitats for humpback chub through the creation of more diverse near shore habitats, i.e. backwaters. Although there is evidence that young humpback chub are lost to predation, there remains uncertainty as to whether these losses will ultimately result in reduced abundance of humpback chub in the LCR area. And finally, Reclamation has developed a history of successfully implementing conservation measures, and will continue to implement these important actions such as translocation and refuge maintenance for the life of the proposed action.

Razorback sucker and Critical Habitat

Continuation of MLFF flows is unlikely to have any significant effect to razorback suckers in the Colorado River inflow area since effects of those releases are attenuated by the time the water reaches what is likely to be occupied habitat, and razorback sucker are very rare in the action area. The HFE flows may have some effect to spawning and recruitment if conducted during the spring; however, the potential for these adverse effects is limited by the number of potential HFE flows that could be conducted in the spring.

- Similar to the discussion of PCEs of Reach 7 for humpback chub, PCEs in the mainstem for razorback sucker will be directly and negatively affected by the proposed actions, but long-term conservation goals will not be precluded. Reclamation operates the dam using adaptive management through the GCDAMP and a series of conservation measures to sustain the existing primary constituent elements.

Razorback Sucker Habitat Assessment and Potential Augmentation

As part of the USFWS concurrence with the determinations made for Reclamation's adoption and implementation of the interim guidelines, the 2007 Opinion (USFWS 2007) states that "Reclamation will, as a conservation measure, undertake an effort to examine the potential of habitat in the lower Grand Canyon for the species (razorback sucker), and institute an augmentation program in collaboration with FWS, if appropriate." Reclamation has initiated a contract for this study with a comprehensive evaluation of razorback sucker habitat and convened a Science Panel in fall of 2009 to evaluate the suitability of habitat in lower Grand Canyon and Lake Mead inflow. Reclamation is undertaking this effort in collaboration with the FWS, GCDAMP, LCR MSCP, NPS, GCMRC, Nevada Department of Wildlife, and the Hualapai Tribe. This measure will help to better understand the status of the razorback sucker in the lower end of the Grand Canyon. Information from the HFE monitoring of habitats in the lower Canyon could lead to a better understanding of how to offset effects of the proposed action.

Kanab ambersnail

- As stated in the 2008 and 2009 Supplemental Opinions, although the MLFF will result in some loss of Kanab ambersnails and their habitat at Vasey's 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 Vasey's Paradise population and is not expected to preclude the species' conservation. HFEs likely will result in the loss of some habitat, and Reclamation will monitor how this effects the population status.

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 ESA and Federal regulations pursuant to section 4(d) of the ESA 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 further 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 which 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 ESA 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 require any applicant 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, the 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

<u>Humpback Chub</u>

Similar to previous consultations related to the operations of Glen Canyon Dam, incidental take is expected from the effects of suboptimal water temperatures and displacement, as well as indirect mortality from increased competition and predation rates by non-native fish predators. Based on the analysis presented in the Effects of the Action section of this Opinion, y-o-y and juvenile humpback chub are likely to be killed or harmed with implementation of the proposed dam operations. In the 2008 and 2009 Supplemental Opinions, a surrogate level of incidental take was determined because of the limitations on estimating the number of y-o-y and age 1 humpback chub. With improved modeling, these estimates are more precise and in the 2010 Cancellation Opinion, Reclamation estimated that between 1,000 and 24,000 y-o-y or juvenile humpback chub will be lost to predation annually as a result of the proposed action, and estimated an average loss of approximately 10,000 fish per year. In years with non-native removal, the incidental take levels may be lower to some unknown extent. But in years such as 2012 when rainbow trout levels are very high, we anticipate higher losses of humpback chub to predation. We do not know how high these losses will be. We can, however, use the results of modeling efforts to estimate losses and through the ongoing adaptive management program implement conservation measures necessary to alleviate losses in the future.

Removal of non-native fish at the LCR reach would only occur if 1) rainbow trout abundance estimates in the portion of the reach from RM 63.0-64.5 exceeds 760 fish, and 2) if the brown trout abundance estimate for this reach exceeds 50 fish (evaluated each calendar year in January); and 3) the abundance of adult humpback chub declines below 7,000 adult fish based on the ASMR. This model estimate will be conducted every 3 years.

