**United States Department of the Interior**
**Fish and Wildlife Service**
**Arizona Ecological Services Office**
9828 N. 31st Avenue, C3
Phoenix, Arizona 85051-2517
Telephone: (602) 242-0210 Fax: (602) 242-2513

In reply refer to:
AESO/SE
02EAAZ00-2012-F-0059
02EAAZ00-2014-CPA-0029

November 28, 2016

Memorandum

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

From: Field Supervisor, Arizona Ecological Services Office, U.S. Fish and Wildlife Service

Subject: Biological Opinion for the Glen Canyon Dam Long-Term Experimental and Management Plan, Coconino County, Arizona

Thank you for your request for formal consultation/conference with the U.S. Fish and Wildlife Service (FWS) pursuant to section 7 of the Endangered Species Act of 1973 (16 U.S.C. § 1531-1544), as amended (Act). Your request was dated August 16, 2016, and received by us via electronic mail the same day. At issue are impacts that may result from the proposed Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP) located in Coconino County, Arizona. The proposed action may affect the endangered humpback chub (*Gila cypha*) and its critical habitat, the endangered razorback sucker (*Xyrauchen texanus*) and its critical habitat, and the endangered Kanab ambersnail (*Oxyloma kanabensis*).

In your memorandum, you requested our concurrence that the proposed action is not likely to adversely affect the endangered southwestern willow flycatcher (*Empidonax traillii extimus*) and the endangered Yuma Ridgway's rail (*Rallus obsoletus yumanensis*). We concur with your determinations. The basis for our concurrences is found in Appendix A.

This biological opinion (BO) replaces the 2008 Final Biological Opinion on the Operation of Glen Canyon Dam (USFWS 2008, 2009, consultation number 22410-1993-F-167 and the court ordered supplements to that opinion, 22410-1993-F-167-R1). This BO also replaces the 2011 Final Biological Opinion on the Operation of Glen Canyon Dam including High Flow Experiments and Non-Native Fish Control (USFWS 2011a, consultation numbers 22410-2011-F-0100 and 22410-2011-F-0112). Since we issued these BOs, the status of the humpback chub, razorback sucker, and their critical habitat have improved, and the proposed LTEMP action includes conservation actions for these species and their habitats beyond what was included in past operations and BOs.

This BO is based on information provided in the August 16 and September 27, 2016, biological assessments (BAs), the 2016 draft environmental impact statement (DEIS) and final EIS (FEIS), telephone conversations, field investigations, and other sources of information. Literature cited in this biological opinion is not a complete bibliography of all literature available on the species of concern, the proposed action and its effects, or on other subjects considered in this opinion. A complete record of this consultation is on file at this office.

**Consultation History**

Details of the consultation history are summarized in Table 1.

**Table 1.** Summary of Consultation History

| Date | Event |
|---|---|
| September 2012-December 2015 | We participated in serval meetings and conference calls to discuss preparation of the DEIS and conservation measures for the proposed action. |
| January 2016-August 2016 | We participated in several coordination calls to discuss the DEIS, proposed action, conservation measures, and draft BA. |
| March 4, 2016 | We met with the U.S. Bureau of Reclamation (Reclamation) Western Area Power Authority (Western), National Park Service (NPS), and the U.S. Geological Survey Grand Canyon Monitoring and Research Center (GCMRC) to discuss the effects of low summer flow to humpback chub and razorback suckers. |
| March 16, 2016 | We received a copy of the draft BA from Reclamation. |
| March 30, 2016 | We provided comments to Reclamation on the draft BA. |
| May 20, 2016 | We had a meeting with Western, NPS, GCMRC, and Reclamation to discuss our comments on the draft BA. |
| June 6, 2016 | We received a second draft BA from Reclamation. |
| June 22, 2016 | We provided comments to Reclamation on the second draft BA. |
| August 16, 2016 | We received Reclamation’s August 16, 2016, request for formal consultation and the BA. |
| August 18, 2016 | We issued a thirty-day letter initiating formal consultation. |
| September 27, 2016 | We received the final updated BA from Reclamation. |
| November 8, 2016 | We submitted a draft BO to Reclamation for review. |
| November 18, 2016 | We received Reclamation’s comments on the draft BO. |

# BIOLOGICAL OPINION

## DESCRIPTION OF THE PROPOSED ACTION

The complete description of the proposed action can be found in your August 16, 2016, BA, the updated September 27, 2016, BA, the 2016 DEIS and FEIS, and other supporting information in the administrative record. These documents are included herein by reference. We have included a summary of the proposed action from the September 27, 2016, BA (pages 4-42).

The U.S. Department of the Interior (DOI), through Reclamation and NPS proposes to develop and implement a Long-Term Experimental and Management Plan (LTEMP) for operations of Glen Canyon Dam, the largest unit of the Colorado River Storage Project (CRSP). The LTEMP provides a framework for adaptively managing Glen Canyon Dam operations over the next 20 years consistent with the Grand Canyon Protection Act of 1992 (GCPA) and other provisions of applicable federal law. The proposed action will help determine specific dam operations and actions that could be implemented to improve conditions and continue to meet the Grand Canyon Protection Act's (GCPA) requirements and to minimize adverse impacts on the downstream natural, recreational, and cultural resources in the two park units, including resources of importance to American Indian Tribes. LTEMP supersedes existing operational plans for Glen Canyon Dam.

The DOI has identified several primary objectives of operating Glen Canyon Dam under the LTEMP, as well as more specific goals to improve resources within the Colorado River ecosystem (primarily from Glen Canyon Dam downstream to the headwaters of Lake Mead) through experimental and management actions. These goals and objectives are listed in the BA (pages 6-8). The preferred alternative in the LTEMP EIS and proposed action under analysis in this BO is Alternative D.

The Glen Canyon LTEMP involves the effects of implementation of flow (operations at Glen Canyon Dam) and non-flow actions that would be triggered by resource conditions over a 20-year period at Glen Canyon Dam and in the Colorado River downstream of Glen Canyon Dam within Glen Canyon National Recreation Area (GCNRA) and Grand Canyon National Park (GCNP), Coconino County, Arizona, to Lake Mead National Recreation Area (LMNRA).

A wide range of possible hydrologic conditions will occur over the LTEMP implementation time frame in response to intra-annual and inter-annual variability in basin-wide precipitation cycles. Within a year, monthly operations are typically adjusted (increased or decreased) based on changing annual runoff forecasts, and, since 2007, the application of the Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007).

Base Operations and Operational Flexibility

Base operations consist of dam operations when no condition dependent or experimental actions are triggered. The proposed action for base operations (Alternative D in the DEIS and FEIS) influences the amount of monthly, daily, and hourly water releases from Glen Canyon Dam, but does not affect the total amount of annual water release determinations. Under the proposed action, the total monthly release volume in October, November, and December would be equal to current operations (Reclamation 2007). The August release volume in the proposed action is set to a moderate volume level (800 thousand acre-feet [kaf] in an 8.23 million acre-feet [maf] release year) to balance sediment conservation needs prior to a potential fall high flow event (HFE), and power production and capacity concerns. The January through July monthly release volumes were set at levels that roughly track Western's contract rate of power delivery. This water release schedule results in a redistribution of monthly release volumes and a relatively even distribution of flows compared to current operations.

Under the proposed action, the allowable within-day fluctuation range of releases from Glen Canyon Dam would be proportional to the volume of water scheduled to be released during the month (10 × monthly volume in kaf in the high-demand months of June, July, and August and 9 × monthly volume in kaf in other months), with a maximum daily fluctuation of 8,000 cubic feet/second (cfs). The down-ramp rate (the rate of river stage or water level reduction) would be increased to 2,500 cfs per hour (hr), but the up-ramp rate (the rate at which the river stage or water level increases) would remain unchanged from current operations at 4,000 cfs/hr. Figure 2 in the BA (p. 15) shows the minimum, mean, and maximum daily flows under the proposed action in an 8.23 maf year.

Reclamation retains the authority to utilize operational flexibility at Glen Canyon Dam because hydrologic conditions of the Colorado River Basin (or the operational conditions of Colorado River reservoirs) cannot be completely known in advance. Consistent with current operations, Reclamation, in consultation with WAPA, would make specific adjustments to daily and monthly release volumes during the water year. Monthly release volumes may be rounded for practical implementation or for maintenance needs. In addition, when releases are actually implemented, minor variations may occur regularly for a number of operational reasons that cannot be projected in advance.

Reclamation also would make specific adjustments to daily and monthly release volumes, in consultation with other entities as appropriate, for a number of reasons, including operational, resource-related, and hydropower-related issues. Examples of these adjustments may include, but are not limited to, the following:

- For water distribution purposes, volumes may be adjusted to allocate water between the Upper and Lower Basins, consistent with the Law of the River as a result of changing hydrology;

- For resource-related issues that may occur uniquely in a given year, release adjustments may be made to accommodate nonnative species removal, to assist with aerial photography, or to accommodate other resource considerations separate from experimental treatments under the LTEMP; and,

- For hydropower-related issues, adjustments may occur to address issues such as electrical grid reliability, actual or forecasted prices for purchased power, transmission outages, and experimental releases from other Colorado River Storage Project dams.

These potential "adjustments" are all part of the general operation of the dam and fall within the context of normal operations and are part of the action under consultation.

In addition, Reclamation may make modifications under circumstances that may include operations that are prudent or necessary for the safety of dams, public health and safety, other emergency situations, or other unanticipated or unforeseen activities arising from actual operating experience (including, in coordination with the Basin States, actions to respond to low reservoir conditions as a result of drought in the Colorado River Basin). Also, the Emergency Exception Criteria established for Glen Canyon Dam will continue unchanged under the proposed action (e.g., Section 3 of the Glen Canyon Operating Criteria at 62 FR 9448, March 3, 1997). The emergency exception criteria allow for the proposed action to be altered temporarily in order to respond to an emergency (e.g., flooding, search and rescue operation, transmission power emergencies). When the emergency exception criteria are invoked, normal operations are suspended until the emergency has ended, or Western has discharged its North American Energy Reliability Council (NERC) responsibility regarding the emergency. Emergency exception criteria are further defined in the operating criteria and in the Memorandum of Understanding (MOU) on Glen Canyon operations signed by Western and Reclamation.

Experimental Elements of LTEMP

The proposed action identifies condition-dependent flow and non-flow actions intended to safeguard against unforeseen adverse changes in resource impacts, and to prevent irreversible changes to those resources. These condition-dependent treatments would be implemented experimentally during the LTEMP period unless they prove ineffective or result in unacceptable adverse impacts on other resources. Prior to implementation of any experiment, the relative effects of the experiment on the following resource areas would be evaluated and considered: (1) water quality and water delivery; (2) humpback chub; (3) sediment; (4) riparian ecosystems; (5) historic and traditional cultural properties; (6) tribal concerns; (7) hydropower production and Western's assessment of the status of the Basin Fund; (8) the rainbow trout (*Oncorhynchus mykiss*) fishery; (9) recreation; and, (10) other resources. Although these key resources are listed for consideration on a regular basis, the DOI intends to retain sufficient flexibility in implementation of experiments to allow for response to unforeseen circumstances or events that involve any other resources not listed here. For example, the 2015 and 2016 discovery of nonnative green sunfish (*Lepomis cyanellus*) reproducing in a slough in the Glen Canyon reach of the project area illustrates the need to be responsive to unforeseen conditions.

The implementation criteria and triggers for experimental flow actions under the proposed action are detailed in Table 3 of the BA (pages 20-23). Triggers for experimental changes in operations, implementation considerations for determining if an experimental treatment should proceed, conditions that would cause the treatment to be terminated prior to completion (i.e., off-ramps), and the number of replicates that are initially considered needed are discussed in Table 3. In many cases, two to three replicates of an experimental treatment would be necessary in order to understand the effects of the action on target and non-target resources. The results of these tests would be used to determine if these condition-dependent treatments should be retained as part of the suite of long-term actions implemented under LTEMP. In other cases, implementation of experimental treatments would continue throughout the LTEMP period if triggered (e.g., spring and fall HFEs), except in years when it was determined that the proposed experiment could result in unacceptable adverse impacts on resource conditions. For these conservation experiments, effectiveness would be monitored and the experiments would be terminated or modified only if sufficient evidence suggested the treatment was ineffective or had unacceptable adverse impacts on other resources. "Sufficient evidence" would be defined through data analysis and discussion through the formal stakeholder process defined in the FEIS. All experimental treatments would be closely monitored for adverse effects to important resources. At a minimum, an unacceptable adverse impact would include significant negative impacts on resources as a result of experimental treatments that have not been analyzed for the proposed action in the LTEMP FEIS. DOI would exercise a formal process of stakeholder engagement to ensure decisions are made with sufficient information regarding the condition and potential effects on important resources (see BA, pages 19 and 24, for a complete description of the process).

Experimental treatments are grouped under three categories: (1) Sediment-Related Experimental Treatments; (2) Aquatic Resource-Related Experimental Treatments; and, (3) Native and Non-native Plant Management and Experimental Actions. The specific types of experimental treatments included under each category are described below.

1. <u>Sediment-Related Experimental Treatments</u> (BA, pages 24-30): Spring and fall HFEs would be implemented when triggered, based on the estimated sand mass balance resulting from Paria River sediment inputs during the spring and fall accounting periods, to rebuild sandbars. These HFEs include sediment-triggered HFEs in spring or fall, proactive spring HFEs as triggered by high annual release volume (> 10 maf), and extended duration (>96 hr) fall HFEs.

2. <u>Aquatic Resource-Related Experimental Treatments</u> (BA, pages 30-41): Nonnative fish control actions would be implemented if the Little Colorado River humpback chub population declined and proactive conservation actions failed to reverse declining populations.
    a. Mechanical removal of nonnative species is a controversial issue in the Colorado River through Glen and Grand Canyons. A spring 2015 meeting of Grand Canyon biologists (NPS, FWS, AGFD, GCMRC) to assess current trout removal

triggers resulted in a concept of early conservation measure intervention to maximize conservation benefit to humpback chub and minimize the likelihood of mechanical predator removal. Under the preferred alternative, mechanical removal of nonnative rainbow and brown trout (and other nonnative predators) would be implemented through a triggered, tiered approach (see Appendix D in BA) near the confluence of the Little Colorado River and the Colorado River if conservation actions designed to reverse declines in the Little Colorado River humpback chub aggregation were ineffective. Two different tiers of population metrics would be used to trigger responses such as actions to increase growth and survival of humpback chub (Conservation Actions, Tier 1), or mechanical nonnative fish control (Tier 2), which would only be implemented when Tier 1 conservation actions (actions would focus on increasing growth, survival and distribution of chub in the Little Colorado River and LCR mainstem aggregation area) fail to slow or reverse the decline in the humpback chub population (see Appendix D in BA, Young et al. 2015). In addition, if humpback chub decline and the identified actions are not working, the FWS, in coordination with action agencies and traditionally associated Tribes, will identify future appropriate actions (among other caveats specified in Young et al. 2015).

b. Experimental Trout Management Flows (TMFs) could be used to control annual rainbow trout production in the Glen Canyon reach for the purposes of managing the rainbow trout fishery and for limiting emigration to Marble Canyon and the Little Colorado River reach. TMFs would be tested early in the experimental period, preferably in the first 5 years.

c. Low summer flows may be tested in the second 10 years of the LTEMP period, for the purpose of achieving warmer river temperatures (> 14°C) to benefit humpback chub and other native species. Under low summer flows, daily fluctuations would be less than under base operations (e.g., approximately 2,000 cfs). Investigating the anticipated effects of and options for providing warmer water temperatures in the mainstem Colorado River through Grand Canyon is an identified management action in the Humpback Chub Recovery Goals (USFWS 2002a).

d. Low steady weekend flows (“bug flows”) would be conducted to test whether the flows would increase insect abundance. On an experimental basis, for example, flows would be held low and steady for two days per week (weekends) from May through August to attempt to improve the productivity of the aquatic food base, and increase the diversity and abundance of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), which are collectively referred to as EPT.

3. <u>Native and Nonnative Plant Management and Experimental Treatments</u> (BA, pages 41-42): Experimental riparian vegetation treatment activities would be implemented by NPS

under the proposed action and would modify the cover and distribution of riparian plant communities along the Colorado River. All activities would be consistent with NPS Management Policies (NPS 2006) and would occur only within the Colorado River Ecosystem in areas that are influenced by dam operations. NPS would work with tribal partners and GCMRC to experimentally implement and evaluate a number of vegetation control and native replanting activities on the riparian vegetation within the Colorado River Ecosystem in GCNP and GCNRA. These activities would include ongoing monitoring and removal of selected nonnative plant species, systematic removal of nonnative vegetation at targeted sites, and native replanting at targeted sites, which may include complete removal of tamarisk (both live and dead) and re-vegetation with native plants. Treatments would include the control of nonnative plant species and re-vegetation with native plant species.

**Conservation Measures**

Conservation measures identified in the 2011 BO on operations of Glen Canyon Dam (USFWS 2011a) included the establishment of a humpback chub refuge, evaluation of the suitability of habitat in the lower Grand Canyon for the razorback sucker, and establishment of an augmentation program for the razorback sucker, if appropriate. Other measures include humpback chub translocation; Bright Angel Creek brown trout (*Salmo trutta*) control; Kanab ambersnail monitoring; determination of the feasibility of flow options to control trout, including increasing daily down-ramp rates to strand or displace age-0 trout, and high flow followed by low flow to strand or displace age-0 trout; assessments of the effects of actions on humpback chub populations; sediment research to determine effects of equalization flows; and Asian tapeworm (*Bothriocephalus acheilognathi*) monitoring. Conservation measures that were not completed are ongoing and are included in the proposed action (e.g., brown trout control, humpback chub translocation, and sediment research to determine the effects of equalization flows), while new conservation measures or adjustments to the existing ones have been developed for the proposed action. These conservation measures are designed to minimize or reduce the effects of the proposed action or benefit or improve the status of listed species as part of the LTEMP and are listed below. The conservation measures were developed by FWS, Reclamation, NPS, and GCMRC. Further planning and compliance may be needed to implement components of the new conservation measures listed below. Decisions regarding the need for further planning and compliance would be made by Reclamation in consultation with the FWS and NPS.

<u>Humpback Chub</u>

*Ongoing actions:*

- Reclamation would continue to support the NPS, FWS, GCMRC, and GCDAMP in funding and implementing translocations of humpback chub into tributaries of the Colorado River in Marble and Grand Canyons, and in monitoring the results of these translocations, consistent with agencies' plans and guidance (e.g., NPS Comprehensive

Fisheries Management Plan [CFMP], FWS Humpback Chub Genetics Management Plan and Translocation Framework, and GCMRC Triennial Work Plan). Translocations allow for opportunities to expand the area occupied by humpback chub and improve the overall status of the species. Specifically, the following would occur:

  - Humpback chub would be translocated from the lower reaches of the Little Colorado River to areas above Chute Falls in an effort to increase growth rates and survivorship.
  - Monitoring would be conducted annually, or as needed, depending on the data required, to determine survivability, population status, or genetic integrity of the Havasu Creek humpback chub population. Intermittent translocations of additional humpback chub in Havasu Creek would be conducted if the FWS and NPS determine it is necessary to maintain genetic integrity of the population.

- Reclamation would continue to fund a spring and fall population estimate annually, or at a different frequency as deemed appropriate in consultation with FWS, using a mark recapture based model for the Little Colorado River or the most appropriate model developed for the current collecting techniques and data. Monitoring the chub population allows us to determine its status (whether it is stable, increasing, or decreasing).

- Reclamation would continue to fund control or removal of nonnative fish in tributaries prior to chub translocations depending on the existing fish community in each tributary. Reclamation, NPS, and FWS would lead any investigation into the possibility of using a chemical piscicide, or other tools, as appropriate. Tributaries and the appropriate control methods would be identified by the FWS, NPS, Reclamation, and GCMRC, in consultation with the Arizona Game and Fish Department (AGFD). Depending on the removal methods identified, additional planning and compliance may be necessary. Removal of nonnative fishes improves the status of chub and other native fishes by reducing competition and predation. The regulation and control of nonnative fish is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

- Reclamation would continue to fund the 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 the Southwestern Native Aquatic Resources and Recovery Center [SNARRC]) 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, the refuge would provide a permanent source of sufficient numbers of genetically representative stock for repatriating the species.

- Reclamation would continue to assist the FWS, NPS and the GCDAMP to ensure that a stable or upward trend of humpback chub mainstem aggregations can be achieved by:

  - Continuing to conduct annual monitoring of the Little Colorado River humpback chub aggregation (e.g., juvenile chub monitoring parameters). Periodically, an open or multistate model should be run to estimate abundance of the entire Little Colorado River aggregation inclusive of mainstem fish.
  - Supporting annual monitoring in the mainstem Colorado River to determine status and trends of humpback chub and continuing to investigate sampling and analytical methods to estimate abundance of chub in the mainstem.
  - Conducting periodic surveys to identify additional aggregations and individual humpback chub.
  - Evaluating existing aggregations and determining drivers of these aggregations, for example, recruitment, natal origins, spawning locations, and spawning habitat (e.g., consider new and innovative methods such as telemetry or the Judas-fish approach) (Kegerries et al. 2015).
  - Exploring means of expanding humpback chub populations outside of the Little Colorado River Inflow aggregation. Evaluate the feasibility of mainstem augmentation of humpback chub that would include larval collection, rearing, and release into the mainstem at suitable areas outside of or within existing aggregations.

- Reclamation would, through the GCDAMP, conduct disease and parasite monitoring in humpback chub and other fishes in the mainstem Colorado. The GCMRC is currently conducting parasite monitoring in the Little Colorado River. However, in order to better understand how/if disease and parasites (primarily Asian tapeworm) are affecting chub and how temperature differences may affect parasite occurrence, this work would be expanded to include investigations of parasites in humpback chub (and surrogate fish if necessary) in the mainstem. Ensuring adequate protection from diseases and parasites is an identified management action needed in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

*New actions:*

- Reclamation would collaborate with the FWS, GCMRC, NPS, and the Havasupai Tribe to conduct preliminary surveys and a feasibility study for translocation of humpback chub into Upper Havasu Creek (above Beaver Falls). The implementation of surveys and translocations, following the feasibility study, would be dependent on interagency discussions, planning and compliance, and resulting outcomes of tribal consultation. As stated above, translocations of chub into currently unoccupied habitat aid in expanding the area occupied by the species. In addition, using a tributary to the Colorado River, such as Upper Havasu Creek, protects translocated fish from the effects of dam operations in the mainstem, but still allow for chub in Havasu Creek to contribute to the mainstem population.

- Reclamation would, in cooperation with the FWS, NPS, GCMRC, and AGFD, explore and evaluate other tributaries for potential translocations.

Razorback Sucker

*Ongoing actions:*

- Reclamation would continue to assist the NPS, FWS, and the GCDAMP in funding larval and small-bodied fish monitoring in order to:
    - Determine the extent of hybridization in flannelmouth and razorback sucker collected in the western Grand Canyon.
    - Determine habitat use and distribution of different life stages of razorback sucker to assist in future management of flows that may help conserve the species. Sensitive habitats to flow fluctuations could be identified and prioritized for monitoring.
    - Assess the effects of TMFs and other dam operations on razorback sucker.

Actions to benefit all native aquatic species

*Ongoing actions:*

- Reclamation, in collaboration with the NPS and FWS, and in consultation with the AZGFD, would investigate the possibility of renovating Bright Angel and Shinumo Creeks with a chemical piscicide, or other tools, as appropriate. Additional planning and compliance, and tribal consultation under Section 106 of the NHPA, would be required. This feasibility study is outlined in the NPS CFMP (2013; see "Feasibility Study for Use of Chemical Fish Control Methods"). The action benefits humpback chub and other native fish by removing nonnative fish that can predate upon and compete with humpback chub. The regulation and control of nonnative fish is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

- Reclamation would continue to fund efforts of the GCMRC and NPS to remove brown trout (and other nonnative species) from Bright Angel Creek and the Bright Angel Creek Inflow reach of the Colorado River, and from other areas where new or expanded spawning populations develop, consistent with the NPS CFMP. After 5 years of removal efforts are completed (in 2017), an analysis of success would be conducted. Piscicides may be considered for removal of nonnative species if determined to be appropriate and following completion of the necessary planning and compliance actions. The regulation and control of nonnative fish is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

*New actions:*

- Reclamation would explore the efficacy of a temperature control device at the dam to respond to potential extremes in hydrological conditions due to climate conditions that could result in nonnative fish establishment. Evaluations would be ongoing for all current and evolving technological advances that could provide for warming and cooling the river in both high- and low-flow discharge scenarios, and high and low reservoir levels. These studies should include evaluating and pursuing new technologies, an analysis of the feasibility, and a risk assessment and cost analysis for any potential solutions. The regulation and control of nonnative fish is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

- Reclamation would pursue means of preventing the passage of deleterious invasive nonnative fish through Glen Canyon Dam. Because Glen Canyon Dam release temperatures are expected to be warmer under low reservoir elevations that may occur through the LTEMP period, options to hinder expansion of warmwater nonnative fishes into Glen and Grand Canyons would be evaluated. Potential options to minimize or eliminate passage through the turbine or bypass intakes, or minimize survival of nonnative fish that pass through the dam would be assessed (flows, provide cold water, other). While feasible options may not currently exist, technology may be developed during the LTEMP period that could help achieve this goal. The regulation and control of nonnative fish is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

- Reclamation would, in consultation with the FWS and AGFD, fund the NPS and GCMRC on the completion of planning and compliance to alter the backwater slough at River Mile (RM) 12 (commonly referred to as "Upper Slough"), making it unsuitable or inaccessible to warmwater nonnative species that can compete with and predate upon native fish, including humpback chub. Depending on the outcome of NPS planning and compliance, Reclamation would implement the plan in coordination with the FWS, AGFD, NPS and GCMRC. Additional coordination would be conducted to determine and access any habitats that may support warmwater nonnatives. The regulation and control of nonnative fish is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

- Reclamation would support the GCMRC and NPS in consultation with the FWS and AGFD on the completion of planning and compliance of a plan for implementing rapid response control efforts for newly establishing or existing deleterious invasive nonnative species within and contiguous to the action area. Control efforts may include chemical, mechanical, or physical methods. While feasible options may not currently exist, new technology or innovative methods may be developed in the LTEMP period that could help achieve this goal. Rapid response to new warmwater fish invasions may become a more frequent need in the future with lower reservoir elevations and warmer dam releases. The regulation and control of nonnative fish is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

- Reclamation, will consider, in consultation with the GCDAMP, the experimental use of TMFs to inhibit brown trout spawning and recruitment in Glen Canyon, or other mainstem locations. Inhibiting brown trout spawning and recruitment will benefit chub by reducing the potential for brown trout to predate upon humpback chub. The regulation and control of nonnative fish is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

Southwestern willow flycatcher and Yuma Ridgway's rail

- Reclamation would partially assist in funding NPS to conduct Yuma Ridgway's rail surveys once every three years for the life of the LTEMP.

- Reclamation would partially assist in funding NPS to conduct southwestern willow-flycatcher surveys once every two years for the life of the LTEMP.

## ANALYTICAL FRAMEWORK FOR THE JEOPARDY AND ADVERSE MODIFICATION DETERMINATIONS

### Jeopardy Determination

In accordance with policy and regulation, the jeopardy analysis in this BO relies on four components: (1) the *Status of the Species*, which evaluates the humpback chub, razorback sucker, and Kanab ambersnail range-wide conditions, the factors responsible for these conditions, and their survival and recovery needs; (2) the *Environmental Baseline*, which evaluates the condition of these species in the action area, the factors responsible for their condition, and the relationship of the action area to the survival and recovery of these species; (3) the *Effects of the Action*, which determines the direct and indirect impacts of the proposed Federal action and the effects of any interrelated or interdependent activities on these species; and (4) *Cumulative Effects*, which evaluates the effects of future, non-Federal activities in the action area on these species.

In accordance with policy and regulation, the jeopardy determination is made by evaluating the effects of the proposed Federal action in the context of the species' current status, taking into account any cumulative effects, to determine if implementation of the proposed action is likely to cause an appreciable reduction in the likelihood of either the survival and recovery of the species in the wild. The jeopardy analysis in this BO considers the range-wide survival and recovery needs of the species and the role of the action area in its survival and recovery as the context for evaluating the significance of the effects of the proposed Federal action, taken together with cumulative effects, for purposes of making the jeopardy determination.

### Adverse Modification Determination

This BO relies on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02[1]. In accordance with policy and regulation, the adverse modification analysis in this Biological Opinion relies on four components: 1) the *Status of Critical Habitat*, which evaluates the range-wide condition of designated critical habitat for the humpback chub and razorback sucker in terms of physical and biological features[2], the factors responsible for that condition, and the intended value of the critical habitat for survival and recovery of these species; 2) the *Environmental Baseline*, which evaluates the condition of the critical habitat in the action area, the factors responsible for that condition, and the value of the critical habitat for survival and recovery of the species in the action area; 3) the *Effects of the Action*, which determines the direct and indirect impacts of the proposed Federal action and the effects of any interrelated or interdependent activities on the physical and biological features and how that will influence the value of affected critical habitat units for survival and recovery of these species; and 4) the *Cumulative Effects*, which evaluates the effects of future, non-Federal activities in the action area on the physical and biological features and how that will influence the value of affected critical habitat units for survival and recovery of these species.

