APPENDIX O:

BIOLOGICAL ASSESSMENT FOR THE GLEN CANYON DAM LONG-TERM EXPERIMENTAL AND MANAGEMENT PLAN

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RECLAMATION
Managing Water in the West

Biological Assessment for the Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP)

U.S. Department of the Interior *August 2016*

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ACRONYMS AND ABBREVIATIONS

ac	acre(s)
ac-ft	acre-foot (feet)
AMWG	Adaptive Management Work Group
ASMR	Age-Structured Mark Recapture Model
AZGFD	Arizona Game and Fish Department
BA	biological assessment
BIA	Bureau of Indian Affairs
BO	Biological Opinion
C	Celsius
CFMP	*Comprehensive Fisheries Management Plan*
CFR	*Code of Federal Regulations*
cfs	cubic feet per second
cm	centimeter(s)
CRSP	Colorado River Storage Project
CRSPA	Colorado River Storage Project Act of 1956
DOI	U.S. Department of the Interior
EA	environmental assessment
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, and Trichoptera
ESA	Endangered Species Act of 1973, as amended
F	Fahrenheit
FR	*Federal Register*
ft	foot (feet)
ft^3	cubic foot (feet)
FWS	U.S. Fish and Wildlife Service
GCDAMP	Glen Canyon Dam Adaptive Management Program
GCMRC	Grand Canyon Monitoring and Research Center
GCNP	Grand Canyon National Park
GCNRA	Glen Canyon National Recreation Area
GCPA	Grand Canyon Protection Act of 1992
HBC	humpback chub
HFE	high-flow experiment
Hg	mercury
hr	hour(s)

IKAMPT	Interagency Kanab Ambersnail Monitoring Team
in.	inch(es)
JCM	juvenile chub monitoring
kaf	thousand acre-feet
km	kilometer(s)
lb	pound(s)
LCRMSCP	Lower Colorado River Multi-Species Conservation Program
LMNRA	Lake Mead National Recreation Area
LTEMP	Glen Canyon Dam Long-Term Experimental and Management Plan
maf	million acre-feet
mi	mile(s)
MLFF	Modified Low Fluctuating Flow
mm	millimeter(s)
MVP	Minimum Viable Population
NEPA	National Environmental Policy Act of 1969, as amended
NHPA	National Historic Preservation Act
NPS	National Park Service
NRHP	*National Register of Historic Places*
OSMRE	Office of Surface Mining Reclamation and Enforcement
ppb	part(s) per billion
Reclamation	Bureau of Reclamation
RM	river mile
ROD	Record of Decision
Se	selenium
SNARRC	Southwestern Native Aquatic Resources and Recovery Center
TL	total length
TMF	trout management flow
TWG	Technical Working Group
UCRC	Upper Colorado River Commission
USC	*United States Code*
USFS	U.S. Forest Service
USGS	U.S. Geological Survey

WAPA	Western Area Power Administration
YOY	young-of-the-year

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1 INTRODUCTION AND BACKGROUND

The Bureau of Reclamation (Reclamation) has prepared this biological assessment (BA) to analyze the potential effects of the proposed Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP) as described in the associated Environmental Impact Statement (EIS) on federally listed species. The BA analyzes the effects of implementation of flow and non-flow actions 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) (Figure 1). This BA was prepared by Reclamation as part of its compliance with the Endangered Species Act of 1973, as amended (ESA; 87 Stat. 884; 16 U.S.C. §1531 et seq.). A BA evaluates the potential effects of the action on listed and proposed species and designated and proposed critical habitat and determines whether any such species or habitat are likely to be adversely affected by the action (50 CFR 402.12).

A total of nine species currently listed under the ESA occur within the project area (Table 1). Five species are addressed in this BA due to potential effects from the proposed action: humpback chub (*Gila cypha*), razorback sucker (*Xyrauchen texanus*), southwestern willow flycatcher (*Empidonax traillii extimus*), Ridgway's Rail (formerly Yuma Clapper Rail) (*Rallus obsoletus*), and the Kanab ambersnail (*Oxyloma kanabensis*). Reclamation made "No effect" determinations for the Mexican spotted owl (*Strix occidentalis lucida*), the western yellow-billed cuckoo (*Coccyzus americanus*), and sentry milk-vetch (*Astragalus cremnophylax cremnophyla*). None of these species, or their habitat, occur in the area where activities would be implemented, and thus they are not considered further in this analysis. Reclamation has previously consulted on the bald eagle (*Haliaeetus leucocephalus*), American peregrine falcon (*Falco peregrinus anatum*), and California condor (*Gymnogyps californianus*). The California condor is an endangered species that would not be affected by this action, and the condors released in Arizona are designated as a non-essential, experimental population under the 10(j) rule of the ESA. The peregrine falcon and bald eagle have been removed from the list of threatened and endangered species and are not addressed in this BA.

TABLE 1 Federally Listed Species Occurring within the Project Area

Name	Species	Status
Mexican Spotted Owl	*Strix occidentalis lucida*	Threatened
Southwestern Willow Flycatcher	*Empidonax traillii extimus*	Endangered
California Condor	*Gymnogyps californianus*	Considered Threatened in National Parks; Experimental Non-Essential population in Northern Arizona
Western Yellow-billed Cuckoo	*Coccyzus americanus*	Threatened
Yuma Ridgway's (formerly Yuma Clapper) Rail	*Rallus obsoletus yumanensis*	Endangered
Kanab Ambersnail	*Oxyloma haydeni kanabensis*	Endangered
Humpback Chub	*Gila cypha*	Endangered
Razorback Sucker	*Xyrauchen texanus*	Endangered
Sentry Milk-vetch	*Astragalus cremnophylax cremnophylax*	Endangered

The BA provides the information and analysis to support Reclamation's conclusions concerning possible effects on the species and habitats listed in Table 1. Based upon the information contained in this BA, Reclamation has determined that the proposed action may affect, but is not likely to adversely affect, the southwestern willow flycatcher and Ridgway's Rail, and requests concurrence from the U.S. Fish and Wildlife Service (FWS). Reclamation has also determined that the proposed action may affect and is likely to adversely affect the humpback chub and its critical habitat, the razorback sucker and its critical habitat, and the Kanab ambersnail, and provides this information to the FWS to initiate formal consultation.

Reclamation is the lead agency within the U.S. Department of the Interior (DOI) that operates Glen Canyon Dam of the Colorado River Storage Project as a multipurpose storage facility in northern Arizona. Construction and operation of the dam were authorized by the 1956 Colorado River Storage Project Act. Operation of the dam is governed by a complex set of compacts, federal statutes and regulations, court decrees, and an international treaty collectively and commonly referred to as the Law of the River.

Development of the proposed action included the evaluation of specific alternatives that could be implemented to meet the Grand Canyon Protection Act's (GCPA's; 1992) requirements and to minimize, consistent with law, adverse impacts on the downstream natural, recreational, and cultural resources in the two park units, including resources of importance to American Indian Tribes. The need for the proposed action stems from the need to use scientific information developed since the 1996 Record of Decision (ROD) and the Operation of Glen Canyon Dam Final Environmental Impact Statement (1995 EIS) to better inform DOI decisions on dam operations and other management and experimental actions so that the Secretary of the Interior (Secretary) may continue to meet statutory responsibilities for protecting downstream resources for future generations, conserving federally listed species, avoiding or mitigating impacts on National Register-eligible properties, and protecting Native American interests, while meeting obligations for water delivery and the generation of hydroelectric power. The action will provide a framework for adaptively managing Glen Canyon Dam over the next 20 years consistent with the GCPA and other provisions of applicable federal law. Several key issues related to natural resources downstream of Glen Canyon Dam and new scientific information related to them are summarized below.

The Colorado River downstream from Glen Canyon Dam is depleted of its natural sediment load due to the presence of the dam, and many types of ongoing dam releases further deplete sediment delivered to the main channel by causing erosion. However, high-flow releases, between approximately 30,000 and 45,000 cfs that are triggered when there is sufficient sediment from the Paria River, mobilize sand stored in the river channel and redeposit it as sandbars and beaches and associated backwater and riparian habitats (Melis et al. 2011). Because sandbars are one of the natural resources addressed by the GCPA that are to be protected, mitigated, and, where possible, improved, the LTEMP EIS uses current comprehensive scientific data and modeling to consider possible improvements related to the use of high-flow experiments (HFEs), as well as possible intervening flow operations, that may help better achieve the goal of retaining sandbars.

Since the 1995 EIS, the status of the endangered humpback chub has continued to be an issue of concern since the population in Grand Canyon, the largest in existence, declined during the late 1990s coincident with cooler water temperatures and high nonnative trout abundance and other factors. The cause of the decline was probably the result of a combination of factors, and based on Age-Structured Mark Recapture (ASMR) and multi-state models (see Figure 8), the species has since rebounded over the last decade, when water temperatures were warmer and trout abundance lower (Yackulic et al. 2014; Yard et al. 2011). Until recently, Rainbow trout have been the nonnative species of concern, but brown trout and warmwater nonnatives are becoming or are likely to become an additional concern. Uncertainty remains as to future humpback chub population response to changes in flows, nonnative species, and water temperatures that are largely driven by reservoir elevation.

There is concern among managers and scientists that nonnative fish compete with or prey upon the native or endangered fish to varying degrees (Yard et al. 2011; Whiting et al. 2014; Gloss and Coggins 2005). The effects of dam operations were examined in the 1995 EIS, and much additional information has been accumulated about the effects of dam operations on native and nonnative fish since that time. The LTEMP EIS applies the best available science and modeling methods to further consider the impacts of a variety of dam operations on native and nonnative fish and to determine what future experimentation is needed regarding these flow regimes to reduce the negative interactions of nonnative fish with native fish.

In addition to humpback chub, other important fish fauna found in the Colorado River below Glen Canyon Dam include razorback sucker (also listed as endangered), and three other native fish, flannelmouth sucker (*Catostomus latippinis*), bluehead sucker (*Catostomus discobolus*), and speckled dace (*Rhinichthys osculus*). Razorback sucker were thought to be extirpated from the Grand Canyon, but adults (Arizona Game and Fish Department [AZGFD], 2012 Data) and larval razorback sucker (Albrecht et al. 2014) have recently been found in the western Grand Canyon. Populations of bluehead and flannelmouth suckers have fluctuated in the Colorado River in the Grand Canyon since the 1995 EIS (Rogowski et al. 2015).

1.1 SYNOPSIS OF THE PROPOSED ACTION

The LTEMP EIS proposed action (Alternative D) affects monthly, daily, and hourly releases from Glen Canyon Dam but does not affect annual water release determinations. Under the proposed action (Alternative D of the EIS), the total monthly release volume of October, November, and December would be equal to that under Modified Low Fluctuating Flows (MLFF), the current operations, to avoid the possibility of the operational tier differing from that of MLFF, as established in the Interim Guidelines (Reclamation 2007a). The August volume was set to a moderate volume level (800 kaf in an 8.23-maf release year) to balance sediment conservation prior to a potential fall HFE, and power production and capacity concerns. January through July monthly volumes were set at levels that roughly track Western Area Power Administration's (WAPA's) contract rate of power delivery. This produced a redistribution of monthly release volumes under the proposed action and results in a relatively even distribution of flows. Under the proposed action, the allowable within-day fluctuation range 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 cfs. The down-ramp rate would be increased to 2,500 cfs/hr, but the up-ramp rate would remain unchanged at 4,000 cfs/hr.

Experimentation under the proposed action includes testing the effects of the following actions:

1. Sediment-triggered spring and fall HFEs through the entire 20-year LTEMP period;

2. 24-hr proactive spring HFEs in high volume years (≥10 maf release volume);

3. Extension of the duration of up to 45,000 cfs fall HFEs for as many as 250 hr depending on sediment availability;

4. Proactive conservation actions for humpback chub if triggered by declines in humpback chub abundance and mechanical removal of nonnative fish near the Little Colorado River confluence, if proactive conservation actions fail to arrest humpback chub population decline;

5. Trout management flows;

6. A test of low summer flows in the second 10 years of the LTEMP period to allow greater warming; and

7. Sustained low flows to improve the aquatic food base.

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, application of the Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a).

1.2 DESCRIPTION OF THE FEDERAL ACTION

1.2.1 Regulatory Context

Past consultations have evaluated the impact of proposed actions on the threatened and endangered species that live in the Colorado River and its floodplain between Glen Canyon Dam and at the time, Separation Canyon, near the inflow area of Lake Mead, Coconino and Mohave Counties, northern Arizona. This BA focuses on the area of the Colorado River from Glen Canyon Dam to Lake Mead below Pierce Ferry Rapid (river mile [RM] 280, [451 km]), although the impacts of some elements of the proposed action could extend downstream and upstream of this area, and into tributary streams. The anticipated area of effect lies within the State of Arizona and in LMNRA, GCNRA, and GCNP. The area is bordered by, or is in proximity to, the Navajo Nation, Havasupai, and Hualapai tribal lands.

1.2.2 Action Area

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, and the river downstream to Lake Mead (see Figure 1 for the locations of Lakes Powell and Mead, Glen Canyon Dam, the Colorado River, and adjacent lands). 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 GCNP. It includes the area where dam operations impact physical,

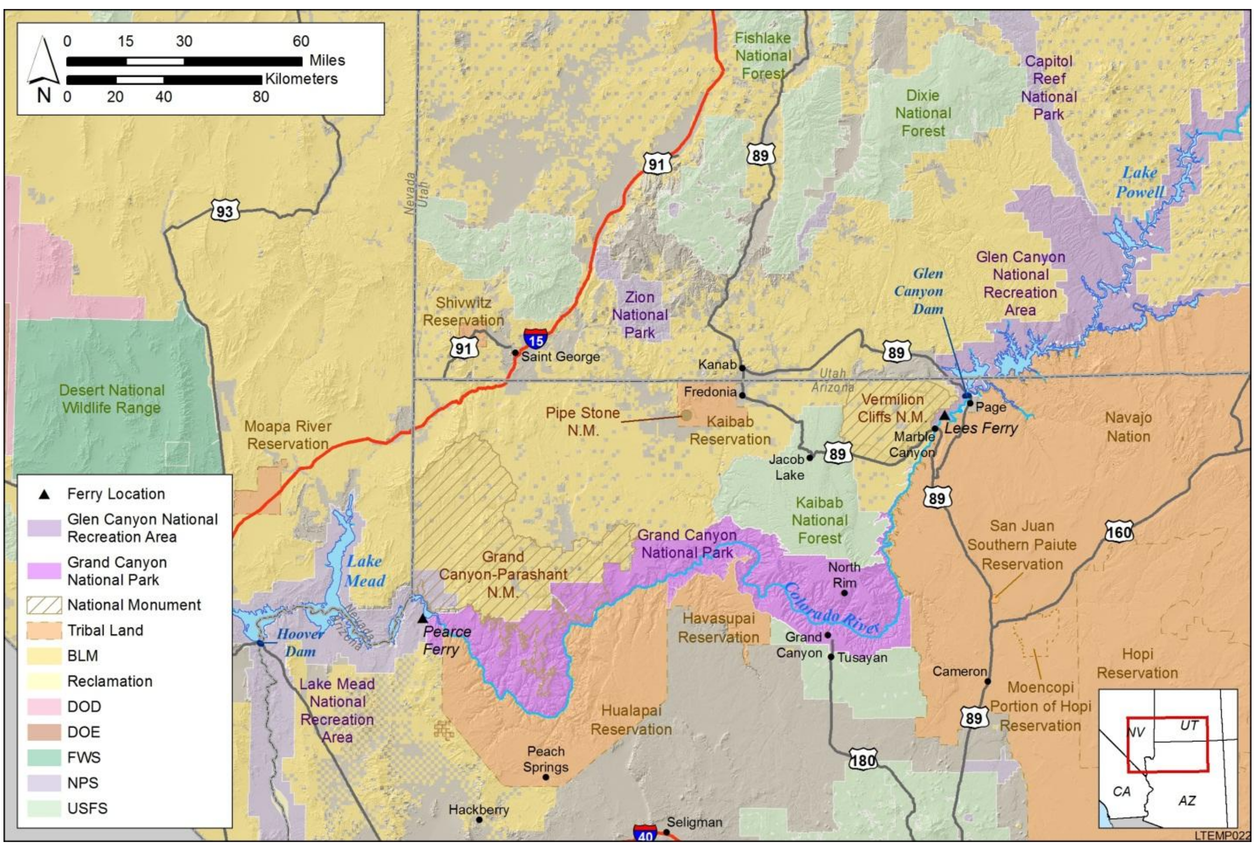


FIGURE 1 Locations of Glen Canyon Dam, Lake Powell, and the Colorado River between Lake Powell and Lake Mead, and Adjacent Lands

biological, recreational, cultural, and other resources. Portions of GCNRA, GCNP, and LMNRA are included within this area.

1.2.3 Project Description

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 objectives and resource goals were considered in the formulation and development of alternatives in this EIS.

The following is a list of the objectives of the LTEMP:

- Develop an operating plan for Glen Canyon Dam in accordance with the GCPA to protect, mitigate adverse impacts on, and improve the values for which GCNP and GCNRA were established, including, but not limited to, natural and cultural resources and visitor use, and to do so in such a manner as is fully consistent with and subject to the Colorado River Compact, the Upper Colorado River Basin Compact, the Water Treaty of 1944 with Mexico, the decree of the U.S. Supreme Court in Arizona v. California, and the provisions of the Colorado River Storage Project Act (CRSPA) of 1956 and the Colorado River Basin Project Act of 1968 that govern the allocation, appropriation, development, and exportation of the waters of the Colorado River Basin and in conformance with the Criteria for Coordinated Long-Range Operations of Colorado River Reservoirs as currently implemented by the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead.

- Ensure water delivery to the communities and agriculture that depend on Colorado River water consistent with applicable determinations of annual water release volumes from Glen Canyon Dam made pursuant to the Long-Range Operating Criteria for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead.

- Consider potential future modifications to Glen Canyon Dam operations and other flow and non-flow actions to protect and improve downstream resources.

- Maintain or increase Glen Canyon Dam electric energy generation, load following capability, and ramp rate capability, and minimize emissions and costs to the greatest extent practicable, consistent with improvement and long-term sustainability of downstream resources.

- Respect the interests and perspectives of American Indian Tribes.

- Make use of the latest relevant scientific studies, especially those conducted since 1996.

- Determine the appropriate experimental framework that allows for a range of programs and actions, including ongoing and necessary research, monitoring, studies, and management actions in keeping with the adaptive management process.

- Identify the need for a Recovery Implementation Program for endangered fish species below Glen Canyon Dam.

- Ensure Glen Canyon Dam operations are consistent with the GCPA, ESA, National Historic Preservation Act (NHPA), CRSPA, and other applicable federal laws.

Reclamation and the National Park Service (NPS) developed resource goals considering public input and desired future conditions (DFCs) previously adopted by the Glen Canyon Dam Adaptive Management Work Group (AMWG). The following resource goals were identified:

1. *Archaeological and Cultural Resources.* Maintain the integrity of potentially affected *National Register of Historic Places* (NRHP)-eligible or listed historic properties in place, where possible, with preservation methods employed on a site-specific basis.

2. *Natural Processes.* Restore, to the extent practicable, ecological patterns and processes within their range of natural variability, including the natural abundance, diversity, and genetic and ecological integrity of the plant and animal species native to those ecosystems.

3. *Humpback Chub.* Meet humpback chub recovery goals, including maintaining a self-sustaining population, spawning habitat, and aggregations in the humpback chub's natural range in the Colorado River and its tributaries below the Glen Canyon Dam.

4. *Hydropower and Energy.* Maintain or increase Glen Canyon Dam electric energy generation, load following capability, and ramp rate capability, and minimize emissions and costs to the greatest extent practicable, consistent with improvement and long-term sustainability of downstream resources.

5. *Other Native Fish.* Maintain self-sustaining native fish species populations and their habitats in their natural ranges on the Colorado River and its tributaries.

6. *Recreational Experience.* Maintain and improve the quality of recreational experiences for the users of the Colorado River ecosystem. Recreation includes, but is not limited to, flatwater and whitewater boating, river corridor camping, and angling in Glen Canyon.

7. *Sediment.* Increase and retain fine sediment volume, area, and distribution in the Glen, Marble, and Grand Canyon reaches above the elevation of the average base flow for ecological, cultural, and recreational purposes.

8. *Tribal Resources.* Maintain the diverse values and resources of traditionally associated Tribes along the Colorado River corridor through Glen, Marble, and Grand Canyons.

9. *Rainbow Trout Fishery.* Achieve a healthy high-quality recreational rainbow trout fishery in GCNRA and reduce or eliminate downstream trout migration consistent with NPS fish management and ESA compliance.

10. *Nonnative Invasive Species.* Minimize or reduce the presence and expansion of aquatic nonnative invasive species.

11. *Riparian Vegetation.* Maintain native vegetation and wildlife habitat, in various stages of maturity, such that they are diverse, healthy, productive, self-sustaining, and ecologically appropriate.

The preferred alternative in the LTEMP EIS is Alternative D, which was developed by the DOI after a full analysis of the other six LTEMP alternatives had been completed. Alternative D adopted operational and experimental characteristics from other alternatives, after the effects of operations under other alternatives were modeled, and the results of that modeling suggested ways in which characteristics of each could be combined and modified to improve performance and reduce impacts, while meeting the purpose, need, and objectives of the LTEMP EIS. Alternative D features condition-dependent flow actions (operations at Glen Canyon Dam) and non-flow actions that would be triggered by resource conditions. Operations under the preferred alternative would use only existing dam infrastructure. There are a number of experimental and management actions that are a part of the preferred alternative; these are described briefly in the list below.