OR

The above conditions 1 and 2 for trout abundance are met, and all of the following three conditions are also met:

1. In any 3 of 5 years during the proposed action using data extending retrospectively to 2008, the abundance estimate of humpback chub in the LCR between 150-199 mm (5.9-7.8 inches) TL within the 95 percent confidence interval drops below 910 fish (evaluated each calendar year in January); and

2. Temperatures in the mainstem Colorado River at the LCR confluence do not exceed 12 degrees 12º C in two consecutive years (evaluated each calendar year in January); and

3. Annual survival of young humpback chub (40-99 mm [1.6-3.15 inches]TL) in the mainstem in the LCR Reach drops 25 percent from the preceding year (evaluated each calendar year in January).

PBR removal may occur at other times in coordination with the GCDAMP. With the occurrence of other lethal and nonlethal stressors from suboptimal water temperatures and unstable shoreline habitat associated with fluctuating flows, we do not anticipate that incidental take will exceed the 24,000 estimate/year in any year. We contemplate that take within these limits will still allow some recruitment to the adult population and therefore not preclude recovery. The incidental take is expected to be in the form of mortality, harm, and harassment. Take from mortality will be predominantly to y-o-y and juvenile humpback chub, size classes that have high mortality rates, and thus these losses may not affect the adult population. If these losses do affect the adult population, or even have measurable effects to young humpback chub, the trigger for LCR removal and other aspects of Reclamation's proposed action are designed to be implemented, through adaptive management, to continue to ensure that the humpback chub status does not decline and continues the improvement seen over the last decade.

<u>Razorback Sucker</u>

Based on the very low numbers of razorback suckers in the action area, we do not believe that incidental take of razorback sucker is reasonably certain to occur.

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 not expected to substantially diminish the size or vigor of the Vasey's Paradise population. The number of individual snails cannot be estimated because of seasonal and annual fluctuations in the population; therefore, as a surrogate measure of take, we will consider anticipated take to be exceeded if the proposed action results in more than 17% of Kanab ambersnail habitat being removed at Vasey's Paradise in any one year and this loss is attributable to the MLFF and/or the HFEs.

EFFECT OF THE TAKE

In this biological opinion, the FWS determines that this level of anticipated take is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

REASONABLE AND PRUDENT MEASURES AND TERMS AND CONDITIONS
In order to be exempt from the prohibitions of section 9 of the ESA, Reclamation must comply with the following terms and conditions, which implement the reasonable and prudent measures, described above and outline required reporting/monitoring requirements. These terms and conditions are non-discretionary.

Humpback chub

The following reasonable and prudent measures and terms and conditions are necessary and appropriate to minimize incidental take of humpback chub.

1. Reclamation has committed to develop, with GCDAMP and stakeholder involvement, additional non-native fish control options during the first two years of the proposed action to reduce recruitment of non-native rainbow trout at, and emigration of those fish from, Lees Ferry. Reclamation will coordinate the development of these actions with the on-going NPS Management Plan for native and non-native fish downriver of Glen Canyon Dam in both the GCNRA and GCNP. Both flow and non-flow experiments focused on the Lees Ferry reach may be conducted in order to experiment with actions that would reduce the recruitment of trout in Lees Ferry, lowering emigration of trout. Additional environmental compliance may be necessary for implementation of the following types of experiments that will be considered.

A. Within two years, Reclamation should include an assessment of the feasibility to disadvantage reproduction of rainbow trout as described in Treatment #3 and Treatment #4 in Valdez et al. 2010, and repeated here.

Treatment 3: Increase Daily Down-Ramp to Strand or Displace Age-0 Trout
This treatment would use dam releases during June through August to strand or displace age-0 trout and reduce rainbow trout survival. Increased down-ramp rates could reduce survival of age-0 trout by stranding them in exposed dewatered areas or by displacing them into less favorable habitats where they are subject to increased predation. Increased fluctuations would be most effective if they occurred daily from June through August

when young fish occupy habitats that are more affected by fluctuating flows; i.e., shallow, low-angle habitats. This treatment may only need to be done once a week. Several dam release options may be used to achieve this treatment including (1) a wider range in flows (higher maximum, lower minimum; e.g., summer normal 16,000 to 10,000 cfs, could be modified to 16,000 to 5,000 cfs and keep at 5,000 cfs for 3 hrs), (2) lower minimum flow than ROD flows (e.g., 3,000 cfs) for a short period of time (e.g., 1 hr) with a step up to a higher minimum that is within the ROD (e.g., 8,000 cfs); and (3) same range as ROD with faster ramp rates.