For purposes of the adverse modification determination, the effects of the proposed Federal action on the species' critical habitat are evaluated in the context of the range-wide condition of the critical habitat, taking into account any cumulative effects, to determine if the critical habitat range-wide would remain functional (or would not preclude or significantly delay the current ability for the physical and biological features to be functionally established in areas of currently unsuitable but capable habitat) such that the value of critical habitat for the conservation of the species is not appreciably diminished.

## STATUS OF THE SPECIES AND CRITICAL HABITAT

The information in this section summarizes the rangewide status of each species that is considered in this BO. Further information on the status of these species can be found in the administrative record for this project, documents on our web page (https://www.fws.gov/southwest/es/arizona/) under Document Library, Document by Species, and in other references cited in each summary below.

### Humpback chub and critical habitat

The humpback chub, an endemic fish to the Colorado River Basin of the southwestern United States, was listed as endangered on March 11, 1967 (32 FR 4001) and the FWS designated critical habitat in 1994 (USFWS 1994). The first recovery plan for the humpback chub was

---

[1] See 81 FR 7214.

[2] The term "primary constituent elements" was introduced in critical habitat designation regulations (50 CFR 424.12) to describe aspects of "physical or biological features", which are referenced in the statutory definition of critical habitat. The Services have removed the term "primary constituent elements" and returned to using the statutory term "physical or biological features" (81 FR 7414). Existing critical habitat designations will not be republished to reflect this change; however, in future rules we will discontinue using the term "primary constituent elements" and instead will use "physical and biological features".

approved in 1979 (USFWS 1979), the plan was revised in 1990 (USFWS 1990). Recovery Goals that amended and supplemented the 1990 revised plan were approved in 2002 (USFWS 2002a), but were withdrawn and declared of no force and effect by court order on January 18, 2006 (Grand Canyon Trust et al., vs. Gale Norton et al., United States District Court for the District of Arizona, Order No. 04-CV-636-PHX-FJM).

The humpback chub is native to the states of Wyoming, Colorado, Utah, and Arizona and there are six recognized populations that occur in mid- and low-elevation, canyon-confined, deep-water regions, including five in the upper basin and one in the lower basin (Lees Ferry is the demarcation line between upper and lower Colorado River basins). The upper basin populations occur in (1) the Colorado River in Cataract Canyon, Utah; (2) the Colorado River in Black Rocks, Colorado; (3) the Colorado River in Westwater Canyon, Utah; (4) the Green River in Desolation and Gray Canyons, Utah; and (5) the Yampa River in Yampa Canyon, Colorado. The only population in the lower basin occurs in the Colorado River in Marble Canyon, the Grand Canyon, and Little Colorado River. The five upper basin populations occupy from 1.4 to 113 km (0.9 to 70 mi) of river with a current abundance of about 500 to 1,600 adult chub. The lower basin population, the Grand Canyon and Little Colorado population of chub, consists of about 12,000 adults in the Little Colorado River and six mainstem aggregations of about 250 adults that occupy about 290 km (180 mi) of the Colorado River in Grand Canyon.

Historically, the humpback chub occurred throughout much of the Colorado River and its larger tributaries from below Hoover Dam upstream into Arizona, Utah, Colorado, and Wyoming (USFWS 2002a). Historic range and abundance levels are unknown. In 1994, the FWS estimated that historical range may have included 2,179 km (1,354 mi) of river (USFWS 1994), but estimates in 2002 and 2011 have been modified to include only canyon-bound reaches of this previously estimated area, estimating an historic range of approximately 756 km (~470 mi) (USFWS 2002a, 2011a). Regardless of the actual historic range, the chub is currently restricted to six population centers that encompass approximately 537 km (334 mi) of river, with only the lower basin population (the population that occurs from Glen Canyon Dam downstream through western Grand Canyon) consisting of a widespread and relatively stable population. The FWS is currently developing a Species Status Assessment (SSA) and revising the recovery plan for the humpback chub, but these documents, which will include a rangewide assessment of species viability, are not completed and are still under review (K. Young 2016, pers. comm.).

The humpback chub is a large, long-lived species endemic to the Colorado River system. This member of the minnow family may attain a length of 20 inches, weigh 2 pounds or more, and live for 20 to 40 years (Andersen 2009). The humpback chub evolved in seasonally warm and turbid water and is highly adapted to the unpredictable hydrologic conditions. Adult humpback chub occupy swift, deep, canyon reaches, but also use eddies and sheltered shoreline habitat (Valdez and Clemmer 1982, Valdez et al. 1990, Valdez and Ryel 1995). Spawning occurs on the descending limb of the spring hydrograph at water temperatures typically between 16 and 22°C. Young require low-velocity shoreline habitats, including eddies and backwaters.

The main spawning area for the humpback chub within the Grand Canyon is the Little Colorado River, which provides warm temperatures suitable for spawning and shallow low-velocity pools for larvae (Gorman 1994). The species spawns primarily in the lower 13.6 km of the Little Colorado River, but spawning likely occurs in other areas of the Colorado River as well (Valdez and Masslich 1999, Anderson et al. 2010). Gorman and Stone (1999) found ripe adults aggregated in areas of complex habitat structure associated with clean gravel deposits among large boulders mixed with travertine masses in or near runs and eddies. Mainstem spawning is suspected near 30 Mile Spring, or in other areas in the western Grand Canyon following the detection of larval humpback chub in recent years (Albrecht et al. 2014, Kegerries et al. 2015).

Young humpback chub seek areas that provide physical cover and contain some low velocity refuges, including shoreline talus, vegetation, and backwaters typically formed by eddy return current channels (AGFD 1996, Converse et al. 1998, Dodrill et al. 2015). Backwaters can have warmer water temperatures than other habitats, and native fish, including the humpback chub, are frequently observed in backwaters, leading to a common perception that this habitat is critical for juvenile native fish conservation. However, backwaters are rare and ephemeral habitats, so they contain only a small portion of the overall population. Dodrill et al. (2015) showed the total abundance of juvenile humpback chub was much higher in talus than in backwater habitats, which could be a factor of availability of talus habitats versus backwaters. The Near Shore Ecology project concluded that backwaters are likely not important to the Little Colorado River chub aggregation because they are not a significant habitat component in that area (Pine 2011).

As young humpback chub grow, they shift toward deeper and swifter offshore habitats. Valdez and Ryel (1995, 1997) found that young humpback chub remain along shallow shoreline habitats throughout their first summer, at low water velocities and depths less than 1 m (3.3 ft). They shift as they grow larger and by fall and winter move 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 discovering that as humpback chub physically develop their behavior changes from diurnally active, vulnerable, nearshore-reliant, to nocturnally active, large-bodied adults, which primarily reside in deep mid-channel pools during the day and move inshore at night.

The humpback chub is primarily an insectivore, with larvae, juveniles, and adults all feeding on a variety of aquatic insect larvae and adults, including dipterans (primarily chironomids and simuliids), Thysanoptera (thrips), Hymenoptera (ants, wasps, bees), and amphipods (such as *Gammarus lacustris*) (AGFD 2001). Donner (2011) found that 65% of humpback chub production in the Grand Canyon was attributed to chironomids and simuliids, and that the potential for competition between humpback chub and nonnative fish was high when nonnative fish abundance was high. Feeding by all life stages may occur throughout the water column as well as at the water surface and on the river bottom. Spurgeon et al. (2015) also found that humpback chub consumed and assimilated native fish, and that they occupied a high trophic position in the food web in a Grand Canyon tributary, similar to rainbow trout.

Primary threats to the species include streamflow regulation and habitat modification (including coldwater dam releases and habitat loss), competition with and predation by nonnative fish species, parasitism, hybridization with other native *Gila*, and pesticides and pollutants (USFWS 1990, 2002a). Upper basin habitat, including channel geomorphology and water temperature have not changed appreciably, but spring peak flow has been reduced and summer and winter base flows have increased. Habitat in the Grand Canyon has been modified by the presence and operation of Glen Canyon Dam, including altered flow and temperature regimes and sediment budget. Predation and competition by nonnative fishes is likely the greatest threat to both upper basin and lower basin populations.

Recovery for the humpback chub is defined by the FWS Humpback Chub Recovery Goals (Recovery Goals) (USFWS 2002a). 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. 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. A 5-Year Review conducted in 2011, relied on the information provided in the recovery goals and provides supplemental information on the species' distribution and status (USFWS 2011b). A change in the status of the humpback chub was not recommended in the 5-Year Review because five of six demographic recovery criteria and four of 22 downlisting criteria had not been met. However, this is mostly due to status of humpback chub in the Upper Basin Recovery Unit; the humpback chub in the Lower Basin Recovery Unit (the population under consultation in this BO that occurs in the mainstem Colorado River in Marble and Grand Canyons and the Little Colorado River) partially met recovery criteria 1a and 1b, and has met criteria 1c (USFWS 2011b)/

*Critical Habitat*

Critical habitat for humpback chub was designated in 1994 in seven reaches for a total of 610 kilometers (km) (379 miles [mi]) (USFWS 1994). There are 319 km (198 mi) of critical habitat in the upper basin (Colorado and Utah) and 291 km (181 mi) in the lower basin (Arizona). In Arizona, critical habitat includes 278 km (173 mi) of the Colorado River through Marble and Grand Canyons (Reach 7) from Nautiloid Canyon (RM 34) to Granite Park (RM 208), and the lower 13 km (8 mi) of the Little Colorado River (Reach 6). The entire Colorado River reach in Arizona and the bottom portion of the Little Colorado River are within the action area for LTEMP.

Critical habitat was designated for the four big river fishes (Colorado Pikeminnow [*Ptychocheilus lucius*], humpback chub, bonytail chub [*Gila elegans*], and razorback sucker) concurrently in 1994, and the primary constituent elements (PCEs) were defined for the four species as a group (USFWS 1994). However, 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. The PCEs are:

- Water: Consists of water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, turbidity, etc.) 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.

- Physical Habitat: This includes areas of the Colorado River system that are inhabited by fish or potentially habitable for use in spawning, nursery, feeding, or corridors between these areas. 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, predation, and competition 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 humpback chub. Predation, although considered a normal component of this environment, is out of balance due to introduced fish species in some areas. This is also true of competition from nonnative fish species.

The PCEs are all integrally related and must be considered together. For example, the quality and quantity of water affect the food base 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 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). It is likely that the future conservation of humpback chub may depend on our ability to control nonnative species, and manipulating the water and physical PCEs of critical habitat to disadvantage non-natives may play an important role. It is for this reason that Reclamation has agreed as part of LTEMP to explore the efficacy of a temperature control device at the dam to respond to potential extremes in hydrological conditions due to climate change that could result in warmwater nonnative fish establishment.

*Previous Consultations*

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. 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, the consultation on Sport Fish Restoration Funding evaluated the USFWS sport fish stocking program in Arizona (USFWS 2011c). Biological opinions on actions potentially affecting humpback chub in Arizona may be found at our website https://www.fws.gov/southwest/es/arizona/ in the Section 7 Biological Opinion page of the Document Library.

**Razorback sucker and critical habitat**

The razorback sucker was listed as endangered in 1991 (USFWS 1991). The Razorback Sucker Recovery Plan was released in 1998 (USFWS 1998) and Recovery Goals were approved in 2002 (USFWS 2002b). Critical habitat for the fish was designated in 1994 (USFWS 1994).

The species is endemic to large rivers of the Colorado River Basin from Wyoming to Mexico; however, the species range has been substantially reduced (Marsh et al. 2015). The razorback sucker was once abundant in the Colorado River and its major tributaries throughout the basin, occupying 3,500 miles of river in the United States and Mexico (USFWS 2002b). 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). Within the Grand Canyon, it is likely that razorback suckers historically occurred throughout the Colorado River to Lake Mead (after Hoover Dam construction), with several documented captures in the mainstem (near Bright Angel and Shinumo Creeks), at the Little Colorado River inflow in 1989 and 1990, and from the Paria River mouth (in 1963 and 1978, as reported in NPS 2013). Until recently, the last razorback sucker collected from the Grand Canyon (RM 39.3) was caught in 1993, and the species was considered extirpated from the Grand Canyon. However, in the 2012 and 2013, adult razorback suckers were captured in western Grand Canyon (NPS 2013, GCMRC 2013). In addition, sampling of channel margin habitats has also documented razorback sucker larvae as far upstream as RM 173 (just upstream of Lava Falls) in 2014 (Albrecht et al. 2014) and 2015 (Kegerries et al. 2015), respectively, indicating that spawning is occurring in the mainstem river in the western Grand Canyon (Albrecht et al. 2014, Kegerries et al. 2015). This is the farthest upstream razorback sucker spawning has been documented in the Grand Canyon (Albrecht et al. 2014). The razorback sucker also occurs in the Green River, upper Colorado River, and San Juan River subbasins; the lower Colorado River between Lake Havasu and Davis Dam; Lake Mead and Lake Mohave; and tributaries of the Gila River subbasin (USFWS 2002b) and Lake Powell (Francis et al. 2015).

Razorback suckers are actively stocked into occupied habitats in the upper and lower basins to prevent extirpation of the species from the wild. The stocking efforts rely on the captive broodstocks in the basins, and the capture of wild-born larvae from Lake Mead and Lake Mohave to provide sub-adult fish for stocking programs. Most populations in the upper Colorado River Basin are maintained by stocking, and in the lower basin, with the exception of Lake Mead, razorback sucker are also maintained through stocking, including populations in Lakes Mohave and Havasu (Marsh et al. 2015). Recruitment has been occurring since the 1970s, sustaining the small population remaining in Lake Mead (Albrecht et al. 2010, USFWS 2012, Mohn et al. 2015); rangewide, however, recruitment is rare or nonexistent in other populations (Marsh et al. 2015).

The razorback sucker is a large river sucker (Catostomidae) with adults reaching lengths up to 3.3 feet and weigh 11 to 13 pounds (Minckley 1973). Razorback suckers are long-lived, reaching the age of at least the mid-40s (McCarthy and Minckley 1987). 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 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 (approximately three feet) during spring and deeper water (five to six feet) during winter (McAda and Wydoski 1980, Tyus and Karp 1989, Osmundson and Kaeding 1989).

Much of the information on spawning behavior and habitat comes from fishes in reservoirs where observations can readily be made. They typically spawn over mixed cobble and gravel bars on or adjacent to riffles or in shallow shorelines in reservoirs in water 3 to10 feet deep (Minckley et al. 1991). Spawning takes place in the late winter to early summer depending upon local water temperatures. Suitable water temperatures for spawning, egg incubation, and growth range from 14 to 25°C (USFWS 2002b), with estimated optimal temperatures of 18°C for spawning, 19°C for egg incubation, and 20°C for growth (Valdez and Speas 2007). Hatching success is temperature dependent, with the potential for complete mortality occurring at temperatures less than 10°C (USFWS 2002b).

Habitat needs of larval and juvenile razorback sucker are reasonably well known. Young razorback suckers require nursery areas with quiet, warm, shallow water such as tributary mouths, backwaters, and inundated floodplains along rivers, and coves or shorelines in reservoirs (USFWS 2002b). 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).

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 (USFWS1998).

Since the arrival of Euro-Americans in the Southwest, the range and abundance of razorback sucker have been significantly decreased due to water manipulations, habitat degradation, and importation and invasion of nonnative 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 nonnative predacious and competitive species has created a hostile environment for razorback sucker larvae and juveniles. Although the suckers can bring off large spawns each year and produce viable young, in many areas the larvae are largely eaten by nonnative fish species (Minckley et al. 1991). The range-wide trend for the razorback sucker is a continued decrease in wild populations due to a lack of sufficient recruitment due to predation by non-native species on the eggs and larvae and the loss of old adults due to natural mortality.

The UCRRP has implemented considerable research, habitat management, nonnative species removal, and stocking actions to benefit the razorback sucker in Colorado, Utah, and Wyoming. The San Juan Program works in the San Juan River in New Mexico and Utah. The Lower Colorado River Multi-Species Conservation Plan (LCR MSCP) is also engaged in research and stocking actions to benefit the razorback in the lower Colorado River of Arizona, California, and Nevada. The razorback sucker is also a covered species in the Bartlett-Horseshoe Habitat Conservation Plan (HCP) on the Verde River.

The 5-year status review for the razorback sucker was completed in 2012 (USFWS 2012). The recovery of the species is based on whether the reduction or removal of threats has occurred, and on whether improvement in the demographic criteria has been achieved. Based on the review, only one of the 10 demographic criteria had been met, two had been partially met, and seven criteria were unmet. In addition, the majority of the most meaningful threats to the species were not mitigated, as only nine of the 29 recovery factor criteria were met. As a result, the FWS determined that a change in the species' endangered status was not warranted (USFWS 2012).

*Critical habitat*

As stated above, critical habitat was designated for the four big river fishes (Colorado Pikeminnow, humpback chub, bonytail chub, and razorback sucker) concurrently in 1994, and the PCEs were defined for the four species as a group (USFWS 1994). However, 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. The biological support document (Maddux et al. 1993) discusses in depth how each designated reach met the PCEs. The PCEs for razorback sucker are:

- Water: This includes a quantity of water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminations, nutrients, turbidity, etc.) that is delivered to a specific location in accordance with a hydrologic regime that is required for the particular life stage.

- Physical habitat: This includes areas of the Colorado River system that are inhabited by razorback suckers or potentially habitable for use in spawning, nursery, feeding, rearing, or corridors between these areas. In addition to river channels, these areas also include bottomlands, side channels, secondary channels, oxbows, backwaters, and other areas in the 100-year floodplain, which, when inundated, provide spawning, nursery, feeding, and rearing habitats.

- Biological environment: Food supply, predation, and competition 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 razorback sucker. Predation, although considered a normal component of this environment, may be out of balance due to introduced fish species in some areas. This may also be true of competition, particularly from non-native fish species.

Critical habitat was designated in 15 river reaches in the historical range of the razorback sucker and includes portions of the Colorado, Duchesne, Green, Gunnison, San Juan, White, and Yampa rivers in the upper basin, and the Colorado, Gila, Salt, and Verde rivers in the lower basin (USFWS 1994).

*Previous Consultations*

Section 7 consultations on razorback sucker include programmatic efforts for the Upper Basin and San Juan recovery programs and Lower Colorado River Multi-Species Conservation Program for new water diversions or changes in points of diversion. Information on these programs is available at their websites. Biological opinions on actions potentially affecting razorback suckers in Arizona may be found at our website https://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 (USFWS 1992) with a recovery plan completed in 1995 (USFWS 1995). No critical habitat is designated for this species. The 5-year status review for the Kanab ambersnail was completed in 2011 (USFWS 2011d). The FWS found that no change in the status of the species was warranted due to the ongoing, existing threats due to private land development, controlled flooding in the Colorado River, climate change, and inadequate existing regulatory mechanisms. However, Arizona and Utah ambersnail populations identified as “Kanab ambersnail” and “Niobrara ambersnail” are based primarily on morphological distinctions. Recent genetic analysis and morphological evaluation by Culver et al. (2013) on ambersnail specimens suggests that the Arizona and Utah populations, including Vasey’s Paradise, are genetically and morphologically similar to other *Oxyloma* populations in the study, and their taxonomic identity may be revised in the future. The consensus appears to be that this snail is part of a much larger population that has higher numbers and distribution.

The FWS did recognize that genetic, anatomical, and morphological information resulted in conflicting views on the taxonomy of the species.

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). 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 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. 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 2011d, 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 2011d). Surveys conducted by AGFD have noted drying and reductions in habitat at Vasey's Paradise due to drought (Sorensen 2016, pers. comm.)

*Previous Consultations*

Section 7 consultations on Kanab ambersnail have occurred on the operations of Glen Canyon Dam in 2007, 2008, 2009, and 2011 and all reached non-jeopardy/non adverse modification conclusions. Biological opinions on actions potentially affecting Kanab ambersnail in Arizona may be found at our website https://www.fws.gov/southwest/es/arizona/ in the Section 7 Biological Opinion page of the Document Library.

## 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.

**Description of the Action Area**

The action area is defined as all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR § 402.02). In delineating the action area, we evaluated the farthest reaching physical, chemical, and biotic effects of the action on the environment.

The action area for this proposed federal action is the Colorado River corridor from Glen Canyon Dam in Coconino County, Arizona, downstream to the Colorado River Inflow in Lake Mead. The action area includes the area potentially affected by implementation of the LTEMP (normal and experimental operations of Glen Canyon Dam and non-flow actions). This area includes Lake Powell, Glen Canyon Dam, the river downstream to Lake Mead and the lower 0.25 mi of the Little Colorado River. More specifically, the scope primarily encompasses the Colorado River Ecosystem, which includes the Colorado River mainstream corridor and interacting resources in associated riparian and terrace zones, located primarily from the forebay of Glen Canyon Dam to the western boundary of Grand Canyon National Park. It includes the area where dam operations impact physical, biological, recreational, cultural, and other resources. Portions of Glen Canyon National Recreational Area, Grand Canyon National Park, and Lake Mead National Recreational Area are included within this area.

The Colorado River Ecosystem is complex and formed in a sediment-laden, seasonally flooded environment and virtually all of the resources are associated with or dependent upon water and sediment. The construction and operation of Glen Canyon Dam altered the natural dynamics of the Colorado River through the collection and storage of water for beneficial purposes in a process which traps sediment and associated nutrients that previously traveled down the Colorado River. The regulated releases from Glen Canyon Dam and Lake Powell have resulted in an altered aquatic and terrestrial ecosystem compared to that which existed before Glen Canyon Dam, and this environment is what defines the environmental baseline for this biological opinion.

The major function of Glen Canyon Dam (and Lake Powell) is water storage to support a multitude of uses. The amount of water and its pattern of release directly or indirectly affect the physical, biological, cultural, and recreational resources within the Colorado River Ecosystem and establish the environmental baseline in which the humpback chub, razorback sucker, and Kanab ambersnail inhabit. As described in the proposed action and FEIS, water releases from Glen Canyon Dam fluctuate on a daily and hourly basis to maximize the value of generated power by providing peaking power during high-demand periods. More power is produced by releasing more water through the dam's generators. Daily releases can range from 5,000 to 31,500 cfs, but actual daily fluctuations are constrained to less than this maximum range as a result of implementing the 1996 Record of Decision for the Operation of Glen Canyon Dam (Reclamation 1996). These constrained fluctuations result in a downstream "fluctuation zone" between low and high river stages (i.e., the water level associated with a given flow) that is inundated and exposed on a daily basis.

Glen Canyon Dam also affects downstream water temperature and clarity. Historically, the Colorado River and its larger tributaries were characterized by heavy sediment loads, variable water temperatures, large seasonal flow fluctuations, extreme turbulence, and a wide range of dissolved solids concentrations. The dam has altered these characteristics in the Colorado River between Glen Canyon Dam and Lake Mead. Before the dam, water temperature varied on a seasonal basis from highs around 27°C (80°F) to lows near freezing. Now, water released from Glen Canyon Dam averages 9°C (48°F) year round, although release temperatures vary depending on the water level in Lake Powell and other factors, and water temperature warms by about 1°C (1.8°F) for every 30 mi traveled downstream during warmer months of the year (Reclamation 1999). Lake Powell traps sediment that historically was transported downstream. The dam releases clear water, and the river becomes muddy when downstream tributaries contribute sediment, as during summer monsoon storms.

In summary, the regulated releases from Glen Canyon Dam and Lake Powell have resulted in an altered aquatic and terrestrial ecosystem compared to that which existed before Glen Canyon Dam. Cold, clear water releases from the dam support an important rainbow trout fishery in the Glen Canyon reach, while native fish, including the endangered humpback chub and razorback sucker, occur further downstream. Vegetation has become established closer to the river's edge due to the elimination of annual flood scouring, and has increasingly become dominated by nonnative plant species.

**Humpback chub and critical habitat**

**A. Status of the species and critical habitat within the action area**

The Colorado River/Little Colorado River population of humpback chub is the largest of the six population centers of the humpback chub (USFWS 2011b). Within the Grand Canyon, this species is most abundant in the vicinity of the confluence of the Colorado River and Little Colorado River (Kaeding and Zimmerman 1983, Douglas and Marsh 1996, Valdez and Ryel 1995). This population is specifically referred to as the Little Colorado River aggregation of humpback chub and includes those fish residing in the Little Colorado River and in the mainstem within proximity of a few miles to the Little Colorado River mouth. In addition, there are eight other areas (aggregation areas) where humpback chub are, or have been, regularly collected within the action area. These aggregation areas are located in the mainstem at 30 Mile, Lava Chuar-Hance, Bright Angel Creek inflow, Shinumo Creek inflow, Stephen Aisle, Middle Granite Gorge, Havasu Creek inflow, and Pumpkin Spring (Valdez and Ryel 1995, Ackerman 2008, Persons et al., *In review*). In addition, since 2009, translocations of humpback chub have been made by the FWS to upstream of Chute Falls in the Little Colorado River, and by the NPS, with assistance provided by Reclamation and FWS, to introduce juvenile fish into Shinumo and Havasu Creeks, with the goal of establishing additional spawning populations within the Grand Canyon (NPS 2013). Surveys conducted in 2013, 2014, and 2015 suggest that translocated humpback chub have successfully spawned in Havasu Creek (NPS 2013). Humpback chub occupy approximately the lower 5.6 km (3.5 mi) of Havasu Creek, from the mouth to Beaver Falls, which is a barrier to upstream movement of fish. The most recent humpback chub population estimate in Havasu Creek was approximately 280 individuals as of May 2015. While reproduction has been documented, the population has increased primarily as a result of continued translocations.

Sampling conducted between October 2013 and September 2014 in western Grand Canyon between Lava Falls (RM 180) and Pearce Ferry (RM 280) captured 144 juvenile humpback chub during sampling of the small-bodied fish community. In addition, 209 humpback chub larvae were collected during sampling of the larval fish community in randomly selected sites (Albrecht et al. 2014). Results were similar in larval and small-bodied fish sampling in 2015: 285 juvenile and 67 age-0 humpback chub were captured during small-bodied and larval fish sampling, respectively, from throughout the study area (Kegerries et al. 2015). These results suggest that young humpback chub are using widespread nursery and rearing habitats between RM 180 and RM 280 in the western Grand Canyon. This information indicates that humpback chub are reproducing and recruiting throughout the project area, which is an improvement in the environmental baseline for the species since our last BO on Glen Canyon Dam operations.

The Little Colorado River population (aggregation) of humpback chub is measured with closed and open population models. Closed models estimate the annual spring and the annual fall abundance of various size classes of chub within the Little Colorado River (Van Haverbeke et al. 2013, 2016). As such, the closed models do not account for chub that are not residing in the Little Colorado River during any particular year (i.e., there is always a portion of the Little Colorado River aggregation that is residing in the nearby mainstem each year). Initial closed mark-recapture population efforts in the Little Colorado River were conducted in the early 1990s (Douglas and Marsh 1996), after which there was a hiatus until they were resumed again in 2000 (Van Haverbeke et al. 2013, 2016). Results from both of these studies indicate that sometime in the mid- to late-1990s, humpback chub underwent a significant decline in the Little Colorado River. This was followed by a period of relatively low, but stable abundance between 2000 and 2006, and by a period (2007–2014) of significantly increased abundance levels (Van Haverbeke et al. 2013). The post-2006 increase in humpback chub ≥150 mm and ≥200 mm was visible during both spring and fall seasons, but it was more apparent during spring months. Spring 2015 monitoring showed significant decrease in abundance of humpback chub ≥150 mm and ≥200 mm compared to the previous several years. The cause of this decline is unknown, but there is evidence from sampling in the mainstem during 2015 that many chub may have simply remained or emigrated into the mainstem during 2015 (i.e., the portion of the Little Colorado River aggregation of chub residing in the nearby mainstem was higher than usual).

In summary, population estimates indicate that the number of adult humpback chub in the Grand Canyon has been increasing since 2000 or 2001 and has been relatively stable for about the last five years. A number of factors have been suggested as being responsible for the observed increases, including experimental water releases, rainbow and brown trout removal, and drought-induced warming (Andersen 2009, Coggins and Walters 2009). In addition, translocations of juvenile humpback chub to Shinumo and Havasu Creeks have resulted in increased numbers of adult humpback chub captured in the mainstem aggregations (Persons et al., *In review*). Translocations to tributaries have been shown to provide an adequate mechanism for rearing juvenile humpback chub that may later disperse to the Colorado River and augment aggregations (Spurgeon et al. 2015).

*Critical habitat*

Critical habitat for humpback chub in the action area includes a portion of Critical Habitat Reach 6, the Little Colorado River, 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 Little Colorado River to its mouth with the Colorado River; however, only about 0.25 mile of this reach is affected by mainstem flow. 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 current condition of critical habitat in the Little Colorado River (Reach 6) is probably similar to historical conditions in many ways. 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.