- Spring and fall HFEs would be implemented when triggered 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 (Section 1.2.9).

- Nonnative fish control actions would be implemented if the Little Colorado River humpback chub population declined, and proactive conservation actions had failed to reverse declining populations. Two different tiers of population metrics would be used to trigger responses such as actions to increase growth and survival of humpback chub (Tier 1), or mechanical nonnative fish control

(Tier 2), which would only be implemented when Tier 1 actions fail to slow or reverse the decline in the humpback chub population (Section 1.2.10; Appendix D).

- Experimental trout management flows (TMFs) could be used to control annual trout production in the Glen Canyon reach for the purposes of managing the trout fishery and for limiting emigration to Marble Canyon and the Little Colorado River reach. Trout management flows will be tested early in the experimental period, preferably in the first 5 years (Section 1.2.10).

- 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) (Section 1.2.10).

- Low steady weekend flows for macroinvertebrate production, "bug flows." The primary objective of bug flows is to test whether these flows will increase insect abundance. On an experimental basis, for example, flows would be held low and steady for 2 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), referred to as EPT. While seeing EPT in the canyon is a worthwhile goal, it is a very long-term goal and unlikely to occur during initial experimentation (Section 1.2.11).

- Preservation of historic properties through a program of research, monitoring, and mitigation to address erosion and preservation of archeological and ethnographic sites and minimize loss of integrity at National Register historic properties.

- Continued adaptive management under the Glen Canyon Dam Adaptive Management Program (GCDAMP), including a research and monitoring component. Research projects have been developed on a 3-year funding cycle under the direction of the GCDAMP, which would continue under the proposed action. The level of fisheries monitoring will be expected to remain the same, or increase slightly, in order to address uncertainties and monitor responses to experiments and changed operations.

In addition, the joint-lead agencies have established "sideboards" that constrain the breadth and nature of the implementation of flow and non-flow actions of the proposed action.

1.2.4 Conservation Measures

Conservation measures identified in the 2011 Biological Opinion (BO) on operations of Glen Canyon Dam (FWS 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 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. Most of these conservation measures 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. These include experimental and management actions at specific sites such as nonnative plant removal, revegetation with native species, and mitigation at specific and appropriate cultural sites.

Five species listed under the ESA are addressed in the BA: humpback chub (*Gila cypha*), razorback sucker (*Xyrauchen texanus*), Kanab ambersnail (*Oxyloma kanabensis*), southwestern willow flycatcher (*Empidonax traillii extimus*), and Yuma Ridgway's rail (*Rallus longirostris yumanensis*). Conservation measures to minimize or reduce the effects of the proposed action or benefit or improve the status of listed species as part of the LTEMP are organized by species below.

1.2.4.1 Humpback Chub

Ongoing actions for the humpback chub include the following:

- Reclamation will continue to support the NPS, FWS, Grand Canyon Monitoring and Research Center (GCMRC), and the 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). Specifically, the following will occur:
  - Humpback chub will 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 will be conducted annually, or as needed, depending on the data required, to determine survivability, population status, or genetic integrity of the Havasu humpback chub population. Intermittent translocations of additional humpback chub in Havasu Creek will be

conducted if the FWS and NPS determine it is necessary to maintain genetic integrity of the population.

- Reclamation will continue to fund a spring and fall population estimate annually, using a mark recapture based model for the Little Colorado River or the most appropriate model developed for the current collecting techniques and data.

- Reclamation will 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 will lead any investigation into the possibility of using a chemical piscicide, or other tools, as appropriate. Tributaries and the appropriate control methods will be identified by the FWS, NPS, Reclamation, and GCMRC, in consultation with the AZGFD. Depending on the removal methods identified, additional planning and compliance (e.g., National Environmental Policy Act [NEPA], NHPA) may be necessary.

- Reclamation will 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, a humpback chub refuge will provide a permanent source of sufficient numbers of genetically representative stock for repatriating the species.

- Reclamation will 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 [JCM] 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) (Keggeries 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.

An ongoing action for the humpback chub that needs enhancement is the following:

- Reclamation will, through the GCDAMP, conduct disease and parasite monitoring in humpback chub and other fishes in the mainstem Colorado. The U.S. Geological Survey (USGS) and GCMRC are 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 will be expanded to include investigations of parasites in humpback chub (and surrogate fish if necessary) in the mainstem.

New actions for the humpback chub include the following:

- Reclamation will 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, will be dependent on interagency discussions, planning and compliance, and resulting outcomes of Tribal consultation under Section 106 of the NHPA.

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

1.2.4.2 Razorback Sucker

Ongoing actions for the razorback sucker include the following:

- Reclamation will 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 larvae collected in the western Grand Canyon through genetic analysis.

- 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.

1.2.4.3 Nonnative Species – Removal and Control Actions (for all native aquatic species)

Nonnative fish are important stressors contributing to the decline of native and endangered fish species in the Colorado River. While many of these species are ubiquitous and likely impossible to remove or control, actions targeted on particular species and locations can decrease nonnative effects on endangered species. Reclamation maintains, through the GCDAMP, the experimental fund that retains funding for emergency needs such as removal of nonnative fish.

Reclamation will continue, in cooperation with, the NPS, FWS, AZGFD, GCMRC, and GCDAMP, funding and implementation of the following ongoing actions:

- Reclamation, in collaboration with the NPS and FWS, and in consultation with the AZGFD, will 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 CFMP (see “Feasibility Study for Use of Chemical Fish Control Methods”).

- Reclamation will 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 will 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.

Reclamation will continue, in cooperation with, the NPS, FWS, AZGFD, GCMRC, and the GCDAMP, funding and implementation of the following new actions:

- Reclamation will explore the efficacy of a temperature control device at the dam to respond to potential extremes in hydrological conditions due to climate change and 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, 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.

- Reclamation will 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 will 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 will be assessed (flows, provide cold water, other). While feasible options may not currently exist, technology may be developed in the LTEMP period that could help achieve this goal.

- Reclamation will, in consultation with the FWS and AZGFD, fund the NPS and GCMRC on the completion of planning and compliance to alter the backwater slough at RM-12, making it unsuitable or inaccessible to warmwater nonnative species. Depending on the outcome of NPS planning and compliance, Reclamation will implement the plan in coordination with the FWS, AZGFD, NPS and GCMRC. Additional coordination will be conducted to determine and access any habitats that may support warmwater nonnatives.

- Reclamation will support the GCMRC and NPS in consultation with the FWS and AZGFD 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.

- Reclamation, in cooperation with the GCDAMP, will explore the use of flow (e.g., TMFs) to inhibit brown trout spawning and recruitment in Glen Canyon, or other mainstem locations.

1.2.4.4 Southwestern Willow Flycatcher and Yuma Ridgway's Rail

Reclamation will fund the NPS to conduct southwestern willow flycatcher and Yuma Ridgway's rail presence/absence, nest surveys, and on-the-ground monitoring of habitat throughout the action area throughout the life of the LTEMP. Specifically, the following will occur:

- Reclamation will partially assist in funding NPS to conduct Yuma Ridgway's rail surveys once every 3 years for the life of the LTEMP.

- Reclamation will partially assist in funding NPS to conduct southwestern willow-flycatcher surveys once every 2 years for the life of the LTEMP.

1.2.5 Base Operations

Under the proposed action, monthly water release volumes correspond closely to the monthly hydropower demand as shown in Table 2. The total monthly release volume of October, November, and December is equal to that under current operations (MLFF) to minimize the possibility of the operational tier differing from that of current operations, as established in the Interim Guidelines (Reclamation 2007a). 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, MLFF.

Under base operations of the proposed action, the allowable daily fluctuation range from Glen Canyon Dam (i.e., the difference between the minimum and maximum flows within a day) is proportional to the volume of water scheduled to be released during the month (10 × monthly volume in thousand acre-feet (kaf) in the high-demand months of June, July, and August and 9 × monthly volume in kaf in other months; Table 2; Figure 2). For example, the daily fluctuation range in July with a scheduled release volume of 800 kaf would be 8,000 cfs, and the daily fluctuation range in December with the same scheduled release volume would be 7,200 cfs. The maximum allowable daily fluctuation range in flows in any month would be 8,000 cfs, which is the same as under current operations. However, the down-ramp rate limit under the proposed action would be increased by 1,000 cfs/hr, to 2,500 cfs/hr. The up-ramp rate would remain the same at 4,000 cfs/hr. Figure 2 shows minimum, mean, and maximum daily flows in an 8.23-milion acre-foot (maf) year, assuming all days in a month adhere to the same mean daily flow within a month. Figure 3 shows the hourly flows in a simulated 8.23-maf year within the constraints of the proposed action.

1.2.6 Operational Flexibility

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, will 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.

TABLE 2 Flow Parameters under the Proposed Action in an 8.23-maf Year[a]

Month	Monthly Release Volume (kaf)	Proportion of Total Annual Volume	Mean Daily Flow (cfs)	Daily Fluctuation Range (cfs)
October	643	0.0781	10,451	5,783
November	642	0.0780	10,781	5,774
December	716	0.0870	11,643	6,443
January	763	0.0928	12,415	6,871
February	675	0.0820	12,157	6,076
March	713	0.0866	11,596	6,417
April	635	0.0772	10,672	5,715
May	632	0.0768	10,278	5,688
June	663	0.0806	11,142	6,630
July	749	0.0910	12,181	7,490
August	800	0.0972	13,011	8,000
September	600	0.0729	10,083	5,400

[a] Within a year, monthly operations may be increased or decreased based on changing annual runoff forecasts and other factors, such as application of the Long-Range Operating Criteria for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a).

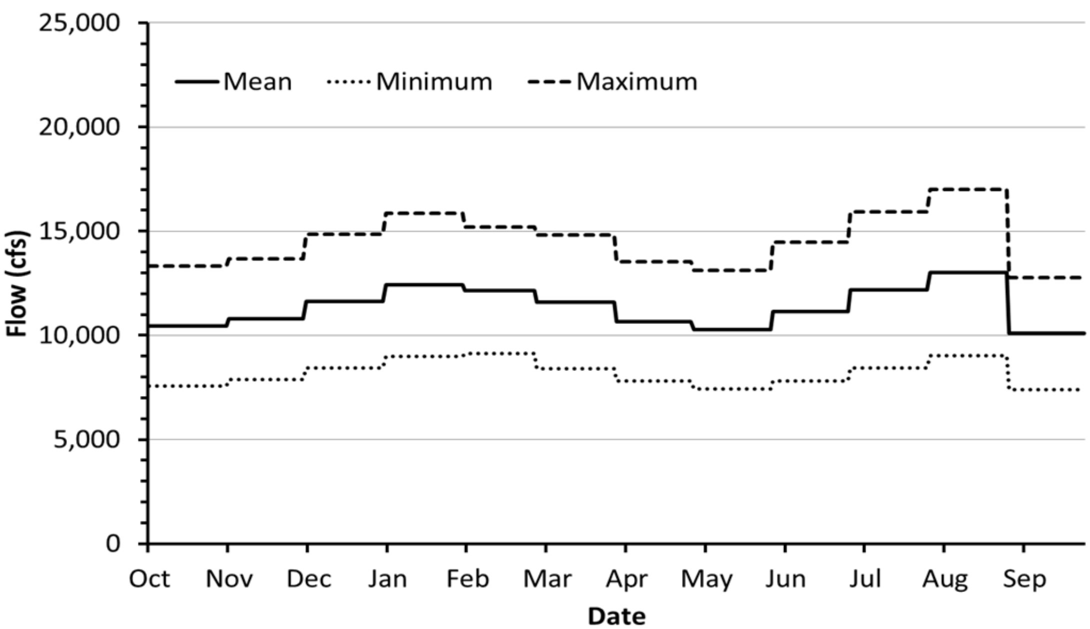


FIGURE 2 Mean, Minimum, and Maximum Daily Flows under the Proposed Action in an 8.23-maf Year

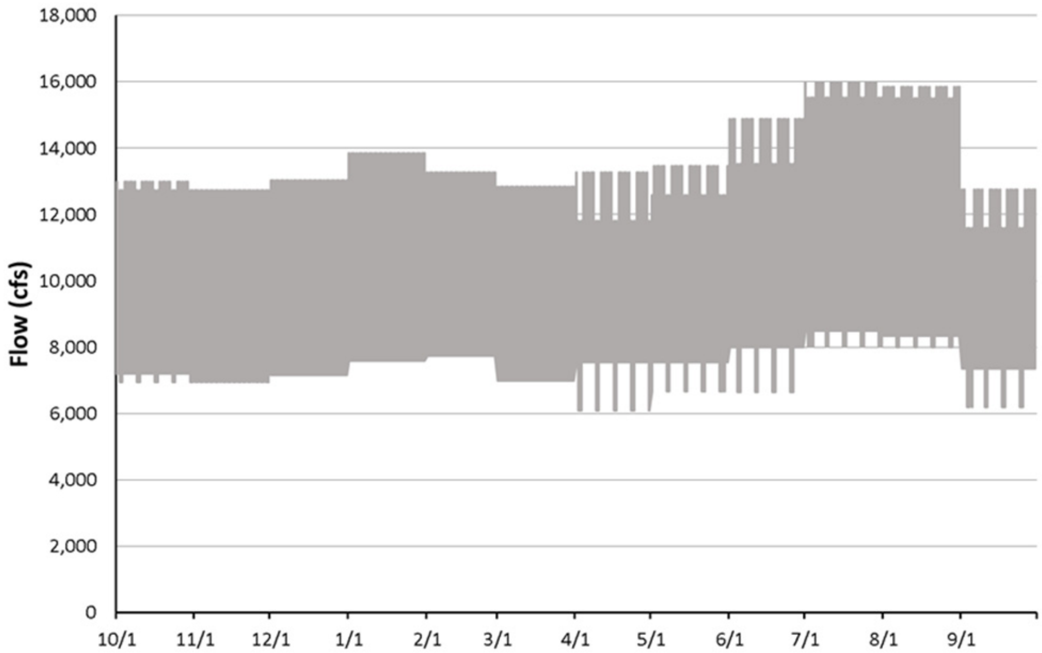


FIGURE 3 Simulated Hourly Flows under the Proposed Action in an 8.23-maf Year (Note that there are differences in the mean, maximum, and minimum flows shown here and in Figure 2. These differences reflect flexibility in operational patterns allowed within the constraints of the proposed action.)

Reclamation also will 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.

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 under the proposed action. (See, e.g., Section 3 of the Glen Canyon Operating Criteria at 62 FR 9448, March 3, 1997.)

1.2.7 Implementation of Experimental Elements

The proposed action identifies condition-dependent flow and non-flow treatments intended to safeguard against unforeseen adverse changes in resource impacts, and to prevent irreversible changes to those resources. These condition-dependent treatments will be implemented experimentally during the LTEMP period unless they prove ineffective or result in unacceptable adverse impacts on other resources. Experimental treatments include sediment treatments, triggered humpback chub conservation actions, TMFs, mechanical removal of nonnative fish, low summer flows, macroinvertebrate production flows, and non-flow-related vegetation treatments.

1.2.8 Overall Implementation Process for Experiments

Prior to implementation of any experiment, the relative effects of the experiment on the following resource areas will be evaluated and considered: (1) water quality and water delivery, (2) humpback chub, (3) sediment, (4) riparian ecosystems, (5) historic properties and traditional cultural properties, (6) Tribal concerns, (7) hydropower production and WAPA's assessment of the status of the Basin Fund, (8) the rainbow trout 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. The recent discovery of nonnative green sunfish in the Glen Canyon reach illustrates the need to be responsive to unforeseen conditions.

The proposed approach differs fundamentally from a more formal experimental design (e.g., before-after control-impact design, factorial design) that attempts to resolve uncertainties by controlling for or treating potentially influential or confounding factors. There are several reasons to avoid such a formal design and instead focus on the condition-dependent approach described here. Among these are (1) the difficulties in controlling for specific conditions in a system as complex as the Colorado River; (2) wide variability in temperature and flow conditions that are important drivers in ecological processes; (3) inherent risk of some experimentation to protected sensitive resources, in particular, endangered humpback chub; (4) conflicting multiple-use values and objectives; and (5) low expected value-of-information for the uncertainties that could be articulated, and around which a formal experimental design would be established. For these reasons, the proposed action includes a condition-dependent adaptive approach.

Table 3 provides the implementation criteria for condition-dependent experimental treatments of the proposed action, and triggers for treatments are discussed under the description below. 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 below. In many cases, two to three replicates of an experimental treatment are considered necessary. The results of these tests will 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 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. All experimental treatments will be closely monitored for adverse side effects on 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 EIS.

In implementing the processes described here and the associated decision process shown in Table 3, the DOI will exercise a formal process of stakeholder engagement to ensure decisions are made with sufficient information regarding the condition and potential effects on important resources. As an initial platform to discuss potential future experimental actions, the DOI will hold GCDAMP annual reporting meetings for all interested stakeholders; these meetings will present the best available scientific information and learning from previously implemented experiments and ongoing monitoring of resources. As a follow-up to this process, the DOI will meet with the Technical Working Group (TWG) to discuss the experimental actions being contemplated for the year.

The DOI also will conduct monthly Glen Canyon Dam operational coordination meetings or calls with the DOI bureaus (USGS, NPS, FWS, Bureau of Indian Affairs [BIA], and Reclamation), WAPA, AZGFD, and representatives from the Basin States and the Upper Colorado River Commission (UCRC). Each DOI bureau will provide updates on the status of resources and dam operations. In addition, WAPA will provide updates on the status of the Basin Fund, projected purchase power prices, and its financial and operational considerations. These meetings or calls are intended to provide an opportunity for participants to share and obtain the most up-to-date information on dam operational considerations and the status of resources (including ecological, cultural, Tribal, recreation, and the Basin Fund). One liaison from each Basin State and from the UCRC will be allowed to participate in the monthly operational coordination meetings or calls.

TABLE 3 Implementation Criteria for Experimental Treatments under the Proposed Action

Experimental Treatment	Trigger and Primary Objective	Replicates	Duration	Annual Implementation Considerations[a]	Long-Term Off-Ramp Conditions	Action, If Successful
Sediment Treatments						
Spring HFE up to 45,000 ft^3/s (cfs) (in Mar. or Apr.)	Trigger: Sufficient Paria River sediment input in spring accounting period (Dec.–Jun.) to achieve a positive sand mass balance in Marble Canyon with implementation of an HFE Objective: Rebuild sandbars	Not conducted during first 2 years of LTEMP, otherwise, implement in each year triggered, dependent on resource condition and response	≤96 hr	Potential short-term unacceptable impacts on the resources listed in footnote (a); unacceptable cumulative effects of sequential HFEs; sediment-triggered spring HFEs will not occur in the same water year as an extended-duration (>96 hr) fall HFE	Sediment-triggered spring HFEs are not effective in building sandbars, or long-term unacceptable adverse impacts on the resources listed in footnote (a) are observed	Implement as adaptive treatment when triggered and resource conditions allow
Proactive spring HFE up to 45,000 cfs (Apr., May, or Jun.)	Trigger: High-volume year with planned equalization releases (≥10 maf) Objective: Protect sand supply from equalization releases	Not conducted during first 2 years of LTEMP, otherwise, implement in each year triggered, dependent on resource condition and response	First test 24 hr; subsequent tests could be shorter, but not longer, depending on results of first tests	Potential short-term unacceptable impacts on the resources listed in footnote (a); unacceptable cumulative effects of sequential HFEs; would not be implemented in same water year as a sediment-triggered spring HFE or extended duration fall HFE	Proactive spring HFEs are not effective in building sandbars; or long-term unacceptable adverse impacts on the resources listed in footnote (a) are observed	Implement as adaptive treatment when triggered and existing resource conditions allow
Fall HFEs ≤ 96 up to 45,000 cfs in Oct. or Nov.	Trigger: Sufficient Paria River sediment input in fall accounting period (Jul.–Nov.) to achieve a positive sand mass balance in Marble Canyon with implementation of an HFE Objective: Rebuild sandbars	Implement in each year triggered dependent on resource condition and response	≤96 hr	Potential unacceptable impacts on resources listed in footnote (a)	This type of HFE was not effective in building sandbars; or long-term unacceptable adverse impacts on the resources listed in footnote (a) are observed	Implement as adaptive treatment when triggered and existing resource conditions allow

TABLE 3 (Cont.)