Treatment 4: High Flow Followed by Low Flow to Strand or Displace Age-0 Trout
Under this treatment, flows would be held high and steady (about 20,000 cfs) for a few days during June and July. Recently emerged trout tend to migrate to the lower edge of the varial zone, and steady flows are expected to produce an aggregation of fish in near-shore habitats. This would be followed by a quick down-ramp to a minimum flow (about 8,000 cfs) which would be held for 12-14 hours. This operation would be done every 2-3 weeks in June and July. Because this operation might not need to be done every day during the summer, there should be less impact to other resources compared to Treatment # 3. However, it could be used more frequently.

B. Explore flow and non-flow options for controlling trout movement downstream (such as coordination with angling community, NPS, AGFD, Tribes, and other groups, to better manage the Lees Ferry trout fishery through such actions as changing fishing regulations).

2. Reclamation shall protect y-o-y and juvenile humpback chub, monitor the incidental take resulting from the proposed action, and report to the FWS the findings of that monitoring.

A. Reclamation shall monitor the action area and ensure the long-term protection of the humpback chub as established by the GCDAMP.

B. Reclamation shall submit annual monitoring reports to the Arizona Ecological Services Office beginning in 2012 in collaboration with other GCDAMP participants including GCMRC, AGFD, NPS, and other cooperators to complete this monitoring and reporting. These reports shall briefly document for the previous calendar year the effectiveness of the terms and conditions and locations of listed species observed, and, if any are found dead, suspected cause of mortality. The report shall also summarize tasks accomplished under the proposed minimization measures and terms and conditions.

Kanab Ambersnail

The following reasonable and prudent measures and terms and conditions are necessary and appropriate to minimize incidental take of Kanab ambersnail.

1. Reclamation shall monitor project effects on Kanab ambersnail and its habitat to document levels of incidental take and report the findings to the FWS.

A. Reclamation shall work in collaboration with the GCDAMP participants including GCMRC, AGFD, and other cooperators to complete this monitoring.

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 the AESO 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 W. Broadway Rd, 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 ESA directs Federal agencies to utilize their authorities to further the purposes of the ESA 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.

1. We recommend that Reclamation provide funding to verify temperature suitability needed for continued maintenance of the aquatic ecosystem food base and y-o-y humpback chub and other native fish. With the creation of the refuge population of HBC at DNFHTC, the FWS has the ability to spawn humpback chub to provide eggs, larvae and y-o-y for research. There remains some outstanding questions related to swimming ability at colder temperatures that have yet to be quantified for humpback chub as well as the question, can we quantify take associated with MLFF for the Incidental Take Statement. We recommend that Reclamation provide funding for life history research in the context of the water temperature profile available from the Glen Canyon Dam. This effort should recognize the on-going USGS work (such as D. Ward studies) and support it or other studies as appropriate.

2. We recommend that Reclamation develop an assessment report within the first two years of the proposed action that identifies and evaluates potential sites that could be used for rearing and release of humpback chub in the event of excessive predation, some other environmental factor, and/or a contaminant spill that eliminates or significantly reduces humpback chub populations.

3. Reclamation should consider providing funds to the FWS and AGFD to carry out preparation of the reports described in 1 and 2 above.

4. Reclamation should consider supporting the recommendations in the Kanab ambersnail 5-year review including convening a team of snail, taxonomy, and genetics experts to conduct a Structured Decision Making exercise focused on reviewing or revising the current taxonomic status of the *Oxyloma* genus.

5. Establish a second, offsite refuge for humpback chub including investigation of the most appropriate facility and infrastructure improvements (quarantine area) if necessary.

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 the Project Description of this Opinion. 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 Reclamation's 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.

In keeping with our trust responsibilities to American Indian Tribes, we encourage you to continue to coordinate with the Bureau of Indian Affairs in the implementation of this consultation and, by copy of this biological opinion, are notifying the following Tribes of its completion: the Southern Paiute Consortium, Fredonia, Arizona, Havasupai Tribe, Hopi Tribe, Hualapai Tribe, Kaibab Band of Paiute Indians, Navajo Nation, Pueblo of Zuni, and San Juan Southern Paiute Tribe. We also encourage you to continue to coordinate with the Arizona Game and Fish Department.

We appreciate the Bureau of Reclamation's efforts to identify and minimize effects to listed species from this project. For further information please contact Debra Bills (ext. 239) or Steve Spangle (ext. 244). Please refer to the consultation number 22410-2011-F-0100, in future correspondence concerning this project.