Critical habitat in Reach 7, in Marble and Grand canyons, has been altered significantly from historical conditions, primarily due to the construction and operation of Glen Canyon Dam (see discussion in USFWS 2011a). The flow of the Colorado River in Marble and Grand canyons has been modified by Glen Canyon Dam since 1964, and the dam and its operation is the primary factor in the function of PCEs in this reach. However, humpback chub use a variety of riverine habitats, with adults 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 persistence of mainstem aggregations of humpback chub. 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 Little Colorado River and the overall importance of habitats in the mainstem to recovery is not well known. This is because most of the humpback chub population occurs in the Little Colorado inflow aggregation, which utilizes the Little Colorado River to a large degree.

Dam discharge and river flow regimes can both destroy and build shoreline rearing habitat, thus affecting juvenile chub survival (Converse et al. 1998). Fluctuating flows can destabilize backwater habitats and may negatively impact aquatic macroinvertebrate production (Kennedy et al. 2016). However, dam releases, such as HFEs, can create shallow backwater habitats associated with sandbars and are thought to provide rearing habitat for native fish, because they may be warmer than the mainstem river water temperature during the summer months due to solar radiation (Behn et al. 2010, Dodrill et al. 2015). Although HFE water releases from Glen Canyon Dam between 2000 and 2008 may have improved some habitat characteristics (e.g., backwaters) for humpback chub, the limited availability of suitable warmwater temperatures in the mainstem may have constrained the potential for positive population responses (Kennedy and Ralston 2011). Additional factors affecting the PCEs of critical habitat are discussed below.

The PCEs, as described in the Status of the Species section, are: Water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, turbidity) that is delivered to a specific location in accordance with a hydrologic regime required for the particular life stage for each species; Physical Habitat, areas for use in spawning, nursery, feeding, and movement corridors between these areas; and Biological Environment, food supply, predation, and competition. In summary, the conditions of the PCEs in Reach 7 are:

- The physical PCE for spawning is present within critical habitat Reach 7. During the early 1990s, nine aggregations of humpback chub were described in Grand Canyon (Valdez and Ryel 1995). These comprised the aggregations at 30-Mile, Little Colorado River, Lava-Hance, Bright Angel, Shinumo, Stephen's Aisle, Middle Granite Gorge, Havasu, and Pumpkin Spring. Except for the Little Colorado River aggregation, population estimates for the additional aggregations were small, ranging from 5-98 adult humpback chub per aggregation, with no population estimation provided for some of the aggregations because of too few recaptured fish (Valdez and Ryel 1995). This trend of low catch in aggregations outside of the Little Colorado River aggregation continued during 2002-2006, although the pattern was reported as low relative abundance (catch per unit effort, CPUE) rather than absolute abundance (Ackerman 2008). Since 2010, annual sampling of the aggregations has again resumed. Major findings have been that relative abundances of adult humpback chub in the aggregations have increased since sampling events during the earlier time periods (Persons et al., *In review*). Additionally, a group of adult chub likely consisting of between 300-600 individuals has been found near 34-Mile in Marble Canyon (D. Van Haverbeke 2016, pers. comm.), and there appears to have been a dramatic increase in the absolute abundances of humpback chub in western Grand Canyon (roughly Havasu Creek downriver), with all size classes being represented. For example, while the number of adults estimated at the Pumpkin Springs aggregation (~RM 213) was only 5 adult fish during the early 1990s, 69 humpback chub were captured in this aggregation during a single day in 2016; 31 of these being adults. Finally, translocations of humpback chub into Shinumo and Havasu creeks have significantly augmented those respective mainstem aggregations.

- Nursery habitat 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 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 Little Colorado River (Hoffnagle et al. 2006), although feeding areas in the mainstem may be limiting for juvenile humpback chub due to the effect of fluctuations on nearshore habitats (AGFD 1996).

- Movement corridors appear to be adequate based on movements of humpback chub throughout the system (Valdez and Ryel 1995, Paukert et al. 2006).

- Food supply is a function of nutrient supply, productivity, and availability to each life stage of the humpback chub. River regulation by Glen Canyon dam decreases turbidity in the tailwaters (the water immediately downstream of a dam) and permits increased algae growth on bottom substrates (Angradi 1994, Shannon et al. 1994), leading to an increased expansion of macroinvertebrate populations in the tailwater reach of Glen Canyon Dam (Blinn et al. 1992, Stevens et al. 1997). Algae biomass and production decrease downstream as water clarity decreases (Carothers and Brown 1991, Stevens et al. 1997, Hall et al. 2010). This drives a downstream decrease in aquatic invertebrate biomass (e.g., midges, snails, and aquatic worms) (Carothers and Brown 1991, Stevens et al. 1997, Kennedy and Gloss 2005, Rosi-Marshall et al. 2010). Cold water temperatures and daily fluctuations in discharge associated with hydropower production are likely responsible for the low diversity and abundance of aquatic insects downstream of the Paria River (Stevens et al. 1997, Kennedy et al. 2016).

- Nonnative fish species that prey on and compete with humpback chub affect the PCEs of the biological environment aspect of critical habitat. Catfish (channel catfish and black bullhead), trout (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 2008, Yard et al. 2008). In 2015 and 2016 green sunfish established in a slough in the Lee's Ferry reach of Glen Canyon and brown trout appear to be increasing in this reach as well. The partner agencies (AGFD, FWS, NPS, Reclamation, and USGS) treated the slough with piscicides in 2015 and 2016 to remove the green sunfish, but it is likely invasions of nonnative, predatory fish will continue.

- The water quality and quantity PCEs in Reach 7 have been modified by Glen Canyon dam by altering water temperatures and flow regimes. However, since 1996, water releases from Glen Canyon Dam have been adaptively managed to improve water quality and quantity for humpback chub in the Colorado River through Grand Canyon (Reclamation 1996). These modified flows reduced daily fluctuations in river flow from peak power plant releases, and allowed for higher spring releases to restore some aspects of the natural hydrograph. These flow actions appear to be assisting with maintenance of this PCE, with the caveat that the requirements necessary for all life stages of humpback chub in the mainstem to support a recovered Grand Canyon population are still under investigation (USFWS 2011b).

**B. Factors affecting species environment and critical habitat within the action area**

Primary factors affecting humpback chub and critical habitat within the action area include habitat alterations associated with dams and reservoirs that have modified water temperature, and the introduction of nonnative fishes (USFWS 2011b), which act as competitors and/or predators of the humpback chub (Andersen 2009, Yard et al. 2011, Kennedy et al. 2013).

- Temperatures, particularly in the upper reaches of the action area, even in warmer years, are not optimal for humpback chub spawning and growth. The coldwater temperatures in most places of the main channel are below the temperature needed for spawning, egg incubation, and growth of the humpback chub. Survival of humpback chub young in the mainstem near the Little Colorado River is thought to be low because of cold mainstem water temperatures (Clarkson and Childs 2000, Robinson and Childs 2001), which may limit hatching success, reduce larval survival and larval and juvenile growth, reduce swimming ability, and increase predation vulnerability (Ward and Bonar 2003, Ward 2011). Water temperatures in the mainstem Colorado River have generally been warmer over the last decade, and warming over the summer increases downstream, due to solar radiation. These warmer water temperatures in the mainstem over the last decade may be providing some temporary benefit and contributing to the improving status of the humpback chub (Reclamation 2011a). For example, maximum daily temperatures exceeded 20°C (68°F) in the lower river (RM 180–RM 280), and daily average temperature was 18.3°C (65°F) in early July (Kegerries et al. 2015). There is some evidence of recruitment at the 30-mi aggregation possibly due to the presence of warm springs. Adult chub captured near RM 35 suggests the possibility of a new aggregation or expansion of the 30-mi aggregation, and during 2013 and 2014, three female humpback chub were captured near the 30-mi aggregation that expressed eggs.

- Predation by rainbow and brown trout at the Little Colorado River confluence has been identified as an additional mortality source affecting humpback chub survival, reproduction, and recruitment (Valdez and Ryel 1995, Marsh and Douglas 1997, Yard et al. 2011). The incidence of piscivory by brown trout has been found to be much higher than for rainbow trout in the Grand Canyon (Yard et al. 2011, Whiting et al. 2014), but rainbow trout are much more abundant in the Colorado River, and thus may impact native fish at a similar magnitude (Yard et al. 2011). Predation by channel catfish and black bullhead are also thought to impact humpback chub in the Grand Canyon, particularly if warmer water conditions occur (NPS 2013). Because of their size, adult humpback chub are less likely to be preyed on by trout; however, emergent fry, young-of-year (YOY), and juvenile humpback chub are susceptible to predation in the Little Colorado River and mainstem Colorado River (Yard et al. 2011).

In addition, the Colorado River now includes nonnative fish parasites, such as the Asian tapeworm and anchor worm, which may infect some humpback chub and affect survival (Clarkson et al. 1997, Andersen 2009). Recent studies also indicated that toxic mercury (Hg) and selenium (Se) concentrations in native fish were elevated in the Grand Canyon (Walters et al. 2015). While humpback chub were not tested in the study, elevated levels of Hg in the food web, and in particular, primary prey items, including blackfly larvae (Simuliidae), may result in negative impacts to humpback chub (Walters et al. 2015).

**Razorback sucker and critical habitat**

**A. Status of the species and critical habitat within the action area**

Within the Grand Canyon, it is likely that razorback sucker historically occurred throughout the Colorado River to Lake Mead (after Hoover Dam construction), with several documented captures in the mainstem (near Bright Angel and Shinumo Creeks), at the Little Colorado River inflow in 1989 and 1990, and from the Paria River mouth (in 1963 and 1978, as reported in NPS 2013). Until recently, the last razorback sucker collected from the Grand Canyon (RM 39.3) was caught in 1993, and the species was considered extirpated from the Grand Canyon.

Recent efforts to better understand the use of the western Grand Canyon by razorback sucker has revealed that the species is present, but likely rare, in Grand Canyon. Adult razorback suckers have recently been captured from the western Grand Canyon. Four fish that were sonic-tagged in Lake Mead in 2010 and 2011 were detected in the spring and summer of 2012 in GCNP up to Quartermaster Canyon (RM 260) (NPS 2013). An additional untagged adult razorback sucker was captured in GCNP near Spencer Creek (RM 246) in October 2012 (NPS 2013), and another adult was captured in late 2013 (GCMRC 2014). Sampling of channel margin habitats has also documented 462 and 81 razorback sucker larvae as far upstream as RM 173 (just upstream of Lava Falls) in 2014 (Albrecht et al. 2014) and 2015 (Kegerries et al. 2015), respectively, indicating that spawning is occurring in the mainstem river in the western Grand Canyon (Albrecht et al. 2014, Kegerries et al. 2015). This is the farthest upstream razorback sucker spawning has been documented in the Grand Canyon (Albrecht et al. 2014). Unfortunately, small-bodied fish sampling designed to detect juvenile razorback sucker in western Grand Canyon has failed to detect any older larval or juvenile fish. The capture of YOY suckers indicates that there is the potential for razorback sucker spawning in Lower Grand Canyon and in-river recruitment (Albrecht et al. 2014). However, based on the presence of larger, older sucker species (i.e., flannelmouth suckers [*Catostomus latipinnis*]) and the lack of predatory nonnative fish species in the lower river, it is possible that razorback suckers could (or do) recruit into the action area. There is also evidence that at the Colorado River inflow to Lake Mead, where six razorback suckers, seven razorback sucker-flannelmouth sucker hybrids, and 251 flannelmouth suckers were captured in 2014, hybridization is occurring between razorbacks and flannelmouth suckers. Although the extent and effect of this hybridization on razorback suckers in the lower Grand Canyon is unknown, it may be that with so many flannelmouth and so few razorback sucker adult fish apparently present (based on capture data), hybridization between the two species is common.

Tagged adult razorback suckers have also been located as far upstream as RM 184.4 near Lava Falls, and along with the collection of larvae, these indicate that the species utilizes the Colorado River above the Lake Mead inflow area more than previously thought (Albrecht et al. 2014). In 2015, submersible ultrasonic receivers (SURs), devices used to detect sonic-tagged razorback suckers, were installed upstream of Lava Falls, to an area below Bright Angel Creek. No detections of razorback sucker were recorded above Lava Falls through September 2015; however, the continued collection of larval fish upstream of Lava Falls indicates spawning is occurring in at least one unknown location in the mainstem or tributaries (Kegerries et al. 2015).

In summary, razorback sucker are located within the project area, from the Colorado River inflow of Lake Mead upstream, as far as an area above Lava Falls in Grand Canyon. The upstream distribution of adult razorback sucker is unknown, but they have been found upstream of Lava Falls. These occurrences since 2013 of adult and larval razorback sucker in Lake Mead and the lower Grand Canyon downstream of RM 180 indicate that the connectivity of the lake to the riverine reaches may be important to maintenance of razorback sucker in the action area.

*Critical habitat*

Critical habitat within the action area includes the Colorado River and its 100-year floodplain from the confluence of the Paria River downstream to Hoover Dam (a distance of about 500 mi), including Lake Mead to full pool elevation (USFWS 1994). Therefore, the entire Colorado River within the action area is razorback sucker critical habitat.

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).

Recent warming river temperatures due to lower Lake Powell elevations, attributed to drought and consumptive water use, may have resulted in more suitable habitat in the western Grand Canyon for razorback suckers. In 2015, river temperatures were within the acceptable range needed for razorback sucker spawning and successful hatching, particularly farther downstream (Kegerries et al. 2015). In addition, fish community composition in the lower river below Diamond Creek has changed dramatically from one dominated by nonnative species, to native species (Kegerries et al. 2015). However, the cause of the change in fish community composition is unknown. The drop in nonnative predator abundance, combined with periodically warmer water temperatures, may have allowed for the expansion of razorback sucker into the western Grand Canyon. Additional research and monitoring are needed to better understand the management implications of these habitat changes for recovery of razorback sucker in Grand Canyon (Albrecht et al. 2014).

**B. Factors affecting species environment and critical habitat within the action area**

The historical decline of the razorback sucker and its critical habitat in the Grand Canyon has been attributed primarily to habitat modification due to dam construction (including coldwater dam releases, habitat loss, and migration impediments), streamflow regulation, and predation by nonnative fish species, which have resulted in a lack of recruitment (USFWS 2002b, Gloss and Coggins 2005).

- Similar to the humpback chub, cold hypolimnetic releases from Glen Canyon Dam have likely contributed to reproductive failure in razorback sucker (Gloss and Coggins 2005).

Flow regulation has decreased the magnitude of spring peak runoff, which is closely linked to reproduction of the razorback sucker. The loss or drastic reduction in peak flows, along with channelization or disconnection of floodplain nursery habitats with the main channel (as a result of loss of peak flows), have resulted in the reduction of reproduction and recruitment as it likely occurred historically (USFWS 2002b). The flow regimes necessary to maintain razorback sucker populations in the action area, including flows that provide adequate spawning cues and spawning and nursery habitat, are presumably present as some razorback suckers have been detected in western Grand Canyon and there is evidence of spawning (Albrecht et al. 2014). However, the low numbers of adults detected and lack of recruitment indicate that habitat may not be adequate for suckers to maintain themselves within the action area at this time.

- Competition with and predation by nonnative fishes have also been identified as important factors in the decline of the razorback sucker (Minckley et al. 1991, USFWS 2002b). The reduced sediment supply and resulting clear water due to dam operations also is thought to favor sight-feeding nonnative predators, over razorback sucker and other native fish that evolved in highly turbid conditions (Gloss and Coggins 2005).

Similar to impacts on humpback chub, elevated Hg and Se described by Walters et al. (2015) may be another factor that affects razorback sucker in the Colorado River. While razorback suckers were not tested, other native suckers with similar diets were found to have high levels of Hg and Se in the Grand Canyon (Walters et al. 2015).

**Kanab ambersnail**

**A. Status of the species within the action area**

The Kanab ambersnail (at least as it is currently recognized) is only found in three locations. Two of these are within the Grand Canyon: the riparian vegetation at Vasey's Paradise and Elves Chasm. Vasey's Paradise is at RM 31.5, and Upper Elves Chasm is at RM 116.6. The latter population was created from snails translocated from Vasey's Paradise (USFWS 2008).

Based on annual survey data, live counts of Kanab ambersnails at Vasey's Paradise declined in 2011 from previous years, although the ambersnail habitat at Vasey's Paradise was in overall good condition in 2011. At Elves Chasm, live counts of Kanab ambersnails remained higher in 2011 than previous years, and habitat at this location was in good condition in 2011 (Sorensen 2012). The population at Vasey's Paradise generally occurs at elevations above 33,000-cfs flows. However, as much as 7.3% of the Vasey's Paradise population occurs below the elevation of 33,000-cfs flow, and as much as 16.4% of the population occurs below the elevation of 45,000 cfs flow. The Elves Chasm population is located above the elevation of 45,000-cfs flow (Reclamation 2011b).

Recent monitoring surveys of the Kanab ambersnail population at Vasey's Paradise in Grand Canyon were conducted in May and June 2013, September 2014, and May 2015 (Sorensen

2016). The results from timed presence/absence count surveys at Vasey's Paradise, compared to past years, are summarized in Table 2. The low CPUE in 2014 and 2015 may be due to drought (see factors affecting species environment, below). Monitoring was also conducted on September 12, 2016, where surveyors found one live, mature Kanab ambersnail in all of the lower habitat patches they surveyed (not all habitat patches were surveyed). Total search time for those patches was 126 minutes (CPUE of 0.01 snails/10min search). This count and CPUE estimate is the lowest ambersnail count AGFD has ever tallied at Vasey's Paradise.

**Table 2.** Kanab ambersnail counts, search effort, and catch-per-unit-effort (CPUE) from timed presence/absence sampling at Vasey's Paradise, 2007-2015 (Sorensen 2016).

| Survey Date | # Live Kanab Ambersnails Observed | Minutes of Search Effort | CPUE (# snails per 10 min search) |
|---|---|---|---|
| May 2007 | 186 | 526 | 3.54 |
| April 2009[1] | 52 | 214 | 2.43 |
| April 2010[1] | 51 | 164.5 | 3.10 |
| May 2011[1] | 28 | 358 | 0.78 |
| May 2012[1] | 38 | 303.5 | 0.80 |
| May 2013[1] | 17 | 339 | 0.50 |
| May 2014 | No survey | | |
| May 2015[1] | 44 | 229.5 | 1.92 |
| | | | |
| July 2009[1] | 106 | 169.5 | 6.25 |
| June 2010 | 141 | 314.5 | 4.48 |
| June 2011 | 82 | 277 | 2.96 |
| July 2011[1] | 34 | 223 | 1.52 |
| June 2012 | 34 | 239.5 | 1.42 |
| June 2013 | 51 | 277.5 | 1.84 |
| June 2014 | No survey | | |
| | | | |
| Sept 2006 | 16 | 219 | 0.73 |
| Sept 2007 | 35 | 217.5 | 1.61 |
| Sept 2008 | 22 | 225.5 | 0.97 |
| Sept 2009 | 66 | 215.5 | 3.06 |
| Sept 2010 | 139 | 292 | 4.75 |
| Sept 2011 | 51 | 308.5 | 1.65 |
| Sept 2012 | 11 | 268 | 0.41 |
| Sept 2013 | No survey | | |
| Sept 2014 | 10 | 270.5 | 0.37 |

[1] AGFD Supervised Citizen Science Trip.

Traditional 20-cm diameter plot sampling was only conducted in June 2013 at Vasey's Paradise, but no live Kanab ambersnails were detected in the six sample plots; however, a few live Kanab ambersnails were observed in suitable habitat outside of the sample plots.

AGFD also supervised small teams of citizen science volunteers to conduct monitoring surveys of the translocated Kanab ambersnail population at Upper Elves Chasm in May 2013 and May 2015. Results from this timed presence/absence count survey, compared to past years, are summarized in Table 3. The estimated CPUE for both the 2013 and 2015 surveys were nearly identical, at 1.51 and 1.50 snails per 10 minute search, respectively.

**Table 3.** Kanab ambersnail counts, search effort, and CPUE from timed presence/absence sampling at Upper Elves Chasm, 2009-2015 (Sorensen 2016).

| Survey Date | # Live Kanab ambersnails Observed | Minutes of Search Effort | CPUE (# snails per 10 min search) |
|---|---|---|---|
| April 2009 | 13 | 113.5 | 1.14 |
| April 2010 | 8 | 69 | 1.16 |
| May 2011 | 20 | 97.5 | 2.05 |
| May 2012 | 7 | 82 | 0.85 |
| May 2013 | 15 | 99 | 1.51 |
| May 2014 | No survey | | |
| May 2015 | 7 | 46.5 | 1.50 |
| | | | |
| June 2009 | 30 | 184.5 | 1.62 |
| June 2010 | 27 | 154 | 1.75 |
| June 2011 | 27 | 65 | 4.15 |

**B. Factors affecting species environment within the action area**

There has likely been some loss of Kanab ambersnails and habitat from the highest flow actions conducted under previous dam operations and flow actions. 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 (current operation 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 these two patches historically, likely because the habitat is of low quality (Sorensen 2009). The abundance of Kanab ambersnail has not returned to levels seen before the drought of 2002-2003 that severely reduced the amount of available habitat and likely reduced the population that year (USFWS 2011d).

The habitat at Vasey's Paradise remains somewhat stable from year-to-year, but is 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). Long-term, climate change has the potential to affect Kanab ambersnail habitat. The water source at Vasey's Paradise consists of waterfalls emanating from groundwater and emerging from the cliff face. In 2014, 2015, and 2016, the flow was reduced, likely as a result of basin-wide drought (and CPUE of snails decreased, see Table 2 and September 12, 2016, survey results above). Consequently, the usually dense vegetation at Vasey's Paradise is notably diminished. Drought associated with climate change will likely diminish the water source supporting Vasey's Paradise and consequently the vegetation and habitat available to the Kanab ambersnail.

The translocated population at Elves Chasm is not affected by dam operations. The population also seems to have recovered from drought conditions, as surveys in 2009 found more snails than in previous years, and surveys in 2010-2013 and 2015 continue to locate snails.

## 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, which 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.

Hydrology directly affects the amount of water and water quality variables in the downstream river environment such as temperature, salinity, and turbidity, which in turn have effects to humpback chub, razorback sucker, and Kanab ambersnail. Sediment transport and channel and floodplain morphology (e.g., pools, rapids, sandbars, and terraces) are controlled and shaped by the river's hydrologic properties and implementation of the proposed action. The water volumes, flow rates, and timing of sediment transport, as well as other aspects of Colorado River hydrology are directly affected by the proposed action. In addition, an extensive suite of ongoing and new conservation measures are included in LTEMP (see proposed action) that will collectively work to minimize the negative effects of the proposed action on listed species, enhance the survival and recovery of the humpback chub; monitor the status and effects to the humpback chub, razorback sucker, and Kanab ambersnail in the action area; and, and allow for Reclamation and their partners to use adaptive management to respond to any changes in listed species status or habitat over time. Since razorback sucker have only recently re-occupied the project area, we are still learning about their use of the area; however, there are conservation actions included in the proposed action that will allow us to better understand how the proposed action may also aid in sucker recovery.

The direct and indirect effects of the proposed action include impacts from base operations and operational flexibility; experimental elements (includes sediment-related, aquatic resource-related, and native/nonnative plant management experimental treatments), and, implementation of ongoing and new conservation measures. We summarize the expected effects of each of these groups of actions and evaluate the impacts to the humpback chub and critical habitat, razorback sucker and critical habitat, and Kanab ambersnail.

**Humpback chub and critical habitat**

There are several aspects of the proposed action that may affect humpback chub through direct impacts to individuals or habitat or by indirectly influencing the abundance and distribution of nonnative fish (that prey upon or compete with chub), or by influencing macroinvertebrate production (food base). Dam operations have the potential to influence water flow, water temperatures, the quantity and quality of nearshore rearing habitats (e.g., backwaters), aquatic insects (food base), and nonnative species presence and abundance. These operations may also result in direct fatality to juvenile native fish through stranding. Other non-flow actions that may have direct and indirect effects to humpback chub include conservation measures (including actions in Appendix D of the BA, mechanical removal of nonnative fish, etc.) and continued fisheries research and monitoring under the GCDAMP.

Effects of Base Operations and Operational Flexibility

Base dam operations will change with the implementation of the proposed action. The distribution of monthly release volumes under the proposed action results in a more even distribution of flows over the course of a water year relative to existing, or baseline, flows. The daily fluctuation in release volumes will be proportional to the Lake Powell reservoir volume (i.e., lower fluctuations during lower flows), with a maximum release volume fluctuation range of 8,000 cubic feet/second, which would be the same as the current maximum fluctuation range, which has been in place since 1996 (Reclamation 1996). The daily downramp rate would be increased, compared to the current condition, by 67% (from 1,500 cfs/hr to 2,500 cfs/hr). Therefore, it is anticipated that year-round, fluctuating flows during the 20-year life of LTEMP may have long-term adverse effects on humpback chub by increasing the risk of stranding juvenile chub, damaging nearshore rearing habitats, degrading aquatic invertebrate prey production, and maintaining cold water temperatures. Conservation measures that allow for recruitment, such as ongoing and proposed expanded translocations in Havasu Creek, would likely reduce the overall effect of this potential loss of young chub, by providing chub with additional habitat that is unaffected by base operations.

The potential for, and the effect of, stranding on individual humpback chub survival caused by Glen Canyon Dam operations in the action area has not been directly investigated; however, fish stranding as a result of hydroelectric and irrigation projects is well-documented (Nagrodski et al. 2012). Stranding of fish, particularly juvenile fish, is a potential outcome of daily hydropeaking (rapid changes in discharge) as a result of hydropower generation (Bunn and Arthington 2002, Nagrodski et al. 2012). Increasing downramp rates under the proposed action may increase the risk of stranding juvenile humpback chub using nearshore habitats. Stranding could include fish being temporarily restricted to isolated habitats away from the main channel until water levels come back up, or complete desiccation. Desiccation of these isolated habitats would result in fatality of any juvenile humpback chub present. Factors that may influence the probability of stranding fish during daily hydropeaking include the rate of flow reduction, water temperature, channel geomorphology, and substrate composition, as well as biotic factors including fish life stage and size (Nagrodski et al. 2012). Increasing drawdown rates under the proposed actions may increase the potential for isolating and/or desiccating nearshore habitats.

Daily fluctuating flows under base operations would also likely continue to degrade nearshore habitats, particularly cobble shoals, riffles, and backwaters in wider sections of the canyon, and where low-angle shorelines susceptible to flow fluctuations are prevalent. For example, cobble riffles and shoals, which are important spawning areas for fish and invertebrate production areas, would be dewatered daily. Generally, based on catch rates, few larval and small-bodied juvenile native fish have been observed in these types of habitats below Lava Falls (Albrecht et al. 2014, Kegerries et al. 2015). However, during a low steady flow experiment, humpback chub were found at higher densities in these habitats than in others (Dodrill et al. 2015).

Hydropeaking has also been demonstrated to have long-term detrimental impacts on aquatic invertebrates (the chub food base) below hydroelectric dams in the western United States (Kennedy et al. 2016). Kennedy et al. (2016) found that hydropeaking was a primary factor implicated in reduced aquatic insect diversity, and the Grand Canyon was found to have the lowest insect diversity and the highest hydropeaking index among 16 dammed rivers in the study. A diverse source of invertebrates is available to colonize the Colorado River from tributary streams (Oberlin et al. 1999, Whiting et al. 2014). However, the proposed action's hydropeaking, along with the existing altered temperature and flow regime, would continue to result in decreased invertebrate production, hence a reduced prey production for humpback chub, over the life of the LTEMP. Implementation of the experimental low steady weekend flows for macroinvertebrate production may improve this situation over time, but until this flow experiment is executed and monitored, we do not know how it will improve the prey base for humpback chub.

Under base operations, river temperatures would continue to be more suitable for coldwater nonnative species (brown and rainbow trout) than for warmwater native and nonnative fish. The estimated average main channel temperatures modeled for LTEMP indicated that temperature conditions would be most suitable for warmwater nonnative species at locations farther downstream from Glen Canyon Dam (e.g., RM 157 and RM 225) compared to upstream locations (e.g., RM 0 and RM 61), where temperatures would be more suitable for coldwater fish, specifically nonnative brown and rainbow trout. However, main channel temperatures at and downstream of RM 61 would be more suitable for both trout species than at locations closer to the dam. The abundance of trout is lower in those locations because other habitat characteristics (e.g., substrate composition and water clarity) are less suitable there.