Experimental Treatment	Trigger and Primary Objective	Replicates	Duration	Annual Implementation Considerations[a]	Long-Term Off-Ramp Conditions	Action, If Successful
Sediment Treatments (Cont.)						
Fall HFEs longer than 96-hr duration up to 45,000 cfs in Oct. or Nov.	Trigger: Sufficient Paria River sediment input in fall accounting period (Jul.–Nov.) to achieve a positive sand mass balance in Marble Canyon with implementation of an HFE longer than a 96-hr, up to 45,000-cfs flow Objective: Rebuild sandbars	Implement in each year triggered; limited to total of four tests in LTEMP period	Up to 250 hr depending on availability of sand; duration of first test not to exceed 192 hr	Potential short-term unacceptable impacts on the resources listed in footnote (a); unacceptable cumulative effects of sequential HFEs.	Extended duration fall HFEs are not effective in building sandbars; resulting sandbars are no bigger than those created by shorter-duration HFEs; or long-term unacceptable adverse impacts on the resources listed in footnote (a) are observed	Implement as adaptive treatment when triggered and existing resource conditions allow
Aquatic Resource Treatments						
Trout management flows	Trigger: Predicted high trout recruitment in the Glen Canyon reach Objective: Test efficacy of flow regime on trout numbers and survival of chub	Implement as needed when triggered; after consultation with Tribes; test may be conducted early in the 20-year period even if not triggered by high trout recruitment[b]	Implemented in as many as 4 months (May–Aug.)	Potential unacceptable impacts on resources listed in footnote (a)	Trout management flows have little or no effect on trout recruitment after at least three tests, or long-term unacceptable adverse impacts on the resources listed in footnote (a) are observed	Implement as adaptive treatment triggered by predicted high trout recruitment in Glen Canyon, taking into consideration Tribal concerns
Tier 1: Expanded translocation of humpback chub in the Little Colorado River	Trigger: Number of adult or subadult humpback chub in the Little Colorado River reach below tier 1 triggers Objective: Increase number of adult and subadult humpback chub	Implement in each year triggered unless determined ineffective.	As needed	Potential short-term unacceptable impacts on resources listed in footnote (a)	Expanded translocation has little or no effect on increasing the number of adult or subadult humpback chub; or long-term unacceptable adverse impacts on the resources listed in footnote (a) are observed	Implement as adaptive treatment when triggered

TABLE 3 (Cont.)

Experimental Treatment	Trigger and Primary Objective	Replicates	Duration	Annual Implementation Considerations[a]	Long-Term Off-Ramp Conditions	Action, If Successful
Aquatic Resource Treatments (Cont.)						
Tier 1: Implement headstart program for larval humpback chub	Trigger: Number of adult or subadult humpback chub in Little Colorado River reach below Tier 1 triggers Objective: Increase number of adult and subadult humpback chub	Implement in each year triggered unless determined ineffective	As needed	Potential short-term unacceptable impacts on resources listed in footnote (a)	Head-start program has little or no effect on increasing the number of adult or subadult humpback chub; or long-term unacceptable adverse impacts on the resources listed in footnote (a) are observed	Implement as adaptive treatment when triggered
Tier 2: Mechanical removal of nonnative fish in Little Colorado River reach	Trigger: Tier 1 actions ineffective; humpback chub number in Little Colorado River below Tier 2 triggers Objective: Increase number of adult and sub-adult humpback chub	Implement in each year triggered unless determined ineffective, after consultation with Tribes	Monthly removal trips (Feb.–Jul.) until “predator index” or adult humpback chub reach acceptable levels (Appendix D)	Potential short-term unacceptable impacts on resources listed in footnote (a)	Mechanical removal has little or no reduction in predator index in the Little Colorado River reach; no population-level benefit on humpback chub or unacceptable adverse impacts on the resources listed in footnote (a) are observed	Implement as adaptive treatment when triggered, taking into consideration Tribal concerns
Low summer flows (minimum daily mean 5,000 to 8,000 cfs) to target ≥ 14°C at Little Colorado River confluence	Trigger: Initial experiment in the second 10 years of the LTEMP period, when target temperature of ≥14°C can only be achieved with low summer flow Objective: Increase humpback chub growth	Subsequent experimental use if (1) initial test was successful, (2) humpback chub population concerns warrant their use, (3) water temperature appears to be limiting recruitment and (4) target temperature of ≥14°C could be achieved only with low summer flow	3 months (Jul.–Sep.)	Potential unacceptable impacts on resources listed in listed in footnote (a)	Low summer flows do not increase growth and recruitment of humpback chub; increase in warmwater nonnative species or trout at the Little Colorado River; or long-term unacceptable impacts on resources listed in footnote (a) are observed, or sufficient warming does not occur as predicted	Implement as adaptive treatment when conditions allow

TABLE 3 (Cont.)

Experimental Treatment	Trigger and Primary Objective	Replicates	Duration	Annual Implementation Considerations[a]	Long-Term Off-Ramp Conditions	Action, If Successful
Aquatic Resource Treatments (Cont.)						
Low steady weekend flows for macroinvertebrate production	Trigger: None Objective: Improve food base productivity and abundance or diversity of mayflies, stoneflies, and caddisflies	Target two to three replicates	Up to 4 months (May–Aug.)	Potential short-term unacceptable impacts on resources listed in footnote (a); coordinate planning with other experiments to avoid confounding conditions or results	Steady weekend flows have little or no benefit on food base, trout fishery, or native fish; increase in warmwater nonnative species or trout in the Little Colorado River reach; or long-term unacceptable adverse impacts on the impacts on resources listed in footnote (a) are observed	Implement as adaptive treatment in target months when conditions allow
Riparian Vegetation Treatments						
Non-flow vegetation treatments	Trigger: None Objective: Improve vegetation conditions at key sites	Not applicable	20 years if successful pilot phase	Potential short-term unacceptable impacts on resources listed in footnote (a)	Control and replanting techniques are not effective or practical; or long-term unacceptable adverse impacts on the resources listed in footnote (a) are observed	Implement as adaptive treatment if invasive species can be reduced and native species increased

[a] Prior to implementation of any experiment, the relative effects of the experiment on the following resource areas will be evaluated and considered: (1) water quality and water delivery, (2) humpback chub, (3) sediment, (4) riparian ecosystems, (5) historic properties and traditional cultural properties, (6) Tribal concerns, (7) hydropower production and WAPA's assessment of the status of the Basin Fund, (8) the rainbow trout fishery, (9) recreation, and (10) other resources.

[b] The decision to conduct TMFs in a given year would consider the resource conditions listed in footnote (a) and would also involve considerations regarding the efficacy of the test based on those resource conditions.

To determine whether conditions are suitable for implementing or discontinuing experimental treatments or management actions, the DOI will schedule implementation/planning meetings or calls with the DOI bureaus (USGS, NPS, FWS, BIA and Reclamation), WAPA, AZGFD, and one liaison from each Basin State and from the UCRC, as needed or requested by the participants. The implementation/planning group will strive to develop a consensus recommendation to bring forth to the DOI regarding resource issues as detailed at the beginning of this section, as well as including WAPA's assessment of the status of the Basin Fund. The Secretary of the Interior will consider the consensus recommendations of the implementation/planning group; however, it retains sole discretion to decide how best to accomplish operations and experiments in any given year pursuant to the LTEMP ROD and other binding obligations.

The DOI will also continue separate consultation meetings with the Tribes, AZGFD, the Basin States, and UCRC upon request, or as required under existing RODs.

Sections 1.2.9 and 1.2.10 describe specific processes for development and implementation of experiments related to sediment, aquatic resources, and riparian vegetation. The overall approach attempts to strike a balance between identifying specific experiments and providing flexibility to implement those experiments when resource conditions are appropriate. As discussed above, rather than proposing a prescriptive approach to experimentation, an adaptive management-based approach that is responsive and flexible would be used to adapt to changing environmental and resource conditions and new information. The potential for confounding interactions among individual experimental treatments is discussed when relevant for each of the proposed treatments. Given the size of the project area, and the variability inherent in the system, this pragmatic approach to experimentation is warranted. Although confounding treatments are possible given the complexity of the experimental plan, they are not expected to limit learning over the life of the LTEMP.

1.2.9 Sediment-Related Experimental Treatments

Figure 4 shows the decision tree for implementation of sediment experiments during the LTEMP period. Under the proposed action, the existing HFE protocol was updated and incorporated into the LTEMP process as specified in Appendix P of the LTEMP EIS. Changes to the existing protocol were related to implementation of the new HFEs that are included under the proposed action and an extension of the protocol to the end of the LTEMP period. This new protocol would replace the existing protocol when the LTEMP ROD is issued. Spring and fall HFEs would be implemented when triggered during the 20-year LTEMP period based on the estimated sand mass balance resulting from Paria River sediment inputs during the spring and fall accounting periods, and the dam release pattern during the accounting period. HFE releases would be 1 to 250 hr long and between 31,500 and 45,000 cfs. Depending on the cumulative amount of sediment input from the Paria River during the spring (December 1 through June 30) or fall (July 1 through November 30) accounting periods, and the expected accumulation of sand, the maximum possible magnitude and duration of HFEs that would achieve a positive sand mass balance in Marble Canyon, as determined by modeling, would be implemented.

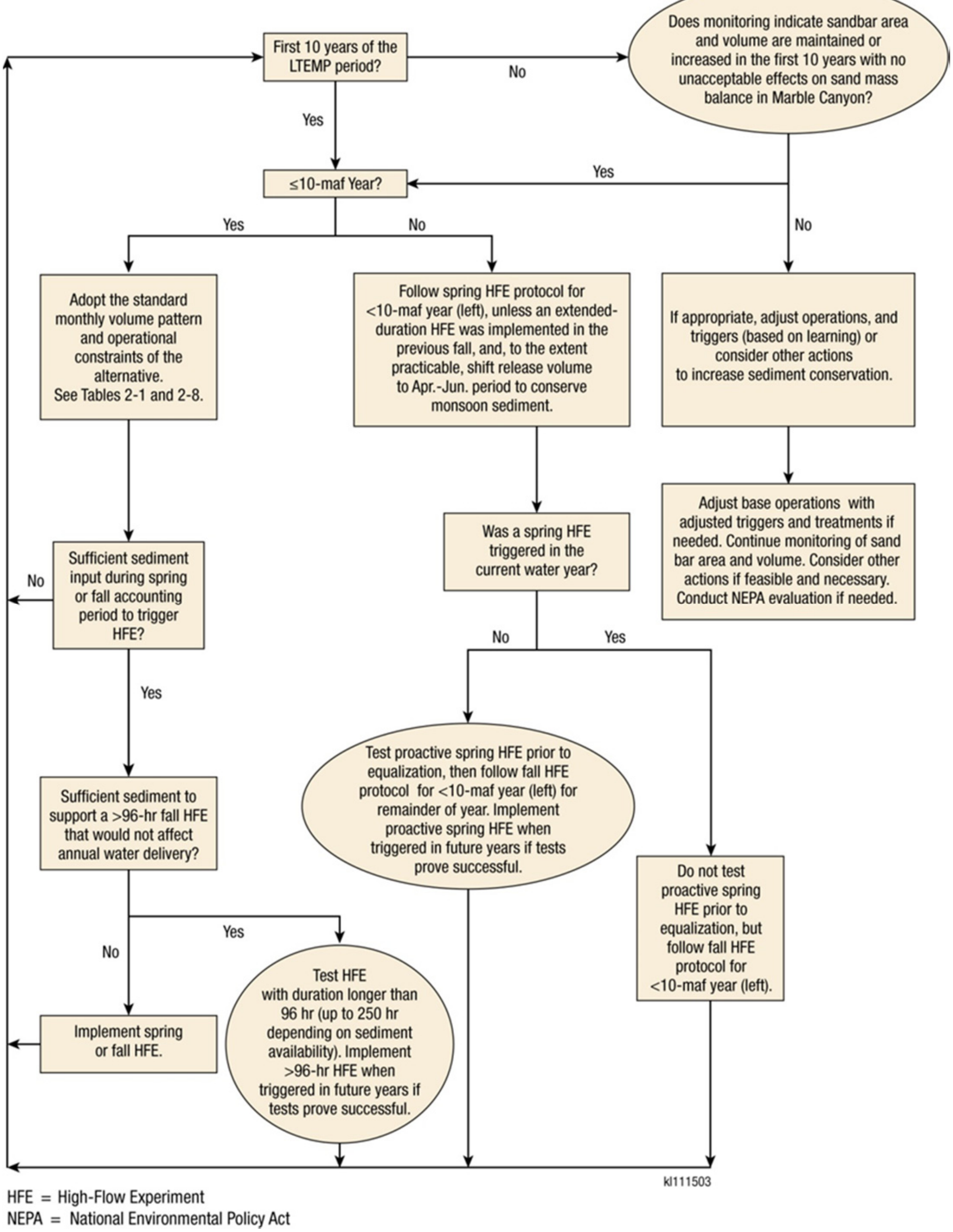


FIGURE 4 Decision Tree for Implementation of Sediment-Related Experimental Treatments under the Proposed Action

Sand mass balance modeling would be used to ensure that the duration and magnitude of an HFE are best matched with the mass of sand present in the system during a particular release window. The magnitude and duration of HFEs will not affect the total annual release from Glen Canyon Dam. Reclamation will consider the total water to be released in the water year when determining the magnitude and duration of an HFE.

Sediment-related experiments under the proposed action include (1) sediment-triggered spring and fall HFEs up to 96-hr duration; (2) short-duration (24-hr) proactive spring HFEs in high-volume equalization years prior to equalization releases; and (3) implementation of up to four extended-duration (>96 hr) HFEs, up to 250 hr long, depending on sediment conditions. The pattern of transferring water volumes from other months to make up the HFE volume would be discussed in the monthly Glen Canyon Dam operational coordination meetings described in Section 1.2.8.

If sediment resources are stable or improving, the combination of base operations, HFE protocols, and other treatments will continue as prescribed. If sediment resource conditions decrease to unacceptable levels during the LTEMP period, operations may be modified to the extent allowable under the LTEMP ROD or would be evaluated and considered under a separate NEPA process, potentially including additional studies of sediment augmentation or other actions.

For all sediment experiments, testing will be modified or temporarily or permanently suspended if (1) experimental treatments are ineffective at accomplishing their objectives, or (2) there were unacceptable adverse impacts on resources (Table 3). Monitoring results will be evaluated to determine whether additional tests, modification of experimental treatments, or discontinuation of experimental treatments are warranted.

Implementation of HFEs would consider resource condition assessments and resource concerns using the annual processes described in Section 1.2.8. HFEs may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 1.2.8. In addition, there is uncertainty associated with cumulative impacts from sequential HFEs. These cumulative impacts would be considered before implementing an HFE.

1.2.9.1 Sediment-Triggered Spring HFEs

Under the proposed action, sediment-triggered spring HFEs will be implemented after an initial 2-year delay in order to enable testing of the effectiveness of TMFs, if warranted, and address concerns raised by the apparent positive response of trout to the 2008 spring HFE (Korman et al. 2011; Melis et al. 2011). Modeling the trout response to spring HFEs for the EIS was based on relationships developed from the observed response to the 2008 spring HFE. That modeling also evaluated uncertainty related to the effectiveness of TMFs to control excess trout produced by HFEs. Modeling indicated that even at a relatively low level of effectiveness (10% reduction in trout recruitment), TMFs could effectively reduce the number of trout out-migrants from Glen Canyon to the Little Colorado River reach (RM 61) where humpback chub occur.

After the first 2 years of the LTEMP period, spring HFEs will be implemented when triggered in accordance with the HFE protocol unless an extended-duration fall HFE occurred in the same water year. Modeling indicates spring HFEs will be triggered in about 26% of the years in the LTEMP period. Sediment-triggered spring HFEs would be implemented when triggered during the entire LTEMP period unless new information indicated they were not effective in building sandbars, or there were unacceptable adverse effects on resources (Section 1.2.8).

Implementation of a spring HFE may provide important replication of the 2008 spring HFE and aid in understanding the effect of spring HFEs on the trout population. It is possible that the strong 2008 response was a result of the specific conditions present in 2008 (e.g., condition of the food base, trout population size). It is unclear whether implementation under current conditions would produce the same result, and there is a good deal of learning that could result from implementation early in the LTEMP period. Implementing a spring HFE early in the LTEMP period when chub numbers are relatively high may also be a relatively low-risk option. To provide a means of controlling trout recruitment following tests of spring HFEs, TMFs will be experimentally implemented and tested for efficacy early in the LTEMP period (see discussion of TMFs below).

Implementation of sediment-triggered spring HFEs would consider resource condition assessments and resource concerns using the processes described in Section 1.2.8. Spring HFEs may not be tested when there appears to be the potential for unacceptable adverse impacts on the resources listed in Section 1.2.8. In addition, there is uncertainty associated with the cumulative impacts of sequential HFEs on sediment, aquatic, and potentially other resources. These cumulative impacts would be considered before implementing a spring HFE particularly if a fall HFE had been implemented in the same water year.

1.2.9.2 Proactive Spring HFEs

GCMRC scientists identified proactive spring HFEs as a potential experimental treatment to transport and deposit in-channel sand at elevations above those of equalization flows. These HFEs will be tested only in years with high annual water volume (i.e., ≥10 maf), and modeling suggests that this would be a relatively rare treatment. A first test would be a 24-hr 45,000-cfs release conducted in April, May, or June. Duration in subsequent tests could be shortened depending on the observed response during the first tests. It would be preferable to test proactive spring HFEs at least two to three times in the 20-year LTEMP period, but being able to do so will be dependent upon annual hydrology. Modeling indicates that proactive spring HFEs would be triggered in about 10% of the years in the LTEMP period.

Proactive spring HFEs would not be tested in the first 2 years of the LTEMP period. In addition, proactive spring HFEs will not be tested in years when there had been a spring HFE or extended-duration fall HFE earlier in the same water year. Proactive spring HFEs could be performed in the same water year as a 96-hr or shorter sediment-triggered fall HFE, although prior to implementation, the potential effects of these HFEs would be carefully evaluated using the processes described in Section 1.2.8. The first test would be carefully evaluated to determine whether additional tests were warranted based on the efficacy of building and maintaining sandbars. If initial tests show positive results without unacceptable adverse effects on the resources listed in Section 2.2.4.3, proactive spring HFEs would be implemented when triggered during the entire LTEMP period..

Implementation of proactive spring HFEs would consider resource condition assessments and resource concerns using the processes described in Section 1.2.8. Proactive spring HFEs may not be tested when there appears to be the potential for unacceptable impacts on the resources identified in Section 1.2.8. The cumulative impacts of sequential HFEs would be considered before implementing a proactive spring HFE.

1.2.9.3 Sediment-Triggered Fall HFEs

The effects of sediment-triggered fall HFEs on trout recruitment are uncertain, but fall HFEs are expected to have less effect on trout production than spring HFEs. HFEs in November 2012, 2013, and 2014 resulted in little or no increase in the number of young-of-the-year (YOY) trout (VanderKooi 2015; Winters et al. 2016), and this observation may be based on the observed resilience of the food base to disturbance in the fall (Kennedy et al. 2015). However, factors affecting trout response to fall HFEs are not well understood. Modeling for the EIS considered the effect of fall HFEs on trout and modeled fall HFEs in two ways: in one, the effect of fall HFEs was half as long as that of a spring HFE (i.e., it affected trout production only in the water year in which it occurred); in the other, fall HFEs had no effect on trout production. Modeling the effect of fall HFEs in these two ways had an effect on the overall predicted number of trout produced, the number of out-migrants, and ultimately their effect on humpback chub. The number of trout produced and out-migrants were higher, and the number of humpback chub was lower if fall HFEs were assumed to have an effect on trout production.

Modeling indicates fall HFEs would be triggered in about 77% of the years in the LTEMP period. Testing fall HFEs is considered to be a relatively low-risk treatment due to the lack of observed or documented trout response from previous fall HFEs, and testing would be implemented when triggered during the entire LTEMP period unless new information indicated fall HFEs were not effective in building sandbars, or there were unacceptable adverse effects.

Implementation of sediment-triggered fall HFEs would consider resource condition assessments and resource concerns using the processes described in Section 1.2.8. Fall HFEs may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 1.2.8. The cumulative impacts of sequential HFEs would be considered before implementing a sediment-triggered fall HFE.

1.2.9.4 Extended-Duration Fall HFEs

Sediment-triggered fall HFEs with durations longer than 96 hr (up to 250 hr) would be tested under the proposed action. The duration of these extended-duration fall HFEs would be based on the amount of sediment delivered from the Paria River during the fall accounting period and would be no more than the maximum magnitude and duration of an HFE that would achieve a positive sand mass balance in Marble Canyon, as determined by modeling. Based on examination of the observed historical sediment input from the Paria River, it was determined that HFEs up to 10.4 days in length (250 hr) could be supported before exhausting seasonal sediment inputs and affecting water delivery requirements. GCMRC scientists have suggested that increasing the duration of HFEs when sediment supply can support a longer duration may lead to more sand being deposited at higher elevations, resulting in bigger sandbars. Modeling indicates that this treatment will be triggered in 25% of the years in the LTEMP period. There will be no more than four extended-duration fall HFEs over the 20-year LTEMP period.

The duration of the first implementation of an extended-duration HFE will be limited to no more than 192 hr (twice as long as the current limit of 96 hr). This duration is considered long enough to produce a measurable result if the treatment represents an effective approach to building sandbars under enriched sediment conditions. The duration of all tests will be based on available sediment, current hydrology, reviews of available information, the expert opinion of GCMRC and other Grand Canyon scientists, and consideration of potential effects on the resources listed in Section 1.2.8. If feasible, monitoring will include real-time observations of sediment concentrations to determine if sediment deposition continues throughout the duration of the extended HFEs.

Implementation of extended-duration fall HFEs would consider resource condition assessments and resource concerns using the processes described in Section 1.2.8. Extended-duration fall HFEs may not be tested when there appears to be potential unacceptable impacts on the resources listed in Section 1.2.8. Because the effects of extended-duration HFEs on Lake Mead water quality are a concern, DOI will coordinate with relevant water quality monitoring programs or affected agencies prior to implementing any test of extended-duration HFEs. The cumulative impacts of sequential HFEs would be considered before implementing an extended-duration fall HFE.