/s/ Steven L. Spangle

cc: Regional Director, Fish and Wildlife Service, Albuquerque, NM (ARD-ES) (J. Bair; M. Oetker)
Project Coordinator, Arizona Conservation Office, Flagstaff, AZ (P. Sponholtz)

Chief, Natural Resources Division, National Park Service, Grand Canyon, AZ

Glen Canyon Natural Recreation Area, Page, AZ
Chief, Habitat Branch, Arizona Game and Fish Department, Phoenix, AZ (B. Stewart)
Director, Environmental Programs, Bureau of Indian Affairs, Phoenix, AZ
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
Southern Paiute Consortium, Fredonia, AZ

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APPENDIX A AND LITERATURE CITED ON THE FOLLOWING PAGES

APPENDIX A

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; USFWS 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; USFWS 2005b). Critical habitat was voluntarily remanded by the FWS in 2009 and revised proposal was published August 15, 2011(76 FR 50542) but does not include the Colorado River through Grand Canyon. The 2005 critical habitat designation remains in effect until the current proposal is finalized. Proposed critical habitat on the Lower Colorado River begins at RM 243. A final recovery plan for the southwestern willow flycatcher was completed in 2002 (USFWS 2002c).

Flycatchers have 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 nesting habitat is extremely disjunct from approximately RM 28 to RM 274 (Holmes et al. 2005, James 2005). Surveys conducted between 1992 and 2007 documented a very small 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). A total of 16 breeding sites have been detected through 2007, with a high of 16 territories detected in 1998 (Sogge and Durst 2008), but that declined to an estimated 4 territories in 2007 (Durst et al. 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.

Non-native tamarisk beetles have recently been found along the Colorado River from Navajo Bridge all the way downstream where intermittent defoliation occurred along the river corridor to just below Lower Lava rapid (~Mile 181). It is likely the beetle will continue to spread through Grand Canyon, which may adversely affect the suitability of flycatcher nesting habitat where tamarisk is an important component of the vegetation (G. Beatty, USFWS, pers. comm., 2011).

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 dewater habitats enough to kill or remove tamarisk, and no loss of southwestern willow flycatcher nesting habitat from flooding or desiccation is anticipated. HFEs may create flows of up to 45,000 cfs for up to 96 hours; similar flows have been tested in past HFEs and have not affected southwestern willow flycatcher habitat.

An important element of flycatcher nesting habitat is the presence of moist surface soil conditions (USFWS 2002c). 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 HFEs may result in the distribution of fine sediments extending farther laterally across the floodplain and deeper underneath the surface providing for the retention of subsurface water, which may provide for the development of the vegetation that provides flycatcher habitat and microhabitat conditions. 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 modify nesting habitat. Thus the proposed action will likely have little effect on the abundance or distribution of southwestern willow flycatcher in the action area.

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. The downstream proposed critical habitat will not 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 or HFEs.
- The flow limits of the MLFF are not expected to desiccate flycatcher habitat to the point that food base for willow flycatcher is affected.
- HFEs may result in the distribution of fine sediments extending farther laterally across the floodplain and deepening the soils surface providing for the retention of subsurface water, which may provide for the development of the vegetation that provides flycatcher habitat and microhabitat conditions.