Previous studies have shown that rainbow trout recruitment and population size within the Glen Canyon reach of the action area appear to be largely driven by dam operations (AGFD 1996; McKinney and Persons 1999; McKinney et al. 2001a,b; Makinster et al. 2011; Wright and Kennedy 2011; Korman et al. 2011, 2012; Avery et al. 2015). Increases in rainbow trout abundance have been attributed to the changes in flows beginning with interim flows in 1991 and later the implementation of Modified Low Fluctuating Flows (MLFF) in 1996. These changes both increased minimum flows and reduced fluctuations in daily flows, which created more stable and productive nursery habitats for rainbow trout in Glen Canyon (McKinney and Persons 1999). More recent declines in rainbow trout abundance (such as those observed from 2001 to 2007) have been attributed to the combined influence of warmer water releases from Glen Canyon Dam, high abundance of rainbow trout resulting in increased intraspecific competition, and periodic dissolved oxygen deficiencies, along with possible limitations in the food base (Makinster et al. 2011). Episodic emigration from the Lees Ferry reach toward the Little Colorado River was likely related to increased trout density, trout condition, and turbidity (Korman et al. 2015).

In addition to providing habitat for nonnative rainbow and brown trout, colder water temperatures (≤12°C) result in negative effects to humpback chub from decreased growth and increased time young chub are susceptible to predation. The effects of cold water on chub include increased egg incubation time (Hamman 1982), reduced egg and fry survival (Hamman 1982), increased larval-to-juvenile transition time (Clarkson and Childs 2000), and reduced growth rates of all other life stages (Clarkson and Childs 2000, Coggins et al. 2011). Essentially, juvenile humpback chub do not grow at temperatures under 12°C. From Glen Canyon Dam to the Little Colorado River inflow, water temperatures are generally <12°C. Consequently, there will be little or no humpback chub reproduction and recruitment in this reach of the mainstem, unless it occurs at isolated locations such as 30-mile springs (RM 30) or springs at RM 34. There is also little opportunity for larval fish to grow in Marble Canyon, unless the limited backwaters provide some thermal opportunities. In the Little Colorado River to Diamond reach, backwaters are more prevalent due to the more open geomorphology, and temperatures have reached or exceeded 16°C near RM 160 during September. The increased water temperature in the lower river reach may provide the conditions necessary for mainstem spawning activity and growth. Restricting the growth of young humpback chub also prolongs the time during which individuals are vulnerable to trout predation (Yackulic et al. 2014). Larger, older juvenile humpback chub may be able to avoid, withstand, or escape predation by rainbow trout under warmer and turbid water conditions; however, temperature and size did not afford the same advantage in escaping brown trout predation (Ward and Morton-Starner 2015).

Operational flexibility in dam operations is necessary to account for unforeseen changes in basin-wide hydrologic conditions, dam maintenance needs, water distribution, resource-related issues, or hydropower-related issues. The degree of flexibility in dam operations would not change from the current conditions, and no additional effects are expected to occur as a result of this need to respond to changing conditions and operational needs.

In summary, under LTEMP base operations, continued hydropeaking flows with increased downramp rates would increase the risk of stranding juvenile humpback chub, degrade nearshore rearing habitats, and limit the establishment of aquatic invertebrates. In addition, implementation of the LTEMP proposed action would continue to result in river temperatures that are more suitable for coldwater nonnative species than for warmwater native and nonnative fish, particularly closer to the dam. As described above, although the coldwater environment does not provide habitat for humpback chub growth and survival, it may assist in reducing the potential for nonnative warmwater fishes to establish in sections of the river.

Effects of Experimental Actions

Glen Canyon Dam has had a negative impact on the aquatic and terrestrial habitats of the Colorado River ecosystem from lower Lake Powell downstream to Lake Mead. In order to minimize these effects (including the previously mentioned effects discussed above) and improve conditions for listed species and their habitats, LTEMP includes experimental conservation actions meant to achieve the following desired future conditions:

- High-elevation open riparian sediment deposits along the Colorado River in sufficient volume, area, and distribution so as to provide habitat to sustain native biota and desired ecosystem processes that include nearshore habitats for native fish and marsh and riparian habitats for food chain maintenance.
- Water quality with regard to dissolved oxygen, nutrient concentrations and cycling, turbidity, and temperature, sufficient to support natural ecosystem functions, visitor safety, and visitor experience to the extent feasible and consistent with the life history requirements of humpback chub and other focal aquatic species including ecosystem-sustaining nutrient distribution, flux, and cycling, and hydro-physical conditions and characteristics necessary to sustain aquatic biota.
- The aquatic food base will sustainably support viable populations of humpback chub and other desired species at all trophic levels.
- Assure that an adequate, diverse, productive aquatic food base exists for humpback chub and other aquatic and terrestrial species that depend on those food resources.
- Sustainably maintain native fish species and their habitats (including critical habitats) throughout each species’ natural ranges in the Colorado River ecosystem.
- Achieve healthy, self-sustaining populations of other remaining native fish with appropriate distribution (flannelmouth sucker, bluehead sucker, and speckled dace).
- Achieve humpback chub recovery in accordance with the Act and the humpback chub comprehensive management plan with the assistance of collaborators within and external to the GCDAMP.
- Achieve a self-sustaining humpback chub population in its natural range in the Colorado River ecosystem.
- Maintain spawning habitat for humpback chub in the Lower Little Colorado River.
- Establish additional humpback chub spawning habitat and spawning aggregations within the Colorado River ecosystem, where feasible and appropriate.
- Promote adequate survival of young-of-year or juvenile humpback chub that enter the mainstem to maintain reproductive potential of the population and achieve population sizes consistent with recovery goals.

These experimental conservation actions are grouped under three categories: (1) Sediment-Related Experimental Treatments; (2) Aquatic Resource-Related Experimental Treatments; and,

(3) Native and Non-native Plant Management and Experimental Actions. If these experimental actions are found to benefit humpback chub, then they will be continued as appropriate and if triggered throughout the course of the next 20 years.

An adaptive management approach is being taken to implement all experimental elements of the LTEMP. This is being done in order to refine existing information regarding the effects of dam operations on affected resources. Information gathered through the adaptive and experimental process may be used to adjust operations within the range of the impacts analyzed in the FEIS. Prior to the implementation of any experimental action, potential impacts on humpback chub (and other resources) would be considered by the DOI, and deliberations would include the FWS and other DOI subject experts. This would help to identify and minimize the potential for adverse effects to humpback chub as a result of the implementation of an experimental conservation action. The following section summarizes the expected or hypothesized effect of the experimental actions on humpback chub. However, we acknowledge that monitoring and research following these experiments will provide more information regarding effects to chub (and other resources) as the LTEMP is implemented.

(1) Effects of Sediment-Related Experimental Treatments

Experimental flows under the proposed action include: sediment-triggered spring and fall HFEs through the entire 20 year LTEMP period; 24-hour proactive spring HFEs in high volume years (≥10 maf release volume); and, extension of the duration of fall HFEs up to 45,000 cfs for as many as 250 hrs depending on sediment availability.

HFEs under the proposed action were designed to increase and retain fine sediment for ecological purposes in Grand Canyon. Sediment is a fundamental component of the riverine ecosystem, and the sediment regime has been drastically altered by Glen Canyon Dam. HFEs have been shown to build sandbars that substantially increased the total area and volume of backwater habitat (Grams et al. 2010). The increased elevation of backwaters also increased the degree of isolation from the main channel, which would likely result in a higher degree of warming in backwater habitats (Trammell et al. 2002, Vernieu and Anderson 2013), which may be important to native fish growth in the summer (Albrecht et al. 2014, Kegerries et al. 2015). However, as discussed in the Status of the Species, studies of habitat used by juvenile humpback chub have been mainly limited to the Little Colorado River inflow reach, and it is unclear how important backwater or embayment habitats are to humpback chub throughout other reaches of the Grand Canyon (Pine 2011, Dodrill et al. 2015).

Under the proposed action, we would expect there to be 19.3 to 21 HFEs (maximum of 38 HFEs) during the 20-year LTEMP period. The more frequent HFEs are expected to favor blackfly and midge production (food base for humpback chub); however, spring and fall HFEs may differ in their effects, so it is unclear what long-term impacts of annual HFEs may have on the food base. Up to four of the fall HFEs implemented could be long-duration HFEs (lasting up to 250 hrs). These extended-duration HFEs would be of higher magnitude and could increase benthic scouring (the removal of aquatic invertebrates from the river bottom), compared to short-duration HFEs. Aquatic invertebrate drift from an extended-duration fall HFE may be elevated due to increased biomass of benthic (sediment-dwelling) invertebrates that may develop over the summer months. This could result in an increase in food supply for humpback chub. However, the four to five months between a fall and spring HFE could preclude full recovery of most benthic invertebrate assemblages. A spring HFE following a fall HFE, particularly a long-duration fall HFE, could scour the remaining primary producers (plants, cyanobacteria, and unicellular organisms that can produce their own food) and susceptible invertebrates and further delay the recovery of the aquatic food base. For this reason, implementation of a spring HFE in years that follow an extended-duration fall HFE would be carefully evaluated prior to carrying out the action.

Proactive spring HFEs would occur in high volume years with planned equalization releases (≥10 maf) in order to protect the sand supply. Fall HFEs longer than 96 hrs in duration will be implemented when there is sufficient Paria River sediment input in the fall accounting period (July–October) to achieve a positive sand mass balance in Marble Canyon. Spring HFEs and high and steady flows (Avery et al. 2015), have both demonstrated an increase in rainbow trout production in the Colorado River, especially in the Lees Ferry reach (16 mi reach below the dam). This increase in survival of juvenile rainbow trout was attributable to an improvement in habitat conditions and food availability in Glen Canyon for recently emerged trout (Korman et al. 2011). Flows and temperature were modeled over the LTEMP period to assess how rainbow trout recruitment and the potential for emigration downstream toward the Little Colorado River may be impacted by flow experiments. Under the preferred alternative, emigration of rainbow trout is estimated to be 11% higher than under the current dam operations, which could increase the likelihood of negative impacts on humpback chub through competition and predation, particularly in cold water release years. To provide a means of controlling trout recruitment following tests of HFEs, TMFs would be experimentally implemented and tested for efficacy as early in the LTEMP period as possible (see discussion of TMFs below). However, if TMFs did not result in decreases in rainbow trout predation of chub at the Little Colorado River, if Tier 1a (adult chub numbers) or 1b(subadult recruitment) of the *Proposed Action Triggers for the Management of Humpback chub* (Appendix D in BA [Young et al. 2015]) are not met, conservation actions defined in that document would be implemented. If the Tier 1 conservation actions are insufficient to stop a humpback chub population decline, then the Tier 2 Trigger (mechanical removal of aquatic predators [e.g., rainbow trout]) would ensue at the Little Colorado River inflow. Although both TMFs and mechanical trout control are considered experimental actions (see below), they are expected to offset risks of trout predation upon juvenile chub at the Little Colorado River because both are designed to reduce trout and/or trout recruitment. In addition, during the ongoing drought in the 2000s, Lake Powell levels generally declined and release temperatures gradually began to warm (Vernieu et al. 2005). Since this time, water release temperatures have continued on a general warming trend compared to the early 1990s. It is expected that basin-wide drought will continue resulting in lower Lake Powell levels over the next 20 years. These conditions are expected to result in warmer dam releases, which could also mitigate the effects of rainbow trout predation upon juvenile humpback chub (Ward and Morton-Starner 2015).

Nonnative brown trout, or warmwater species occurrence or abundance, may also be influenced by the HFEs. Brown trout spawning occurs mostly in tributaries, primarily in Bright Angel Creek (Reclamation 2011a,b); consequently, reproduction is not expected to be significantly affected by the flow operations of the dam. However, recent increases in brown trout recruitment in 2014-2015 have occurred in the Lees Ferry reach of the Colorado River in Glen Canyon (Stewart 2016). Brown trout were observed to be spawning near the 4-mile bar in Glen Canyon during the fall of 2014, and an increase in age-1 brown trout was observed in 2015 (Korman et al. 2015). Spawning of brown trout was also observed during October and November of 2015 near the 4-mile bar in Glen Canyon (Korman et al. 2015). It is unclear if flow operations, including recent fall HFEs, may have caused an increase in brown trout in recent years or if other factors are supporting the rise in brown trout recruitment. The YOY of fall-spawning brown trout would benefit from increased food availability, similar to rainbow trout, if the fall HFE effects on benthic invertebrates are similar to those of the spring HFEs (Cross et al. 2011). The proposed action would include continued monitoring and potential research regarding the effects of fall HFEs on brown trout populations, particularly in the Glen Canyon reach of the action area.

Although increases in brown trout recruitment are not known to be related to HFEs, it is possible that the establishment of green sunfish in 2015 in a warmwater slough downstream of Glen Canyon Dam may be related to dam operations (Reclamation 2016). If this assumption is correct, combined with expected occasional warmwater flow release periods during drought years, there is potential for warmwater nonnative fish occurrence below Glen Canyon Dam to increase over time. Rapid increases in dam discharge from base flow to up to 45,000 cfs during HFE implementation may increase the chance that abundant warmwater nonnative fish near the intakes become entrained in the bypass tubes. The risk would increase during periods of low Lake Powell levels because when this occurs intakes are closer to the surface and lake littoral zones where smallmouth bass or green sunfish are present. During basin-wide drought years, warmer discharge would increase the risk further, because warmer water could facilitate reproduction of these species in the Grand Canyon, potentially near the Little Colorado River inflow. Conservation measures were developed to address this risk and include investigating the means to prevent warmwater species passage through the dam, planning and implementing actions to make warmwater sloughs less hospitable to warmwater nonnative fish, and developing a rapid response protocol that includes chemical control and other methods not included in the NPS CFMP.

In summary, sediment-related experimental treatments have the potential to negatively affect humpback chub individuals and habitat by increasing rainbow trout emigration to the Little Colorado River reach. This may increase predation or competition effects, alter the food base, or increase the risk of establishment of warmwater nonnative fish. However, these negative impacts may be offset by conservation actions such as humpback chub translocations, monitoring and management of mainstem aggregations (outside of the Little Colorado River aggregation), triggered mechanical removal[3] of nonnative fish (trout or warmwater nonnative

---

3 Reclamation and the NPS are committed to continue to consult with the Tribes regarding nonnative fish control.

fish) to benefit juvenile humpback chub rearing, the development of a rapid response protocol, and warmwater species habitat modification. Further, backwaters created following HFEs may provide warmwater rearing habitat for juvenile humpback chub.

Sediment treatments would not continue to be tested if they are not effective in achieving their purpose or have unacceptable adverse impacts on humpback chub, the rainbow trout fishery, or other resources.

(2) Effects of Aquatic Resource-Related Experimental Treatments

*Effects of Triggered Conservation Actions and Mechanical Removal of Nonnative Fish Experiments*

Mechanical removal of nonnative species is a controversial issue in the Colorado River through Glen and Grand Canyons. In an attempt to reduce the need for mechanical removal of trout at the confluence of the Colorado and Little Colorado Rivers, Young et al. (2015, Appendix D of the BA) developed a tiered, triggered approach to address mechanical removal of nonnative fish. The purpose of this document is to minimize the need for mechanical predator removal through early implementation of humpback chub conservation measures. The tiered, triggered approach identifies two tiers of sequential actions. Tier 1 would emphasize conservation actions (i.e., expansion of translocation actions in the Little Colorado River, head-starting larval chub to later translocate) that would take place early during an adult or sub-adult humpback chub population decline (should that happen). Tier 2 would serve as a backstop prescribing mechanical nonnative predator removal (threat reduction) if conservation measures did not mitigate a decline in chub abundance.

As designed, the tiered, adaptive approach to responding to humpback chub declines is expected to reduce the need for mechanical removal of rainbow trout (or other nonnative predatory fishes) at the Little Colorado mainstem aggregation area.

*Effects of Trout Management Flows (TMF)*

TMFs are a special type of fluctuating flow designed, at least at this time, to reduce the recruitment of rainbow trout by disadvantaging YOY trout, and hence reducing recruitment. The purpose of trout management activities is to enhance the survival of the endangered humpback chub by reducing the numbers of rainbow trout in the river. Reducing the rainbow trout population would reduce competition with and predation on YOY humpback chub near the

---

Reclamation committed in agreements with Tribes in 2012 to consider live removal when feasible; however, the presence of whirling disease prohibits live removal of trout due to the risk of spreading the disease to other waters. Reclamation and the NPS have worked with the Tribes to determine a beneficial use of the removed fish on other projects and understand that what is considered beneficial use may not be the same for all Tribes. Reclamation and the NPS are committed to consult further with the Tribes to determine acceptable mitigation for nonnative fish control.

confluence with the Little Colorado River from trout moving downstream from reaches just below Glen Canyon Dam. TMFs will be implemented when there is predicted high rainbow trout recruitment in the Glen Canyon reach. For the FEIS modeling, a trigger of 200,000 YOY trout was used to determine when TMFs would be implemented. A TMF is a highly variable flow pattern of water releases at Glen Canyon Dam intended to control the number of YOY rainbow trout in the Glen Canyon reach of the Colorado River and, subsequently, the migration of trout to downstream areas such as the confluence of the Little Colorado River. A typical TMF would consist of several days at a relatively high sustained flow (e.g., 20,000 cfs) that would prompt young fish (specifically, rainbow trout) to move into the shallows along the channel margins. The high flows would be followed by a rapid drop to a low flow (e.g., 5,000 cfs), stranding YOY trout and, depending on the time of year, possibly exposing the eggs, thus preventing them from hatching. Under the proposed action, TMFs could be implemented early in the LTEMP period, in as many as four months (May – August), even if not triggered by predicted high trout recruitment. TMFs would initially be conducted as experiments and would be implemented only if they prove to be successful in reducing trout recruitment in the Glen Canyon reach. In general, TMFs would most likely be triggered when spring HFEs, which can stimulate the food base and thus trout production, are followed by relatively high steady summer flows. If TMFs prove successful, it would reduce the number of times mechanical removal would be triggered.

TMFs are designed to cause fatality in YOY rainbow trout by inundating low-angle, nearshore habitats for several days, and then quickly reducing dam discharge, which would strand YOY fish; however, there is also potential for stranding and increased fatality of juvenile humpback chub. Although the Lees Ferry reach trout population is the target of TMFs, an examination of USGS hydrograph data from Lees Ferry (RM 0) and National Canyon (approximately RM 166) indicated there may be little reduction in the peak of the hydrograph as it moves downstream due to flows downstream in the Marble and Grand Canyons. YOY humpback chub are found primarily in the Little Colorado River inflow reach, as well as further downstream, in unknown numbers. Stranding of these small YOY or larval fish may occur as a result of TMFs. It is less likely that TMFs would affect adult or juvenile chub, because they have a greater ability to swim out of confined spaces as flows dropped. TMFs could occur throughout the summer, overlapping with periods when larval humpback chub are found in nearshore habitats (May–August; Albrecht et al. 2014, Kegerries et al. 2015) and would be susceptible to extreme flow fluctuations under TMFs. At this time, TMFs are designed to disadvantage rainbow trout; should brown trout become a focus of TMFs, there may need to be changes to the TMF protocol if flow modification (e.g., increased or reduced flows) were identified as a possible tool to disadvantage brown trout recruitment.

*Effects of Low Summer Flow Experiments*

Investigating the anticipated effects of and options for providing warmer water temperatures in the mainstem Colorado River through Grand Canyon is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a).

Low summer flow experiments involve holding flows low (approximately 8,000 cfs) and relatively steady, compared to base operations during warm summer months. A first test of a low summer flow would feature low flow of 8,000 cfs and relatively little fluctuation (±1,000 cfs per day). Depending on the results of the first test with regard to warming and humpback chub response, the magnitude of the low flow could be adjusted up or down (as low as 5,000 cfs), and the level of fluctuation also modified up to the full range allowed under the proposed action (i.e., 10 × monthly volume [in kaf] in July and August, and 9 × monthly volume [in kaf] in September). Lower flows have the potential for more water warming via heat transfer from the air compared to higher flows and would be tested when the water temperature has been <12°C for two consecutive years and a target temperature of ≥14°C can be achieved at the Little Colorado River confluence. The goal of the experiment is to temporarily achieve warmer river temperatures to benefit humpback chub. A secondary benefit that may occur is increased stability in shoreline habitats (due to the steady flow), which could also temporarily improve juvenile humpback chub rearing habitat.

Low summer flows could be considered a potential tool for improving the physical growth and recruitment of young humpback chub if temperature had been limiting these processes for a period of years. Low summer flows may lead to warmer water temperatures in the Little Colorado River reach and farther downstream, as well as contributing to enhanced growth rates of young humpback chub. Low summer flows may also negatively affect humpback chub due to an increase in warmwater nonnative fish or a decrease in the aquatic food base. In moderate or higher water years, the April–June monthly volumes would have to be quite high and would likely be at or near 25,000 cfs. Following these high flows, there would be an abrupt drop to 8,000 cfs or lower (e.g., 5,000 cfs), which would likely leave much or all of the food base in Glen Canyon and downriver up above the new lower water line (Kennedy and Ralston 2011). These values represent declines in midges and Gammarus in the portions of the channel that have been dewatered, and only a small portion of the channel is actually dewatered. Low summer flows would also provide ideal egg laying conditions for aquatic insects, which should facilitate a rapid recovery of the invertebrate prey base to the reduced habitat area associated with this type of experiment. Nonetheless, the potential for low summer flow experiments to negatively impact the food base exist, and measures that seek to minimize any negative impacts would be considered if a low summer flow is implemented. One test of low steady summer flows was conducted below Glen Canyon Dam in 2000; the results, however, relative to humpback chub were not conclusive (Ralston 2011).

However, because of the uncertainty related to the effects of low summer flows on humpback chub, other native fish, warmwater nonnative fish, water quality, and potentially other resources, DOI would ensure that the appropriate baseline data are collected throughout the implementation of LTEMP. In addition, DOI would convene a scientific panel that includes independent experts prior to the first potential use of low summer flows to synthesize the best available scientific information related to low summer flows. The panel may meet periodically to update the information, as needed and information would be shared as part of the Adaptive Management Working Group (AMWG) annual reporting process.

If tested, low summer flows would occur for 3 months (July, August, and September), and only in the second 10 years of the LTEMP period. The duration of low summer flows could be shortened to less than three months in successive experiments if supported by the scientific panel described above or based on the scientific data and observed effects. The probability of triggering a low summer flow experiment is considered low (about 7% of years) because the water temperature conditions that would allow such a test occur infrequently.

Under this design, the effect of the low summer flow experiment upon humpback chub growth, rearing, and recruitment would be difficult to determine, because results are likely to be confounded by other factors (variation in annual precipitation, turbidity, etc.). The low summer flow experiment would not continue if the results of the experiment do not detect an increase in the growth of individual growth and recruitment of humpback chub; if there is an increase in trout or warmwater nonnative species at the Little Colorado River; or, if there are unacceptable adverse impacts on the rainbow trout fishery, humpback chub population, or other resources.

Low summer flows may allow for a prolonged test of the effect of steady flows on the diversity and abundance of aquatic invertebrates, similar to the intent of the low steady weekend flows for macroinvertebrate production experiments (see below). Base operations have been, and would continue to be, characterized as hydropeaking or load-following, which is an operational regime that has been demonstrated to have long-term detrimental impacts on aquatic invertebrates below hydroelectric dams (Kennedy et al. 2016). Consistently more stable flows over the summer could result in successful egg-laying and reproduction by sensitive macroinvertebrate taxa (e.g., mayflies), which are also important prey for humpback chub. However, the experiment may only be implemented 1 to 3 times in the second ten years of LTEMP, which would limit the ability of this experiment to benefit humpback chub food base over the long term. Therefore, only short-term (within the year of the test) beneficial effects to the food base would be expected.

*Effects of Low Steady Weekend Flows for Macroinvertebrate Production Experiments*

Experimental low steady flows are steady flows that would be provided every weekend from May through August (34 days total) to test the hypothesis that daily flow fluctuations to meet hydropower demand negatively affect habitat quality along the shorelines to improve the invertebrate assemblage within the action area. The duration and other characteristics of experimental macroinvertebrate production flows would be adjusted within the range of the analysis based on the results of initial experiments. Implementing these experimental flows is an attempt to increase invertebrate production and diversity, and may benefit nearshore habitats by providing stability and some warming in habitats that are more isolated from the mainstem (low flows would be held steady plus/minus 1,000 cfs fluctuation on approximately 34 weekend days over the summer). This experiment would not be conducted during the first 2 years of LTEMP. The goal is to replicate it two to three times to determine its effectiveness.

Sustained low flows for benthic invertebrate production may benefit humpback chub and other fish species by providing additional aquatic insect prey. Kennedy et al. (2016) demonstrated that hydropeaking flows in rivers below hydroelectric facilities may prevent the maintenance of viable populations of many aquatic invertebrates (e.g., mayflies, stoneflies, caddisflies) that would constitute important components of the food base for humpback chub. Many shoreline egg-laying invertebrates were absent from western rivers with higher degrees of hydropeaking fluctuations. This experiment may allow some shoreline egg-laying invertebrates to avoid desiccation, which results in a high degree of egg mortality (Kennedy et al. 2016), and potentially would allow for increased production and possibly diversity of aquatic invertebrates.

In addition to potential benefits of increased aquatic food base production, low steady flows on weekends may help to improve the quality of nearshore habitats for juvenile humpback chub two days per week. However, it is unclear whether two days per week of nearshore habitat stability would result in a measureable impact on juvenile growth, rearing, and recruitment. This treatment would be discontinued if there is no observed increase in invertebrate production that results in benefits to native fish or the trout fishery.

(3) Effects of Native and Nonnative Plant Management and Experimental Treatments

Sediment monitoring and research and efforts to manage riparian vegetation are not expected to have impacts on humpback chub individuals or habitat. Riparian vegetation management would occur in only small, localized areas within the project area and will not result in measurable direct or indirect effects to humpback chub or its habitat.

Effects of Conservation Measures

LTEMP includes ongoing and new conservation measures (see Description of the Proposed Action section above) that are designed to minimize or reduce the effects of the proposed action or benefit or improve the survival and recovery of humpback chub as part of the LTEMP. The intention of these conservation measures is to minimize or offset potential impacts to humpback chub and habitat that may result due to the implementation of the LTEMP. These conservation measures were developed in consultation with the FWS and biologists from Reclamation, NPS, and GCMRC.

Conservation measures include actions identified in the Humpback Chub Recovery Goals (USFWS 2002a), such as the control of nonnative species and investigating the effects of parasites. Those conservation measures, as well as others provided for in the proposed action, will assist in increasing the resiliency (sufficiently large populations for the species to withstand stochastic events), redundancy (sufficient number of populations for the species to withstand catastrophic events), and representation (the breadth of genetic makeup of the species to adapt to changing environmental conditions) of the humpback chub. Humpback chub resiliency will be maintained through protection of the Little Colorado River population and enhanced through the possible expansion of the Havasu Creek population (above Beaver Falls, if appropriate). The Little Colorado River continues to support a robust population of humpback chub, but Havasu Creek has the potential to provide for a second large population within the project area. The redundancy of chub populations will be increased through the establishment of or increasing existing chub populations outside of and within the mainstem Colorado River. As a result of the proposed action, translocations of chub will continue above Chute Falls in the Little Colorado River, within tributary habitat in the project area, and mainstem aggregations could be enhanced or expanded, as appropriate. Finally, the conservation measures will also increase humpback chub representation through the continued funding of the refuge population at SNARRC and implementation of the Humpback Chub Genetics Management Plan and Translocation Framework to guide all translocations. Management of the refuge and use of the best science in conducting translocations will ensure that the genetic diversity within and among chub populations is maintained and capable of adapting to environment changes over time.

Although some fatality of individual humpback chub may occur because of these studies, the information gained will be important for understanding population-level impacts on the species due to dam operations and experimental actions under the proposed action. The adaptive management structure of the LTEMP will allow for adjustments in management actions throughout the life of the LTEMP. Thus, negative effects on individuals would likely be offset by population-level benefits that may be expected if adjustments in operations are made as a result of these studies.

Summary

In summary, LTEMP would have both negative and positive effects to humpback chub and their habitat. The stranding of young chub could occur during HFEs, TMFs, and downramp rates, but longer-term beneficial impacts to older age classes may result from actions taken to reduce nonnative predators. Adverse effects to humpback chub habitat include direct, minor, short-term reductions in nearshore habitat that could occur near the Little Colorado River with changes in flow stage, but long-term benefits are expected from flows designed to rebuild and maintain nearshore and backwater nursery habitats. Although base operations would likely continue to degrade the food base, experimental flows are planned to aid in alleviating this impact and increasing the abundance of invertebrates, thus increasing the food base for chub. Continued predation from an expanded population of rainbow trout is expected under cold water discharge, especially with spring or multiple HFEs; the effect of fall HFEs on brown trout recruitment and potential population increases are still unknown. However, implementation of conservation measures, including translocations, nonnative control, triggered mechanical removal, and triggered proactive conservation actions, are designed to minimize and/or offset population level impacts to humpback chub. Implementation of the ongoing and new conservation measures listed in the proposed action will promote the survival and recovery of humpback chub by increasing the redundancy, representation, and resiliency of humpback chub. The proposed action includes continued protection and monitoring of the Little Colorado River chub population; funding and implementation of translocations of chub into tributaries of the Colorado River in Marble and Grand Canyons; managing against existing coldwater nonnatives, where appropriate (e.g., rainbow and brown trout); designing actions to address the future establishment of warmwater nonnative fish or the expansion of brown trout in the Lees Ferry Reach (e.g., modification of habitat at Upper Slough, the possible modification of timeframe for TMFs); and looking to address future climate change threats through exploration of the efficacy of a temperature control device and pursuing means of preventing the passage of invasive nonnative fish through the dam.