Another important concern that results from the large volume of water bypassed is water delivery. Water delivery issues would be considered before deciding to implement an extended-duration fall HFE. An extended-duration HFE would not be implemented if annual release volume would be affected. It is possible that in lower volume years there would not be sufficient water available to support an extended-duration HFE. A 250-hr extended-duration HFE would result in a monthly total release of approximately 1.2 maf. In lower volume release years (e.g., 7.0 maf or 7.48 maf), the maximum duration may be less than 250 hr. In addition, a sediment-triggered spring HFE or proactive spring HFE would not be conducted in the same water year as an extended-duration fall HFE. If an extended-duration fall HFE was triggered but not implemented for any of the reasons described above, a fall HFE 96 hr or less in duration could be implemented instead. Implementation would necessitate reducing water volume in other months of the same water year.

In order to fully test the efficacy of these longer HFEs, several replicates would be desirable in the 20 year LTEMP period. Extended-duration HFEs would be considered successful and would be continued up to a total of four times in the 20-year LTEMP period as part of an adaptive experimental treatment if there was a widespread increase in bar size relative to ≤96-hr HFEs, and if sand mass balance was not significantly compromised relative to the ability to maintain a long-term equilibrium. Extended-duration HFEs would not continue to be tested if they were not effective in building sandbars, if resulting total sandbar volumes were no bigger than those created by shorter-duration HFEs, or if unacceptable adverse impacts on the resources listed in Section 1.2.8 were observed.

1.2.10 Aquatic Resource-Related Experimental Treatments

Under the proposed action, most experimental flow and non-flow actions will be triggered or adjusted by considering the estimated number of humpback chub, number of rainbow trout, number of other nonnative fish, water release temperature, or a combination of these variables, depending on the action under consideration. Humpback chub triggers and trout triggers were developed in consultation with the FWS, NPS, and AZGFD. These triggers may be modified based on experimentation conducted early in the LTEMP period.

Aquatic resource experiments that will be tested include (1) TMFs, (2) Tier 1 conservation actions for humpback chub; (3) Tier 2 mechanical removal of nonnative fish, (3) low summer flows in the second 10 years of the LTEMP, and (4) macroinvertebrate production flows. Aquatic resource experiments would seek to refine our understanding of the impacts of water releases, HFEs, and TMFs on these resources. The primary uncertainty surrounding HFEs revolves around the extent to which the seasonality of HFEs or the number of adult rainbow trout determines the strength of rainbow trout recruitment.

Experimental nonnative fish control actions would be implemented if the humpback chub population declined, and proactive conservation actions had failed to reverse declining populations. Two different tiers of population metrics would be used to trigger responses including actions to increase growth and survival of humpback chub (Tier 1) and mechanical removal of nonnative fish (Tier 2); these would only be implemented when Tier 1 actions fail to slow or reverse the decline in the humpback chub population. This tiered approach and the triggers that would be used to implement it are described below.

For all aquatic resource experiments, testing will be modified or temporarily or permanently suspended if (1) experimental treatments are ineffective at accomplishing their objectives, or (2) there are potential unacceptable adverse impacts on the resources listed in Section 1.2.8. Monitoring results will be evaluated to determine whether additional tests, modification of experimental treatments, or discontinuation of experimental treatments are warranted.

Implementation of aquatic resource experiments would consider resource condition assessments and resource concerns using the processes described in Section 1.2.8. Aquatic resource experiments may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 1.2.8.

1.2.10.1 Trout Management Flows

Mechanical removal of nonnative fish is a controversial issue in the Colorado River through Glen and Grand Canyons. A spring 2015 meeting of Grand Canyon biologists (NPS, FWS, AZGFD, and GCMRC) to assess current 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. Trout management flows are a potential tool that could be used to control annual trout production in the Glen Canyon reach for the purposes of managing the trout fishery and for limiting emigration from the Glen Canyon reach to Marble Canyon and the Little Colorado River reach.

Trout management flows are a special type of fluctuating flow designed to reduce the recruitment of trout by disadvantaging YOY trout (Figure 5). Trout management flows have been proposed and developed on the basis of research described in Korman et al. (2005). The underlying premise of TMFs is based on observations that YOY trout tend to occupy nearshore shallow-water habitats to avoid predation by larger fish. A potential scenario for TMFs features repeated fluctuation cycles that consist of relatively high flows (e.g., 20,000 cfs) sustained for a period of time (potentially ranging from 2 days to 1 week) followed by a rapid drop to a low flow (e.g., 5,000 to 8,000 cfs). This low flow will be maintained for a period of less than a day (e.g., 12 hr) to prevent adverse effects on the food base. Low flows would be timed to start in the morning, after sunrise, to expose stranded fish to direct sunlight and heat. Up-ramp rates to the

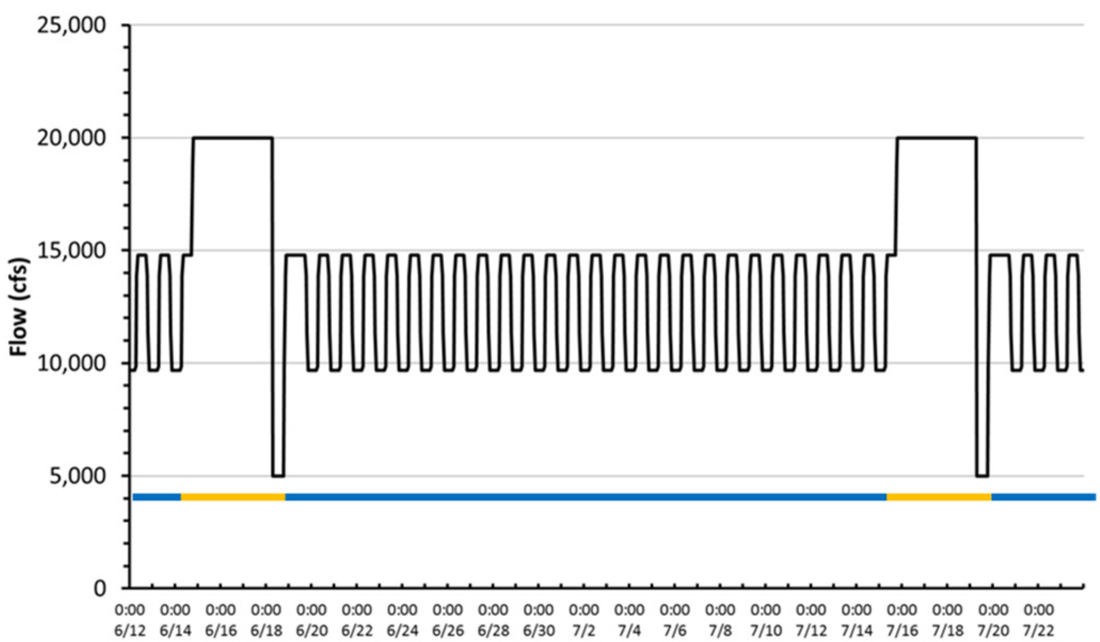


FIGURE 5 Example Implementation of a Two-Cycle Trout Management Flow in June and July with Resumption of Normal Fluctuations between Cycles and Afterward (Monitoring for effectiveness would occur before and after each cycle. The horizontal line below the graph shows periods of normal fluctuation [blue] and TMFs [orange].)

peak TMF will be the same as the limit for the proposed action overall (i.e., 4,000 cfs/hr). The down-ramp from peak to base would be over a single hour (e.g., 15,000 cfs/hr for a drop from 20,000 cfs to 5,000 cfs). These flow levels and rates are not fixed in order to allow flexibility in their design. In a TMF cycle, YOY trout are expected to occupy nearshore habitat when flows are highest, and would be subsequently stranded by the sudden drop to low flow. Because older age classes of trout tend to occupy deeper habitats toward the middle of the river channel, they are less susceptible to stranding and are less likely to be directly affected by TMFs. Trout management flows will be used to control trout recruitment in the Glen Canyon reach to manage the rainbow trout fishery, and to limit emigration of juvenile trout to downstream reaches, particularly to habitat occupied by humpback chub near the confluence with the Little Colorado River. Triggers for implementation of TMFs will be determined in consultation with the AZGFD, GCMRC, NPS, and Reclamation.

If resource conditions are appropriate, TMFs may be tested early in the experimental period, preferably in the first 5 years. These first tests could be triggered by modeled trout recruitment levels or otherwise implemented to test the effectiveness of TMFs. The intent of early tests is to determine the effectiveness of TMFs and a best approach to trout management. If TMFs are determined to be effective for controlling trout numbers while minimizing impacts on other resources, they may be deployed as an adaptive experimental treatment triggered by estimated trout recruitment.

It should be noted that several Tribes have expressed concerns about TMFs as a taking of life within the canyon without a beneficial use. The Pueblo of Zuni has expressed concern that the taking of life by trout stranding has an adverse effect on the Zuni value system. The joint-lead agencies will continue to work with the Tribes regarding options for trout management and to determine the most appropriate means of mitigating impacts on Tribal values when TMFs are implemented.

As many as three TMF cycles per month in a period of up to 4 months during May through August could be tested, depending on the results of early tests. Aspects of TMF design that would be investigated include:

- Duration of high flows needed to lure YOY rainbow trout into nearshore habitats,

- Magnitude of the high flow that would be more effective in luring YOY trout to nearshore habitats,

- Whether or not moving to high flows first is needed to reduce YOY trout numbers (as opposed to simply dropping rapidly from normal flows to minimum flows),

- Timing of TMF cycles during the May–August period of trout emergence, and

- Number of cycles necessary to effectively limit trout recruitment.

If TMFs prove to be effective in controlling trout production and emigration to the Little Colorado River reach and they become an integral part of the LTEMP, regular implementation of TMFs may need to include variable timing to prevent adaptation of the population to specific timing (e.g., increase in recruitment by fall-spawning rainbow trout).

Certain aspects of TMF effectiveness can be addressed through observational studies (e.g., the number of YOY rainbow trout observed in the nearshore environment in daily increments after the high flow is initiated)[1]; others may be addressed through consideration of the physical environment in Glen Canyon (i.e., what areas are inundated or exposed at different flows). Ultimately, however, effectiveness will be judged based on comparison of fall trout recruitment estimates to expectations based on prior years. It may take several years to make this determination, depending on the strength of the response and the type of TMFs tested. Ultimately, however, effectiveness will be based on the ability of TMFs to reduce recruitment in and emigration from the Glen Canyon reach. The driving forces behind emigration are not fully understood, but they are expected to be related to population size and food base in the Glen Canyon reach.

For the EIS modeling, a trigger of 200,000 YOY trout was used to determine when TMFs would be implemented. A regression equation based on annual volume, the variability in flows from May through August, and the occurrence of a spring HFE was used to predict the number of YOY. The actual trigger used could be higher or lower depending on the results of experiments that will be conducted on the effectiveness of TMFs. In addition, the predictive regression equation could be modified based on new information. The trigger and predictive equation used would be modified as needed in an adaptive management context utilizing the process described in Section 1.2.8. Triggers for implementation of TMFs would also be developed in consultation with the AZGFD and other entities as appropriate.

Monitoring of other resources, particularly the food base and the physiologic condition of adult rainbow trout, will also be considered. In addition, the number of YOY trout at the end of the summer would be estimated to determine if it equals or exceeds the estimated number of recruits needed to sustain the desired number of adult trout. If the estimated number of recruits is less than the recruitment target, TMFs will be re-evaluated for modification before implementation in subsequent years. It is anticipated that the trout population could rebound from a 1-year drop below this target level.

As discussed in relation to sediment experiments above, there is concern among scientists and stakeholders with regard to the risk associated with the implementation of spring HFEs as related to trout response and subsequent effects on the humpback chub population. For this reason, TMFs will be implemented and tested for effectiveness early in the LTEMP period if possible; preferably before the first spring HFEs are triggered, even if not triggered by high trout recruitment. Trout management flows could be implemented in years that featured a spring HFE and in the water year that follows an equalization flow because of the expected positive effects of

[1] Because older age classes of trout tend to occupy deeper habitats toward the middle of the river channel, they are less susceptible to stranding and are less likely to be directly affected by TMFs.

equalization on rainbow trout recruitment. Modeling indicates TMFs will be triggered by trout recruitment numbers in 32% of the years in the LTEMP period.

There is potential for confounding effects when coupling TMFs with HFEs. If trout recruitment is still high after implementation of TMFs that follow HFEs, this would suggest that TMFs were not as effective as designed for that trial. If recruitment is lower than expected after TMF implementation, however, uncertainty will remain about whether an HFE failed to stimulate trout recruitment or whether TMFs were effective in suppressing otherwise strong recruitment. It may not be necessary to determine the underlying effect on trout numbers unless TMFs have undesirable side effects on other resources or the trout population.

If TMFs are found to be highly effective in controlling trout recruitment and emigration of trout, and emigration only occurs or primarily occurs immediately following high recruitment years, it may be possible to limit TMF implementation and achieve multiple resource goals, particularly if unintended impacts of TMFs on other resources such as native fish become evident. If adverse impacts of TMFs become evident, this may also suggest revisiting whether or not TMFs are necessary in response to spring HFEs. Lastly, if there is an observed increase in trout recruitment due to fall HFEs, then application of TMFs in the spring following a fall HFE would be considered.

Implementation of TMFs would consider resource condition assessments and resource concerns using the processes described in Section 1.2.8. TMFs may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 1.2.8.

1.2.10.2 Tier 1 Conservation Actions for Humpback Chub

Tier 1 conservation actions designed to improve rearing and recruitment of juvenile humpback chub would be implemented if the combined point estimate for adult (≥200 mm) humpback chub in the Colorado River mainstem Little Colorado River aggregation (RM 57–RM 65.9) and in the Little Colorado River falls below 9,000 (2,000 in the mainstem and 7,000 in the Little Colorado River) as estimated by the currently accepted humpback chub population model, or if recruitment of subadult (150–199 mm) humpback chub does not meet or exceed estimated adult mortality. Tier 1 actions would include expanded translocations of YOY humpback chub within the Little Colorado River to areas within the river that have relatively few predators (i.e., above Chute Falls, Big Canyon), or larval fish would be taken to a rearing facility and released in the Little Colorado River inflow area once they reach 150 to 200 mm. In addition to these translocation activities, 300 to 750 larval or YOY humpback chub would be collected from the Little Colorado River and reared in a fish hatchery to less vulnerable sizes before releasing them. Once these fish reach 150 to 200 mm, they would be translocated to the Little Colorado River in the following year.

1.2.10.3 Tier 2 Mechanical Removal of Nonnative Fish

Experimental implementation of mechanical removal of nonnative fish will incorporate aspects of the protocol outlined in Reclamation's Non-Native Fish Control Environmental Assessment (NNFC EA) (Reclamation 2011b). However, modifications to the trigger criteria (Appendix D) were made to address Tribal concerns related to "taking of life" in the canyon, which prioritize proactive humpback chub conservation actions over mechanical removal of nonnative fish at the Little Colorado River when humpback chub abundance begins to decline. These modifications attempt to minimize the likelihood of mechanical removal, and mechanical removal of nonnative fish at the Little Colorado River would only occur if proactive conservation actions failed to reverse declines in adult humpback chub, and the adult abundance falls below 7,000. Modeling conducted for the EIS indicated that mechanical removal at this level was effective unless immigration rates into the Little Colorado River reach were high.

Two tiers of sequential actions were identified; the first would emphasize conservation actions that would take place early during an adult or subadult humpback chub population decline (Section 1.2.10.2). The second tier would serve as a backstop prescribing predator removal (Threat Reduction) if conservation measures did not mitigate a decline in humpback chub abundance.

Many factors affect humpback chub population dynamics such as water temperature and turbidity in the Colorado River, and potentially the hydrology of the Little Colorado River. These factors may constrain the effectiveness of available conservation actions that can be implemented in the event of a declining population of humpback chub. Juveniles and YOY can be translocated to other areas within and outside the Little Colorado River system; YOY or juvenile humpback chub can be head-started (temporarily held until sufficient growth is achieved) at a hatchery, and predator control can be implemented. Under current constraints, these are the only conservation tools available for humpback chub within the Colorado River reach and associated tributaries between Glen Canyon Dam and Lake Mead.

While healthy wildlife populations are rarely static, trigger objectives include prescribing actions to reverse/ameliorate impacts in order to maintain the Little Colorado River humpback chub population within an acceptable range, and, secondarily to reduce reliance on mechanical removal of nonnative fish. For the purposes of these triggers, it is assumed that the primary drivers of humpback chub population dynamics are interspecific interactions with nonnative species, especially rainbow trout (or brown trout), and low water temperature in the mainstem of the Colorado River (Kaeding and Zimmerman 1983; Douglas and Marsh 1996; FWS 2002a; Coggins et al. 2011; Yard et al. 2011). It is suspected that coldwater temperatures suppress growth and thus subject young humpback chub to predation for extended periods of time. The triggers focus on management of predator impacts only, if management actions are found to be ineffective or other factors are found to negatively control the humpback chub population, adaptation of triggers and conservation responses will be necessary.

The DOI recognizes that lethal mechanical removal is a concern for Tribes, particularly the Hopi Tribe and Pueblo of Zuni, who view it as a taking of life in the canyon without a beneficial use. Reclamation had committed in agreements with Tribes in 2012 to consider live removal when feasible (Reclamation 2012a); however, the presence of whirling disease prohibits live removal of trout due to the risk of spreading the disease to other waters. Reclamation and 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 NPS are committed to consult further with the Tribes to determine acceptable mitigation for nonnative fish control.

1.2.10.4 Low Summer Flows

Low summer flows could be considered a potential tool for improving the 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. There are also potential negative effects from low summer flows to several resources such as hydropower, sediment, water quality, vegetation, and recreation. 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. 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 et al 2012).

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 will ensure that the appropriate baseline data are collected throughout the implementation of LTEMP. In addition, DOI will 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. This information will be shared as part of the AMWG annual reporting process.

It is thought that the potential benefit of an increase in temperature will be greatest if a water temperature of at least 14°C could be achieved at the Little Colorado River, because these warmer temperatures could favor higher growth rates of humpback chub (nearly 60% higher). For comparison, the July through September growth increments of YOY humpback chub are estimated to be 4, 7, 11, 14, and 17 mm at temperatures of 12, 13, 14, 15, and 16°C, respectively, based on a growth-temperature regression in Robinson and Childs (2001). Note that reduction in summer flows would necessitate increasing flows in other months relative to base operations (Table 4; Figure 6).

TABLE 4 Flow Parameters for a Year with Low Summer Flows under the Proposed Action in an 8.23-maf Year[a]

Month	Monthly Release Volume (kaf)	Proportion of Total Annual Volume	Mean Daily Flow (cfs)	Daily Fluctuation Range (cfs)
October	643	0.0781	10,451	5,783
November	642	0.0780	10,781	5,774
December	716	0.0870	11,643	6,443
January	764	0.0928	12,423	6,874
February	675	0.0820	12,153	6,074
March	691	0.0840	11,245	6,223
April	859	0.1044	14,433	7,730
May	851	0.1034	13,841	7,659
June	930	0.1130	15,631	8,000
July	492	0.0598	8,000	2,000
August	492	0.0598	8,000	2,000
September	476	0.0578	8,000	2,000

[a] Within a year, monthly operations may be increased or decreased based on changing annual runoff forecasts and other factors, such as application of the Long-Range Operating Criteria for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a).

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 3 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.

Low summer flows would only be implemented in years when the projected annual release was less than 10 maf, and if the temperature at the Little Colorado River confluence would be below 14°C without low summer flows, and release temperature was sufficiently high that 14°C could be achieved at the Little Colorado River with the use of low summer flows.

The ability to achieve target temperatures at the Little Colorado River confluence by providing lower flows is dependent on release temperatures, which are in turn dependent on reservoir elevation. For example, using the temperature model of Wright et al. (2008), in a 8.23-maf year, release temperatures of 10.8°C, 11.0°C, and 11.7°C would be needed in July, August, and September, respectively, to achieve a target temperature of 14°C at the Little Colorado River confluence at flows of 8,000 cfs.