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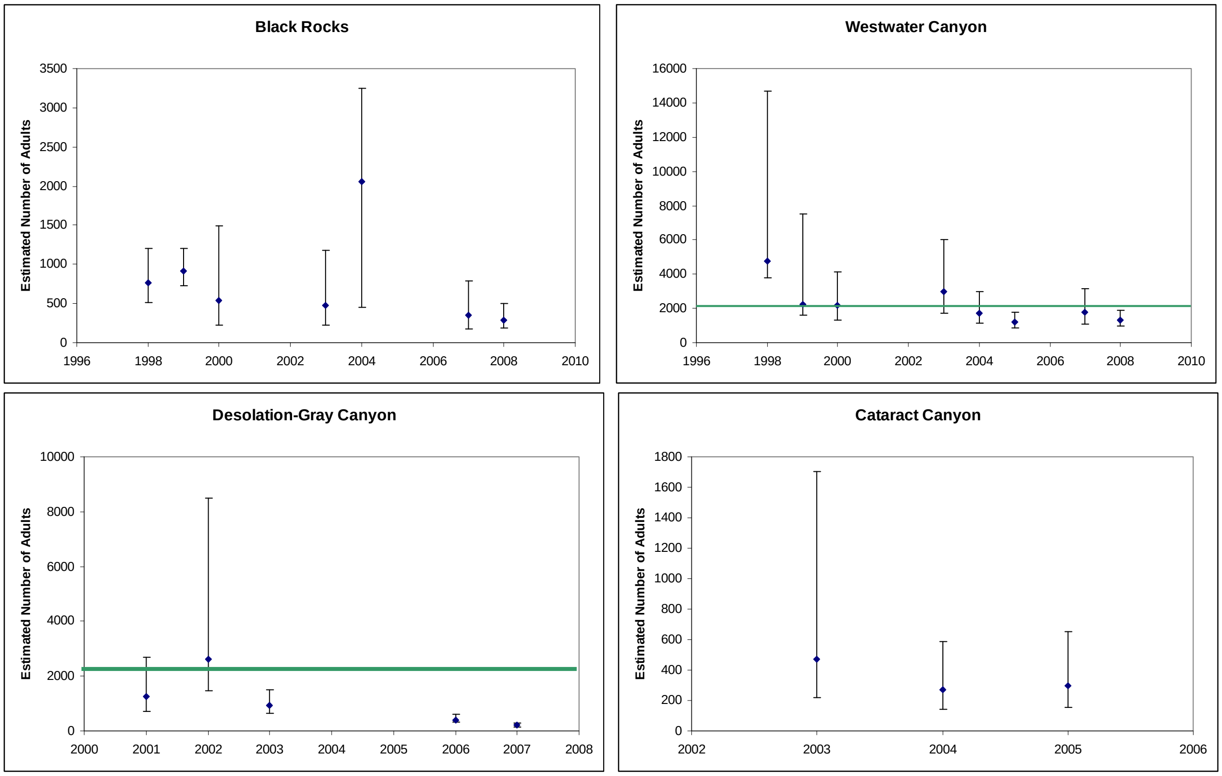
FIGURES –

BIOLOGICAL OPINION ON 10-YEAR MODIFIED LOW FLUCTUATING FLOW, HIGH FLOW PROTOCOL AND NON-NATIVE FISH CONTROL BELOW GLEN CANYON DAM

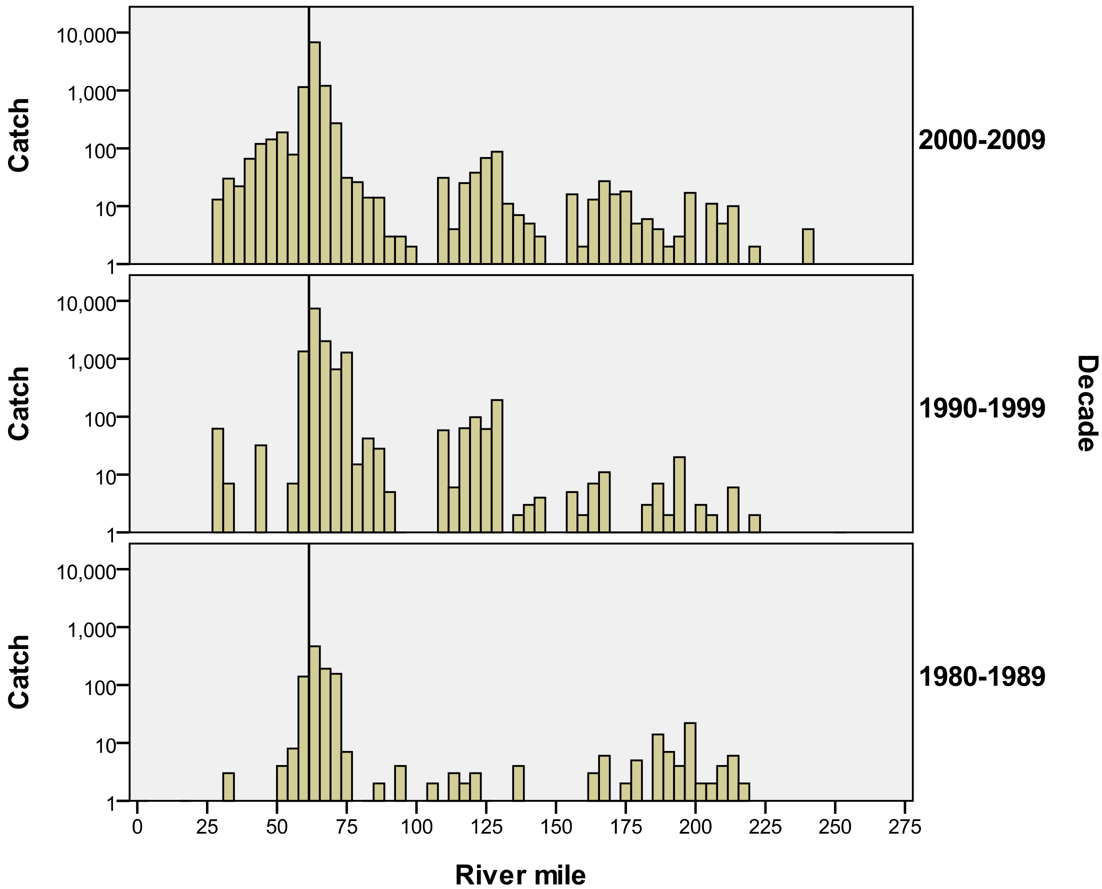
Figure 1. Distribution of humpback chub in the Colorado River System