***Effects of the action on humpback chub critical habitat***

In our analysis of the effects of the action on critical habitat, we consider whether or not a proposed action would result in the destruction or adverse modification of critical habitat. In doing so, we must determine if the proposed action would result in effects that appreciably diminish the value of critical habitat for the recovery of a listed species. To determine this, we analyze whether the proposed action would adversely modify any of the PCEs that were the basis for determining the habitat to be critical. To determine if an action results in adverse modification of critical habitat, we must also evaluate the current condition of all designated CHUs, 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 CHUs in recovery must also be considered because, collectively, they represent the best available scientific information as to the recovery needs of the species.

Below, we describe the primary constituent elements or "PCEs" for humpback chub critical habitat that we are evaluating and then briefly describe the "effects" to these PCEs within Reach 6 (Little Colorado River) and Reach 7 (Colorado River from Marble through Grand Canyon) from implementation of LTEMP.

***Water Quality/Quantity PCE:*** This PCE calls for water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, turbidity, etc.) that is delivered in sufficient quantity to a specific location in accordance with a hydrologic regime that is required for the each of the life stages of humpback chub.

***Effect:*** Implementation of the proposed action would have limited effects to water quality and no effect to water quantity in Reach 6. Colder water may move into the lowest 0.25 mile of the Little Colorado River as a result of base operations or sediment-related experiments (e.g., HFE), but this would not result in biologically meaningful changes to water quality (i.e., temperature, dissolved oxygen, nutrients), and would not change the quantity of water in critical habitat Reach 6.

Implementation of the proposed action could result in both negative and beneficial effects to the Colorado River from Marble Canyon through Grand Canyon (critical habitat Reach 7). Overall, the beneficial effects will aid in promoting survival and recovery. The main factor resulting in adverse effects to water quality in Reach 7 is the maintenance of reduced water temperatures ($\leq$12°C) from base operations that can result in decreased growth of chub and increased time young chub are susceptible to predation from nonnative trout. In addition, the cooler water temperatures in the mainstem support habitat for nonnative brown and rainbow trout, which can compete with and prey upon humpback chub. However, the proposed action also includes low summer flow experiments that could, at least temporarily, provide warmer river temperatures to benefit humpback chub growth. As stated above, low summer flow experiments would not occur until the second 10 year period of LTEMP and may only occur one or two times. Therefore, the expected benefit to water temperature (and this PCE) is likely to be extremely limited. The experimental low steady weekend flows for macroinvertebrate production may also result in beneficial effects if the low and steady flows (water quantity change) improve invertebrate production and abundance in critical habitat Reach 7, resulting in an increased prey base for humpback chub, which could help to reduce the effects of reduced growth in cold water by increasing food production.

***Physical Area PCE:*** This PCE includes the physical areas of the Colorado River system that are inhabited by humpback chub or potentially habitable for use in spawning, nursery, feeding, or corridors between these areas. In addition to the main river channel, this includes 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.

***Effect:*** There would be insignificant effects to spawning, nursery, feeding, or corridor habitat within critical habitat Reach 6 from base operations and experimental flow treatments because these actions would result in little change to the physical environment within the Little Colorado River. Implementation of the proposed action could result in short-term beneficial changes to the confluence area (i.e., increased water temperature from low summer flows, reduction in nonnative fishes from TMF or other actions), but would not likely modify the existing habitat condition for chub at the mouth of the Little Colorado River or within most of the 8-mile reach of critical habitat. The proposed action is designed to maintain (e.g., manage nonnative fishes) or enhance (e.g., warm the temperature) habitat within the Little Colorado River spawning aggregation and effects from the proposed action to this PCE should be beneficial. Aquatic resource-related experimental treatments (e.g., TMF, low summer flows, low steady weekend flows for macroinvertebrate production) and conservation measures (e.g., removal of nonnative fishes, etc.) would aid in maintaining and protecting the area used by spawning and feeding chub in this area.

In critical habitat Reach 7, the physical habitat for spawning, nursery habitat, feeding areas, and movement corridors of humpback chub critical habitat could be affected both negatively and positively by the proposed action. Currently the baseline condition of these habitats in Reach 7 is providing for the physical areas necessary to support humpback chub from the Little Colorado River confluence downstream to the inflow area at Lake Mead (see Environmental Baseline section above). There are spawning, nursery, and feeding locations in Marble Canyon (a group of adult chub likely consisting of between 300-600 individuals has been found near RM 34) and Grand Canyon (there appears to have been a dramatic increase in the absolute abundances of humpback chub in western Grand Canyon - roughly Havasu Creek downriver - with all size classes being represented). It is clear that ongoing management (flow actions that build backwaters and potential nursery habitat) and conservation actions (such as the chub translocations to Shinumo and Havasu) have assisted in improving the functionality of this PCE. The proposed action would build on this momentum with implementation of sediment-related flows that would continue to aid in building and maintaining these habitats over time. However, there may also be adverse effects to spawning and nursery habitats, or feeding areas. Adverse effects, such as degradation of nearshore habitats potentially used by juvenile humpback chub, could occur as a result of hydropeaking during base operations. Sediment-related flow actions could also increase rainbow trout emigration to the Little Colorado River reach. This may increase predation or competition effects, alter the food base, or increase the risk of establishment of warmwater nonnative fish. However, long-term benefits are expected from the implementation of sediment-related flows (e.g., HFEs) designed to rebuild and maintain nearshore and backwater nursery habitats. These backwater habitats may be important to native fish growth in the summer as they tend to have warmer water temperatures, which can provide for increased physical growth of young fish.

In addition, the proposed action includes sustained low flows for benthic invertebrate production that may improve feeding areas for humpback chub and other fish species by providing additional aquatic insect prey. As stated above, Kennedy et al. (2016) demonstrated that hydropeaking flows in rivers below hydroelectric facilities may prevent the maintenance of viable populations of many aquatic invertebrates that constitute important components of the food base for humpback chub. This experiment may allow some shoreline egg-laying invertebrates to avoid desiccation that results in egg mortality (Kennedy et al. 2016), and potentially would allow for increased production and possibly diversity of aquatic invertebrates. Furthermore, low steady flows on weekends may help to temporarily improve the quality of nearshore habitats for juvenile humpback chub.

The entirety of Reach 7 allows for movement of humpback chub (Valdez and Ryel 1995, Paukert et al. 2006) and we would not expect the proposed action to modify this PCE. However, the presence of nonnative predators may influence the chub’s ability to move into habitats within the action area. The implementation of TMFs and Triggered Conservation Actions to negatively influence trout recruitment in the action area would benefit this PCE component if trout numbers decline over time as a result of these actions. In addition, conservation measures designed to reduce or remove nonnative fish from tributaries (e.g., Bright Angel Creek trout removal) and remove or modify habitats conducive to warmwater nonnative recruitment in Glen Canyon (i.e., Upper Slough) would also assist in improving the ability of humpback chub to move throughout critical habitat Reach 7.

***Biological Environment PCE:*** This PCE includes important elements of the biological environment, food supply, predation, and competition. Food supply is a function of nutrient supply, productivity, and availability to each life stage of the species. Predation and competition (i.e., for food and/or habitat resources) are considered normal components of this environment; but, are likely not at “natural” levels due to the presence of introduced, nonnative fish (e.g., brown and rainbow trout) within the action area.

***Effect:*** The food supply for humpback chub in critical habitat Reach 6 (Little Colorado River) is unlikely to be affected by the proposed action. Reach 6 is the Little Colorado River, and although actions in the mainstem can affect the confluence and a short distance upstream of the confluence, this critical habitat reach’s ability to provide invertebrates for chub to eat is unlikely to be affected by the proposed action, as critical habitat extends eight miles upstream of the confluence and neither base operations nor flow actions affect enough area upstream of the confluence to negatively affect the food supply within the Little Colorado River.

Predation and competition within the lower sections of the Little Colorado River could be influenced by increases in rainbow trout or other nonnative fish at the confluence. If these nonnative fish were to increase in abundance in the mainstem, they could predate upon and compete with humpback chub associated with the aggregation at the confluence. However, the proposed action includes continued monitoring of the Little Colorado River aggregation and the humpback chub within the Little Colorado River. Therefore, any potential increases in trout or other nonnative fish in these areas would trigger the appropriate conservation measures to benefit chub and disadvantage trout (i.e., TMF, mechanical removal, etc.).

Food supply within critical habitat Reach 7 would likely continue to be reduced during base operations due to decreased invertebrate production resulting from desiccation of eggs along the shoreline as the water levels change. However, food supply may be positively impacted by low summer flows (if they occur) and low steady weekend flows that are being implemented specifically to improve habitat and survival of invertebrates and increase the food supply for humpback chub.

The FEIS and BA state that sediment-related experiments in critical habitat Reach 7 (i.e., HFEs) have the potential to negatively affect humpback chub by increasing rainbow trout emigration to the Little Colorado River reach. An increase in rainbow trout, or other predatory nonnative fish, may increase predation or competition effects, alter the food base, or increase the risk of establishment of warmwater nonnative fish. However, the proposed action states that these negative impacts would be offset by Triggered Conservation actions (e.g., TMF) to disadvantage recruitment or mechanical removal of nonnative fish (trout or warmwater nonnative fish) and intended to reduce competition and predation; the development of a rapid response protocol to address nonnative species encroachment or their potential to move into critical habitat; and, warmwater species' habitat modification (e.g., addressing potential of the Upper Slough to provide habitat for green sunfish). Furthermore, as stated above, HFEs are intended to create beaches and backwaters, which may provide warmwater rearing habitat for juvenile humpback chub.

Over the 20-year life of LTEMP, uncontrolled warm water releases may occur as a result of the elevation and subsequent water temperature of withdrawals from Lake Powell. Although increased temperatures may benefit humpback chub spawning and growth, warmer water may also allow for warmwater nonnative species to colonize or expand within critical habitat. Warming water could benefit many nonnative fish species that compete with or prey upon native aquatic species as warmer temperatures may provide suitable conditions for these nonnative fish (e.g., smallmouth bass, green sunfish) to spawn, incubate, and grow in the action area. Conservation actions to remove nonnative fishes from tributaries, and efforts to address nonnative fishes higher in the watershed, are included to address the potential for warmwater nonnatives to establish within critical habitat. In addition, because the establishment of warmwater nonnative fishes could be a factor in humpback chub recovery within critical habitat, as a part of LTEMP Reclamation has committed to exploring new technologies for controlling the temperature of water discharged into the Colorado River and technologies to prevent the passage of fish through the dam in order to attempt to reduce the potential for warmwater nonnative fish species to establish in the action area.

*Effects of the action on the role of critical habitat in recovery of the species*

Adverse effects and associated incidental take from implementation of the LTEMP are not expected to negatively affect humpback chub recovery or further diminish the conservation contribution of critical habitat to the recovery of the humpback chub because the LTEMP includes actions, conservation measures, and actions designed to adaptively modify the proposed action to conserve the humpback chub and its habitat. These actions and measures were identified by the FWS, project proponents, and partners as being necessary to conserve and recover the humpback chub. The LTEMP would implement these actions in designated critical habitat. These actions include the following:

- The LTEMP is designed to aid in meeting humpback chub recovery goals, including maintaining a self-sustaining population, spawning habitat, and aggregations in the Colorado River and its tributaries below the Glen Canyon Dam. Ongoing population status monitoring for humpback chub would continue, which would provide data for evaluating the effects of LTEMP actions and the status and trend of the humpback chub (e.g., monitoring demographic and vital parameters that are defined in the recovery goals). Full implementation of LTEMP, including the conservation measures, is expected to benefit the species and its critical habitat.

- The proposed action identifies condition-dependent flow and non-flow treatments intended to safeguard against unforeseen adverse changes to humpback chub and their habitat, and to prevent irreversible changes to those resources. Specifically, monitoring conducted in response to all experimental actions in conjunction with ongoing monitoring of humpback chub, will allow for detection of deleterious effects to chub that would result in changes to how the proposed action is implemented (adaptive management). In addition, the aquatic resource related experimental treatments are designed almost entirely to benefit humpback chub.

- The proposed action includes ongoing and new conservation measures that are designed to minimize or reduce the effects of the proposed action or benefit or improve the status of humpback chub as part of the LTEMP.

Over the long-term, these actions should increase the sustainability and resiliency of humpback chub critical habitat (particularly through implementation of the conservation measures). Therefore, implementation of the LTEMP is not expected to further diminish the conservation contribution of critical habitat to the recovery of the humpback chub.

**Razorback sucker and critical habitat**

There are several aspects of the proposed action that may affect razorback suckers through direct impacts to individuals or habitat or by indirectly influencing the abundance and distribution of nonnative fish (that prey upon or compete with suckers), or by influencing macroinvertebrate production (food base). Dam operations have the potential to influence flow, water temperatures, the quantity and quality of nearshore rearing habitats (e.g., backwaters), aquatic insects (food base), and nonnative species presence and abundance. These operations may also result in direct fatality to juvenile native fish through stranding. Other non-flow actions that may have direct and indirect effects to razorback sucker include conservation measures (including actions in Appendix D of the BA, mechanical removal of nonnative fish, etc.) and continued fisheries research and monitoring under the GCDAMP. However, unlike the humpback chub, which occurs relatively frequently throughout the action area, the razorback sucker is relatively rare within the action area and effects to larval fish would only occur in western Grand Canyon (or approximately the lower 100 river miles of the action area).

Effects of Base Operations and Operational Flexibility

As described above, base dam operations would change with the implementation of the proposed action. The distribution of monthly release volumes under the proposed action results in a more even distribution of flows over the course of a water year relative to existing, or baseline, flows. The daily fluctuation in discharge would be proportional to the reservoir volume (i.e., lower fluctuations during lower flows), with a maximum discharge fluctuation range of 8,000 cubic feet/second, which would be the same as the current maximum fluctuation range that has been in place since 1996 (Reclamation 1996). The daily downramp rate would be increased, compared to the current condition, by 67% (from 1,500 cfs/hr to 2,500 cfs/hr). Therefore, it is anticipated that year-round, fluctuating flows over the 20-year life of LTEMP may have adverse effects on razorback suckers through stranding of larval fish, damaging nearshore rearing habitats, degrading aquatic invertebrate prey production, and maintaining cold water temperatures.

The stranding of larval razorbacks sucker is a potential outcome of daily hydropeaking (Bunn and Arthington 2002, Nagrodski et al. 2012), should larval fish be present in nearshore habitats. Increasing downramp rates under the proposed action may increase the risk of stranding larval razorback sucker, depending upon the level of stage changes that occurs during base operations, how that flow attenuates downstream, and the steepness of shallow nearshore areas. Thus far, juvenile (older than larval) life stages of razorback sucker have not been sampled in two years of study in the Grand Canyon since razorbacks were rediscovered in Grand Canyon (Albrecht et al. 2014, Kegerries et al. 2015). It is unclear whether larval razorback sucker experience near 100% mortality prior to transformation to juveniles from unknown causes (unlikely related to Glen Canyon dam operations), or if sucker larvae drift to Lake Mead and rear in the lake. However, to date, surveys have not detected razorback sucker recruitment in the action area. Thus, potential stranding effects would likely only affect larval age classes of suckers, not juvenile fish.

If stranding occurs where larval suckers are present, it could include fish being temporarily (i.e., until flows came back up hours later) restricted to isolated habitats away from the main channel, which may or may not become desiccated, as a result of dropping water levels. Desiccation of these isolated habitats would result in fatality of any larval fish (razorback sucker or other species) present. Larval razorback suckers, like other larval fish, have limited swimming ability, and thus are at high risk of stranding. Increasing drawdown rates under the preferred alternative would likely increase the risk of fatality to larval fish in these areas; however, how much of an effect this would be to the razorback sucker population is unknown since there is little information regarding their abundance. Larval sampling in the lower Grand Canyon found razorback sucker larvae to be distributed throughout most shoreline habitats from Lava Falls approximately (RM 179) to Pearce Ferry (RM 280) from May to July. The highest densities of larvae were found in isolated pools, which composed less than 2% of all habitats sampled. These pools have a high likelihood of desiccation with daily flow fluctuations; however, survival rates among different habitats have not been studied. The potential for, and the effect of stranding on, individual razorback sucker survival has not been directly investigated; however, as indicated in the humpback chub effects section, fish stranding as a result of hydroelectric and irrigation projects is well documented (Nagrodski et al. 2012).

Daily fluctuating flows under base operations would also likely continue to degrade nearshore habitats, particularly cobble shoals, riffles, and backwaters in wider sections of the canyon, and where low-angle shorelines susceptible to flow fluctuations are prevalent. For example, cobble riffles and shoals, which are important spawning areas for razorback suckers and invertebrate production areas, would be dewatered daily. Razorback suckers spawn on cobble bars and other gravel substrates near or associated with riffles. Riffles and spawning bars may occur in wider, shallower areas of the channel. Therefore, eggs deposited in these habitats are susceptible to being buried in sediment or washed away due to flow fluctuations. Continued daily flow fluctuations, combined with increased downramp rates, would likely increase the risk of desiccation of spawning areas and incubating razorback sucker eggs, leading to increased mortality rates of eggs. Adult razorbacks can swim off of bars as flows decline, and therefore are not likely to be stranded. Generally, based on catch rates, few larval and small-bodied juvenile native fish have been observed on cobble shoals and riffles below Lava Falls (Albrecht et al. 2014, Kegerries et al. 2015).

Under base operations, river temperatures are expected to continue to be more suitable for coldwater nonnative species than for warmwater nonnative fish, particularly closer to the dam. In general, the estimated average main channel temperatures modeled for the LTEMP EIS indicated that temperature conditions would be most suitable for warmwater nonnative species, as well as native fish such as razorback sucker at locations farther downstream from Glen Canyon Dam (e.g., RM 157 and RM 225) compared to upstream locations (e.g., RM 0 and RM 61), where temperatures would be more suitable to coldwater nonnative fish (e.g., brown and rainbow trout). Razorback sucker are distributed within the project area, from the Colorado River inflow of Lake Mead (~RM 289) and upstream at least as far as an area above Lava Falls (~RM 173) in Grand Canyon. The actual upstream distribution of razorback sucker is unknown. Warm temperatures may be even more critical for larval razorback suckers than other native suckers to transform into juveniles (Bestgen 2008). Therefore, continued cold temperatures under base operations during the LTEMP implementation period should negatively impact razorback suckers and their habitat in the upper 200 miles of the project area. However, razorback suckers have recently been detected in lower Grand Canyon following many years of existing dam operations. Therefore, predicting at this time what the true effects of base operations would be on suckers in the lower 100 river miles of the action area is difficult. Experimental stable flows (steady flows to increase macroinvertebrate production) may provide some benefit to offset these potential impacts through increased prey abundance.

As stated above, hydropeaking has been demonstrated to have long-term detrimental impacts on aquatic invertebrates (the chub food base) below hydroelectric dams (Kennedy et al. 2016). The continued hydropeaking under LTEMP, along with the existing altered temperature and flow regime, would continue to result in decreased invertebrate production, hence a reduced prey production of insect larvae for razorback suckers, over the life of the LTEMP. Implementation of the low steady weekend flows for the macroinvertebrate production experiment may improve this situation over time in the mainstem river corridor, but until this flow experiment is executed and monitored, the effect of this action, particularly in the lower third of the action area where suckers occur, is unknown.

In summary, under base operations and coldwater conditions, continued hydropeaking flows with increased downramp rates compared to the existing conditions would increase the risk of stranding larval fish, continue to degrade nearshore rearing habitats, and prevent the establishment of aquatic insect larvae (food base). Because we do not know the abundance or distribution of larval razorback sucker, it is difficult to assess how base operations and flow actions would actually affect razorback sucker persistence in lower Grand Canyon, where effects are likely somewhat different than in Glen and upper Grand Canyons. In order to address this issue, LTEMP includes a conservation measure to continue funding larval and small-bodied fish monitoring in lower Grand Canyon in order to determine habitat use and distribution of different life stages of razorback sucker and to determine the extent of hybridization in flannelmouth and razorback sucker larvae through genetic analysis to assist in future management of flows in order to conserve the species. This information would assist Reclamation in identifying sensitive habitats to flow fluctuations to prioritize for monitoring. In addition, Reclamation would also use this survey data to assess the effects of base operations on razorback suckers. Therefore, even though there is potential for daily fluctuating flows to adversely affect razorback sucker spawning habitat, these negative effects would be lessened by conservation measures that would be taken as part of the LTEMP.

Effects of Experimental Actions

Experimental actions are grouped under three categories: (1) Sediment-Related Experimental Treatments; (2) Aquatic Resource-Related Experimental Treatments; and, (3) Native and Non-native Plant Management and Experimental Actions. The anticipated effects of these experimental treatments are described below.

An adaptive management approach is being taken to implement all experimental elements of the LTEMP. Prior to the implementation of any experiment, potential impacts would be considered by the DOI, including the FWS, GCMRC and other DOI subject experts. This would help to identify and minimize the potential for adverse effects to razorback suckers as a result of the implementation of an experimental treatment. The following section summarizes the expected or hypothesized effect of the experimental elements on razorback suckers. However, just as with the humpback chub, we acknowledge that monitoring and research following these experiments would provide more information regarding effects to suckers as the LTEMP is implemented. This is particularly true of the razorback sucker due to the fact that we have very few adult fish detections and have limited knowledge regarding larval fish persistence within western Grand Canyon.

(1) Effects of Sediment-Related Experimental Treatments

Experimental flows under the proposed action include: sediment-triggered spring and fall HFEs through the entire 20 year LTEMP period; 24-hr proactive spring HFEs in high volume years (≥10 maf release volume); and, extension of the duration of fall HFEs up to 45,000 cfs for as many as 250 hr depending on sediment availability.

Larval fishes in rivers generally rely on low-velocity nearshore environments for rearing. Backwaters potentially created by both HFEs and low summer flows are one such nearshore habitat frequently used by native fishes in the Grand Canyon, and these habitats and their use by native fishes, including razorback suckers, have been a major focus of research (Albrecht et al. 2014). These backwaters, although short lived, may provide ideal rearing conditions for native fishes because water temperatures are often much greater than in the mainstem, particularly when flows are steady.

Due to the fact that HFEs create and maintain backwater habitats important to larval razorback sucker, these HFE experiments would be expected to benefit razorback sucker through creation and maintenance of these habitats. Spring HFEs may be particularly beneficial to razorback suckers if these sediment-related flows create backwater habitat during a time period that coincides with spawning and emergence of larval fish. However, since February-March is the peak of spawning for suckers in western Grand Canyon (Kegerries et al 2015), spring HFEs (March or April) could have adverse impacts on spawning suckers and their habitats. While spring HFEs may mimic the general timing of a natural hydrograph, which historically may have facilitated the transport of larval fish into suitable backwater habitats for rearing (Valdez et al. 2012), in the current altered temperature and sediment regime, the same benefit may not be expected. The degree of adverse impacts to spawning razorback suckers may depend on the timing of a proposed HFE and spawning in a given year.

The magnitude of floods on wide rivers decreases downstream if a substantial amount of the floodwaters temporarily occupies the flood plain. However, the magnitude of a flood can increase downstream if there are large inflows from tributaries. In narrow-bottomed canyons, such as Grand Canyon, flood attenuation caused by overbank flooding is small, and the primary downstream changes in flood magnitude occur when a high flow coincides with tributary inflows. During the 1996 HFE, tributary inflow was minimal, and flow of the Colorado River at Diamond Creek (RM 226) downstream from the dam, exceeded the release at the dam by about 500 cfs, which was only a one percent increase in flood magnitude. In contrast, substantially more tributary inflow was measured in 2004 and in 2008, and discharge at Diamond Creek exceeded the magnitude of the dam release by about five percent (Schmidt and Grams 2011). Therefore, the effects to larval razorback sucker from HFEs since they currently occur at the western edge of the project area is likely dependent upon the amount of water released in the HFE, any tributary flooding that may also be occurring, and width of the canyon where fish are present.

(2) Effects of Aquatic Resource-Related Experimental Treatments

*Effects of Triggered Conservation Actions and Mechanical Removal of Nonnative Fish Experiments*

As stated above in the humpback chub Effects section, Young et al. (2015, Appendix D of the BA) developed a tiered, triggered approach to address mechanical removal of nonnative fish. The purpose of this document is to minimize the need for mechanical predator removal through early implementation of humpback chub conservation measures. The tiered, triggered approach identifies two tiers of sequential actions, which are described above. The focus of these actions is on the Little Colorado River humpback chub aggregation. Razorback sucker have not been sampled near the Little Colorado River inflow since the 1980s or early 1990s. In general, removal of nonnative fish would benefit razorback sucker because removing nonnative fishes from any portion of the action area means that there are fewer fish to compete with or predate upon razorback suckers in western Grand Canyon. However, this action would likely have limited beneficial effects to the razorback sucker because the emphasis on nonnative removal is not where suckers have been detected and predominately (at this time) deals with rainbow and brown trout that occur much higher in the action area than where suckers are present. Warmer and more turbid waters characterize the lower (western) Grand Canyon. The farthest upstream locations where larval razorback sucker were detected is about RM 179 (Albrecht et al. 2014). These locations are less suitable for trout due to temperature and turbidity, so removal of nonnative trout near the Little Colorado River, which is approximately 117 river miles from this most upstream location of larval suckers, would likely have negligible impacts on razorback sucker. Similarly, Tier 1 conservation actions developed to conserve humpback chub, including actions to enhance rearing and translocations, would likely have no effect to razorback sucker because these actions would occur within the Little Colorado River and its inflow.

*Effects of Trout Management Flows*

TMFs are a special type of fluctuating flow designed to reduce the recruitment of rainbow trout by disadvantaging YOY trout. The purpose of trout management activities is to enhance the survival of the endangered humpback chub by reducing the numbers of trout in the river.

The potential for TMFs to strand and cause fatality to razorback sucker could increase under the proposed action. However, it is unclear based on what we currently know of razorback sucker distribution, what the magnitude of effect from TMFs on nearshore habitats and potential stranding of larval razorback suckers in western Grand Canyon would be. TMFs could be implemented from May through August, which would overlap with the presence of larval razorback sucker in rearing habitat. Given that razorback sucker spawning was documented for the first time in the action area in 2014 (and continued in 2015) potential impacts from the proposed action on the species are particularly difficult to predict because prior to the last two years, there was no indication razorback suckers were present in the action area. In addition, it is unclear how attenuation of flows would affect backwaters at the lower end of the action area between approximately RM 179 and RM 279 (at the inflow to Lake Mead) where larval razorback sucker are currently known to occur. However, in both 2014 and 2015, catch-per-unit-effort of razorback sucker larvae was higher in isolated pools and/or backwaters (Albrecht et al. 2014, Kegerries et al. 2015), which could mean that larval razorback sucker may be particularly sensitive to the drastic and rapid fluctuations associated with TMFs due to its dependence upon low-velocity backwater habitats.

In addition, although the location or habitat preference for spawning adult razorback suckers has not been identified or defined in the Grand Canyon, the species is known to spawn on clean cobble bars in other systems (USFWS 2002b). Valdez et al. (2012b) identified potential spawning bars in the Grand Canyon at tributary inflows and canyon mouths including Diamond Creek (RM 226), Spencer Canyon (RM 246), and Surprise Canyon (RM 248.3). These and other shallow cobble bars that provide habitat for spawning and egg incubation may be sensitive to flow variation. Large fluctuations during the spawning period (February or March to July; Kegerries et al. 2015) associated with TMFs implemented between May and August may impact spawning and incubation habitat by dewatering.

In summary, TMFs could have negative impacts on larval razorback sucker and rearing habitats that would continue to occur for the duration of the action. The risk to larval razorback sucker would likely vary by location depending upon the level of stage changes experienced and the steepness of shallow nearshore areas. Monitoring of the impacts of TMFs throughout GCNP, particularly in the western Grand Canyon where larval razorback suckers are present, would be implemented to assess the effectiveness of the action, as well as the potential for detrimental effects to razorback sucker and other native fishes.

*Effects of Low Summer Flow Experiments*

Low summer flow experiments involve holding flows low (approximately 8,000 cfs) and relatively steady, compared to base operations during warm summer months. The goal of this flow experiment is to temporarily achieve warmer river temperatures to benefit humpback chub. A secondary benefit that may occur is increased stability in shoreline habitats (due to the steady flow), which could also improve potential rearing habitat for razorback suckers.