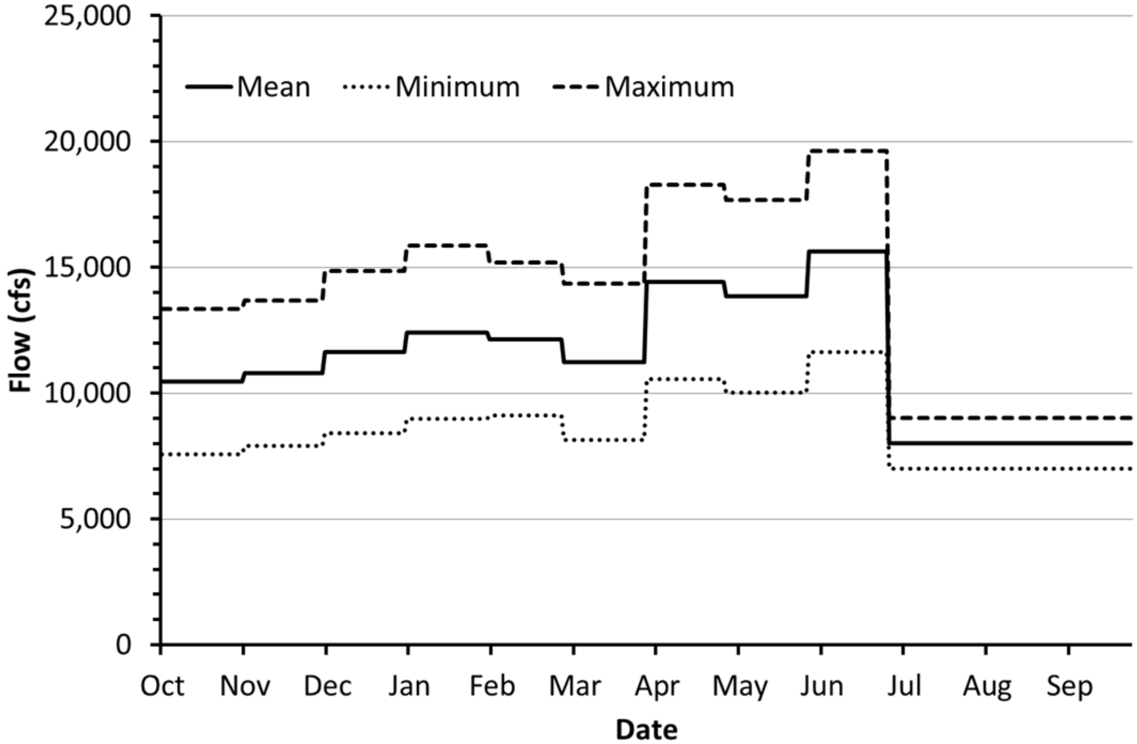


FIGURE 6 Mean, Minimum, and Maximum Daily Flows under Triggered Low Summer Flows of the Proposed Action in an 8.23-maf Year Based on the Values Presented in Table 4

Release temperatures fall into three categories for any temperature target: (1) too low to achieve the target temperature at the Little Colorado River even at low flow, (2) high enough to achieve the target temperature at the Little Colorado River only if low flows (5,000 to 8,000 cfs) are provided, and (3) high enough to achieve target temperature at the Little Colorado River regardless of the flow level. Low summer flows would only be triggered in years that fell into the second category.

Implementation of a low-flow experiment is complicated by two factors: the earliest date at which it could be determined that a target temperature of at least 14°C could be achieved in all 3 months, and the ability to release the remaining annual volume once that determination is made. The earliest time a determination could be made would be in early April of each year, and it would be based on the April 1 forecast of reservoir elevation. Because low summer flows could be implemented in the 3 months at the end of the water year, it is possible that by the time a determination was made to conduct a low summer flow experiment, it may not be possible to release enough water in the remainder of the spring to compensate for the low-flow period. A low-flow experiment would only be tested in years when performing the experiment would not result in a deviation from the annual Glen Canyon Dam release volumes made pursuant to the Long-Range Operating Criteria for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a).

It is possible that a low summer flow could negatively impact humpback chub through impacts on the 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 will 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 will be considered if a low summer flow is implemented.

Finch et al. (2015) found that humpback chub grew more slowly during steady flows than they did during fluctuating flows in the same year, but that turbidity was potentially confounding in this analysis. Recent evidence suggests that not only is the system food limited in most years (Cross et. al. 2013), but that in 2014 and 2015, a system-wide reduction in fish numbers and condition resulting from food limitation was observed. This was a strong enough response that spring Little Colorado River adult estimates were extremely low, and the leading hypothesis was that the adults were skipping spawning and remaining in the mainstem due to lack of sufficient conditions to spawn, yet temperatures were quite warm in 2014 and 2015 (reaching 16°C and 15°C, respectively). Thus, it would seem that under the right conditions, low summer flow could benefit chub, but under conditions that already show high numbers of fish and relatively low food availability, the impacts could be adverse, the rate of skip spawning could increase, and the net impact on chub could be low reproduction and recruitment for that year. However, in 3 years of monitoring the Little Colorado River in June and July, YOY numbers were highest despite the lowest number of spawners (Van Haverbeke 2015). Also key to this experiment being successful is the number of YOY humpback chub being produced in the Little Colorado River, which was pointed out as a confounding factor in the 2000 low summer flow experiment. Production in the Little Colorado River was low (poor habitat conditions), and thus few fish were in the mainstem to be exposed to the treatment. If similar conditions occur, low summer flow would be expected to not have a beneficial impact on the population.

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).

The first test of low summer flows will be determined to be successful or unsuccessful for humpback chub based on input from an independent scientific panel review. If the first test was determined to be unsuccessful (and it was determined to have been implemented properly without major confounding factors), then additional tests would not be performed. Low summer flows would be considered successful if it can be determined that they produced sufficient growth of YOY humpback chub and that growth resulted in an increase in recruitment, but avoided unacceptable increases in warmwater nonnative fishes, trout, or aquatic parasites, or resulted in unacceptable adverse impacts on other aquatic resources. If it was determined to be successful, then additional low summer flows would occur only when humpback chub population concerns warranted them and water temperature has been colder for a period of years and the desired warming could be achieved only with low summer flows. The temperature target could be adjusted 1°C higher based on the results of the first test or the limitations between predicted and measured temperatures.

Implementation of low summer flows would consider resource condition assessments and resource concerns using the processes described in Section 1.2.8. Low summer flows may not be conducted in years when there appears to be the potential for unacceptable impacts on the resources listed in Section 1.2.8.

The effects of low summer flows on Lake Mead water quality are an identified concern. DOI will coordinate with relevant water quality monitoring programs or affected agencies prior to implementing any test of low summer flows. There are concerns related to the risk of warmwater nonnative fish expansion or invasion (e.g., the elevation of Lake Mead was high or the number of warmwater nonnative fish was high). These issues are potential off-ramps as described in Section 1.2.8.

1.2.10.5 Low Steady Weekend Flows for Macroinvertebrate Production

A more diverse and productive aquatic food base could benefit a variety of priority resources including native fish (including the endangered humpback chub), the rainbow trout fishery, and other riparian species that occur in Glen, Marble, and Grand Canyons. Mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), collectively referred to as EPT, are notably absent from the Glen and Marble Canyon reaches and very low in abundance and diversity in the Colorado River in the Grand Canyon. Furthermore, it has been demonstrated that EPT taxa are recruitment limited, because daily flow fluctuations to meet hydropower demand cause high egg mortality and which is the limiting factor. The rationale behind this hypothesis is that fluctuations from Glen Canyon Dam create a varial (intermittently wetted) zone along shorelines that is large enough to dewater eggs. The varial zone is primarily determined by the shape of the canyon, and in narrow stretches of the canyon the varial zone can be high, while in wider stretches of the river the varial zone is much smaller. Because the Colorado River in Glen, Marble, and Grand Canyons is canyon-bound and the tributaries that join the river all have comparatively low flow, the size of the varial zone does not appreciably decrease with distance downstream. Thus, although water temperature regimes become more naturalized with distance downstream, the effect that daily flow fluctuations to meet hydropower demand have on the stability of shoreline habitat does not attenuate with distance from the dam.

This hypothesis attributes the absence of EPT and the poor health of the invertebrate assemblage to the width of the varial zone, similar to earlier investigations (Blinn et al. 1995), but focuses on the effects unstable shorelines have on the eggs of these species. This hypothesis assumes that egg-laying by EPT occurs principally along shorelines. According to the hypothesis, EPT taxa downstream of Glen Canyon Dam are recruitment limited, because daily flow fluctuations to meet hydropower demand negatively affect habitat quality along the shorelines where egg-laying is assumed to occur. This could have been tested during the 2000 Low Steady Summer Flow experiment or in the fall steady-flow experiment from 2008 to 2012, but food base field research was not adequate at the time to detect any changes in EPT related to the steady flows. However, even though substantial steady flow periods were implemented, especially in 2000, increases in EPT species and production were not observed (Kennedy and Ralston 2011).

To test this hypothesis, steady flows would be provided every weekend from May through August (34 days total).[2] The flow on weekends would be held to the minimum flow for that month, which would ensure that the insect eggs laid during weekends would remain submerged throughout larval development. If the hypothesis is true, there would be an increase in insect production, and possibly diversity, due to the reproductive success of insects that laid eggs during weekends. No changes in monthly volumes, ramping rates, or the maximum daily range in flow during weekdays would be required for this experiment. To offset the smaller water releases that would occur during weekends within a given month, larger releases would need to occur during the weekdays within a given month.

Implementation of macroinvertebrate production flows would consider resource condition assessments and resource concerns using the processes described in Section 1.2.8. These flows may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 1.2.8.

Effects of the tests would be evaluated using observations to determine the locations where insect eggs are deposited and the emergence rates of species. Depending on the outcome of the tests, the experiment could be discontinued if there were unacceptable effects on other resources. There is also the possibility that implementation would result in confounding interactions with TMF experiments, and this would be discussed during the process described in Section 1.2.8.

1.2.11 Native and Nonnative Plant Management and Experimental Actions

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 will 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 plants, species in the corridor, systematic removal of nonnative vegetation at targeted sites, and native replanting at targeted sites and subreaches, which may include complete removal of

[2] The duration and other characteristics of experimental macroinvertebrate production flows could be adjusted within the range of the analysis based on the results of initial experiments.

tamarisk (both live and dead) and revegetation with native vegetation. Treatments would fall into two broad categories, including the control of nonnative plant species and revegetation with native plant species. Principal elements of this experimental riparian vegetation proposal include:

- Control nonnative plant species affected by dam operations, including tamarisk and other highly invasive species;
- Develop native plant materials for replanting through partnerships and use of regional greenhouses;
- Replant native plant species to priority sites along the river corridor, including native species of interest to Tribes;
- Remove vegetation encroaching on campsites; and
- Manage vegetation to assist with cultural site protection.

2 ENVIRONMENTAL BASELINE

2.1 DESCRIPTION OF SPECIES IDENTIFIED FOR ANALYSIS

2.1.1 Kanab Ambersnail

2.1.1.1 Legal Status

The Kanab ambersnail, *Oxyloma haydeniensis*, was listed as endangered in 1992 (FWS 1995). The Kanab ambersnail is the only threatened, endangered, or sensitive invertebrate species that may occur along the Colorado River in the Grand Canyon. However, recent evidence from anatomical and molecular genetics studies indicates that this is a geographically widespread taxon whose listing under the ESA may have been incorrect (Littlefield 2007). In a study of *Oxyloma* specimens collected from 12 locations throughout the western United States, including Kanab ambersnail from the Grand Canyon, morphometric and genetic results indicated that the Kanab ambersnail can be regarded as a member of the same species as the other *Oxyloma* populations analyzed (Culver et al. 2013). However, until this taxonomic change occurs, the Kanab ambersnail remains a listed species (FWS 2011b). No critical habitat is designated for this species.

2.1.1.2 Recovery Goals and Status

The recovery plan for Kanab ambersnail was completed in 1995 (FWS 1995). The Kanab ambersnail may be considered for downlisting to threatened when the following criteria have been attained:

1. The location and/or establishment of additional populations. Maintain 10 separate populations which have been demonstrated to have population numbers large enough to allow for the long-term viability of the population. This criterion is provisional. It is probable that this criterion will be modified as additional information is acquired concerning the species distribution, abundance, and stability of its separate populations.

2. The establishment of formal land management designations and/or implementation of land management plans which provide long-term, undisturbed habitat for the Kanab ambersnail for the above 10 populations.

The 5-year status review for the Kanab ambersnail was completed in 2011 (FWS 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 Vaseys 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.

2.1.1.3 Historic and Current Range

Globally, the Kanab ambersnail 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 (FWS 2008). The third location for the Kanab ambersnail is Three Lakes, Utah (Reclamation 2007b).

2.1.1.4 Habitat

The Kanab ambersnail lives in association with watercress (*Nasturtium officinale*), cardinal monkeyflower (*Mimulus cardinalis*), cattails (*Typha*), sedges (*Carex*), and rushes (*Juncus*). Populations within the Grand Canyon occur in areas with water sources originating from limestone or sandstone geologic strata (Meretsky and Wegner 2000; Sorensen 2009). The increase in cover, reduction in beach-scouring flows, and introduction of the nonnative watercress led to a >40% increase in suitable Kanab ambersnail habitat area at Vasey's Paradise compared to pre-dam conditions (Stevens et al. 1997a).

Climate change has the potential to affect the Kanab ambersnail habitat. The water source at Vasey's Paradise consists of waterfalls emanating from groundwater and emerging from the cliff face. In 2014 and 2015, the flow was noticeably reduced, likely as a result of basinwide drought. Consequently, the usually dense vegetation at Vasey's Paradise is notably diminished.

2.1.1.5 Life History

Kanab ambersnails live 12 to 15 months and are capable of self-fertilization. Mating and reproduction occur from May to August. Subadults dominate the overwinter population. Snails enter dormancy in October–November and become active in March–April. Overwinter mortality ranges between 25 and 80% (Stevens et al. 1997a; IKAMT 1998). During mild winters, they can continue their life cycle without dormancy or may go in and out of dormancy several times throughout the winter (Sorensen and Nelson 2002).

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).

2.1.2 Humpback Chub

2.1.2.1 Legal Status

The humpback chub (*Gila cypha*) is currently listed as "endangered" under the ESA. It was first included in the List of Endangered Species issued by the Office of Endangered Species on March 11, 1967 (32 FR 4001) and was considered endangered under provisions of the Endangered Species Conservation Act of 1969 (16 U.S.C. 668aa). The humpback chub was included in the United States List of Endangered Native Fish and Wildlife issued on June 4, 1973 (38 FR 33085), and received protection as endangered under Section 4(c)(3) of the original ESA of 1973. Critical habitat includes 280 km of the Colorado River through Marble and Grand Canyons from Nautiloid Canyon (RM 34) to Granite Park (RM 208), and the lower 13 km of the Little Colorado River. 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 (FWS 1990, 2002a).

2.1.2.2 Recovery Goals and Status

Recovery for the humpback chub was defined by the FWS Humpback Chub Recovery Goals (Recovery Goals) (67 FR 55270) (FWS 2002a). In 2006, a U.S. District Court ruling set aside the Recovery Goals, because they lacked time and cost estimates for recovery. Nevertheless, the recovery programs and the GCDAMP continue to utilize the underlying science in the Recovery Goals. The FWS's 2011 Humpback Chub 5-Year Review relies on the information provided in the recovery goals and provides supplemental information on the species' distribution and status.

The court did not fault the Recovery Goals as deficient in any other respect, thus the FWS, the GCDAMP, and the Upper Colorado River Endangered Fish Recovery Program (UCRRP), the program that addresses conservation of all of the upper Colorado River basin populations of humpback chub, continue to utilize the underlying science in the Recovery Goals. In the 2009 Supplemental Opinion, the FWS referenced the draft 2009 revisions to the Recovery Goals document because that document provided updates on species biology and distribution and represented the best available scientific information at that time. The draft 2009 revisions to the Recovery Goals included the same demographic criteria found in the 2002 Recovery Goals. Thus, we are using the demographic criteria found in both the 2002 Recovery Goals and

2009 draft Recovery Goals. The FWS's 2011 Humpback Chub 5-Year Review relies on the information provided in the Recovery Goals and provides supplemental information on the species' distribution and status.

That supplemental information, as well as the demographic criteria found in the Recovery Goals, has been considered in this BA and is summarized here.

The Recovery Goals consist of actions to improve habitat and minimize threats.

The Recovery Goal demographic criteria for downlisting (endangered to threatened) are as follows:

Upper Basin Recovery Unit

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

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

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

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

Lower Basin Recovery Unit

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

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

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

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

The Recovery Goal demographic criteria for delisting are as follows:

Upper Basin Recovery Unit

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

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

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

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

Lower Basin Recovery Unit

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

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

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

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

The 5-year status review for the humpback chub was completed in 2011 (FWS 2011c). A change in the status of the humpback chub was not recommended because 5 of 6 demographic recovery criteria and 4 of 22 downlisting criteria had not been met. Factors continuing to threaten the Grand Canyon humpback chub population are described below.

2.1.2.3 Historic and Current Range

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 in., weigh 2 lb or more, and live as long as 40 years (Andersen 2009). Historically, this species occurred throughout much of the Colorado River and its larger tributaries from below Hoover Dam upstream into Arizona, Utah, Colorado, and Wyoming (FWS 2002b and refs. therein). Although historic abundance levels are unknown, the humpback chub is currently thought to occupy 24% of its historic range, restricted to six population centers, five in the upper Colorado River basin and one in the lower basin (FWS 2002b). 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 (FWS 2011a).

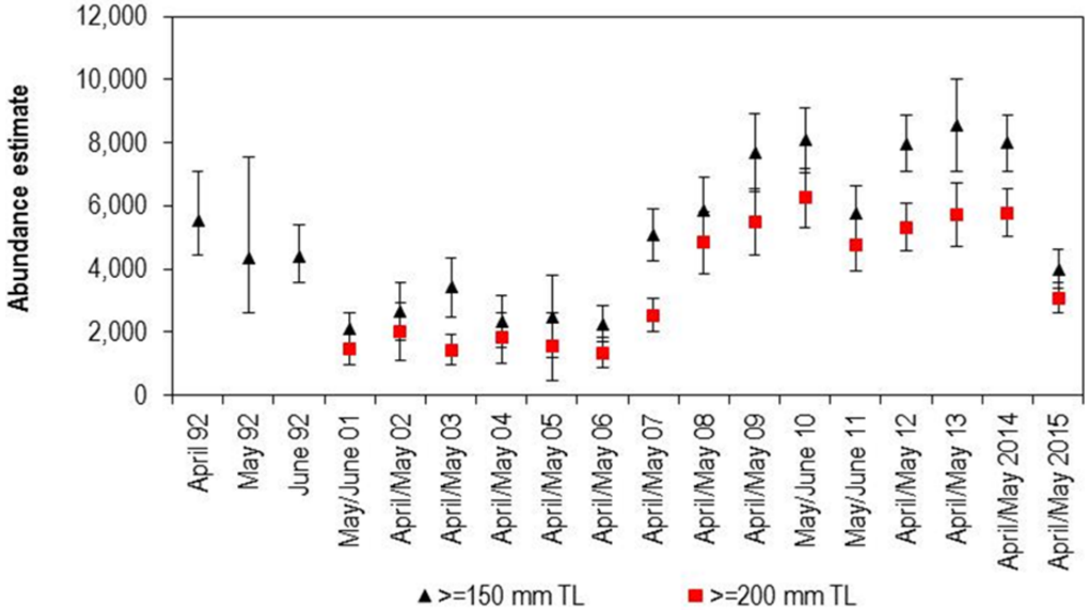
The Colorado River/Little Colorado River population is the largest of the six population centers of the humpback chub (FWS 2011c). Within the Grand Canyon, this species is most abundant in the vicinity of the confluence of the Colorado River and Little Colorado River (Kaeding and Zimmerman 1983; Douglas 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; 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 (Figure 7; Valdez and Ryel 1995; Ackerman 2008; Persons et al. 2016). In addition, since 2009, translocations of humpback chub have been made by the FWS to introduce juvenile fish upstream of Chute Falls in the Little Colorado River, and by the NPS, with assistance provided by Reclamation, to introduce juvenile fish into Shinumo and Havasu Creeks, with the goal of establishing additional spawning populations within the Grand Canyon (NPS 2013). Survey data collected in 2013, 2014, and 2015 suggest that translocated humpback chub have successfully spawned in Havasu Creek (NPS 2013). Humpback chub occupy approximately 3.5 mi (5.6 km) of lower Havasu Creek, from the mouth to Beaver Falls, which is a barrier to upstream movement of fish.

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 (Kegerries et al. 2015): 285 juvenile and 67 age-0 humpback chub were captured during small-bodied and larval fish sampling, respectively, from throughout the study area. 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.

2.1.2.4 Population within the Action Area

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

A.



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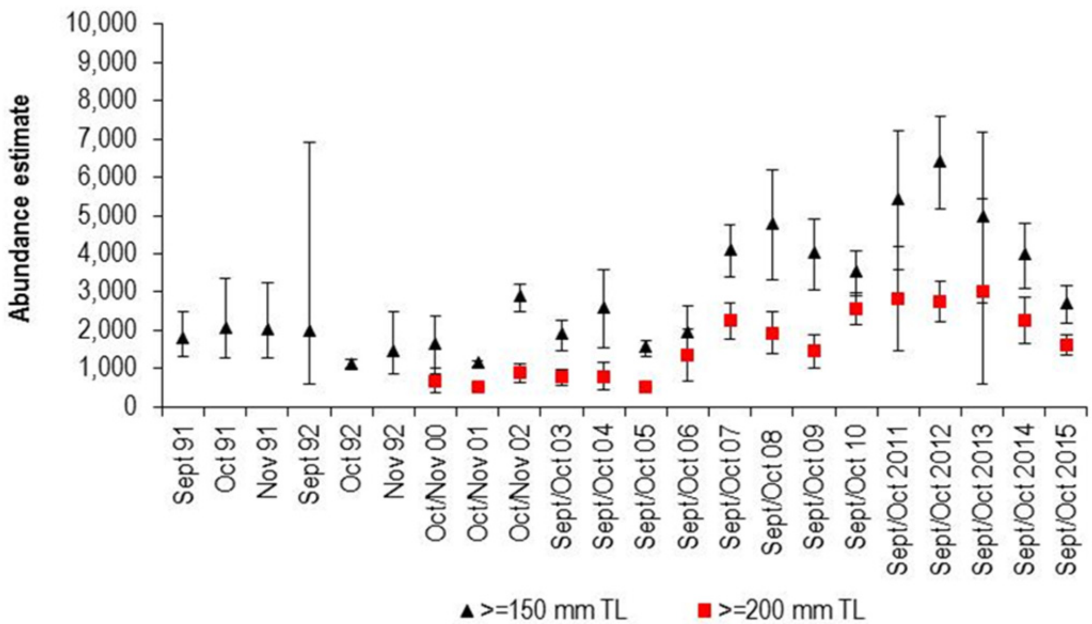

FIGURE 7 Closed Chapman Petersen Abundance Estimates (±95% CI) of Humpback Chub ≥150 mm and ≥200 mm in the Little Colorado River during (A) Spring (2001–2015) and (B) Fall Seasons (2000–2015) (Closed spring and fall abundance estimates of humpback chub >150 mm in the Little Colorado River during 1991 and 1992 are from Douglas and Marsh [1996].)