Figure 2



Estimated numbers of humpback chub adults (≥ 200-mm TL) in 4 of 5 populations of the Upper Colorado River Basin. Error bars are 95% confidence intervals. The line at 2,100 represents the minimum viable population number; for core populations they need to exceed this level. Data from Black Rocks (McAda 2003a; 2007), Westwater Canyon (Elverud 2008), Desolation/Gray Canyons (P. Badame, Utah Division of Wildlife Resources, pers. comm.), and Cataract Canyon (Badame 2008) (From the USFWS 5-Year Review 2011)

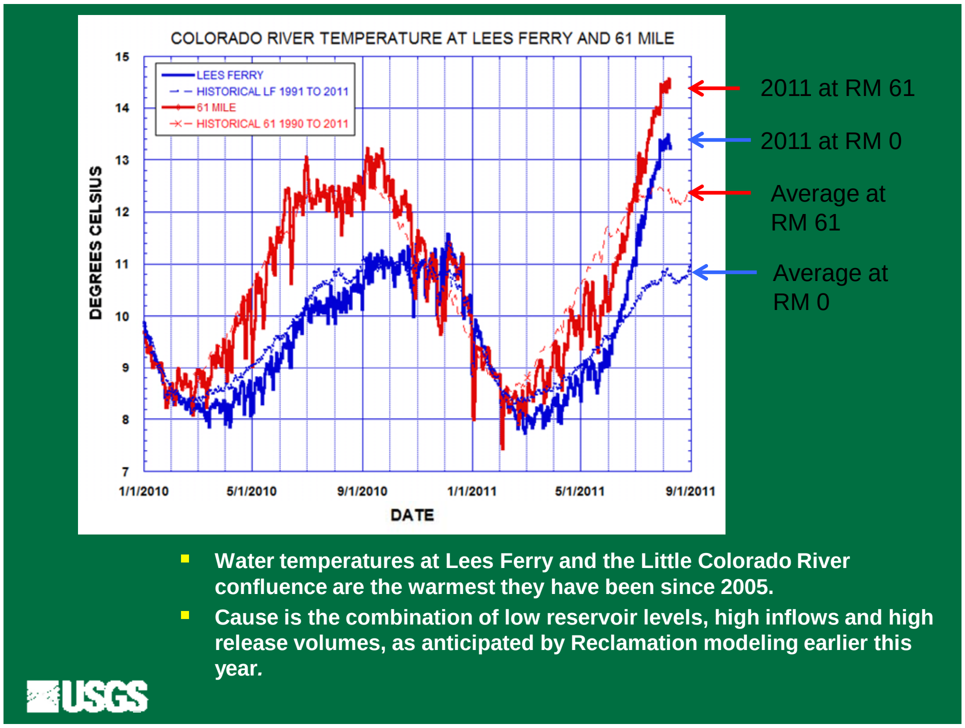
Figure 3



Number of humpback chub collected in Colorado River by river mile, 1980-2009. Vertical line is at River mile 61.5, the confluence of the Little Colorado River. Note y axis is log scale.