Few studies have investigated the use of backwaters or other shoreline habitats that may be important to razorback sucker rearing in the western Grand Canyon, where water temperatures are more suitable (warmer) for native fish rearing than closer to Glen Canyon Dam. Shoreline habitats have the potential to provide warmer rearing habitat than the mainstem under certain conditions (Grams et al. 2010, Trammell et al. 2002). Given razorback suckers' need for warm, productive floodplain or backwater habitats for rearing larval fishes, and the lack or low abundance of nonnative fish found in recent backwater sampling where razorback suckers were found (Albrecht et al. 2014, Kegerries et al. 2015), reduced fluctuations, lower flows, or low summer flows may be beneficial for razorback sucker by providing warm and persistent backwater habitats. During the 2000 Low Steady Summer Flow experiment, which included steady flows of 8,000 cfs from June through September 2000, mainstem temperatures were 1.4–3°C higher than under previous dam operations, and backwaters were 0.3–5.3°C warmer (Trammell et al. 2002). Similarly, NPS sampling of 47 backwaters located between RM 115 and RM 220 under steady flows in September 2009 showed that at least 21 backwaters were at least 2°C warmer than the adjacent mainstem (Speas and Trammell 2009). The longer residence time of water in nearshore and backwater habitats with steady flows results in warmer temperatures than in the mainstem (Behn et al. 2010), which may provide suitable rearing habitat for larval razorback sucker.

Low summer flows included under the proposed action as an experiment after the first 10 years of the LTEMP period would likely increase warming and overall stability in these nearshore habitats, thereby benefitting razorback sucker in Grand Canyon. Implementation of the experiment may occur only under rare conditions, so the potential for this action to be implemented is unlikely. However, due to the positive effect on habitat low summer flows may have on the creation, maintenance, and warming of backwater habitats important to larval razorback sucker, these experiments would likely benefit razorback sucker.

*Effects of Low Steady Weekend Flows for Macroinvertebrate Production Experiments*

Experimental low steady flows are steady flows that would be provided every weekend from May through August (34 days total) to test the hypothesis that daily flow fluctuations to meet hydropower demand negatively affect habitat quality along the shorelines to improve the invertebrate assemblage within the action area.

In addition to potential benefits of increased aquatic food base production (Kennedy et al. 2016), steady flows on weekends may help improve the quality of nearshore habitats for larval razorback sucker. We do not know whether two days per week of nearshore habitat stability would result in a measureable impact on larval growth, rearing, and recruitment. However, under current operations it does not appear that razorback sucker are successfully recruiting from the larval to juvenile life stages, possibly due to cooler water temperatures and lack of stable rearing habitats. Because larval razorback sucker need stable, low-velocity, warm, productive habitats for rearing, a beneficial effect to suckers is expected under this experiment (combined with HFEs to build bars and backwaters).

(3) Effects of Native and Nonnative Plant Management and Experimental Treatments

Sediment monitoring and research and efforts to manage riparian vegetation are not expected to have impacts on humpback chub individuals or habitat. Riparian vegetation management would occur in only small, localized areas within the project area and will not result in measurable direct or indirect effects to humpback chub or its habitat.

Effects of Conservation Measures

LTEMP includes ongoing and new conservation measures (see Description of the Proposed Action section above) that are designed to minimize or reduce the effects of the proposed action or benefit or improve the status of listed species, including razorback suckers, as part of the LTEMP. These conservation measures were developed in consultation with the FWS and biologists from Reclamation, NPS, and GCMRC. As stated above, razorback suckers have only recently reoccupied the project area and the most urgent need is for increased knowledge regarding how suckers are using habitats in the project area, spatially and temporally; and, the response of the species to base operations and experimental flow actions under the proposed action.

As a part of LTEMP, Reclamation would continue to fund ongoing studies designed to understand the status of the razorback sucker population in the Grand Canyon and Lake Mead. Specifically, these conservation measures include: (a) studies to determine the extent of hybridization in flannelmouth and razorback sucker larvae collected; (b) studies to determine habitat use and distribution of different life stages of razorback sucker to assist in future management of flows that may help to conserve the species (including identification of habitats sensitive to flow fluctuations); and, (c) studies to assess the effects of TMFs and other dam operations on the species. These studies will aid in our ability to better incorporate sucker needs into the proposed action over time. In addition, razorback sucker will benefit from all conservation measures in the proposed action designed to reduce both cold- and warmwater nonnatives.

Although some fatality of individual razorback sucker may occur as a result of these studies, including fatality of larval fish, as has occurred in 2014 and 2015 related to larval studies (Albrecht et al. 2014, Kegerries et al. 2015), the information gained would be important for understanding population-level impacts on the species due to dam operations and experimental actions under the proposed action. The adaptive management structure of the LTEMP would allow for adjustments in management actions throughout the life of the LTEMP. Thus, negative effects on individuals would likely be offset by population-level benefits that may be expected if adjustments in operations are made as a result of these studies.

Summary

In summary, there is the potential (depending upon timing, flow attenuation, water temperature, and other factors) for the short-term dewatering of spawning areas and stranding of larval and young-of-year razorback sucker in nearshore habitats as a result of base operations (daily fluctuating flows, including increased downramp rates). Spring HFEs should they occur in March, which overlaps with the peak of spawning activities (Kegerries et al. 2015), may also result in the scouring of spawning habitat. However, spring and fall HFEs may also result in the creation of warm, productive nursery backwater habitats for razorback suckers. Although base operations would likely continue to degrade the food base, low summer flows and low steady weekend flows may alleviate these negative effects and improve the quality of nearshore habitats for larval razorback suckers and increase the food base for all fish.

***Effects of the action on razorback sucker critical habitat***

In our analysis of the effects of the action on critical habitat, we consider whether or not a proposed action would result in the destruction or adverse modification of critical habitat. In doing so, we must determine if the proposed action would result in effects that appreciably diminish the value of critical habitat for the recovery of a listed species. To determine this, we analyze whether the proposed action would adversely modify any of the PCEs that were the basis for determining the habitat to be critical. To determine if an action results in adverse modification of critical habitat, we must also evaluate the current condition of all designated CHUs, 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 CHUs in recovery must also be considered because, collectively, they represent the best available scientific information as to the recovery needs of the species.

Below, we describe the PCEs for razorback sucker critical habitat and briefly describe the effects to these PCEs within the critical habitat that includes the Colorado River from where the Paria River joins the Colorado down to Lake Mead from implementation of LTEMP. Many of the potential effects described are more thoroughly summarized above. Razorback suckers have always been rare in the action area, and although we have recent records of adult fish and spawning occurring in the lower portion of the action area (~ lower 100 river miles), the ability of the Glen and Grand Canyon reaches of the Colorado River (~ upper 200 river miles) to fully provide the PCEs is uncertain due to the greater influence of Glen Canyon dam operations in Glen and upper Grand Canyon.

***Water Quality/Quantity PCE:*** This PCE calls for water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, turbidity, etc.) that is delivered in sufficient quantity to a specific location in accordance with a hydrologic regime that is required for the each of the life stages of razorback sucker.

***Effect:*** The water temperature in the upper portion of the this critical habitat unit (from Paria Canyon down to the upper portion of Grand Canyon) would likely remain too cold to provide the water quality needed to support razorback suckers. The main factor resulting in adverse effects to water quality here is reduced water temperatures (≤12°C) from base operations that would likely continue to result in suckers not using the Colorado River from Paria Canyon (RM 0.9) down to approximately Lava Falls (known upstream extent of razorback suckers in the action area, ~RM 173). The proposed action also includes low summer flow experiments that could, at least temporarily, provide somewhat warmer river temperatures at the Little Colorado River and downstream. As stated above, low summer flow experiments would not occur until the second 10 year period of LTEMP and may only occur one or two times. Therefore, the expected benefit to water temperature (and this PCE) is likely to be extremely limited. The experimental low steady weekend flows for macroinvertebrate production may also result in beneficial effects if the low and steady flows (water quantity change) improve invertebrate production and abundance in critical habitat, potentially resulting in an increased invertebrate prey base.

Implementation of the proposed action would result in discountable effects to water quantity (overall), but may temporally and spatially affect the presence of habitat as flows increase and decrease to provide power (i.e., hydropeaking) or improve habitat (e.g., low summer flows, low steady weekend flows for macroinvertebrates). Low summer flow experiments (including low steady weekend flow experiments) would, at least temporarily, provide potentially warmer river temperatures that could benefit habitat for both adult and larval razorback suckers by providing warmer water temperatures for growth of larvae and spawning of adult fish. However, low summer flow experiments would not occur until the second 10 year period of LTEMP and may only occur one or two times. Therefore, the expected benefit to water temperature (and this PCE) is likely to be extremely limited.

***Physical Area PCE:*** This PCE includes the physical areas of the Colorado River system that are inhabited by razorback sucker or potentially habitable for use in spawning, nursery, feeding, or corridors between these areas. In addition to the main river channel, this includes 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.

***Effect:*** The physical habitat for spawning, nursery habitat, feeding areas, and movement corridors of razorback sucker critical habitat could be affected both negatively and positively by the proposed action. Adverse effects from hydropeaking include continued degradations of nearshore habitats and backwaters used by larval razorback sucker. Potential positive effects could occur from HFEs that create and/or build up backwater habitats.

Razorback sucker spawning areas below Lava Falls could be affected by HFEs, particularly in the spring when razorbacks are spawning (February to late March; Kegerries et al. 2015). The increased amount of water moving from the river to the lake would raise water levels at the Lake Mead inflow and possibly increase turbidity through additional sedimentation once the water slows down in the upper lake. This could potentially encourage spawning if this occurred at the right time of year (i.e., in March). In addition, if suckers have already spawned, sediment deposition that occurred during egg incubation could result in damage or fatality to the eggs if the eggs were buried in sediment. However, because incubation time for razorback sucker eggs occurs over approximately seven days, the effects of a spring HFE conducted later in April could have less of an impact. Larval razorback sucker may also be displaced from nursery areas and moved into unsuitable habitats as the water deepens with passage of the HFE. The actual impacts likely depend upon the timing of spawning, water temperature, and other factors (e.g., weather conditions) in any individual year. Our knowledge of the razorback sucker population is limited, and factors controlling reproduction and the lack of recruitment in the action area is unknown, which makes it difficult to predict what effects would occur from implementation of flow actions, other than the potential stranding of larval suckers in nearshore habitats.

In addition, the proposed action includes sustained low flows for benthic invertebrate production that may improve feeding areas for humpback chub and other fish species by providing additional aquatic insect prey. As stated above, Kennedy et al. (2016) demonstrated that hydropeaking flows in rivers below hydroelectric facilities may prevent the maintenance of viable populations of many aquatic invertebrates that constitute important components of the fish food base. This experiment may allow some shoreline egg-laying invertebrates to avoid desiccation that results in egg mortality (Kennedy et al. 2016), and potentially would allow for increased production and possibly diversity of aquatic invertebrates. Furthermore, low steady flows on weekends may help to temporarily improve the quality of nearshore habitats for larval razorback suckers.

Based upon the locations of adult razorback suckers upstream of Lava Falls, it would appear that movement of fish, at least in western Grand Canyon, is not impeded by existing management of Glen Canyon dam, but is it unclear how sediment-related or aquatic species flow actions would modify or enhance movement of suckers from Lake Mead, upstream to Lava Falls.

***Biological Environment PCE:*** This PCE includes important elements of the biological environment, food supply, predation, and competition. Food supply is a function of nutrient supply, productivity, and availability to each life stage of the species. Predation and competition (i.e., for food and/or habitat resources) are considered normal components of this environment, but are likely not at "natural" levels due to the presence of introduced, nonnative fish (e.g., brown and rainbow trout) within the action area.

***Effect:*** The food supply for razorback sucker could be negatively and positively affected by the proposed action. Although base operations would continue to result in decreased invertebrate production, hence a reduced food base for razorback suckers, food supply may be positively impacted by low summer flows (if they occur) and low steady weekend flows that are attempting to improve habitat and survival of invertebrates. Because our knowledge of razorback suckers in the project area is still developing, it is difficult to determine exactly how these actions would affect the fish. However, if the proposed action is successful, the proposed action will ultimately aid in promoting the survival and recovery of razorback suckers through increased food production.

Over the 20-year life of LTEMP, uncontrolled warm water releases may occur as a result of the elevation and subsequent water temperature of withdrawals from Lake Powell. Although increased temperatures may benefit razorback sucker spawning and growth, warmer water may also allow for warmwater nonnative species to colonize or expand within critical habitat. Warming water could benefit many nonnative fish species that compete with or prey upon suckers as warmer temperatures may provide suitable conditions for these nonnative fish (e.g., smallmouth bass, green sunfish) to spawn, incubate, and grow in the action area. Because the establishment of warmwater nonnative fishes would be detrimental to razorback suckers within the action area, as a part of LTEMP Reclamation has committed to exploring new technologies for controlling the temperature of water discharged into the Colorado River and technologies to prevent the passage of fish through the dam in order to attempt to reduce the potential for warmwater nonnative fish species to establish in the action area.

*Effects of the action on the role of critical habitat in recovery of the species*

Adverse effects and associated incidental take from implementation of the LTEMP are not expected to negatively affect razorback sucker recovery or further diminish the conservation contribution of critical habitat to the recovery of the species because the LTEMP includes actions, conservation measures, and “off-ramps” designed to adaptively modify the proposed action to conserve the razorback sucker and its habitat. These actions and measures were identified by the FWS, project proponents, and partners as being necessary to conserve and recover the sucker. The LTEMP will implement these actions in designated critical habitat. These actions include the following:

- The proposed action includes funding larval and small-bodied fish monitoring in order to:
    - Determine the extent of hybridization in flannelmouth and razorback sucker collected in the western Grand Canyon.
    - Determine habitat use and distribution of different life stages of razorback sucker to assist in future management of flows that may help conserve the species. Sensitive habitats to flow fluctuations could be identified and prioritized for monitoring.
    - Assess the effects of TMFs and other dam operations on razorback sucker.

  This research would allow us learn how razorback suckers are using the action area and how the proposed action might be modified to benefit and/or minimize effects to razorback suckers from the proposed action.

- The conservation measures that address removal and/or control of nonnative fish would all lead to beneficial impacts on razorback sucker habitat by reducing competition and predation and perhaps aid in improving recruitment of suckers to the limited population in Grand Canyon.

Over the long-term, these actions should increase the sustainability and resiliency of razorback sucker critical habitat (particularly through implementation of the HFEs designed to build backwater habitat and steady flow experiments that may benefit the food base and larval rearing habitats). Therefore, implementation of the LTEMP is not expected to further diminish the conservation contribution of critical habitat to the recovery of the razorback sucker.

**Kanab ambersnail**

Components of the proposed action that have the potential to affect Kanab ambersnails and their habitat include sediment-related experiments (such as HFEs) and nonnative vegetation management. Other experiments or changes in dam operations included in the proposed action (i.e., changes in base operations, TMFs, nonnative fish control, low summer flows, and sustained low flows for invertebrates) would have no impact on the Kanab ambersnail, because these activities would not occur in occupied areas or in suitable habitat. The effects of changes in base operations, low summer flows, and sustained low flows for invertebrates would be limited to areas within the river channel, where no Kanab ambersnails or habitat occur. Nonnative fish control would occur in the river, in the vicinity of the Little Colorado River inflow, which does not contain habitat for Kanab ambersnail; however, no fish control would occur in off-channel springs.

Effects of Experimental Elements

*Effects of Sediment-Related Experimental Treatments*

Within the Grand Canyon, populations of the Kanab ambersnail occur at Vasey's Paradise and Elves Chasm. Because the Elves Chasm population is located above the 100,000 cfs stage (USFWS 2008), this population would not be affected by any of the proposed actions. At Vasey's Paradise, 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. However, some Kanab ambersnail habitat would likely be adversely affected by scouring if river flows exceed 17,000 cfs (Kennedy and Ralston 2011). The HFE's proposed under LTEMP may reach flows of up to 45,000 cfs which at that stage would inundate approximately 16.4% of the Kanab ambersnail habitat at Vasey's Paradise and likely scour the vegetation and wash some snails downstream.

Most Kanab ambersnail habitat at Vasey's Paradise is located above the 33,000 cfs stage (Reclamation 2011b) and very little habitat and few individuals occur below the 25,000 cfs stage (Meretsky and Wegner 2000, Sorensen 2009). Surveys conducted following HFEs to date did not detect substantial declines in the Kanab ambersnail population (Kennedy and Ralston 2011). This may be due in part to the fact that Kanab ambersnails can survive up to 32 hours underwater in cold, well-oxygenated water (USFWS 2011a); so as long as they are not washed away, Kanab ambersnails could survive inundation from short-term HFEs.

Recovery of Kanab ambersnail habitat scoured by HFEs can take up to 2.5 years (Sorensen 2009). Therefore, frequent HFEs may result in long-term loss of Kanab ambersnail habitat (USFWS 2011a). Under LTEMP, HFEs could occur much more frequently than they have under baseline conditions (19.3 HFEs, or one almost every year, could occur over the life of LTEMP). This means that the loss of habitat due to scouring could extend several years beyond the LTEMP period at Vasey's Paradise. In addition, depending on the elevation of maximum dam discharge during TMFs, temporary scouring of habitat could occur during those flows as well; however, these flows would be unlikely to reach Kanab ambersnail habitat that is above the 30,000 cfs elevation. Therefore, due to the fact that most snails and their habitat are above the level that would be affected by HFEs, implementation of LTEMP should not diminish the long-term sustainability of the population at Vasey's Paradise.

*Effects of Native and Nonnative Plant Management and Experimental Treatments*

Vegetation management may occur, on rare occasions, near or within habitat at Vasey's Paradise, which could result in disturbance to Kanab ambersnails within small areas. If nonnative vegetation encroaches on the spring during the life of LTEMP, careful manual removal of the vegetation would occur. If removal of vegetation at Vasey's Paradise occurs, biologists would conduct surveys and relocate any ambersnails found to habitat away from the treatment area. Because ambersnails can be difficult to locate, it is possible that some individual snails could be killed during the vegetation treatment; however, pre-treatment surveys and relocation of snails would minimize the loss of snails. In addition, vegetation management should aid in maintaining ambersnail habitat.

Effects of Conservation Measures

Kanab ambersnail monitoring would continue under the LTEMP. Monitoring would allow for detection of any declines in the population and/or changes to habitat.

Summary

In summary, the LTEMP flow actions most likely to result in adverse effects (i.e., inundation and scouring of habitat) to Kanab ambersnails are HFEs. Other experiments or changes in dam operations included in the proposed action (i.e., changes in base operations, TMFs, nonnative fish control, low summer flows, and sustained low flows for invertebrates) would have no impact on the Kanab ambersnail, because these activities would not occur in occupied areas or in suitable habitat.

## 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 Act. The Colorado River Watershed within the action area is predominately managed by the NPS. Since the land within the action area is almost exclusively managed by the NPS, most activities that could potentially affect listed species are Federal activities and subject to additional section 7 consultations.

Humpback chub and critical habitat

Cumulative effects to the humpback chub and its critical habitat outside of NPS lands 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 are projected to have minimal effects to humpback chub and its critical habitat due to the small scale at which they occur.

The Navajo Nation has proposed a 420-ac development project, known as the Grand Canyon Escalade, on the Grand Canyon's eastern rim on the western edge of the Navajo reservation at the confluence of the Little Colorado and Colorado rivers. The development would include a gondola to transport visitors 3,200 ft from the rim to the canyon floor. On the rim, the development would include retail shops, restaurants, a museum, a cultural/visitor center, a hotel, multiple motels and shops, a lodge with patio, roads, and parking for cars and recreational vehicles. Analysis for this project has not been conducted, so impacts have not been fully determined; however, the construction and operation of the Escalade project could result in adverse impacts on natural and cultural resources in the areas of the Little Colorado River confluence, wilderness, visual resources, and resources of importance to multiple Tribes.

There is the potential for non-native fishes, including those hosting parasites, to invade the lower Little Colorado River from upriver sources 155 miles (250 km) away during certain flood events travelling through the intermittent river segments (Stone et al. 2007). Non-native fishes stocked into the area in Arizona utilizing federal funds have been evaluated under section 7 and are not anticipated to significantly affect humpback chub or its critical habitat (USFWS 2011c).

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 because these effects are diffuse over a wide area, and are distant from humpback chub and its critical habitat.

Increased uranium mining on state and private lands could increase the amount of uranium, arsenic, and other trace elements in local surface water and groundwater flowing into the Colorado River (Alpine 2010). Uranium, other radionuclides, and metals associated with uranium mines can affect the survival, growth, and reproduction of aquatic biota. However, aquatic biota and habitats most likely to be affected during mine development and operation are those associated with small, ephemeral, or intermittent drainages, which are not areas used by humpback chub or razorback sucker in the action area and do not connect to habitats used by these fish within the action area.

In addition, although the Little Colorado River stretches almost 550 km (340 mi), only the headwaters and the lowermost reaches flow year-round. The lower 21 km (13 mi) of the Little Colorado River is fed by groundwater springs. As stated earlier in the document, this reach of the Little Colorado River is occupied by the largest self-sustaining population of humpback chub, and the lower 13 km (8 mi) is designated critical habitat. These water sources may also be vulnerable to basin-wide drought and climate change impacting overall habitat availability and the humpback chub. As the population in the Basin States grows and expands, municipal, industrial, and agricultural water demand continues to increase. A study in 2012 showed that the demand for Colorado River Basin water may exceed supply before 2060 (Reclamation 2012a), which may result in lower Lake Powell levels and changes in flow, sediment, and water temperature regimes in the Grand Canyon.

Razorback sucker and critical habitat

Razorback sucker and its critical habitat would be affected through the same activities as humpback chub and its critical habitat.

Kanab ambersnail

Kanab ambersnail occurrence in the action area is entirely on Federal lands managed by Grand Canyon National Park. However, their habitat is created by springs, and it is conceivable that a 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. Extended drought is currently affecting the flow of water Vasey's Paradise and we expect continued drought as a result of climate change will continue to reduce habitat at this site. Fortunately, the Elves Chasm site has not suffered the same drying effects from drought.

Climate change

Climate change is predicted to affect climate and hydrology in the region, which could affect humpback chub, razorback sucker, and Kanab ambersnails within the action area. In the arid/semiarid western states, climate change is having serious consequences on the region's scarce water supplies; this particularly applies to the snow that makes up most of the region's precipitation and that, when melted, provides 70% of its water. To date, decreases in snowpack, less snowfall, earlier snowmelt, more winter rain events, increased peak winter flows, and reduced summer flows in rives have been documented (Saunders et al. 2008).

A key Reclamation document that provides information regarding climate change is the 2011 SECURE Water Act Report (Reclamation 2011c). In this report, Reclamation identified challenges likely to occur within the Colorado River Basin:

- On average, Colorado River Basin temperature is projected to increase by 5 to 6°F during the 21st century, with slightly larger increases projected in the upper Colorado Basin.
- Precipitation is projected to increase by 2.1% in the upper basin while declining by 1.6% in the lower basin by 2050.
- Mean annual runoff is projected to decrease by 3.5 to 8.5% by 2050.
- Warmer conditions will likely transition snowfall to rainfall, producing more December to March runoff and less April to July runoff.

Warmer climatic and weather conditions may also cause changes to fisheries habitat, shifts in species geographic ranges, increased water demands for instream ecosystems and thermoelectric power production, increased power demands for municipal uses (including cooling), and increased likelihood of invasive species infestations. These effects could substantially change the environmental baseline of the humpback chub, razorback sucker, and Kanab ambersnail.

Although no studies specifically evaluate the potential effects of climate change on Lake Powell or the Colorado River between Lake Powell and Lake Mead, decreases in Lake Powell elevation and corresponding increases in temperatures of water releases from Glen Canyon Dam and in water temperature of the Colorado River downstream (as well as to tributaries of the Colorado River) are important potential effects of climate change on the project area. Projections of future supply and demand in the basin indicate that inflows into Lake Powell may decrease, and the effect of climate change is likely to exacerbate this effect (Reclamation 2012b). Climate-induced changes in inflow, evaporation, and evapotranspiration all have the potential to influence water quality. For example, increased temperatures would increase metabolic rates of aquatic biota, increasing the demand for nutrients and oxygen, and potentially changing the quality of habitat for various organisms (Wrona et al. 2006, Heino et al. 2009, Woodward et al. 2010).

Increases in the water temperature of the Colorado River mainstem and its tributaries in the Grand Canyon due to climate change could expand the distribution of warmwater-adapted nonnative fishes (Eaton and Scheller 1996, Rahel and Olden 2008), which can prey on and compete with native fishes such as endangered humpback chub and razorback sucker. Climate-change-driven warmer water temperatures across the United States are predicted to expand the distribution of existing aquatic nonnative species by providing 31% more suitable habitat for aquatic nonnative species, based upon studies that compared the thermal tolerances of 57 fish species with predictions made from climate change temperature models (Mohseni et al. 2003). Climate change also may facilitate expansion of nonnative parasites such as Asian tapeworm (Rahel et al. 2008), another threat to native fishes. Cold water temperatures in the mainstem Colorado River in Marble and Grand Canyons have so far prevented these warmwater fishes and parasites from expanding their distribution in the project area. Warmer climate trends could result in warmer overall water temperatures, increasing the prevalence of these species and threating native fish populations.

In addition to water temperature, other aspects of water quality are also affected by Lake Powell's elevation. Dissolved oxygen concentrations in the tailwater are usually slightly below saturation but have not dropped to concentrations low enough to affect the aquatic ecosystem in the Grand Canyon. However, climate-change driven decreases in the elevation of Lake Powell could increase the chances of water that is low in dissolved oxygen being released from Glen Canyon Dam (Vernieu et al. 2005). Similarly, an increase in water temperatures of the Colorado River driven by climate change could cause low levels of dissolved oxygen in Lake Mead that could adversely affect native and nonnative fish (Tietjen 2014).

## CONCLUSION

After reviewing the current status of the humpback chub and its critical habitat, the razorback sucker and its critical habitat, and the Kanab ambersnail, the environmental baseline for the action area, the effects of the proposed action, and the cumulative effects, it is our biological opinion that the LTEMP, as proposed, is not likely to jeopardize the continued existence of these species, and is not likely to destroy or adversely modify designated critical habitat for the humpback chub and razorback sucker. No critical habitat has been designated for the Kanab ambersnail; therefore, none will be affected. We base these conclusions on the following:

Humpback chub and critical habitat

- LTEMP includes implementation of ongoing and new conservation measures that are designed to reduce the effects of the proposed action and improve the status of humpback chub. Conservation measures identified in the 2011 BO on operations of Glen Canyon Dam (USFWS 2011a) included the establishment of a humpback chub refuge, which has been created and will continue to be funded as a part of this action. Other conservation measures include humpback chub translocation; Bright Angel Creek brown trout control; determination of the feasibility of flow options to control trout, including increasing daily down-ramp rates to strand or displace age-0 trout, and high flow followed by low flow to strand or displace age-0 trout; assessments of the effects of actions on humpback chub populations; sediment research to determine effects of equalization flows; and Asian tapeworm monitoring. Conservation measures that were not completed are ongoing and are elements of existing management practices (e.g., brown trout control, humpback chub translocation, and sediment research to determine the effects of equalization flows), while new conservation measures or adjustments to the existing ones have been developed for the proposed action. Many of these conservation measures meet management objectives identified in the Humpback Chub Recovery Goals (USFWS 2002a), including investigating the anticipated effects of and options for providing warmer water temperatures in the mainstem Colorado River through Grand Canyon, ensuring adequate protection from diseases and parasites, and the regulation and control of nonnative fish.

- Population modeling indicates an overall upward trend in the number of adult humpback chub over the last decade in the action area, which continues to be the largest population range wide. This is in part due to humpback chub populations in the Little Colorado River which is largely unaffected by dam operations. The upward trend is also likely due to implementation of the ongoing conservation measures (translocations, nonnative control, triggered mechanical removal, triggered proactive conservation actions, and other conservation measures) associated with LTEMP that have resulted in beneficial effects to humpback chub in the action area.

- New conservation actions for humpback chub include expanding the Havasu Creek translocation area; identifying new translocation areas; exploring the efficacy of a temperature control device at the dam to respond to potential extremes in hydrological conditions due to climate change that could result in nonnative fish establishment; pursuing means of preventing the passage of deleterious invasive nonnative fish through Glen Canyon Dam; completion of planning and compliance to alter the backwater slough at RM12, making it unsuitable or inaccessible to warmwater nonnative species; and, completing planning and compliance of a plan for implementing rapid response control efforts for deleterious invasive nonnative species within and contiguous to the action area. These conservation measures are designed to minimize or reduce the effects of the proposed action or benefit or improve the status of listed species as part of the LTEMP.

- The proposed action includes funding and support of 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 trend in the humpback chub population were to change. In addition, the proposed action requires the action agencies to respond where necessary, in consultation with the FWS, to respond to unanticipated or adverse effects that would be taken to reverse significant declines in the humpback chub population.

- Although LTEMP would result in adverse effects to some PCEs, the proposed action overall would maintain, and likely enhance, the function and conservation role of critical habitat for the humpback chub.