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 (Figures 7 and 8). 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 (Figure 7). Spring 2015 saw a significant lowering of 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 addition, open population models are conducted to estimate the abundance of the Little Colorado River aggregation of humpback chub (Coggins and Walters 2009; Yackulic et al. 2014), both those fish residing in the Little Colorado River and those residing in the nearby mainstem. Because the open models use capture histories of humpback chub that span across years and because most humpback chub will eventually be captured either in the Little Colorado River or in the mainstem (and thus accounted for in the open models), the open models estimate the abundance of humpback chub in the Little Colorado River as well as those residing in the nearby mainstem. As such, the open models provide annual abundance estimates that are higher than the closed model estimates described above. Open models show that from 1989 through 2001, there was a decline of adult humpback chub within the Grand Canyon, with estimated numbers of the Little Colorado River aggregation declining from approximately 11,000 adults (age 4+) in 1989 to about 5,000 adults in 2001 (Coggins and Walters 2009) (Figure 8). However, since about 2001, the downward population trend reversed, with the estimated number of adult fish increasing to approximately 8,000 fish by 2008 (Figure 8) (Coggins and Walters 2009). More recently, abundance estimates for 2009 to 2012 suggest the population has continued to increase to approximately 11,000 adults (Figure 9) (Yackulic et al. 2014). Unlike the closed models, Coggins and Walters (2009) open models suggested that the increasing trend in adult humpback chub abundance began earlier than 2007. They explain that this may be an effect of aging error, with the least biased estimates for recruitment and adult abundance trends being those most proximal to the end of the dataset being analyzed. As such, one might expect to see the adult increases in abundances beginning earlier in their open models (Figure 8). Importantly, both the closed and open population estimators provide the same trend, and that is that the humpback chub experienced a period of significant decline followed by a period of significant increase.

Aside from the Little Colorado River aggregation, based on sampling within and outside the other known aggregations of humpback chub by Persons et al. (2016), catch rates of humpback chub generally increased as well. Factors suggested as being responsible for this estimated increase are discussed later in this section. In addition, recent preliminary population estimates for humpback chub aggregations suggest that humpback chub in several aggregations

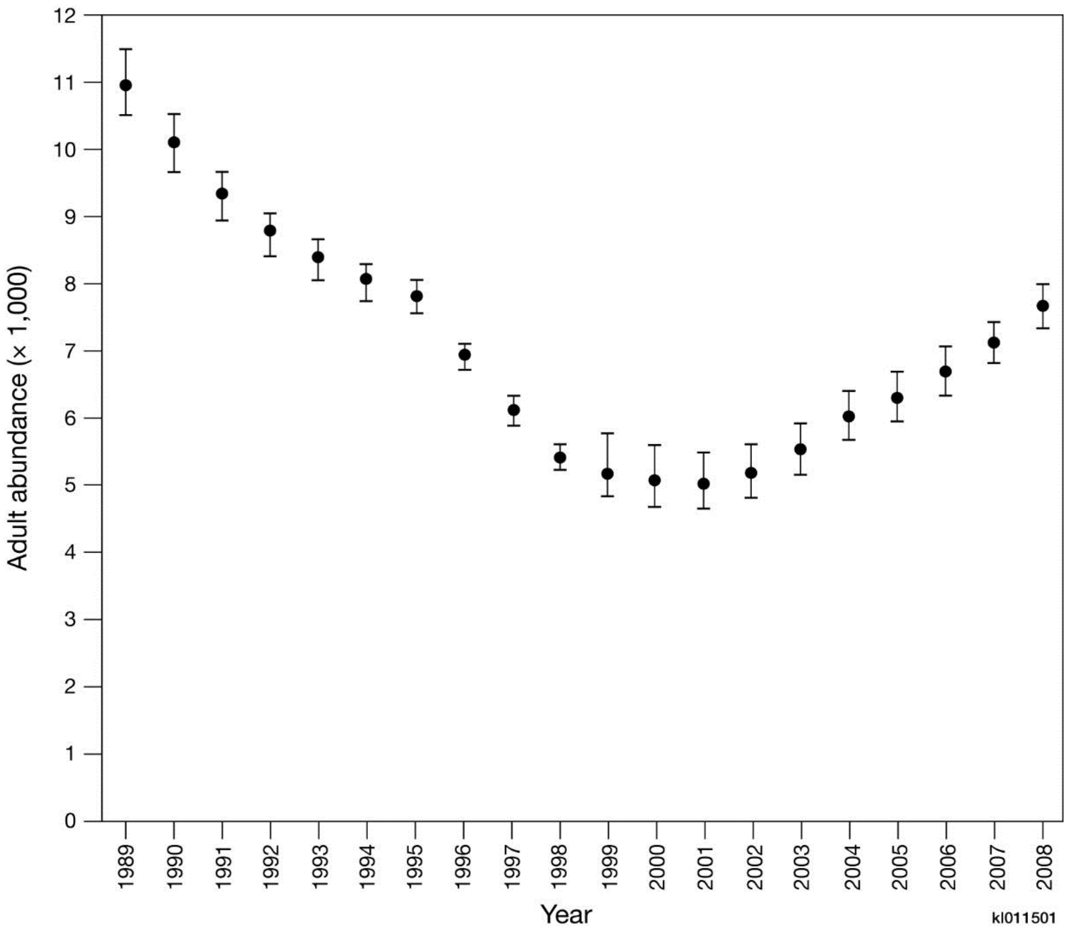

FIGURE 8 Estimated Adult Humpback Chub Abundance (Age 4+) from Age-Structured Mark-Recapture Model Incorporating Uncertainty in Assignment of Age (Error bars represent minimum 95% confidence intervals and do not consider uncertainty in growth or mortality.) (Source: Coggins and Walters 2009)

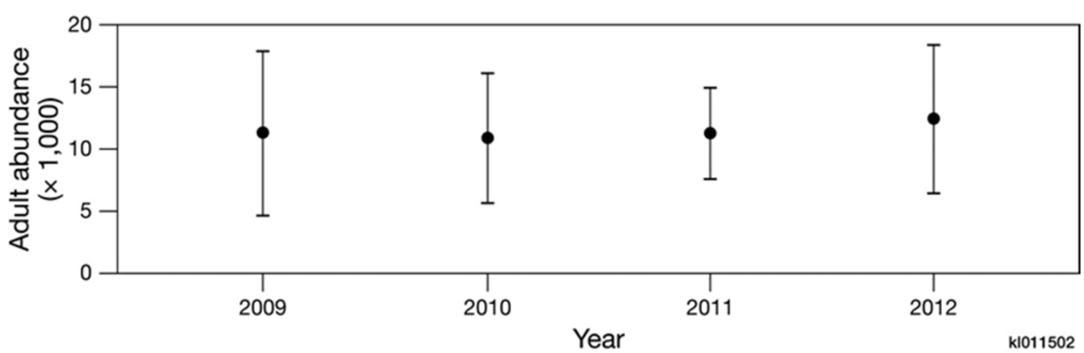

FIGURE 9 Estimated Total Adult Abundance of Humpback Chub in the Lower 8 mi of the Little Colorado River and a 2-mi Portion of the Colorado River Just Downriver of the Confluence of the Little Colorado and Colorado Rivers, for September 2009 through 2012 (Error bars represent the 95% confidence intervals.) (Source: Yackulic et al. 2014)

may have increased as a result of (1) translocations to Shinumo and Havasu Creeks; (2) good production in the Little Colorado River; (3) water temperatures that were about 1°C warmer since the early 2000s; (4) significantly warmer than normal water temperatures in 2004, 2005, and 2011; and (5) trout control implemented at the Little Colorado River inflow (NPS 2013; Yackulic et al. 2014).

The most recent humpback chub population estimate in Havasu Creek was approximately 280 individuals as of May, 2015 (Figure 10). While reproduction has been documented, the population has increased primarily as a result of continued translocations, and less attributed to recruitment.

2.1.2.5 Habitat

Adult humpback chub occupy swift, deep, canyon reaches of the river (Valdez and Clemmer 1982; Valdez and Ryel 1995), with microhabitat use varying among age-groups (Valdez 1990; Stone and Gorman 2006; Gerig et al 2014; Dodrill et al 2015). Within the Grand Canyon, the largest number of humpback chub and their primary spawning are in the vicinity of the Little Colorado River and its inflow reach (RM 57–RM 77; Persons et al. 2016; (Figure 11), with adults being associated with large eddy complexes. Mark-recapture studies in the Grand Canyon reported that most captures of humpback chub occurred in and around the Little Colorado River, with more than 80% of recaptured fish being collected in the same mainstem river reach or tributary where they were originally tagged (Paukert et al. 2006; Persons et al. 2016). However, some of the marked fish were determined to have moved as much as 154.5 km (96 mi) throughout the Grand Canyon (Paukert et al. 2006).

Valdez and Ryel (1995, 1997) reported on adult humpback chub habitat use in the Colorado River in GCNP. They found adults used primarily large recirculating eddies, occupying areas of low velocity adjacent to high-velocity currents that deliver food items. Within GCNP, adults demonstrate high microsite fidelity and occupy main channel eddies, while subadults use nearshore habitats (Valdez and Ryel 1995; Robinson et al. 1998, Stone and Gorman 2006). Adults also congregated at tributary mouths and flooded side canyons during high flows.

Recently, a study conducted in 2010 examined the habitat use and movement of 30 radio-tagged adult humpback chub in the Colorado River during 2 months of fluctuating flow followed by 2 months of steady flow (Gerig et al. 2014). The radio-tagged fish were found to use eddies extensively while avoiding runs. During both flow treatments, the tagged fish exhibited only small daily movements of about 33 ft/day, and no effect of flow was observed on either habitat selection or movement.

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 occasional spawning is suspected 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

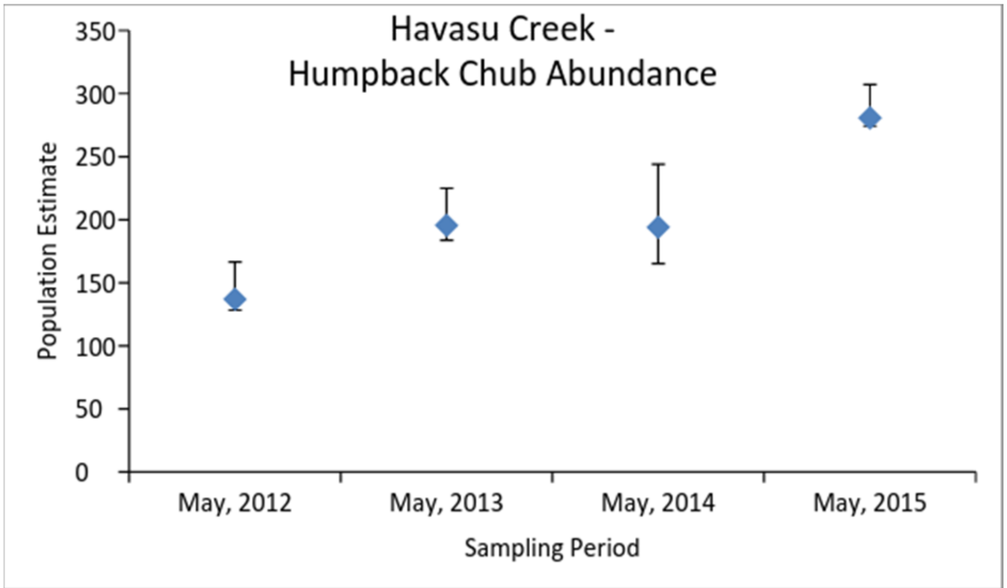

FIGURE 10 Total Abundance of Humpback Chub in Havasu Creek, Based on Annual Population Estimates between 2012 and 2015 (Error bars represent 95% confidence intervals.)

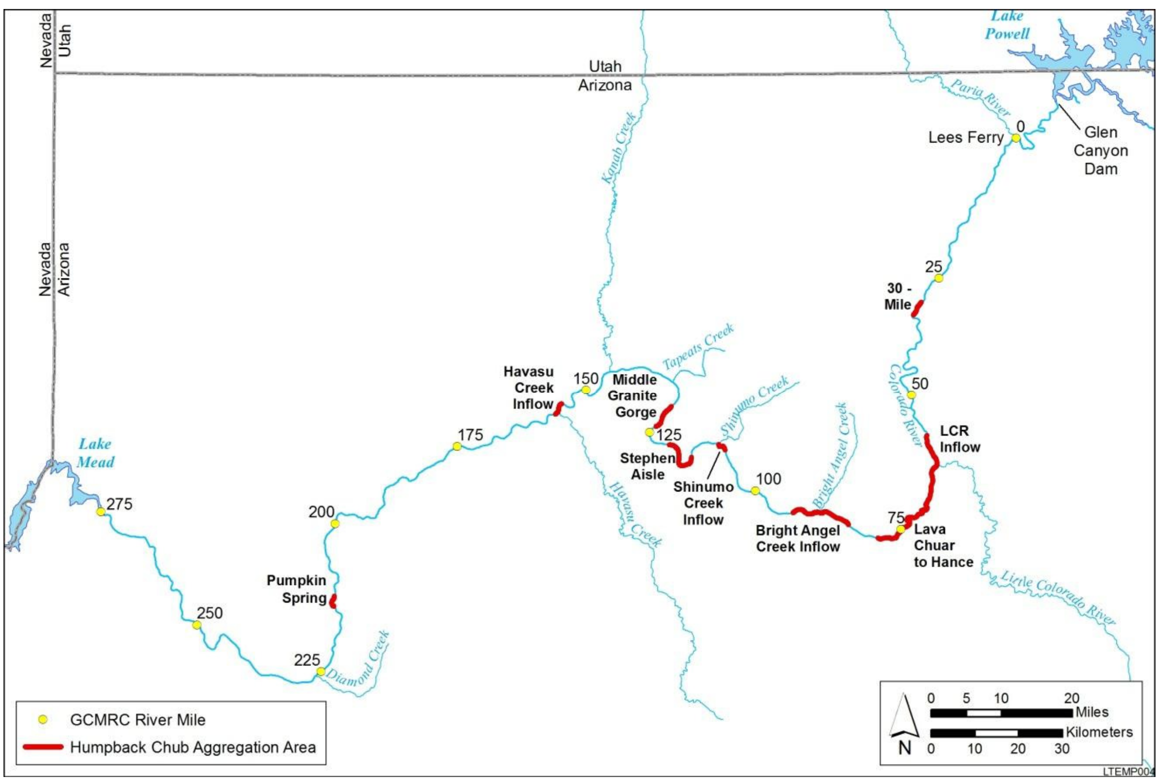

FIGURE 11 Humpback Chub Aggregation Areas along the Colorado River between Glen Canyon Dam and Lake Mead (Sources: NPS 2013)

deposits among large boulders mixed with travertine masses in or near runs and eddies. While 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), studies have not been completed to identify spawning areas or habitat in the Colorado River in the Grand Canyon.

Young humpback chub seek areas that provide physical cover and contain some velocity refuges, including shoreline talus, vegetation, and backwaters typically formed by eddy return current channels (AZGFD 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. For example, Dodrill et al. (2015)) showed the total abundance of juvenile humpback chub was much higher in talus than in backwater habitats. Moreover, when extrapolated to relative densities based on estimates of backwater prevalence directly after a controlled flood, the majority of juvenile humpback chub were still found outside of backwaters. This suggests that the role of controlled floods in influencing native fish population trends may be limited. As young humpback chub grow, they exhibit an ontogenic shift toward deeper and swifter offshore habitats. Valdez and Ryel (1995, 1997) found that young humpback chub (21–74 mm [0.83–2.9 in.] TL) 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 (75–259 mm [2.95–10.20 in] TL), 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 humpback chub undergo an ontogenesis from diurnally active, vulnerable, nearshore-reliant YOY (30–90 mm [1.81–3.54 in.] TL) to nocturnally active, large-bodied adults (180 mm [7.09 in.] TL), which primarily reside in deep mid-channel pools during the day and move inshore at night. This ontogenetic habitat shift may be important for smaller streams to which humpback chub have been translocated. Spurgeon (2012) found that larger humpback chub translocated to Shinumo Creek were more likely to emigrate, and in addition, most movements were nocturnal.

Young humpback chub prefer shallow, low-velocity nearshore pools and backwaters, vegetated undercut banks often harbor high densities of juvenile chub in the Little Colorado River; they move to deeper and faster areas with increasing size and age, within the Little Colorado River (AZGFD 2001). In the mainstem of the Colorado River, juvenile fish may be found in backwater and other nearshore, slow-velocity areas that may serve as nursery habitats (Valdez and Ryel 1995; Robinson et al. 1998; AZGFD 2001; Stone and Gorman 2006); however, detection probability is also higher in these areas. Juvenile humpback chub (<3 years old) have been collected in all types of nearshore habitats by the Nearshore Ecology Study, with the highest density found in backwaters in both years of the study. However, the greatest number of humpback chub were collected from talus slopes (Dodrill et al. 2015). Backwater habitats are perceived to be important to juvenile native fish in the Grand Canyon; however, they are relatively rare habitats in the Little Colorado River inflow reach, and thus support only a small proportion of the native fish there (Dodrill et al. 2015). Thus the significance of these backwater habitats to the overall population is unclear.

The low summer flow experiment conducted in 2000 studied four nearshore geomorphic unit types between the confluence of the Colorado and Little Colorado Rivers and Lava Canyon in the summer and fall of 2010, for study periods of 10 to 27 days. Five to seven sites were studied during each interval. Persistent thermal gradients greater than the 0.2°C accuracy of the instruments were not observed in any of the sampled shoreline environments. Temperature gradients between the shoreline and mainstem on the order of 4°C, believed to be important to the habitat-seeking behavior of native or nonnative fishes, were not detected (Ross and Grams 2013). Temperature differences between main channel and nearshore habitats that are isolated from the main channel can be pronounced in backwaters and other low-velocity areas. The extent of warming is variable and depends on the timing of the daily minimum and maximum flows, the difference between air and water temperatures, and the topography and orientation of the backwater relative to solar insolation (Korman et al. 2006). For example, summertime water temperatures in backwaters have been reported to be as high as 25°C (77°F), while main channel temperatures are near 10°C (50°F) (Maddux et al. 1987). The amount of warming that occurs in backwaters is affected by daily fluctuations that drain and fill backwater habitats with cold main channel waters (Valdez 1991; Angradi et al. 1992; AZGFD 1996; Behn et al. 2010). During the low summer flow experiment, temperatures in one backwater were as much as 13°C (23°F) warmer than in the adjacent main channel during some portions of the day; temperature differences were much less at night (Vernieu and Anderson 2013). Backwater temperatures in summer have been reported to be as much as 2 to 4°C (3.6 to 7.2°F) warmer under steady flows than under fluctuating flows (Hoffnagle 1996; Trammell et al. 2002; Korman et al. 2006; Anderson and Wright 2007).

Although the use of thermal refugia such as backwaters has been documented in a variety of systems (e.g., Tyus and Haines 1991; Bodensteiner and Lewis 1992; Torgersen et al. 1999; Ebersole et al. 2001; Westhoff et al. 2014), the overall importance of backwater habitats in the Colorado River relative to humpback chub survival and recruitment is uncertain (Reclamation 2011b). While juvenile humpback chub have been reported to show positive selection for backwater habitats, the spatial extent of such habitats in the Colorado River in the Little Colorado River inflow reach is small compared to other nearshore habitats such as talus slopes (Dodrill et al. 2015). Nevertheless, the presence of backwaters and other types of nearshore habitats that may be important to native fish varies by reach in the Grand Canyon and is related to sediment deposition that is dependent on the reach geomorphology (i.e., reach width and depth, etc.; reviewed in Stevens et al. 1997b).

2.1.2.6 Life History

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*) (AZGFD 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.

Adult humpback chub move into the Little Colorado River from the Colorado River to spawn from March to May (Gorman and Stone 1999). Relatively little spawning and juvenile rearing occur in the mainstem of the Colorado River, primarily because of the cold mainstem water temperatures (Kaeding and Zimmerman 1983; Minckley et al. 1991); however, in recent years, some evidence of rearing has been observed in the western Grand Canyon (Albrecht et al. 2014; Kegerries et al. 2015). Optimal spawning temperature for the species is 16°C, but mainstem water temperatures typically have ranged from 7 to 12°C (45 to 54°F) near the Little Colorado, due to coldwater releases from Glen Canyon Dam (Wright et al. 2008). Drought-induced warming has resulted in mainstem water temperatures since 2003 consistently exceeding 12°C (54°F) in the summer and fall months, which may have played a role in the estimated increase in the humpback chub population in the system since that time (Andersen 2009; Coggins and Walters 2009; Yackulic et al. 2014). Water temperatures in Havasu Creek typically exceed 16 degrees by April (GCMRC 2016), and humpback chub in spawning condition have been captured in mid-May during monitoring trips (Healy and Nelson 2013; Nelson et al. 2015).