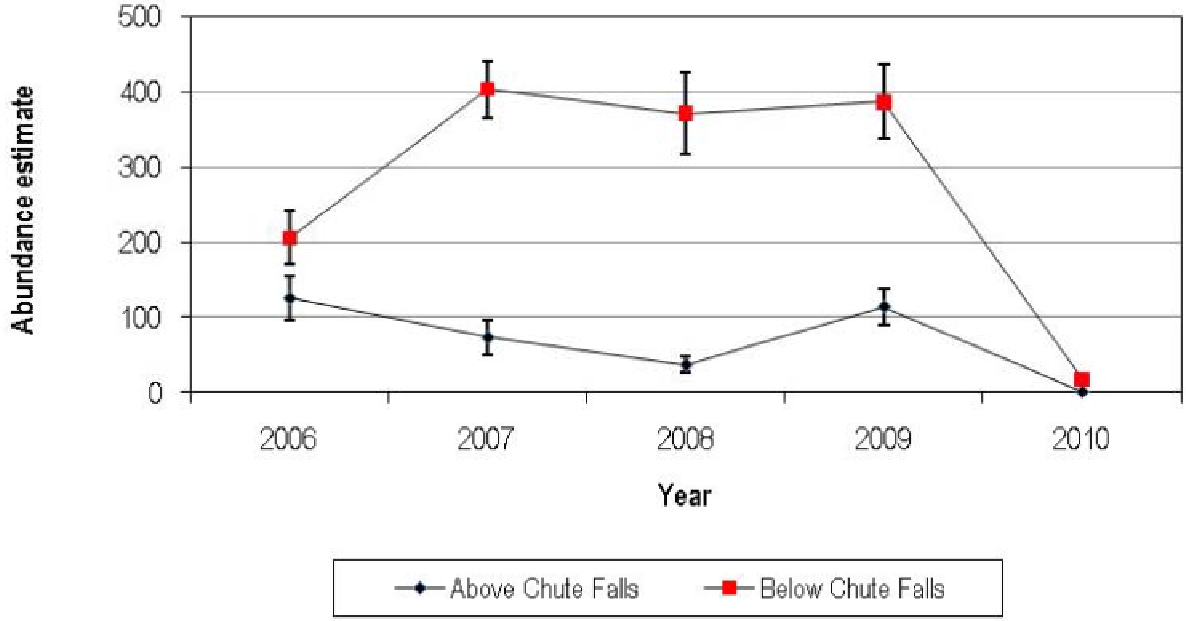
1977-1989 n = 1,081
1990-1999 n = 13,447
1999-2009 n = 10,958

Figure 4



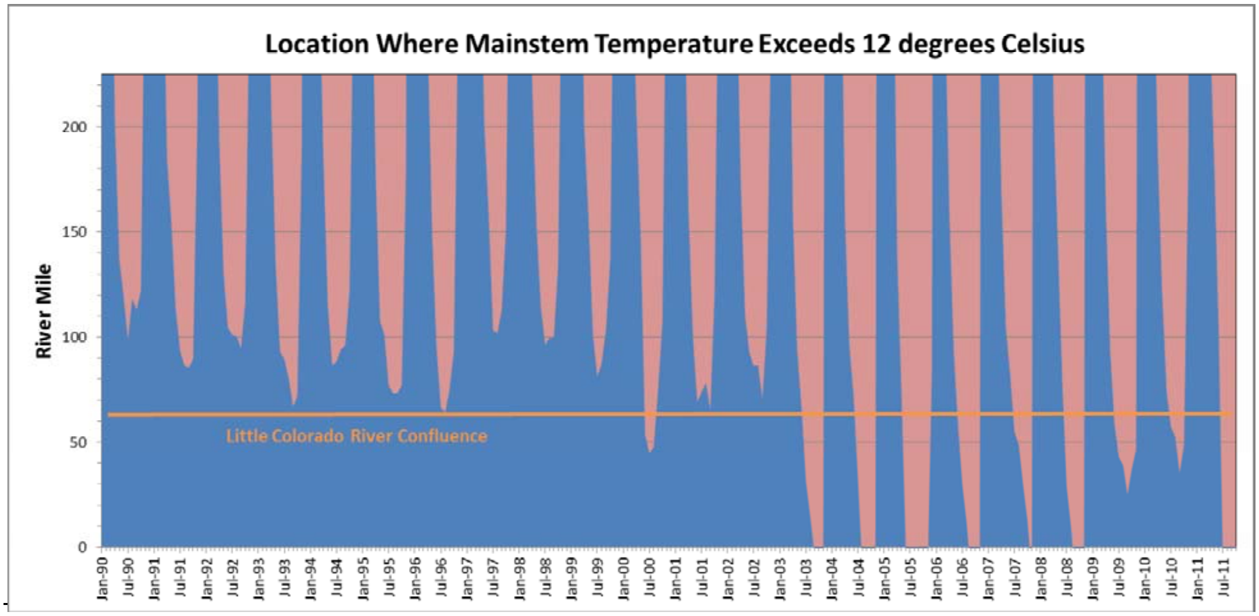
Colorado River water temperatures at Lees Ferry and the LCR confluence from January 2010 to September 1, 2011; upublished data from USGS.