Razorback sucker and critical habitat

- Although razorback sucker appear to be increasing within the action area, they are still relatively rare and it is unclear if much of the action area would ever provide suitable habitat for all life stages. However, implementation of LTEMP is likely to improve habitat through experimental steady flows and the required adaptive management. The research and monitoring included as part of the proposed action will allow FWS and the action agencies to adjust management as necessary to aid razorback survival and recovery.

- LTEMP includes experimental components that would likely improve habitat for razorback suckers within the action area. There is the potential for creation of warm, productive nursery habitats for razorback suckers from increased reshaping of nearshore deposits and backwater development resulting from HFEs.

- Although LTEMP would result in adverse effects to some PCEs, overall, the proposed action would maintain, and likely enhance, the function and conservation role of critical habitat for the razorback sucker within the action area. Conservation measures identified in the 2011 BO on operations of Glen Canyon Dam (USFWS 2011a) included the evaluation of the suitability of habitat in the lower Grand Canyon for the razorback sucker, which was initiated under the 2011 BO and will continue under the proposed action. In addition, the proposed efforts to control nonnative fish in the project area, is an identified management action in the Razorback Sucker Recovery Goals (USFWS 2002b) and will aid in creation of more suitable habitat for suckers in the project area.

Kanab ambersnail

- Most snails and their habitat are above the level that would be affected by HFEs; therefore, implementation of LTEMP should not affect the sustainability of the population at Vasey's Paradise.

- The Elves Chasm population would not be affected by any of the proposed actions.

- Monitoring status of Kanab ambersnails would continue under the proposed action an ongoing conservation measure.

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

## INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulations pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is 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 Act provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

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

**AMOUNT OR EXTENT OF TAKE**

Humpback chub

Incidental take of humpback chub is reasonably certain to occur as a result of implementation of the LTEMP. This incidental take is expected to be in the form of harm (including direct fatality) and harassment resulting from the effects of the proposed action on chub. Incidental take could potentially occur from the stranding of young chub (larval and small juvenile fish only as medium and large juvenile fish are unlikely to be stranded due to their increased swimming ability) during base operations, sediment-related flow actions (HFEs), and TMFs. In addition, there is likely to be ongoing harassment to an unknown number of chub from the degraded food base which could affect all size classes of chub through non-lethal harassment. The FWS anticipates incidental take of humpback chub would be difficult to detect for the following reason(s): 1) dead or impaired individuals are almost impossible to find (and are readily consumed by other fish or predators) and losses of fish may be masked by seasonal fluctuations in environmental conditions; 2) the humpback chub estimated population is changing over time through immigration, emigration, and natural loss; 3) the species occurs within almost 300 miles of river within the action area in extremely remote locations, so individual fish are difficult to locate; and, 4) the larvae and small juvenile life stages of chub that are most at risk to the changing water levels associated with flow actions are already the most vulnerable life stages to natural mortality factors (i.e., predation) and are extremely difficult to monitor. However, even though it is difficult to find, assess, and monitor small-bodied life stages of chub, we are not using a surrogate to estimate the amount of incidental take for the species, but are estimating the number based on modeling conducted for humpback chub in the Little Colorado River (Pine et al. 2013). This is currently the best available information regarding how many chub may be incidentally taken from the population without affecting the species persistence within the action area, which is why we are using this information in this BO to calculate the incidental take.

The Little Colorado River is responsible for much of the recruitment and persistence of humpback chub in the Lower Basin and project area. Most of the larval humpback chub produced in the Little Colorado River are protected from flow actions because the Little Colorado River itself is really not affected by flow actions associated with LTEMP (see Effects section). As stated in the Environmental Baseline, recent survey data indicates that the relative abundance of adult humpback chub in Colorado River mainstem aggregations has increased (Persons et al., *In review*). Additionally, an aggregation consisting of between 300-600 individuals has been found near 34-Mile in Marble Canyon and there appears to have been a dramatic increase in the absolute abundances of humpback chub in western Grand Canyon (roughly Havasu Creek downriver), with all size classes being represented. Because of this, we expect that incidental take of larval and small juvenile fish as a result of the proposed action would occur only in the mainstem Colorado River, where fish could be stranded and/or habitat is desiccated as a result of flow actions associated with LTEMP.

Under existing management of Glen Canyon Dam, numbers of humpback chub in the mainstem and the Little Colorado River have been stable (Van Haverbeke et al, 2013, Yackulic et al.

2015). Pine et al. (2013) assessed extinction risk and resiliency of humpback chub in Grand Canyon using a population viability assessment (PVA) model to evaluate incidental or permitted take. This assessment was conducted to model the effects to the chub population in the Little Colorado River of culling of larval and small juvenile humpback chub to translocate to new areas; but, the model results are also applicable to determining a number of chub that could be incidentally taken as a result the proposed LTEMP action (Pine et al. 2013). The model assessed the change in the number of age-1 and older humpback chub from cropping either 10% or 50% of the available female fish from different size classes in the Little Colorado River. The calculated yield is the average number of fish available for cropping in the last year of a five year removal period (Pine et al. 2013). Based upon the PVA model and results, at the 50% cropped level, 127,000 to 128,000 larval fish <30 mm TL and 7,500 to 8,000 small juvenile 30-60 mm TL fish could be cropped from the Little Colorado River, before a decline in the adult population would occur. Both of these modeled scenario runs resulted in a “0” extinction probability (Pine et al. 2013).

Therefore, we think it is appropriate to use the PVA model data from the Little Colorado River to estimate the number of larval and/or small juvenile chub that could be incidentally taken as a result of flow actions associated with LTEMP. We know that spawning and recruitment is occurring within the Colorado River based on recent survey data of mainstem aggregations. Hence, we are using the PVA model estimates to provide estimated numbers of larval and small juvenile chub in the mainstem that could be harmed as a result of LTEMP flow actions and not affect humpback chub survival and recovery. We would consider incidental take to be exceeded if more than 128,000 larvae (chub less than 30 mm total length [TL] and 8,000 small juveniles (chub 30-60 mm TL) are stranded as a result of base operations and flow actions (sediment-related flow actions or TMFs) in a five year period. This incidental take also accounts for reduced reproduction in individual chub that may be negatively impacted through reduced fitness, but not killed, as a result of a degraded food base due to the proposed action.

Pine et al. (2013) found that the Little Colorado River population of humpback chub is robust to removals of up to 50% of the larvae or small juveniles over a five year period. There is also evidence to suggest there are other mainstem aggregations of humpback chub contributing to recruitment of chub to the lower basin (below Glen Canyon dam) chub population; therefore, basing the number of fish that could be incidentally taken as a result of the action on the Little Colorado River population would further ensure that this expected take would not jeopardize the chub by significantly reducing either survival or recovery potential.

Incidental take within these limits would still allow for recruitment to the adult population. Recruitment is important to survival and recovery of the species because species only persist when they successfully reproduce and enough of those young fish survive to reproductive age, and produce more fish. In addition, ongoing population monitoring would continue under the proposed action. Incidental take from fatality would be predominantly to larvae (<30 mm TL) and small juvenile (30-60 mm TL) humpback chub, size classes that have high mortality rates, and thus losses of this amount would not result in an appreciable loss of recruitment to the adult population (Pine et al 2013). Further, ongoing population monitoring, as well as additional conservation actions (i.e., tiered, triggered conservation actions which include predator removal either through flow actions or mechanical means) and other aspects of Reclamation's proposed action are designed to be implemented to ensure that the humpback chub status does not decline and continues the improvement in population numbers seen over the last decade.

While we have estimated the number of humpback chub that could be incidentally taken as a result of the proposed action, as described above, we acknowledge that assessing and monitoring the incidental take of larval and small juvenile humpback chub associated with this action is extremely difficult. We have no feasible means of locating these fish when nearshore habitat or backwater habitats become separated from the mainstem Colorado River and potentially desiccate due to dropping water levels. Therefore, we are quantifying the incidental take of larval and small juvenile fish based upon the information in Pine et al. (2013) as described above; however, we are basing the measure of our exceedance criteria on the action triggers identified in the "Proposed Action Triggers for the Management of Humpback Chub" (Young et al. 2015, Appendix D in BA). If the Tier 1 (point abundance estimate for adult chub in the Colorado River mainstem aggregation and Little Colorado River fall below 9,000 as estimated by the currently accepted population model OR if recruitment of sub-adult chub [150-199 mm] does not equal or exceed estimated adult mortality as described in document) and Tier 2 triggers (point abundance estimate of adult chub decline to <7,000 fish, as estimated by the currently accepted humpback chub population model) are met and the prescribed conservation measures and remedial actions under each trigger do not mitigate a decline in the humpback chub population, then incidental take will have been exceeded. Additionally, as described in Young et al. (2015), if monitoring detects declines in the humpback chub, the FWS, in coordination with action agencies and traditionally associated Tribes, will identify appropriate actions to reverse the decline.

<u>Razorback sucker</u>

Incidental take of razorback sucker is reasonably certain to occur as a result of implementation of the LTEMP. This incidental take is expected to be in the form of harm (including direct fatality) and harassment resulting from the effects of the proposed action on razorback suckers. The FWS anticipates incidental take of razorback suckers would be difficult to detect for the following reason(s): 1) dead or impaired individuals are almost impossible to find (and are readily consumed by predators) and losses may be masked by seasonal fluctuations in environmental conditions; 2) the status of the species within the action area is still relatively unknown; 3) at some stages of development razorback and flannelmouth suckers are too small for species identification in the field; 4) the species is very rare in the action area; and, the species occurs within almost 100 miles of river within the action area in extremely remote locations, so individual fish are difficult to locate. Because razorback suckers are extremely rare within the project area and it is impossible in the field to identify larval razorback suckers from larval flannelmouth suckers, we are using flannelmouth suckers as a surrogate for incidental take of razorback suckers. Larval flannelmouth sucker occupy the same habitats within the project area as larval razorback suckers that may be affected by the proposed action, but flannelmouth sucker are more abundant and changes in recruitment of young fish can be estimated as described below. Therefore, we think that it appropriate to measure flannelmouth sucker recruitment responses over time to base operations and flow actions (e.g., HFEs, TMFs) that could result in take of larval fish, as a surrogate measure for incidental take of razorback suckers.

Incidental take is expected to occur due to stranding of larval razorback sucker in nearshore habitats as a result of base operations (daily fluctuating flows, including increased downramp rates) and HFEs. Based on the analysis presented in the Effects of the Action section of this BO, an unknown number of larval razorback suckers have the potential to be killed or harmed with implementation of the LTEMP, as these fish would be unable to swim out of backwaters or nearshore habitats that become disconnected or even desiccate as a result of flow actions. As stated above, we cannot measure the number of razorback suckers taken as a result of this action because razorback suckers are rare and we have very little data on actual numbers of adult, larval, or other age/size classes of suckers that may be present in western Grand Canyon.

Flannelmouth sucker are known to hybridize with razorback suckers and the two species habitat needs overlap in western (lower) Grand Canyon. While there are differences between the two species, the similarities in spawning requirements have resulted in these two sucker species hybridizing throughout their ranges, particularly where flannelmouth are abundant. In addition, both larval flannelmouth and razorback suckers are occurring in the same or similar habitats in western Grand Canyon. Although juvenile razorback suckers were not captured during small-bodied fish community sampling in 2013–2014 (juvenile fish are a later stage of development than larval fish), Albrecht et al. (2014) used flannelmouth sucker capture information to show that should small-bodied razorback suckers occur within the lower Grand Canyon, the monitoring methods used would allow for razorback sucker captures in the future. Therefore, there is some precedent in this system for using flannelmouth suckers as a surrogate species for razorback suckers.

Currently, flannelmouth suckers are reproducing and recruiting in the areas of western Grand Canyon where razorback suckers are thought to have spawned and larval fish have been detected. Therefore, we are using adult flannelmouth sucker as a surrogate for recruitment of larval razorback sucker into the population. This would be measured using CPUE data collected by AGFD on their yearly Colorado River System-Wide Electrofishing surveys. The primary goal of the System Wide Electrofishing project is to provide baseline status and trend information on native and nonnative fish in the Colorado River from Lees Ferry to Lake Mead (Rogowski et al. 2015).

We will consider incidental take of razorback suckers to be exceeded if actions associated with LTEMP base operations and experimental flow actions result in a statistically significant decline (95% confidence intervals) in mean catch per unit effort (CPUE) of adult flannelmouth suckers for a consecutive 3-year period following the occurrence of experimental flow(s) actions. This would be measured using CPUE data collected by AGFD in lower Grand Canyon where flannelmouth sucker overlap with known locations of larval razorback suckers (approximately from RM 179.1 to RM 225 [AGFD sampling Reach 5] and >RM 225 [AGFD sampling Reach 6]). We are providing for a relatively large change in the adult flannelmouth sucker mean CPUE to account for natural variability and for possible shifts in the CPUE following large flannelmouth sucker recruitment events that could result in mature fish moving upstream, out of the identified river reaches.  Although using the relatively abundant flannelmouth sucker as a surrogate for the relatively rare razorback sucker is not ideal, our reasoning is that a reduction in the flannelmouth sucker population in the identified sampling reaches would provide for reasonable inference of a concomitant reduction in the confamilial razorback sucker.

Kanab ambersnail

Incidental take of Kanab ambersnails is reasonably certain to occur as a result of implementation of the LTEMP.  This incidental take is expected to be in the form of harm (including direct fatality) and harassment resulting from the effects of the proposed action on snails.  The FWS anticipates incidental take of Kanab ambersnails would be difficult to detect for the following reason(s):  1) ambersnails are difficult to detect when alive due to their small size, finding dead or impaired individuals would be almost impossible; and, 2) losses of ambersnails may be masked by seasonal fluctuations in environmental conditions.

The level of take that could occur from the proposed action would be in the form of harm or fatality resulting from scouring of habitat during the highest flows of the proposed action.  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 incidental take to be exceeded if photo monitoring of the habitat following an HFE shows that more than 17% of Kanab ambersnail habitat is removed at Vasey's Paradise in any one year and this loss is attributable to LTEMP flow actions.  The anticipated take is not expected to substantially diminish the size or vigor of the Vasey's Paradise population because these areas are not currently providing habitat for most of the population.  Approximately 16.4% of the population occurs below the elevation of 45,000 cfs flow.  Since experimental HFE flows could be as much as 45,000 cfs, if more than 17% of the habitat is inundated in a year, then incidental take would be exceeded.

The Elves Chasm population is located above the elevation of 45,000-cfs flow; therefore we do not expect any incidental take resulting from flow operations at this site.

## 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 humpback chub, razorback sucker, or Kanab ambersnail, or destruction or adverse modification of critical habitat for the reasons stated in the Conclusions section.

## REASONABLE AND PRUDENT MEASURES

**Humpback chub**

We determine that the proposed action incorporates sufficient conservation measures that reasonably and prudently minimize the effects of incidental take of humpback chub as well as aim to maintain and improve the status of the species. The proposed conservation measures are at least as strong, and likely stronger, than any reasonable and prudent measures we would require. The FWS worked with Reclamation, NPS, and GCMRC to review ongoing conservation actions and reasonable and prudent measures from past biological opinions and identify new conservation measures for the action area, and all measures were incorporated into the proposed action. Thus, no reasonable and prudent measures are included in this incidental take statement.

**Razorback suckers**

We determine that the proposed action incorporates sufficient conservation measures that reasonably and prudently minimize the effects of incidental take of razorback suckers. All reasonable measures to minimize take have been incorporated into the project description. Thus, no reasonable and prudent measures are included in this incidental take statement. The FWS worked collaboratively with Reclamation and NPS to ensure that all conservation measures needed to minimize the effect of incidental take were included in the proposed action.

**Kanab ambersnail**

We determine that the proposed action incorporates sufficient conservation measures (Kanab ambersnail monitoring and reporting) that reasonably and prudently minimize the effects of incidental take of Kanab ambersnails. All reasonable measures to minimize take have been incorporated into the project description. Thus, no reasonable and prudent measures are included in this incidental take statement.

**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, 4901 Paseo del Norte NE, Suite D, Albuquerque, NM 87113; 505-248-7889) within three working days of its finding. Written notification must be made within five calendar days and include the date, time, and location of the animal, a photograph if possible, and any other pertinent information. The notification shall be sent to the Law Enforcement Office with a copy to this office. Care must be taken in handling sick or injured animals to ensure effective treatment and care, and in handling dead specimens to preserve the biological material in the best possible state.

## CONSERVATION RECOMMENDATIONS

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

1. We recommend that Reclamation and NPS work with FWS, Tribes, GCMRC, AGFD, and other partners to continue discussions regarding the taking of life related to nonnative fish control and to further discussions regarding the beneficial use of fish killed as a result of implementation of the conservation measures associated with LTEMP (e.g., nonnative removal). We support selecting for actions that do not result in the taking of life and ensuring beneficial use of life taken occurs, but we would like to pursue further discussions with the Tribes regarding how we practicably and efficiently implement ways to disadvantage nonnative species, achieve beneficial use, and expand upon the potential uses that could be considered beneficial.

2. We recommend that Reclamation, NPS, FWS, AGFD, GCMRC, and other partners review and consider modifying the timeframe for implementing TMFs specifically to control brown trout, and consider modifying the HFE protocol if implementation of HFEs is found to be associated with brown trout recruitment. Additional planning and compliance may be needed in order to make modifications to flow actions.

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

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 Havasupai Tribe, Hopi Tribe, Hualapai Tribe, Kaibab Band of Paiute Indians, Las Vegas Paiute Tribe, Moapa Band of Paiute Indians, Navajo Nation, Pueblo of Zuni, Shivwits Band of Paiute Indians, Southern Paiute Consortium, Ute Mountain Ute Tribe, Yavapai-Apache Nation, and Bureau of Indian Affairs of its completion. We also encourage you to coordinate the review of this project with the Arizona Game and Fish Department.

We appreciate the Reclamation's efforts to identify and minimize effects to listed species from this project. Please refer to the consultation number, 02EAAZ00-2012-F-0059 in future correspondence concerning this project. Should you require further assistance or if you have any questions, please contact Shaula Hedwall at (928) 556-2118 or Brenda Smith at (928) 556-2157.

/s/ Steven L. Spangle

cc (electronic):

Assistant Field Supervisor, Fish and Wildlife Service, Flagstaff, AZ
(Attn: John Nystedt)
Project Leader, Arizona Fish and Wildlife Conservation Office, Flagstaff, AZ
Assistant Project Leader, Arizona Fish and Wildlife Conservation Office, Flagstaff, AZ
Assistant Field Supervisor, Fish and Wildlife Service, Phoenix, AZ
(Attn: Mike Martinez and Jessica Gwinn)
Chief, Aquatic Resources Branch, Arizona Game and Fish Department, Phoenix, AZ
Chief, Terrestrial Branch, Arizona Game and Fish Department, Phoenix, AZ
Regional Supervisor, Arizona Game and Fish Department, Flagstaff, AZ (Attn: Scott Rogers)
Arizona Game and Fish Department, Phoenix, AZ (Attn: Dave Weedman)
Department of Interior, Tribal Liaison, Office of Assistant Secretary for Water and Science,
Tucson, AZ (Attn: Sarah Rinkevich)
Tribal Secretary, Havasupai Tribe, Supai, AZ
Chairman, Hopi Tribe, Kykotsmovi, AZ
Director, Cultural Preservation Office, Hopi Tribe, Kykotsmovi, AZ
Senior Archaeologist, Cultural Preservation Office, Hopi Tribe, Kykotsmovi, AZ
Chairperson, Hualapai Tribe, Peach Springs, AZ
Program Manager, Tribal Historic Preservation Office, Hualapai Tribe, Peach Springs, AZ
Chairperson, Kaibab Band of Paiute Indians, Fredonia, AZ
Chairman, Las Vegas Paiute Tribe, Las Vegas, NV
Natural Resources Program, Moapa Band of Paiute Indians, Moapa, NV
President, Navajo Nation, Window Rock, AZ
Director, Historic Preservation Department, Navajo Nation, Window Rock, AZ
Chairwoman, Shivwits Band of Paiute Indians, Ivins, UT
Director, Southern Paiute Consortium, Fredonia, AZ

Environmental Programs Director, Ute Mountain Ute Tribe, Towaoc, CO
Archaeologist, Yavapai-Apache Nation, Camp Verde, AZ
Governor, Pueblo of Zuni, Zuni, NM
Director, Zuni Heritage and Historic Preservation Office, Zuni, NM
Director, Western Regional Office, Bureau of Indian Affairs, Phoenix, AZ
Branch Chief, Environmental Quality Services, Western Regional Office, Bureau of Indian Affairs, Phoenix, AZ

W:\Shaula Hedwall\Final Docs\LTEMP Biop_11-25-16 (2).Docx:cgg

**LITERATURE CITED FOR BIOLOGICAL OPINION**

Ackerman, M.W. 2008. 2006. Native fish monitoring activities in the Colorado River, Grand Canyon: Flagstaff, Ariz., SWCA Environmental Consultants, report to Grand Canyon Monitoring and Research Center, Cooperative Agreement 04WRAG0011. 77 pp.

Albrecht, B.A., P.B. Holden, R.B. Kegerries, and M.E. Golden. 2010. Razorback Sucker Recruitment in Lake Mead, Nevada-Arizona, Why Here? Lake and Reservoir Management 26:4.

Albrecht, B., R. Kegerries, J.M. Barkstedt, W.H. Brandenburg, A.L. Barkalow, S.P. Platania, M. McKinstry, B. Healy, J. Stolberg, and Z. Shattuck. 2014. Razorback Sucker *Xyrauchen texanus* Research and Monitoring in the Colorado River Inflow Area of Lake Mead and the Lower Grand Canyon, Arizona and Nevada. Final report prepared by BIO-WEST, Inc., for U.S. Bureau of Reclamation, Upper Colorado Region, Salt Lake City, Utah.

Alpine, A.E. (ed.). 2010. Hydrological, Geological, and Biological Site Characterization of Breccia Pipe Uranium Deposits in Northern Arizona, Scientific Investigations Report 2010-5025, U.S. Geological Survey.

Andersen, M.E. 2009. Status and Trends of the Grand Canyon Population of Humpback Chub, U.S. Geological Survey Fact Sheet 2009-3035, April.

Andersen, M.E., M.W. Ackerman, K.D. Hilwig, A.E. Fuller, and P.D. Alley. 2010. Evidence of Young Humpback Chub Overwintering in the Mainstem Colorado River, Marble Canyon, Arizona, USA. The Open Fish Science Journal 2010(3):42–50.

Angradi, T.R. and D.M. Kubly. 1994. Concentration and transport of particulate organic matter below Glen Canyon Dam on the Colorado River, Arizona. Journal of the Arizona-Nevada Academy of Science 28(1/2):12–22.

Arizona Game and Fish Department (AGFD). 1996. The Ecology of Grand Canyon Backwaters, Cooperative Agreement Report (9 FC-40-07940) to Glen Canyon Environmental Studies, Flagstaff, Ariz.

_____. 2001. *Gila cypha* Humpback Chub. Heritage Data Management System, Phoenix, Ariz.

Avery, L.A., J. Korman, and W.R. Persons. 2015. Effects of Increased Discharge on Spawning and Age-0 Recruitment of Rainbow Trout in the Colorado River at Lees Ferry, Arizona. North American Journal of Fisheries Management 35:671–680.

Bestgen, K.R. 1990. Status review of the razorback sucker, *Xyrauchen texanus*. Report to U.S. Fish and Wildlife Service, Salt Lake City, Utah. Contribution 44, Larval Fish Laboratory, Colorado State University, Fort Collins, Colorado.

_____. 2008. Effects of Water Temperature on Growth of Razorback Sucker Larvae. Western North American Naturalist 68(1):15–30.

Behn, K.E., T.A. Kennedy, and R.O. Hall, Jr. 2010. Basal Resources in Backwaters of the Colorado River Below Glen Canyon Dam - Effects of Discharge Regimes and Comparison with Mainstem Depositional Environments, U.S. Geological Survey Open-File Report 2010-1075. Available at http://pubs.usgs.gov/of/2010/1075/.

Blinn, D.W. and G.A. Cole. 1991. Algal and Invertebrate Biota in the Colorado River: Comparison of Pre- and Post-Dam Conditions. Pages 102-123 *In* Committee to Review the Glen Canyon Environmental Studies, Water Science and Technology Board, National Research Council, eds., Colorado River Ecology and Dam Management. National Academy Press, Washington DC. 276pp.

Blinn, D.W., L.E. Stevens and J.P. Shannon. 1992. The effects of Glen Canyon Dam on the aquatic food base in the Colorado River Corridor in Grand Canyon, Arizona, Glen Canyon Environmental Study-II-02.

Bunn, S.E. and A.J. Arthington. 2002. Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. Environmental Management 30:493–507.

Carothers, S.W. and B.T. Brown. 1991. The Colorado River Through Grand Canyon: Natural History and Human Change, University of Arizona Press, Tucson, Arizona.

Clarkson, R.W. and M.R. Childs. 2000. Temperature Effects of Hypolimnial-Release Dams on Early Life Stages of Colorado River Basin Big-River Fishes. Copeia 2002:402–412.

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

Coggins L.G. Jr. 2008. Abundance trends and status of the Little Colorado River population of humpback chub; an update considering 1989-2006 data: U.S. Geological Survey Open-File Report 2007-1402.

Coggins, L.G., Jr. and C.J. Walters. 2009. Abundance Trends and Status of the Little Colorado River Population of Humpback Chub: An Update Considering Data from 1989–2008, Open-File Report 2009-1075, U.S. Geological Survey.

Coggins Jr., L.G., Yard, M.D. and W.E. Pine III. 2011. Non-native Fish Control in the Colorado River in Grand Canyon, Arizona: An Effective Program or Serendipitous Timing? Transactions of the American Fisheries Society 140(2):456-470.

Converse, Y.K., C.P. Hawkins, and R.A. Valdez. 1998. Habitat Relationships of Subadult Humpback Chub in the Colorado River through Grand Canyon: Spatial Variability and Implications of Flow Regulation. Regulated Rivers: Research and Management 14:267–284.

Cross, W.F., C.V. Baxter, K.C. Donner, E.J. Rosi-Marshall, T.A. Kennedy, R.O. Hall, Jr., H.A. Wellard Kelly, and R.S. Rogers. 2011. Ecosystem Ecology Meets Adaptive Management: Food Web Response to a Controlled Flood on the Colorado River, Glen Canyon. Ecological Applications 21(6):2016–2033.

Culver, M., H.-W. Hermann, M. Miller, B. Roth, and J. Sorensen. 2013. Anatomical and Genetic Variation of Western *Oxyloma* (Pulmonata: Succineidae) Concerning the Endangered Kanab Ambersnail (*Oxyloma haydeni kanabense*) in Arizona and Utah. Scientific Investigations Report 2013-5164, U.S. Geological Survey, Reston, Virgina.

Dodrill, M.J., C.B. Yackulic, B. Gerig, W.E. Pine, J. Korman, and C. Finch. 2015. Do Management Actions to Restore Rare Habitat Benefit Native Fish Conservation? Distribution of Juvenile Native Fish among Shoreline Habitats of the Colorado River. River Research and Applications. doi:10.1002/rra.2842.

Donner, K.S. 2011. Secondary Production Rates, Consumption Rates, and Trophic Basis of Production of Fishes in the Colorado River, Grand Canyon, AZ: An Assessment of Potential Competition for Food. M.S. thesis, Idaho State University, Pocatello, Idaho, April.

Douglas, M.E. and P.C. Marsh. 1996. Population Estimates/Population Movements of *Gila cypha*, an Endangered Cyprinid Fish in the Grand Canyon Region of Arizona. Copeia 1:15–28. Available at http://www.jstor.org/stable/pdfplus/1446938.pdf.

Eaton, J.G. and R.M. Scheller. 1996. Effects of climate warming on fish thermal habitat in streams of the United States. Limnology and Oceanography 41(5):1109-1115.

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

Francis, T., D.S. Elverud, B.J. Schleicher, D.W. Ryden, and B. Gerig. 2015. San Juan River Arm of Lake Powell Razorback Sucker (*Xyrauchen texanus*) Survey: 2012, draft interim progress report to the San Juan River Endangered Fish Recovery Program.

Fuller, M.J. 2009. Lower Yampa River channel catfish and smallmouth bass control program, Colorado, 2001-2006. U.S. Fish and Wildlife Service, Vernal, Utah. 32pp.

Gilbert, C.H. and N.B. Scofield. 1898. Notes on a collection of fishes from the Colorado basin in Arizona. Proceedings of the U.S. National Museum 20:1131.

Gloss, S.P., and L.G. Coggins. 2005. Fishes of Grand Canyon,Chapter 2 in The State of the Colorado River Ecosystem in Grand Canyon, U.S. Geological Survey Circular 1282, S.P. Gloss et al. (eds.), U.S. Geological Survey, Reston, Virginai.