Following spawning, larvae have been reported to drift in the Little Colorado River from April through June, and many drift out into nearshore habitats of the Colorado River (FWS 2008). Robinson et al. (1998) estimated about 38,000 larval humpback chub drifted from the Little Colorado River into the mainstem in May and June 1993. In addition, larval and juvenile humpback chub have been relatively common in the first 2 years of a study that includes sampling of nearshore habitats from Lava Falls (RM 180) to Pearce Ferry (RM 208; Albrecht et al. 2014; Kegerries et al. 2015). The natal source of these fish is unknown; however, data on the timing, age, and location of these larval humpback chub captures may suggest spawning in the mainstem or tributaries (Albrecht et al. 2015; Kegerries et al. 2015). Juveniles generally have lower monthly rates of movement than adults, with the exception of a high probability of juveniles being transported from the Little Colorado River to the Colorado River during high flows of the monsoon season, when numbers of juvenile humpback chub in the mainstem have been documented to increase by as much as 4,000 fish (Yackulic et al. 2014).

Although survival of larval and juvenile fish in the mainstem was once thought to be very rare because of seasonally constant, low water temperatures (Clarkson and Childs 2000), more recent information suggests that juveniles can successfully rear to adulthood in the Colorado River mainstem, at least under recent environmental conditions that include warmer water (Yackulic et al. 2014; Albrecht et al. 2014; Kegerries et al. 2015). Increasing water temperatures have been shown in the laboratory to increase hatching success and larval survival (Hamman 1982), larval and juvenile growth (Clarkson and Childs 2000), and improve swimming ability and reduce predation vulnerability (Ward 2011). Yackulic et al. (2014) postulated that, with warmer water, growth and survival of juveniles in the mainstem will be greater and result in increased mainstem recruitment, and thus contribute to the overall adult population.

2.1.2.7 Factors Affecting Distribution and Abundance in the Grand Canyon

Primary threats to humpback chub include habitat alterations associated with dams and reservoirs and the introduction of nonnative fishes (FWS 2011c), which act as competitors and/or predators of the humpback chub (Andersen 2009; Yard et al. 2011; Kennedy et al. 2013). 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). While coldwater releases from Glen Canyon Dam have been implicated in affecting reproduction and recruitment of humpback chub (and other native fishes) in the mainstem Colorado River, 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). 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 impacts on the species (Walters et al. 2015).

Population estimates indicate that the number of adult humpback chub in the Grand Canyon has been increasing since 2000 or 2001 and has been stable for about the last 5 years (Figure 8). A number of factors have been suggested as being responsible for the observed increases, including experimental water releases, 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. 2016). 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).

Dam discharge and river flow regimes have mixed results. They both may impact the shoreline rearing habitat, and thus survival of juvenile humpback chub (Converse et al. 1998). Releases such as HFEs can create shallow backwater habitats associated with sandbars and are thought to provide rearing habitat for native fish, because they can be warmer than the mainstem river during the summer months due to solar radiation (Behn et al. 2010, reviewed in Dodrill et al. 2015). Flow regimes include, for example, fluctuating flows, which destabilize backwater habitats and may impact warming and primary production (Behn et al. 2010). Backwater habitat is relatively rare in the Little Colorado River inflow area, and thus may be less important to maintaining the Little Colorado River aggregation of humpback chub than previously thought (Dodrill et al. 2015). Even though HFE water releases from Glen Canyon Dam between 2000 and 2008 may have improved some habitat characteristics (e.g., backwaters for humpback chub and other native fish), the limited availability of suitably warmwater temperatures in the mainstem may have constrained the potential for positive population responses (Kennedy and Ralston 2011). Some experimental releases, such as the November HFE in 2004, may have affected nonnative fish (possible humpback chub predators or competitors) and improved humpback chub habitat along the main channel (Korman et al. 2010). However, the March 2008 HFE may have improved the quality of spawning habitat for rainbow trout in the Lees Ferry reach, and the abundance of rainbow trout (using catch-per-unit-effort as a surrogate for abundance) in this reach was reported to be about 300% larger in 2009 than in 2007 (about

3.9 fish per minute versus 1.3 fish per minute, respectively) (Makinster et al. 2011). A similar increase in rainbow trout abundance between 2007 and 2009 was observed at the Little Colorado River confluence (RM 56–RM 69) (Kennedy and Ralston 2010). The effects of HFEs on trout abundance are discussed in more detail in Section 1.2.9. Complete evaluations of more recent fall HFEs, conducted in 2013 and 2014, are incomplete.

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 have been 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, YOY, and juvenile humpback chub are susceptible to predation in the Little Colorado River and mainstem Colorado River (Yard et al. 2011).

Experimental removal of nonnative brown and rainbow trout was conducted in the Colorado River in the Grand Canyon between 2003 and 2006. Twenty-three trips to remove trout from the vicinity of the confluence of the Little Colorado River (RM 56–RM 66) resulted in the removal of more than 23,000 fish (mostly rainbow trout). During this time, the rainbow trout population in the Colorado River in the vicinity of the Little Colorado River was reduced by more than 80% (Andersen 2009), while estimated humpback chub abundance increased during this time (Figure 9). However, this increase may be attributable to a variety of other factors, including warmer water temperatures that occurred during this time and the HFE experimental flows (Andersen 2009; Coggins et al. 2011).

As previously discussed, 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. 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. Ultrasonic images of several hundred adult humpback chub from many locations in the mainstem, as well as in the Little Colorado River and Havasu and Shinumo Creeks, indicated that adult female humpback chub are able to produce eggs in the mainstem Colorado River. In 2013, approximately 33% of humpback chub examined from the mainstem Colorado River, 52% of chub examined from the Little Colorado River, and 23% of chub examined from Havasu Creek were females with eggs (GCMRC 2015).

Temperatures, particularly in the upper reaches of the Colorado River, even in warmer years, are not optimal for humpback chub spawning and growth. However, juveniles can now successfully rear to adulthood in the Colorado River mainstem, and mainstem recruitment is likely contributing to the overall adult population that increased from about 5,000 adults in 2000 to about 11,000 adults in 2012 (Yackulic et al. 2014; Figures 8 and 9). Water temperatures below Glen Canyon Dam began increasing in 2003 as a result of drought conditions that lowered the level of Lake Powell and resulted in the release of warmer water from the dam (Andersen 2009; Andersen et al. 2010); temperatures have remained elevated relative to operations during the 1980s and 1990s due to continued drought-induced lower Lake Powell reservoir levels and somewhat due to relatively high inflow in 2008, 2009, and 2011. In 2005, maximum mainstem water temperature exceeded 15°C (59°F) at Lees Ferry and approached 18°C (64°F) in the vicinity of the Little Colorado River (RM 61), the warmest temperature at those locations since the reservoir was filled in 1980. Maximum water temperature in the mainstem at Lees Ferry reached about 14°C (57°F) in 2008 (USGS 2014), similar to temperatures in 2003 when drought effects from low Lake Powell levels began to raise Glen Canyon Dam release temperatures. In 2011, maximum mainstem water temperatures at the Little Colorado River confluence (RM 61) reached about 15°C (59°F) and 16°C (61°F), respectively (Figure 12). This warmer water appears to have benefitted the humpback chub and other native fish, but they may have benefitted nonnative warmwater species as well (Andersen 2009; Coggins and Walters 2009; Kennedy and Ralston 2011). Low reservoir levels can be attributed to drought, as well as consumptive water use in the Colorado River basin.

Increased water temperatures may also affect predation of YOY humpback chub by rainbow and brown trout (Ward 2011; Yard et al. 2011; Ward and Morton-Starner 2015). Ward (2011) reported that in the laboratory, the level of attempted predation by brown trout was positively correlated with increasing water temperature, but predation success of rainbow trout on YOY humpback chub decreased as water temperature increased from 10°C to 20°C (50°F to 68°F); predation success by brown trout did not change significantly over the same temperature range (Ward 2011; Ward and Morton-Starner 2015). Yard et al. (2011) examined the effects of temperature on trout piscivory in the Colorado River and reported no relationship between water temperature and the incidence of piscivory by rainbow trout, but a significant positive correlation was found between water temperature and the incidence of piscivory for the brown trout.

Climate change and drought have direct influences on hydrologic patterns and water temperature, thus impacting humpback chub. In the Colorado River Basin, hydrologic impacts include lower precipitation and decreased inflow to the reservoir system, resulting in more frequent lower reservoir release volumes, potentially impacting shoreline habitats and riparian areas. More frequent droughts and warmer atmospheric temperatures have the potential to result in warmer temperature of water being released from the dam. Although this may improve thermal suitability for humpback chub, any subsequent benefits may be offset by increased abundance and expansion of warmwater nonnative fish and aquatic fish parasites.

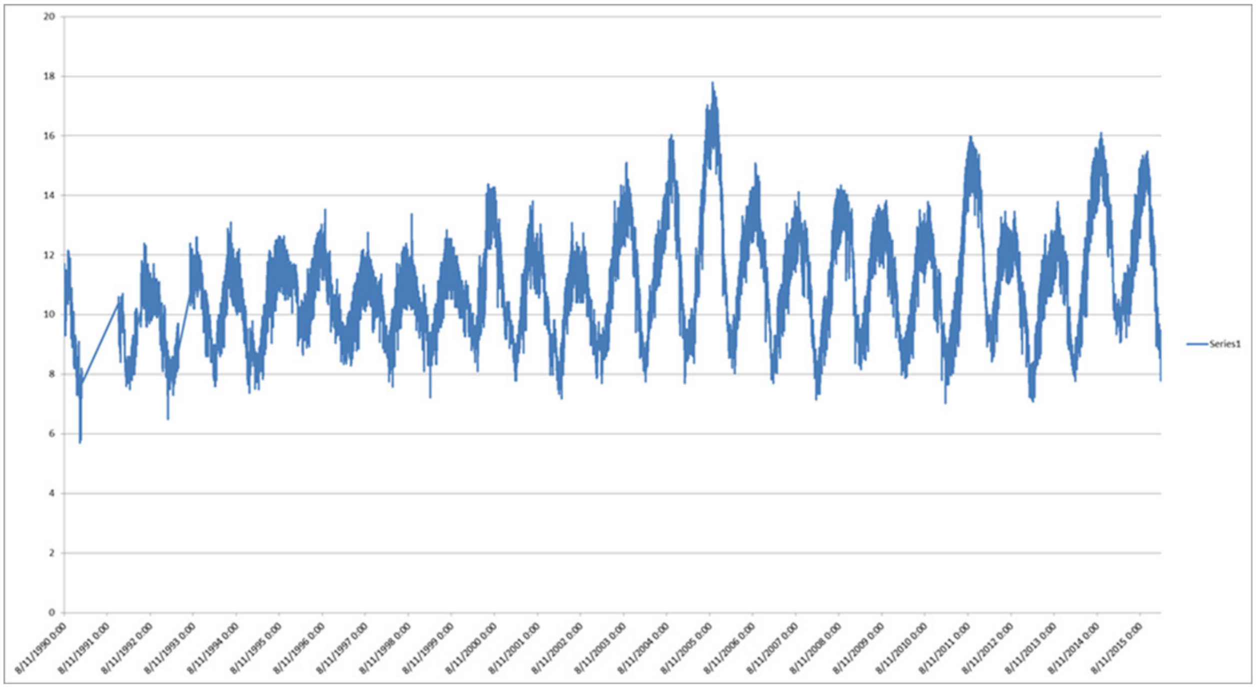

FIGURE 12 Water Temperatures at the Little Colorado River Confluence (RM 61), 1995 to Present (Source: USGS 2014)

Although the Little Colorado River stretches almost 340 m (550 km), only the headwaters and the lowermost reaches flow year-round. The lower 13 mi (21 km) of the Little Colorado River is fed by groundwater springs. This reach is occupied by the largest self-sustaining population for the species, and the lower 8 mi (13 km) is designated critical habitat. These water sources may also be vulnerable to basinwide drought and climate change impacting overall habitat availability and the population.

The development of a second population of reproducing humpback chub in the Grand Canyon was identified as an important conservation action in the 1995 EIS on the operations of Glen Canyon Dam, in case of catastrophic loss of the Little Colorado River population (Valdez et al. 2000). While some reproduction of humpback chub has been documented in Havasu Creek (Healy and Nelson 2013) near 30-mile spring (RM 30; Valdez and Masslich 1999) and may occur in the western Grand Canyon (Albrecht et al. 2015; Kegerries et al. 2015), it is likely limited in the Colorado River by water temperature, rearing habitat, or other factors.

2.1.3 Razorback Sucker

2.1.3.1 Legal Status

The razorback sucker (*Xyrauchen texanus*) was listed as endangered under the ESA on October 23, 1991 (56 FR 54957). The final rule for determination of critical habitat was published on March 21, 1994 (59 FR 13374), and the final designation became effective on April 20, 1994. Designated critical habitat within the project area includes the Colorado River and its 100-year floodplain from the Paria River downstream through Marble and Grand Canyons to Hoover Dam, including the full pool elevation of Lake Mead.

2.1.3.2 Recovery Goals and Status

Recovery goals for razorback sucker were established in 2002 (FWS 2002b). Demographic criteria that describe numbers of populations and individuals (adults and juveniles) for downlisting and delisting are presented for upper and lower basin recovery units in the FWS's razorback sucker Recovery Goals document:

> These criteria require four genetically and demographically viable, self-sustaining populations (two in each recovery unit), based on requirements of no significant decline in numbers of adults for each population and recruitment equal to or exceeding adult mortality. In addition, a genetic refuge needs to be maintained in Lake Mohave of the lower basin recovery unit (based on the majority opinion of lower basin biologists, the number of adults for maintaining this refuge is 50,000).

Monitoring is also necessary to determine if the recovery criteria are met. Adequate habitat and sufficient range are required to support recovered populations, in addition to demographic criteria.

The 5-year status review for the razorback sucker was completed by the FWS in 2012 (FWS 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 1 of the 10 demographic criteria had been met, 2 had been partially met, and 7 were unmet. In addition, the majority of the most meaningful threats to the species were not mitigated, as only 9 of the 29 recovery factor criteria were met. As a result, the FWS decided that a change in the species' endangered status was not warranted (FWS 2012).

2.1.3.3 Historic and Current Range

The razorback sucker is a large river sucker (Catostomidae) endemic to the Colorado River system. It is a large fish, with adults reaching lengths up to 3 ft and weighing as much as 13 lb, and it may live 40 years or more (FWS 2002b). The species is endemic to large rivers of the Colorado River Basin from Wyoming to Mexico; however, the specie's range has been substantially reduced (Figure 13; Marsh et al. 2015). Currently, it 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 (FWS 2002b) and Lake Powell (Francis et al. 2015).

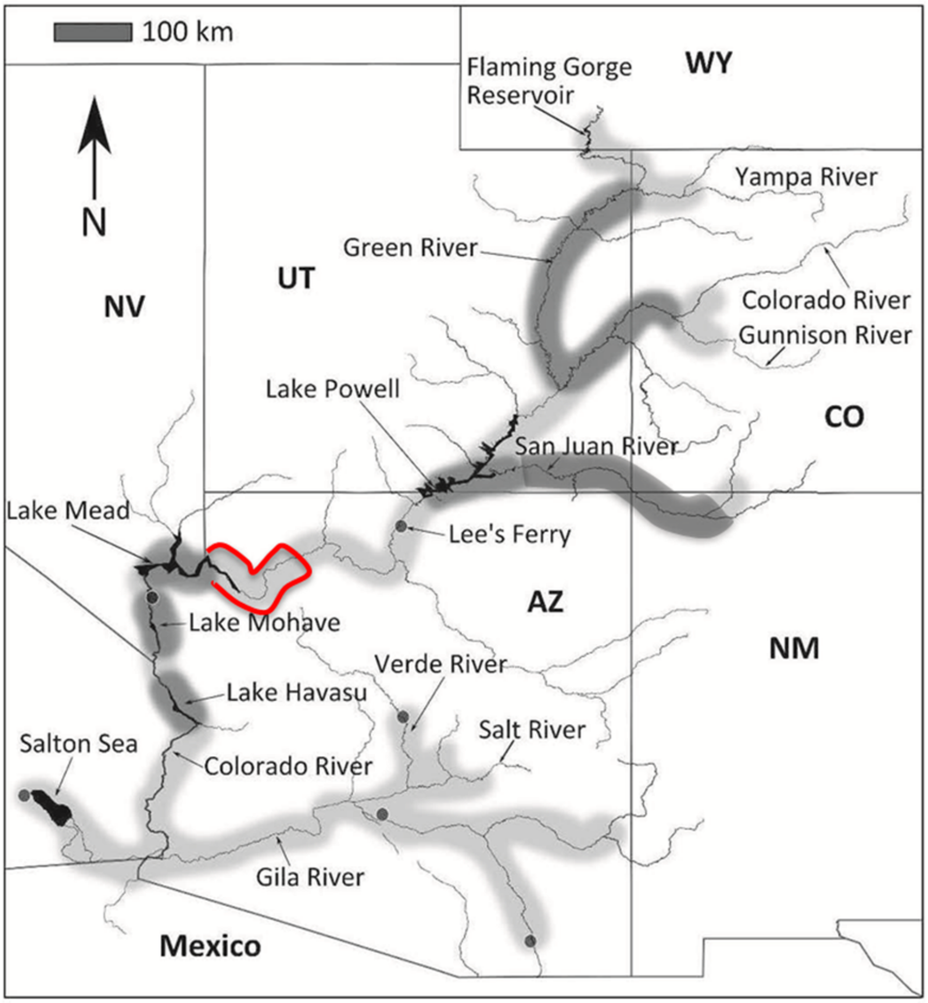

FIGURE 13 Historic (light gray) and Present Range (dark) of Razorback Sucker in the Colorado River Basin (The lower Grand Canyon/Colorado River inflow area of Lake Mead, where razorback sucker larvae have been detected is shown in red [Albrecht et al. 2014; Kegerries et al. 2015].) Source: Marsh et al. (2015)

Recent estimates of razorback sucker populations were summarized by Marsh et al. (2015), but the authors noted that the precision of many estimates was questionable given low recapture rates of marked individuals. Despite this, collectively, the number of remaining individuals is likely only a fraction of historic populations. Many 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 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; FWS 2012; Mohn et al. 2015), which was estimated to consist of approximately 596 individuals through 2012 (95% Confidence Interval: 468–786; Albrecht et al. 2013). Low numbers of recaptures likely precluded a population estimate for the sampling period between 2013 and 2015 in

Lake Mead (Mohn et al. 2015). Lake Mead contains one of the smaller populations; rangewide, however, recruitment is rare or nonexistent in other populations (Marsh et al. 2015).

2.1.3.4 Population within the Action Area

Inventories of fish populations in the pre-dam Grand Canyon were extremely rare, and thus describing historic fish distribution and abundance is difficult (Webb et al. 2002). 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.

Adult razorback suckers have recently been captured from the western Grand Canyon (summarized in NPS 2013). 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) (Kegerries and Albrecht 2012, as cited in NPS 2013). An additional untagged adult razorback sucker was captured in GCNP near Spencer Creek (RM 246) in October 2012 (as reported in 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 179 (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). However, small-bodied fish sampling designed to detect juvenile razorback sucker in western Grand Canyon has failed to detect any older larval fish or those that have transformed to juveniles.

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, indicates 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), which are devices that 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 (Kegerries et al. 2015) indicates spawning is occurring in an unknown location in the mainstem or tributaries.

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 project area.

2.1.3.5 Habitat

Razorback sucker use a wide variety of habitats, including rivers and streams and their associated floodplains, as well as reservoirs (Valdez et al. 2012a). Habitat use varies by life stage and by habitat type (i.e., lentic vs. lotic habitats). Valdez et al. (2012a) completed a comprehensive review of razorback sucker habitat use studies conducted throughout the species' range. In rivers, habitat requirements of adults in spring include low-velocity runs, eddies, backwaters, and areas of inundated vegetation (e.g., flooded off-channel areas); in summer, runs and mid-channel bars; and in winter, low-velocity runs, pools, and eddies (reviewed in Valdez et al. 2012a). Razorback suckers spawn on cobble and gravel bars in rivers, and on gravel and cobble shorelines in reservoirs. In reservoirs, adults prefer areas with water depths of 3 ft or more over sand, mud, or gravel substrates. Young require nursery areas with quiet, warm, shallow water such as tributary mouths, backwaters, and inundated floodplains along rivers and coves or shorelines in reservoirs (FWS 2002a). Recent captures of larval razorback sucker in the western Grand Canyon found the highest density of larvae in isolated pools, which comprised less than 2% of all habitat sampled (Albrecht et al. 2014). Similar results were found in 2015, when the highest catch of larval razorback sucker was found in isolated pools, followed by backwaters, which composed 2.1% and 9.1% of habitats sampled, respectively (Kegerries et al. 2015). Larval razorback sucker may drift along the shoreline adjacent to the main channel until settling into warmer, shallow backwaters, or floodplain wetlands (Valdez et al. 2012a).

Critical habitat was designated for this species in 1994, and within the project area, including 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 (59 FR 13374).