Figure 5



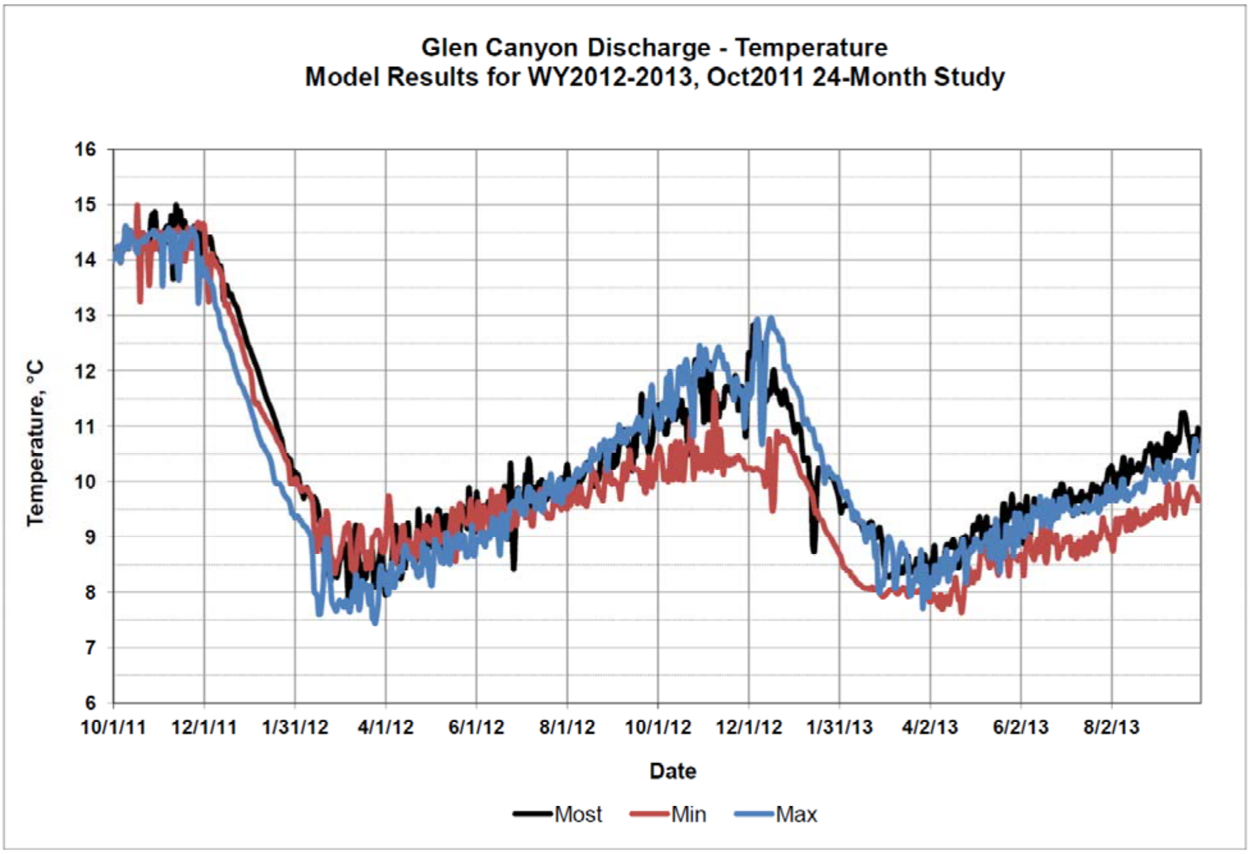
Abundances of adult humpback chub (≥ 200 mm) from lower reach below Chute Falls (13.6 to 14.1 km) and from upper reach above Chute (14.1 to 18 km) since summer 2006 (from Van Haverbeke et al. 2011).

Figure 6



Location in the mainstem Colorado River in River miles downstream from Lees Ferry by year from January 1990 through July 2011 of temperatures exceeding 12 °C (USGS GCMRC unpublished data using the temperature model of Wright et al. 2008).

Figure 7



Forecasted Glen Canyon Dam release temperature modeling results based on the October 2011 24-Month Study for projected operations for the Colorado River system reservoirs (Bureau of Reclamation unpublished data).