Gloss, S.P., J.E. Lovich, and T.S. Melis (editors). 2005. The state of the Colorado River ecosystem in Grand Canyon. A report of the Grand Canyon Monitoring and Research Center 1991-2004. U.S. Geological Survey Circular 1282. U.S. Geological Survey, Flagstaff, Arizona.

Gorman, O.T. 1994. Habitat Use by Humpback Chub, *Gila cypha*, in the Little Colorado River and Other Tributaries of the Colorado River, prepared by U.S. Fish and Wildlife Service, Arizona Fisheries Resources Office, Flagstaff, Ariz., for U.S. Bureau of Reclamation, Glen Canyon Environmental Studies.

Grand Canyon Monitoring and Research Center (GCMRC). 2014. Grand Canyon Monitoring and Research Center Fiscal Year 2014 Annual Project Report for the Glen Canyon Dam Adaptive Management Program, annual report prepared for Upper Colorado Region, Bureau of Reclamation.

Hamman, R.L. 1982. Induced Spawning and Culture of Bonytail Chub. Progressive Fish Culturist 44:201–203.

Heino, J., R. Virkkala, and H. Toivonen. 2009. Climate change and freshwater biodiversity: detected patterns, future trends and adaptations in northern regions. Biological Reviews 84:39-54.

Hoffnagle, T.L., A. Choudhury, and R.A. Cole. 2006. Parasitism and body condition in humpback chub from the Colorado and Little Colorado Rivers, Grand Canyon, Arizona. Journal of Aquatic Animal Health 18(3):184-193.

Jordan, D.S. 1891. Report of explorations in Colorado and Utah during the summer of 1889 with an account of the fishes found in each of the river basins examined. Bulletin of the United States Fish Commission 9:24.

Kaeding, L.R. and M.A. Zimmerman. 1983. Life History and Ecology of the Humpback Chub in the Little Colorado and Colorado Rivers in Grand Canyon. Transactions of the American Fisheries Society 112:577–594.

Kegerries, R., B. Albrecht, R. Rogers, E. Gilbert, W.H. Brandenburg, A.L. Barkalow, S.P. Platania, M. McKinstry, B. Healy, J. Stolberg, E. Omana Smith, C. Nelson, and H. Mohn. 2015. Razorback Sucker (*Xyrauchen texanus*) Research and Monitoring in the Colorado River Inflow Area of Lake Mead and the Lower Grand Canyon, Arizona and Nevada. Final Report, prepared by BIO-WEST, Inc., for the U.S. Bureau of Reclamation, Upper Colorado Region, Salt Lake City, Utah.

Kennedy, T.A. and S.P. Gloss. 2005. Aquatic Ecology: The role of organic matter and invertebrates," Chapter 5 in The State of the Colorado River Ecosystem in Grand Canyon, U.S. Geological Survey Circular 1282, S.P. Gloss et al. (eds.), U.S. Geological Survey, Reston, Virginia.

Kennedy, T.A. and B.E. Ralston. 2011. Biological Responses to High-Flow Experiments at Glen Canyon Dam," pp. 93–125 *In* Effects of Three High Flow Experiments on the Colorado River Ecosystem Downstream from Glen Canyon Dam, Arizona, T.S. Melis (ed.), Circular 1366, U.S. Geological Survey, Reston, Virginia.

Kennedy, T.A., W.F. Cross, R.O. Hall, Jr., C.V. Baxter, and E.J. Rosi-Marshall. 2013. Native and Nonnative Fish Populations of the Colorado River Are Food Limited - Evidence from New Food Web Analyses, U.S. Geological Survey Fact Sheet 2013–3039. Available at http://pubs.usgs.gov/fs/2013/3039/.

Kennedy, T.A., J.D. Muehlbauer, C.B. Yackulic, D.A. Lytle, S.W. Miller, K.L. Dibble, E.W. Kortenhoeven, A.N. Metcalfe, and C.V. Baxter. 2016. Flow Management for Hydropower Extirpates Aquatic Insects, Undermining River Food Webs. BioScience, Advanced Access, May 2, 2016.

Kirsch, P.H. 1889. Notes on a collection of fishes obtained in the Gila River at Fort Thomas, Arizona. Proceedings of the U.S. National Museum 11:555-558.

Korman, J., M. Kaplinski, and T.S. Melis. 2011. Effects of Fluctuating Flows and a Controlled Flood on Incubation Success and Early Survival Rates and Growth of Age-0 Rainbow Trout in a Large Regulated River. Transactions of the American Fisheries Society 140:487–505.

Korman, J., S.J.D. Martell, C.J. Walters, A.S. Makinster, L.G. Coggins, M.D. Yard, and W.R. Persons. 2012. Estimating Recruitment Dynamics and Movement of Rainbow Trout (*Oncorhynchus mykiss*) in the Colorado River in Grand Canyon Using an Integrated Assessment Model. Canadian Journal of Fisheries and Aquatic Sciences 69(11):1827–1849.

Korman, J., M.D. Yard, and C.B. Yackulic. 2015. Factors Controlling the Abundance of Rainbow Trout in the Colorado River in Grand Canyon in a Reach Utilized by Endangered Humpback Chub. Canadian Journal of Fisheries and Aquatic Science 73:105–124.

Maddux, H.R, W.R. Noonan, and L.A. Fitzpatrick. 1993. Draft Colorado River endangered fishes critical habitat, biological support document. U.S. Fish and Wildlife Service, Salt Lake City, Utah. 225pp.

Makinster, A.S., W.R. Persons, and L.A. Avery. 2011. Status and Trends of the Rainbow Trout Population in the Lees Ferry Reach of the Colorado River Downstream from Glen Canyon Dam, Arizona, 1991–2009, Scientific Investigations Report 2011–5015, U.S. Geological Survey, Reston, Virgina.

Marsh, P.C., and M.E. Douglas. 1997. Predation by Introduced Fishes on Endangered Humpback Chub and Other Native Species in the Little Colorado River, Arizona. Transactions of the American Fisheries Society 126:343–346.

Marsh, P.C., T.E. Dowling, B.R. Kesner, T.F. Turner, and W.L. Minckley. 2015. Conservation to Stem Imminent Extinction: The Fight to Save Razorback Sucker *Xyrauchen texanus* in Lake Mohave and Its Implications for Species Recovery. Copeia 103(1):141–156.

McAda, C.W. and R.S. Wydoski. 1980. The razorback sucker, *Xyrauxchen texanus*, in the upper Colorado River basin, 1974-76. U.S. Fish and Wildlife Service Technical Paper 99. 50pp.

McCarthy, C.W., and W.L. Minckley. 1987. Age estimation for razorback sucker (Pisces: Catostomidae) from Lake Mohave, Arizona and Nevada. Journal of the Arizona-Nevada Academy of Science 21:87-97.

McKinney, T. and W. R. Persons. 1999. Rainbow Trout and Lower Trophic Levels in the Lees Ferry Tailwater below Glen Canyon Dam, Arizona - A Review.

McKinney, T., D.W. Speas, R.S. Rodgers, and W.R. Persons. 2001a. Rainbow Trout in a Regulated River below Glen Canyon Dam, Arizona, Following Increased Minimum Flows and Reduced Discharge Variability. North American Journal of Fisheries Management 21(1):216–222.

McKinney, T., A.T. Robinson, D.W. Speas, and R.S. Rodgers. 2001b. Health Assessment, Associated Metrics, and Nematode Parasitism of Rainbow Trout in the Colorado River below Glen Canyon Dam, Arizona. North American Journal of Fisheries Management 21:62–69.

Meretsky, V. and D. Wegner. 1999. Kanab ambersnail at Vasey's Paradise, Grand Canyon National Park, 1998 Monitoring and Research. SWCA Environmental Consultants Inc. Flagstaff, AZ: U.S. Department of the Interior, U.S. Geological Survey.

Meretsky, V., and D. Wegner. 2000. Kanab Ambersnail at Vasey's Paradise, Grand Canyon National Park, 1998–1999 Monitoring and Research, final report, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Meretsky, V.J., D.L. Wegner, and L.E. Stevens. 2000. Balancing endangered species and ecosystems: A case study of adaptive management in Grand Canyon. Environmental Management 25(6): 579-586.

Minckley, W.L. 1973. The Fishes of Arizona. Arizona Game and Fish Department, Phoenix, Arizona.

_____. 1983. Status of the razorback sucker, *Xyrauchen texanus* (Abbott), in the lower Colorado River Basin. The Southwestern Naturalist 28:165-187.

_____. 1991. Native fishes of the Grand Canyon region: An obituary? Pages 124-177 *In* Committee to Review the Glen Canyon Environmental Studies, Water Science and Technology Board, National Research Council, eds., Colorado River Ecology and Dam Management. National Academy Press, Washington DC. 276pp.

Minckley, W.L., P.C. Marsh, J.E. Brooks, J.E. Johnson, and B.L. Jensen. 1991. Management toward recovery of the razorback sucker *In* W.L. Minckley and J.E. Deacon [eds.], The battle against extinction. University of Arizona Press, Tucson Arizona.

Mohn, H., B. Albrecht, R.J. Rogers, and R. Kegerries. 2015. Razorback Sucker Studies on Lake Mead, Nevada and Arizona: 2014–2015 Final Annual Report, prepared for U.S. Bureau of Reclamation, Lower Colorado River Multi-Species Conservation Program, Boulder City, Nevada.

Mohseni, O., H.G. Stefan, and J.G. Eaton. 2003. Global warming and potential changes in fish habitat in U.S. streams. Climatic Change 59:389-409.

Nagrodski, A., G.D. Raby, C.T. Hasler, M.K. Taylor, and S.J. Cooke. 2012. Fish Stranding in Freshwater Systems: Sources, Consequences, and Mitigation. Journal of Environmental Management 103:133–141.

National Park Service (NPS). 2006. Management Policies 2006, U.S. Department of Interior, Washington, D.C. Available at http://www.nps.gov/policy/mp2006.pdf. Accessed October 21, 2016.

_____. 2013. Comprehensive Fisheries Management Plan, Environmental Assessment, Grand Canyon National Park and Glen Canyon National Recreation Area, Coconino County, Arizona, U.S. Department of the Interior.

Nelson, C.B. and J.A. Sorensen. 2001. Investigations of the endangered Kanab ambersnail: monitoring of translocated populations and surveys of additional habitat. Nongame and Endangered Wildlife Program Technical Report 200. Phoenix, Arizona: Arizona Game and Fish Department.

Oberlin, G.E., J.P. Shannon, and D.W. Blinn. 1999. Watershed Influence on the Macroinvertebrate Fauna of Ten Major Tributaries of the Colorado River through Grand Canyon, Arizona. The Southwest Naturalist 44:17–30.

Osmundson, D.B. and L.R. Kaeding. 1989. Studies of Colorado squawfish and razorback sucker use of the "15-mile reach" of the Upper Colorado River as part of conservation measures for the Green Mountain and Ruedi Reservoir water sales. Final Report, U.S. Fish and Wildlife Service, Region 6, Grand Junction, Colorado. 81pp.

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

Persons, W.R., D.R. Van Haverbeke, and M.J. Dodrill. *In review*. Colorado River fish monitoring in Grand Canyon, Arizona: 2002-2014.

Pilsbry, H.A. 1948. Land Mollusca of North America. The Academy of Natural Sciences of Philadelphia Monographs II: 521-1113.

Pine W. 2013. Nearshore Ecology of Grand Canyon Fish Final Report, prepared for the Upper Colorado Region, Bureau of Reclamation, Interagency Agreement: 08-AA-40-2808, University of Florida, Aug.

Pine, W.E., B. Healy, E. Omana Smith, M. Trammell, D. Speas, R. Valdez, M. Yard, C. Walters, R. Ahrens, R. Van Haverbeke, D. Stone, and W. Wilson. 2013. An individual-based model for population viability analysis of humpback chub in Grand Canyon. North American Journal of Fisheries Management 33:626-641.

Rahel, F.J. and J.D. Olden. 2008. Assessing the effects of climate change on aquatic invasive species. Conservation Biology 22(3):521–533.

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

Ralston, B.E. 2011. Summary report of responses of key resources to the 2000 low steady summer flow experiment, along the Colorado River downstream from Glen Canyon Dam, Arizona: U.S. Geological Survey Open-File Report 2011–1220. 129pp.

Robinson, A.T. and M.R. Childs. 2001. Juvenile Growth of Native Fishes in the Little Colorado River and in a Thermally Modified Portion of the Colorado River. North American Journal of Fisheries Management 21:809–815.

Rogowski, D.L., P.L. Wolters, and L.K. Winters. 2015. Colorado River fish monitoring in Grand Canyon, Arizona—2014 Annual Report. Submitted to: Grand Canyon Monitoring and Research Center, Flagstaff, AZ, Cooperative Agreement # G13AC00086, February 2015. Arizona Game and Fish Department, Phoenix, AZ. 43pp.

Rosi-Marshall, E.J., T.A. Kennedy, D.W. Kincaid, W.F. Cross, H.A.W. Kelly, K.A. Behn, T. White, R.O. Hall, Jr., and C.V. Baxter. 2010. Short-term effects of the 2008 high-flow experiment on macroinvertebrates in the Colorado River below Glen Canyon Dam, Arizona, U.S. Geological Survey Open-File Report 2010–1031, U.S. Geological Survey, Reston, Virginia.

Saunders S., C. Montgomery, T. Easley, and T. Spencer. 2008. Hotter and drier: the West's changed climate. The Rocky Mountain Climate Organization and Natural Resources Defense Council, March. Available at http://www.rockymountainclimate.org/website%20pictures/Hotter%20and%20Drier.pdf. Accessed November 1, 2016.

Schmidt, J.C., and P.E. Grams. 2011. The High Flows-Physical Science Results pp. 53–91 *In* Effects of Three High-Flow Experiments on the Colorado River Ecosystem Downstream from Glen Canyon Dam, Arizona, U.S. Geological Survey Circular 1366.

Shannon, J.P., D.W. Blinn and L.E. Stevens. 1994. Trophic interactions and benthic animal community structure in the Colorado River, Arizona, U.S.A. Freshwater Biology 31:213-220.

Sorensen, J.A. 2009. Kanab Ambersnail habitat mitigation for the 2008 high flow experiment: Phoenix, Arizona Game and Fish Department, Nongame and Endangered Wildlife Program, Technical Report 257.

Sorensen, J.A. 2012. Kanab Ambersnail 2011 Status Report, Technical Report 268, Arizona Game and Fish Department, Phoenix, Arizona

_____. 2016. Summary of Kanab Ambersnail Monitoring Results from Arizona Game and Fish Department, 2007-2015. Arizona Game and Fish Department, Phoenix, Arizona. March 24, 2014. 4pp.

Sorensen, J.A. and D.M. Kubly. 1997. Investigations of the endangered Kanab ambersnail: monitoring, genetic studies, and habitat evaluation in Grand Canyon and Northern Arizona *In* Nongame and Endangered Wildlife Program Technical Report 122. Phoenix, Arizona: Arizona Game and Fish Department.

Speas, D. and M. Trammell. 2009. Aquatic Habitat Characteristics by River Mile in Lower Grand Canyon; Preliminary Results of 2009 Field Survey, Bureau of Reclamation and National Park Service, Salt Lake City, Utah.

Spurgeon, J.J., C.P. Paukert, B.D. Healy, M.T. Trammell, D.W. Speas, and E. Omana-Smith. 2015. Translocation of Humpback Chub into Tributary Streams of the Colorado River: Implications for Conservation of Large-River Fishes. Transactions of the American Fisheries Society 144(3):502–514.

Stevens, L.E., F.R. Protiva, D.M. Kubly, V.J. Meretsky and J. Petterson. 1997. The ecology of Kanab ambersnail (Succineidae: *Oxyloma haydeni kanabensis* Pilsbry, 1948) at Vasey's Paradise, Grand Canyon, Arizona: 1995 Final Report. Edited by Glen Canyon Environmental Studies Program. Flagstaff, AZ: U.S. Department of the Interior, Bureau of Reclamation, Glen Canyon Environmental Studies Program Report.

Stewart, B. 2016. Brown Trout Update Lees Ferry. Presentation at Glen Canyon Dam Adaptive Management Technical Work Group Annual Reporting Meeting, January 26–27.

Stone, D.M. and O.T. Gorman. 2006. Ontogenesis of Endangered Humpback Chub (*Gila cypha*) in the Little Colorado River, Arizona. American Midland Naturalist 155:123–135.

Stone, D., D.R. Van Haverbeke, D.L. Ward, and T. Hunt. 2007. Dispersal of Non-native Fishes and Parasites in the Intermittent Little Colorado River, Arizona. Southwestern Naturalist 52(1): 130-137.

Tietjen, T. 2014. Lake Mead Water Quality: Upstream Influences, Regional Water Quality, Southern Nevada Water Authority, Nov. 17.

Trammell, M., R. Valdez, S. Carothers, and R. Ryel. 2002. Effects of a Low Steady Summer Flow Experiment on Native Fishes of the Colorado River in Grand Canyon, Arizona, prepared by SWCA Environmental Consultants, for Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Tyus, H.M. and C.A. Karp. 1989. Habitat use and streamflow needs of rare and endangered fishes, Yampa River, Colorado. US Fish and Wildlife Service, Biological Reports 89(14):1-27.

U.S. Bureau of Reclamation (Reclamation). 1996. Record of Decision, Operation of Glen Canyon Dam Colorado River Storage Project, Final Environmental Impact Statement, U.S. Department of the Interior, Bureau of Reclamation, Salt lake City, Utah, Oct. Available at http://www.usbr.gov/uc/rm/amp/pdfs/sp_appndxG_ROD.pdf.

_____. 1999. Plan and Draft Environmental Assessment, Modifications to Control Downstream Temperatures at Glen Canyon Dam, U.S. Department of the Interior, Jan.

_____. 2007. Environmental Impact Statement—Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead, U.S. Department of the Interior, Bureau of Reclamation, Upper and Lower Colorado Region, Oct. Available at http://www.usbr.gov/lc/region/programs/strategies.html.

_____. 2011a. Environmental Assessment - Development and Implementation of a Protocol for High-Flow Experimental Releases from Glen Canyon Dam 2011–2020, U.S. Department of the Interior, Bureau of Reclamation, Upper Colorado River Region, Salt Lake City, Utah.

_____. 2011b. Environmental Assessment - Non-native Fish Control Downstream from Glen Canyon Dam, U.S. Department of the Interior, Bureau of Reclamation, Upper Colorado River Region, Salt Lake City, Utah.

_____. 2011c. SECURE Water Act Section 9503(c) – Reclamation Climate Change and Water 2011, U.S. Department of the Interior, Policy and Administration, April.

_____. 2012a. Colorado River Basin Water Supply and Demand Study, U.S. Department of the Interior, Bureau of Reclamation.

_____. 2012b. Colorado River Basin Water Supply and Demand Study: Technical Report D—System Reliability Metrics, U.S. Department of the Interior, Dec. Available at http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/studyrpt.html.

_____. 2016. Biological assessment for the Glen Canyon long-term experimental and management plan (LTEMP). U.S. Bureau of Reclamation, September 27, 2016. 184pp.

U.S. Fish and Wildlife Service (USFWS). 1979. Humpback chub recovery plan. Report of Colorado River Fishes Recovery Team to U.S. Fish and Wildlife Service, Region 6, Denver, Colorado.

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

_____. 1991. Final rule determining endangered status for the razorback sucker. Federal Register 56:54957-54967.

_____. 1992. Endangered and threatened wildlife and plant: final rule to list the Kanab ambersnail as an endangered species. Federal Register 57:13657-13661.

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

_____. 1995. Kanab ambersnail (*Oxyloma haydeni kanabensis*) Recovery Plan. U.S. Fish and Wildlife Service, Denver, Colorado. 21pp.

_____. 1998. Razorback sucker (*Xyrauchen texanus*) recovery plan. U.S. Fish and Wildlife Service. Denver, Colorado. 81pp.

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

_____. 2002b. Razorback sucker (*Xyrauchen texanus*) recovery goals: Amendment and supplement to the Razorback Sucker Recovery Plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

_____. 2008. Final Biological Opinion on the Operations of Glen Canyon Dam dated February 27, 2008. Arizona Ecological Services Office, Phoenix, Arizona. 88pp.

_____. 2009. Supplement to the 2008 Final Biological Opinion for the Operation of Glen Canyon Dam dated October 29, 2009. Arizona Ecological Services Office, Phoenix, Arizona. 148pp.

_____. 2011a. Final Biological Opinion on the Operation of Glen Canyon Dam Including High-Flow Experiments and Non-Native Fish Control. Arizona Ecological Services Office, Phoenix, Arizona. December 23, 2011. 150pp.

_____. 2011b. 5-Year Review: Humpback Chub (*Gila cypha*) Summary and Evaluation, Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

_____. 2011c. Biological and Conference Opinion on the Wildlife and Sport Fish Restoration Funding of Arizona Game and Fish Department's Statewide Urban Fisheries Stocking Program for 2011-2021. Arizona Ecological Services Office, Phoenix, Arizona.

_____. 2011d. Kanab ambersnail (*Oxyloma haydeni kanabensis*) 5 year review: summary and evaluation. U.S. Fish and Wildlife Service, Ecological Services – Utah Field Office, West Valley City, Utah. 26pp.

_____. 2012. 5-Year Review: Razorback sucker (*Xyrauchen texanus*) Summary and Evaluation, Upper Colorado River Endangered Fish Recovery Program Denver, Colorado.

Valdez, R.A. and G.H. Clemmer. 1982. Life History and Prospects for Recovery of the Humpback Chub and Bonytail Chub, pp. 109–119 *In* Fishes of the Upper Colorado River System: Present and Future, W.H. Miller et al. (eds.), American Fisheries Society, Western Division, Bethesda, Maryland.

Valdez, R.A. and W.J. Masslich. 1999. Evidence of Reproduction of Humpback Chub in a Warm Spring of the Colorado River in Grand Canyon, Arizona. The Southwestern Naturalist 44(3):384–387.

Valdez, R.A. and R.J. Ryel. 1995. Life History and Ecology of the Humpback Chub (*Gila cypha*), in the Colorado River, Grand Canyon, Arizona: Final Report. Available at http://www.gcmrc.gov/library/reports/biological/Fish_studies/gces/valdez1995f.pdf.

_____. 1997. Life History and Ecology of the Humpback Chub in the Colorado River in Grand Canyon, Arizona, pp. 3–31 *In* Proceedings of the Third Biennial Conference of Research on the Colorado Plateau, C. VanRiper III and E. T. Deshler (eds.).

Valdez, R. A. and D. W. Speas. 2007. A risk assessment model to evaluate risks and benefits to aquatic resources from a selective withdrawal structure on Glen Canyon Dam. Bureau of Reclamation, Salt Lake City, Utah.

Van Haverbeke, D.R., D.M. Stone, and M.J. Pillow. 2013. Long-Term Monitoring of an Endangered Desert Fish and Factors Influencing Population Dynamics. Journal of Fish and Wildlife Management 4(1):163–177.

Van Haverbeke, D.R., K.L Young, and B. Healy. 2016. Translocation and Refuge Framework for Humpback Chub (*Gila cypha*) in Grand Canyon, USFWS-AZFWCO-FL-16-03, U.S. Fish and Wildlife Service, Flagstaff, Arizona.

Vernieu, W.S. and C.R. Anderson. 2013. Water Temperatures in Select Nearshore Environments of the Colorado River in Grand Canyon, Arizona, during the Low Steady Summer Flow Experiment of 2000, Open-File Report 2013–1066, U.S. Geological Survey.

Vernieu, W.S., S.J. Hueftle, and S.P. Gloss. 2005. Chapter 4, "Water Quality in Lake Powell and the Colorado River," *In* The State of the Colorado River Ecosystem in Grand Canyon, J.E. Lovich and T.S. Melis (eds.), U.S. Geological Survey Circular 1282, U.S. Geological Survey, Reston, Va. Available at http://pubs.usgs.gov/circ/1282/c1282.pdf.

Walters, D.M., E. Rosi-Marshall, T.A. Kennedy, W.F. Cross, and C.V. Baxter. 2015. Mercury and Selenium Accumulation in the Colorado River Food Web, Grand Canyon, USA. Environmental Toxicology and Chemistry 34(10):2385–2394.

Ward, D.L. 2011. How Does Temperature Affect Fish?" presented at Knowledge Assessment II: 2nd Synthesis Workshop with the Grand Canyon Technical Workgroup - Aquatic Resources, October 18–19, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Ward, D.L. and S.A. Bonar, 2003. Effects of Cold Water on Susceptibility of Age-0 Flannelmouth Sucker to Predation by Rainbow Trout. The Southwestern Naturalist 48(1):43–46.

Ward, D.L., and R. Morton-Starner. 2015. Effect of Water Temperature and Fish Size on Predation Vulnerability of Juvenile Humpback Chub to Rainbow Trout and Brown Trout. Transactions of the American Fisheries Society 144(6):1184–1191.

Webb, M.A. and R.A. Fridell. 2000. Kanab ambersnail distribution surveys in the East Fork of the Virgin River, Upper Parunuweap Canyon, Utah. Publication No. 00-29. Salt Lake City, UT: Utah Division of Wildlife Resources.

Whiting, D.P., C.P. Paukert, B.D. Healy, and J.J. Spurgeon. 2014. Macroinvertebrate Prey Availability and Food Web Dynamics of Nonnative Trout in a Colorado River Tributary, Grand Canyon. Freshwater Science 33(3):872–884.

Woodward, G., J.B. Dybkjer. J.S. Ólafsson, G.M. Gíslason, E.R. Hannesdóttir, and N. Friberg, 2010. Sentinel systems on the razor's edge: effects of warming on arctic geothermal stream Ecosystems. Global Change Biology 16:1979-1991.

Wright, S.A. and T.A. Kennedy. 2011. Science-Based Strategies for Future High-Flow Experiments at Glen Canyon Dam *In* Effects of Three High-Flow Experiments on the Colorado River Ecosystem Downstream from Glen Canyon Dam, Arizona, T.S. Melis (ed.), U.S. Geological Survey Circular 1366.

Wrona, F.J., T.D. Prowse, J.D. Reist, J.E. Hobbie, L.C. Lévesque, and W.F. Vincent. 2006. Climate change effects on aquatic biota, ecosystem structure and function. Ambio 35(7):359-369.

Yackulic, C.B., M.D. Yard, J. Korman, and D.R. Van Haverbeke. 2014. A Quantitative Life History of Endangered Humpback Chub That Spawn in the Little Colorado River: Variation in Movement Growth and Survival. Ecology and Evolution 4(7):1006–1018.

Yard. M.D., L.G. Coggins, and C.V. Baxter. 2008. Foraging ecology of non-native trout in the Colorado River, Grand Canyon: predation on native fishes and the effects of turbidity. U.S Geological Survey, Powerpoint presentation to the Glen Canyon Dam Adaptive Management Program, Technical Work Group, June 16-17, 2008.

Yard, M.D., L.G. Coggins, C.V. Baxter, G.E. Bennett, and J. Korman. 2011. Trout Piscivory in the Colorado River, Grand Canyon: Effects of Turbidity, Temperature, and Fish Prey Availability. Transactions of the American Fisheries Society 140:471–486

Young, K., D. Van Haverbeke, S. Vanderkooi, D. Ward, C. Yackulic, M. Yard, B. Healy, M. Trammell, D. Rogowski, M. Crawford. 2015. Draft Final Proposed action triggers for the management of humpback chub, Colorado River, Grand Canyon, November 2015. 11pp.

# APPPENDIX A – CONCURRENCES

This appendix contains our concurrences with your "may affect, not likely to adversely affect" determinations for the endangered southwestern willow flycatcher (*Empidonax traillii extimus*) and the endangered Yuma Ridgway's rail (*Rallus obsoletus yumanensis*).

Southwestern willow flycatcher

We concur with your determination that the proposed action may affect, but is not likely to adversely affect the endangered southwestern willow flycatcher. We base this concurrence on the following:

- Southwestern willow flycatchers are not expected to be in the action area when spring HFEs could occur (March – April). In addition, high flows of 45,000 cfs or less are not expected to have measurable effects on potential foraging or nesting habitat.

- Designated critical habitat for the southwestern willow flycatcher does not occur in the area of the proposed action; therefore, there will be no effects to critical habitat.

Yuma Ridgway's rail

We concur with your determination that the proposed action may affect, but is not likely to adversely affect the endangered Yuma Ridgway's rail. We base this concurrence on the following:

- The project area has very little cattail/marsh habitat that would provide suitable habitat for rails. In addition, due to the dropping water levels in Lake Mead, this potential habitat in the lowest portion of Grand Canyon is now ten or more feet above the flowing river level, and therefore is out of reach of fluctuating flows, including HFEs. Therefore, if rails used the habitat, it is not close enough to the river to be impacted by HFEs because HFEs have minimal stage change in this broad floodplain habitat.

- Designated critical habitat for the Yuma Ridgway's rail does not occur in the area of the proposed action; therefore, there will be no effects to critical habitat.