2.1.3.6 Life History

Razorback suckers are long-lived (40+ years) and exhibit relatively fast growth the first 5 to 7 years of life in warm, food-rich environments, until adulthood, and after which growth slows and possibly stops (FWS 2002b). Both sexes are sexually mature by age 4 and can reach a maximum size of about 1 meter. As described above, spawning in rivers occurs over bars of cobble, gravel, and sand substrates during spring runoff at widely ranging flows and at water temperatures as low as 6°C (reviewed in Marsh 1985), but typically greater than 14°C (57°F) (FWS 2002b). High flow and temperature cues during spring were thought to be important to the initiation and success of spawning (reviewed in FWS 2002b). For example, vegetated floodplain wetlands and other off-channel habitats inundated by spring high flows provide warmer, food-rich rearing habitats for drifting larval razorback sucker (reviewed in Modde et al. 2001). High flows may also have flushed fine sediment from cobble bars, maintaining interstitial space for egg deposition and incubation. In reservoirs, spawning occurs over wave-swept rocky shoals and shorelines.

Historically, this species exhibited upstream migrations in spring for spawning, although current populations include groups that are sedentary and others that move extensively (Minckley et al. 1991). Adults in the Green River subbasin have been reported to move as much as 62 mi to specific areas to spawn (Tyus and Karp 1990). In Lake Mohave, individuals have been reported to move 12 to 19 mi between spring spawning and summer use areas (Mueller et al. 2000). Sonic-tagged razorback sucker, either stayed near spawning areas, or have moved great distances, up to 361 km (224 mi) within the western Grand Canyon, the Colorado River inflow to Lake Mead, and throughout the lake (Kegerries et al. 2015).

Razorback sucker have high fecundity, with the average number of eggs per female ranging from 27,614 to 103,000 in various studies (reviewed in FWS 2002b). Eggs incubate for 6 to 7 days before hatching, prior to emerging from cobbles and being transported downstream to floodplains or backwaters. Hatching success is temperature dependent, with the potential for complete mortality occurring at temperatures less than 10°C (50°F; Marsh 1985; Bozek et al. 1990). Marsh (1985) found the highest survival of embryos and percentage hatched was at 20°C in laboratory studies, while Bozek et al. (1990) showed that hatching success was between 32 and 65% in 15°C water.

In the Grand Canyon, the estimated onset of spawning was in mid-February, based on back-calculation from the dates of larval collection, when average daily water temperatures were between 10 and 12°C (50 and 53.6°F; Kegerries et al. (2015). Spawning appeared to peak toward the end of March when water temperatures ranged from 12 to 14°C, but the duration of spawning was protracted—occurring between mid-February and July (Kegerries et al. 2015). A faster larval razorback sucker growth rate is thought to benefit survival by minimizing the time larvae are susceptible to predation by small-bodied fish. Growth was 50% greater at 19.5°C compared to growth in 16.5°C water, with the highest growth rates at 25.5°C (Bestgen 2008). As described above, following hatching, larval razorback sucker may drift into low-velocity, warm, backwaters or floodplain wetlands to rear. Maturity is reached in 2 to 5 years.

Both adults and immature fish are omnivorous, feeding on algae, zooplankton, and aquatic insect larvae; however, diet varies by life stage. In Lake Mohave, their diet has been reported to be dominated by zooplankton, diatoms, filamentous algae, and detritus (Marsh 1987). Larval razorback sucker feed on planktonic organisms, switching to benthic organisms as their sub-terminal mouth develops, with chironomid larvae being a primary food item (FWS 2002b).

2.1.3.7 Factors Affecting Distribution and Abundance in the Grand Canyon

The decline of the razorback sucker in the Grand Canyon and throughout its range 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 (FWS 2002b; Gloss and Coggins 2005). For example, the estimated 80% rangewide reduction in distribution of this species has been attributed to the construction of Hoover, Parker, Davis, and Glen Canyon Dams on the Colorado River and Flaming Gorge Dam on the Green River (Valdez et al. 2012a). Similar to the humpback chub, as described above, cold hypolimnetic releases from dams, including Glen Canyon Dam, have also contributed to reproductive failure in razorback sucker (Gloss and Coggins 2005). Flow regulation and water diversions have 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 elimination of reproduction and recruitment (FWS 2002b). In 2012, the FWS (2012) determined that flow regimes necessary to establish and maintain razorback sucker populations in the lower basin, including flows that provided adequate spawning cues and spawning and nursery habitat, had not been established. Similar to impacts on humpback chub, elevated Hg and Se described by Walters et al. (2015) may be another factor that may impact razorback sucker. While 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).

The large reservoirs formed by dams also provide habitat for nonnative sport fishes, which were stocked with nonnative sport fish predators. Competition with and predation by nonnative fishes have also been identified as important factors in the decline of this razorback sucker (Minckley et al. 1991; FWS 2002a). 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 (reviewed in Gloss and Coggins 2005). Large-scale nonnative fish control and management programs have been implemented to meet recovery goals for razorback sucker in the upper basin, including control of small- and large-bodied predators in the San Juan and Upper Colorado River Basins, and revising nonnative fish stocking procedures (FWS 2012). Marsh et al. (2015) professed that only complete elimination of nonnative fish from razorback sucker spawning and nursery areas, such as off-channel ponds, would lead to successful conservation of the species in Lake Mohave. The success of stocking programs has been limited by the presence of nonnative predators. For example, Schooley and Marsh (2007) found that few individuals survived out of millions of small razorback suckers that had been stocked in the lower basin, likely because of predation by nonnative fish, and larger stocked fish had a much higher likelihood of survival.

In the Grand Canyon, the decline of native fish, including razorback sucker, has been attributed in large part to an increased diversity and abundance of nonnative fishes, along with the effects of Glen Canyon Dam on water temperatures, flow, and sediment (Gloss and Coggins 2005). As described above, recent efforts to better understand the use of the western Grand Canyon by razorback sucker has revealed that the species is more widespread there than previously thought. Spawning has occurred in unknown locations in the river or tributaries from Lake Mead to at least to areas upstream of Lava Falls in the Grand Canyon, or in the inflow areas of tributaries to Lake Mead, which has led to the maintenance of a small, but recruiting population in the project area (Albrecht et al. 2014). It is unclear whether razorback sucker spawning had been occurring previous to larval fish studies initiated in the western Grand Canyon in 2014.

Through the first 2 years of the first phase of a study to determine the habitat suitability and status of razorback sucker in the Grand Canyon (see NPS 2013), it was found that adult razorback sucker moved throughout the study area, and spawned, but no habitat preference could be inferred. Larval razorback sucker catches were higher in isolated pools and backwaters than other nearshore habitats that were sampled (Kegerries et al. 2015). Despite the presence of adults and larval fish, no juvenile razorback sucker had been captured (Kegerries et al. 2015). Plausible explanations for this, assuming appropriate habitats are sampled for juvenile suckers, could be that all larval suckers are consumed by nonnative fish prior to their transformation to juveniles, or suitable low-velocity nursery habitats with sufficient food and water temperatures may not be available in the western Grand Canyon. However, relatively few nonnative fish have been sampled in the past 2 years in nearshore habitats from Lava Falls to Pearce Ferry, compared to native fish (Albrecht et al. 2014; Kegerries et al. 2015), and Valdez et al. (2012a) observed that there were backwaters similar to those on the San Juan River that are used by razorback sucker larvae, downstream of Lava Falls. Since the flow and temperature regime of the Colorado River in the Grand Canyon has been altered (i.e., reduced sediment supply, lack of high annual peaks, daily fluctuating flows, and cold dam releases), leading to less backwater stability and more frequent flushing (Behn et al. 2010), these backwaters may be less suitable for rearing than under stable summer flows (see Trammell et al. 2002; Vernieu and Anderson 2013). Alternatively, larval razorback sucker may drift out of the Grand Canyon and rear in the Colorado River Inflow of Lake Mead, which may provide suitable cover (turbidity) and temperatures (Valdez et al. 2012b; Kegerries et al. 2015). Captures of an age-2 and an age-3 immature razorback sucker, and an age-0 juvenile in or near the Colorado River Inflow of Lake Mead, suggests that some recruitment is occurring associated with the Colorado River in the Grand Canyon (summarized in Kegerries et al. 2015), despite altered habitats.

The presence of razorback suckers and their use of habitats in the Grand Canyon have only recently been investigated, and it is unclear how long spawning has been occurring, since larval fish studies were not conducted prior to 2014. Recent warming river temperatures due to lower Lake Powell elevations, attributed to drought and consumptive water use, may have resulted in more suitable habitats in the western Grand Canyon. For example, 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 (reviewed in 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 for recovery of razorback sucker in this reach of its range (Albrecht et al. 2014).

More frequent droughts and warmer atmospheric temperatures as a result of climate change and warmer temperature of water being released from the dam are likely to impact razorback suckers in the Grand Canyon. Razorback suckers are currently located in the lower reaches of the canyon where backwater habitat is more available. Warmer water temperatures may create more suitable habitat for larvae and juveniles. However, these effects may be offset by increased abundance and expansion of nonnative fish and aquatic fish parasites. Also, lower reservoir releases may result in fewer backwater habitats available for spawning and rearing of razorback sucker.

2.1.4 Southwestern Willow Flycatcher

2.1.4.1 Legal Status

The southwestern willow flycatcher (*Empidonax traillii extimus*) is one of four currently recognized willow flycatcher subspecies (Phillips 1948; Unitt 1987; Browning 1993). On March 29, 1995, the southwestern willow flycatcher was listed as endangered (60 FR 10694) in its entire range, which is known to include Arizona, California, Colorado, New Mexico, Texas, Utah, and Mexico. In August 2002, the FWS released the "Final Recovery Plan for the Southwestern Willow Flycatcher." The Recovery Plan establishes six recovery units that are further subdivided into management units. These Recovery and Management Units are based on watershed and hydrologic units within the breeding range of the flycatcher (FWS 2002c).The Grand Canyon is within the Lower Colorado Recovery Unit. This Recovery Unit encompasses the Colorado River and its tributaries from Glen Canyon Dam downstream to the Mexican border. Despite the large size of this Recovery Unit, the unit contains only 146 known territories (15% of the rangewide total) (FWS 2002c).

2.1.4.2 Recovery Goals and Status

The Recovery Plan and goals for the southwestern willow flycatcher were completed in 2002 (FWS 2002c). The recovery objective for the species is to attain a population size and distribution of habitat sufficient to maintain metapopulations over the long term. Threats to the species must be addressed to achieve this goal. In general, the minimum number of territories needed and maintained over a 5-year period is 1,950 (approximately 3,900 individuals), distributed geographically to allow for functioning metapopulations. In addition, the total known population would need to be increased to 1,500 territories (3,000 individuals) distributed geographically among the Management Units and Recovery Units, so that the species is no longer in danger of extinction.

The 5-year status review for the southwestern willow flycatcher was completed by the FWS in 2014 (FWS 2014). It was determined that the status of the species had improved due to an increase in the number of known territories since it was listed in 1995. However, ongoing threats related to the spread of tamarisk leaf beetle and land management remained concerns. Due to these ongoing threats, a decline in the rangewide distribution of the species, and anticipated future adverse effects of the tamarisk leaf beetle to its habitat, the FWS determined that no change in status was warranted.

2.1.4.3 Historic and Current Range

The southwestern willow flycatcher is a neotropical migrant that breeds in the southwestern United States and migrates to Mexico, Central America, and possibly northern South America during the non-breeding season (Phillips 1948; Stiles and Skutch 1989; Peterson 1990; Ridgely and Tudor 1994; Howell and Webb 1995). The Pacific lowlands of

Costa Rica appear to be a key winter location for the southwestern willow flycatcher, although other countries in Central America may also be important (Paxton et al. 2011). Historically, the range of the flycatcher in Arizona included portions of all major watersheds (FWS 2002c); however, these watersheds have changed in many cases. As a result, most of the areas where flycatchers were locally abundant now support few or no individuals (FWS 2002c). Habitat and population numbers of southwestern willow flycatchers have declined in recent decades due to several factors, including loss, degradation, and fragmentation of riparian habitat; invasion by nonnative plants; brood parasitism by brown-headed cowbirds; and loss of wintering habitat (Stroud-Settles et al. 2013).

2.1.4.4 Population within the Action Area

Seventeen flycatcher sites were identified in the 2002 Recovery Plan (FWS 2002c) within the Grand Canyon. Flycatcher territories in the Grand Canyon are generally located in the tamarisk-dominated riparian vegetation along the river corridor but not in the mesquite-acacia and hackberry-dominated habitats higher on the slopes (Sogge et al. 1997a). The flycatcher's nesting habitat is dynamic in that it varies in occupancy, suitability, and location over time. In GCNRA, southwestern willow flycatchers are uncommon restricted migrants in riparian areas, rare summer residents, and probable breeders (Spence et al. 2011). Historic and recent nesting site locations in the Grand Canyon have been documented below Lees Ferry in Marble Canyon and in lower Grand Canyon below Diamond Creek (RM 225.5–RM 277) (Appendix B). No southwestern willow flycatcher nests or nesting behavior have been identified in the inner gorge (RM 77.9–RM 116.5); however, migrant birds have been documented. Because river channels, river flows, and floodplains are varied and can change over time, the location and quality of nesting habitat may also change over time. This is especially noticeable in the lower Grand Canyon where dropping lake levels in Lake Mead have resulted in high walls (approximately 10 to 20 ft high in many areas) of sediment topped with tamarisk bordering the Colorado River. The backwaters and saturated soils preferred by southwestern willow flycatchers have become rare.

Numbers of southwestern willow flycatcher detections in the Grand Canyon have declined since the 1980s, which is based on studies referenced below. There is little information on the number of willow flycatchers along the river before the construction of the Glen Canyon Dam. However, what data are available suggest that southwestern willow flycatchers were not common breeders along the Colorado River in the Grand Canyon (Brown 1988a,b; Brown 1991; Sogge et al. 1997b). Studies conducted along the river from 1982 to 1991 between Lees Ferry and Phantom Ranch found a total of 47 adult southwestern willow flycatchers—14 pairs, and 15 nests (Brown 1988a; Sogge et al. 1997a). From 1992 to 2001, the breeding population fluctuated between 1 and 4 breeding pairs per year with a total over the 10 years of 66 adult southwestern willow flycatchers, 14 pairs, and 20 nests (Brown 1988a,b; Brown 1991; Sogge et al. 1997a; Sogge and Tibbitts 1992; Sogge et al. 1993; Sogge and Tibbitts 1994; Sogge et al. 1995; Petterson and Sogge 1996; Sogge 1998; Yard 2001, 2002, 2003). Appendix B summarizes southwestern willow flycatcher observation data, territories, and nesting sites located in the Grand Canyon from 1909 to 2011. Although surveys were conducted in 2012, southwestern willow flycatchers were not detected. Survey methods followed the most recent

USGS survey protocol, at the time of survey, and involved the use of broadcast calling to elicit southwestern willow flycatcher responses (Sogge et al. 2010). Nest searches were not conducted during the 2010–2012 surveys at the Grand Canyon; however, due to behavior and timing of southwestern willow flycatcher detections at RM 275 in 2010, two breeding pairs were suspected to be present. Appendix A and Appendix B provide information on the locations of birds and nests from 1982 to 2011. Data are based on the following monitoring reports: Sogge et al.1997a; McKernan and Braden 1997, 1998, 1999, 2000, 2001, 2002, 2004; Paradzick et al. 2001; Smith et al. 2002, 2003, 2004; Koronkiewicz 2004, 2005, 2006, 2007, 2008; Yard et al. 2004; Albert 2005; Laczek-Johnson and Ward 2006; Ward and Haynes 2007; Northrip et al. 2008; Slayton et al. 2009; Palarino et al. 2010; Stroud-Settles and Lawrence 2011.

After the 2004 survey season, the USGS and GCMRC elected to discontinue their monitoring of known southwestern willow flycatcher nesting habitat in the Grand Canyon. Beginning in 2005, the Grand Canyon conducted annual surveys from Lees Ferry to Phantom Ranch, but funding prevented surveying the isolated habitat patches between Phantom Ranch and Diamond Creek. From 2004 to 2008, only two southwestern willow flycatchers were detected between Lees Ferry and Phantom Ranch.

2.1.4.5 Lees Ferry to Diamond Creek

Suitable habitat is located disjunctly through the river corridor from approximately RM 28.3 to RM 275. Surveys conducted between 1992 and 2004 indicated a small resident breeding population between Lees Ferry and Cardenas Marsh (RM 71), but no territories from RM 71 through RM 246 have been located. Recent (2007–2009) surveys have only detected non-resident/migratory flycatchers between Lees Ferry and Phantom Ranch (Palarino et al. 2010). Formal nest searches have not been conducted above Diamond Creek since 2004 (Stroud-Settles et al. 2013).

From 1993 to 2004, flycatchers were consistently present during the breeding season at RM 50.5–RM 51.5, but have not been present since 2004 (Ward and Haynes 2007; Northrip et al. 2008). In 2003, 2004, and 2010, the area around RM 28–RM 29 was occupied. Another area of importance in the mid-1990s was RM 71–RM 71.5; however, this area does not appear to have been occupied for the last 17 years. In 2004, the Grand Canyon instituted an emergency closure at two sites. This closure was in effect between May 1 and July 15 and included closure of visitor use, including hiking, camping, and river landings at RM 28.1–RM 28.5, river left, and RM 50.2–RM 50.6, river left. Closures at RM 28 and RM 50 have been put in place intermittently in the past; closure at Cardenas (RM 71) was instituted in the early and mid-1990s.

2.1.4.6 Lower Grand Canyon

Koronkiewicz et al. (2004) reported that the Colorado River in the Grand Canyon downstream of Separation Canyon (RM 234) is strongly influenced by water levels in Lake Mead. Potential southwestern willow flycatcher habitat in this area has changed dramatically in the last several years as the result of a 105-ft drop in the level of Lake Mead since 2000. Areas that were inundated in the late 1990s are now well above the current water level, and the existing riparian vegetation in many of these areas is dead or dying. A 5-year boost in detections along this stretch of river that occurred from 1997 to 2001 is likely due to favorable water levels of Lake Mead in combination with increased survey effort (Stroud-Settles et al. 2013). The river corridor continues to provide essential habitat for migrating southwestern willow flycatcher (Stroud-Settles et al. 2013).

Southwestern willow flycatchers have been detected in the lower Grand Canyon below RM 234 since 1995 with the exception of 2002, 2003, 2011, and 2012 (Appendix B). In 2004, Koronkiewicz et al. identified approximately 76 hectares of suitable habitat at several sites between RM 239 and RM 275 within the Grand Canyon. These disjunct habitat patches have been inconsistently monitored during the past 11 years for both flycatcher presence and habitat suitability. Suitability ranking of these sites has proven to be largely dependent on current hydrological conditions of the Colorado River. As a result, a habitat assessment survey conducted during one year may result in a habitat ranking that is deemed suitable, but a revisit to the same site during a different year may rank the site as only potential habitat.

2.1.4.7 Life History and Habitat

The southwestern willow flycatcher eats insects and needs riparian habitats to complete its life cycle. It breeds and forages in dense, multi-storied riparian vegetation near saturated soils, slow-moving water, or surface water (Sogge et al. 1995). The southwestern willow flycatcher breeds across the lower Southwest from May through August (Reclamation 2007b). The southwestern willow flycatcher arrives on the breeding grounds throughout May and early June, eggs are generally laid beginning in May, and fledging occurs between June and August (Sogge et al. 1997a, 2010). Occupied sites most often have a patchy interior of dense vegetation or dense patches of vegetation intermingled with openings. Most often, this dense vegetation occurs within the first 3 to 4 m above the ground (FWS 2002c). The structures of occupied patches vary, with a scattering of small openings, shorter vegetation, and open water. Occupied patches can be as small as 2 acres and as large as several hundred acres, but are typically >10 m wide (Reclamation 2007b).

The southwestern willow flycatcher breeds in dense riparian habitats from sea level in California to approximately 8,500 ft in Arizona and southwestern Colorado. Throughout its range, the southwestern willow flycatcher arrives on breeding grounds in late April and May (Sogge and Tibbitts 1992; Sogge et al. 1993; Sogge and Tibbitts 1994; Muiznieks et al. 1994; Maynard 1995; Sferra et al. 1995, 1997). Nesting begins in late May and early June, and young fledge from late June through mid-August (Willard 1912; Ligon 1961; Brown 1988a,b; Whitfield 1990; Sogge and Tibbitts 1992; Sogge et al. 1993; Muiznieks et al. 1994; Whitfield 1994; Maynard 1995). The entire breeding cycle, from egg laying to fledging, is approximately 28 days. Nesting occurs during the spring and early summer months (May 1–August 31) in the Grand Canyon.

Historical egg/nest collections and species descriptions throughout its range identify the southwestern willow flycatcher's widespread use of willow (*Salix spp*.) for nesting (Phillips 1948; Phillips et al. 1964; Hubbard 1987; Unitt 1987; San Diego Natural History Museum 1995). Other habitats are also used, including nonnative species such as tamarisk (*Tamarix spp*.) and Russian olive (*Eleagnus angustifolia*). Throughout the southwestern willow flycatcher's current range, suitable riparian habitats tend to be rare, widely separated small and/or linear locales separated by vast expanses of arid lands.

2.1.4.8 Factors Affecting Distribution and Abundance in the Grand Canyon

The southwestern willow flycatcher has experienced extensive loss and modification of habitat and is also endangered by other factors, including brood parasitism by the brown-headed cowbird (*Molothrus ater*). The southwestern willow flycatcher was listed primarily due to riparian habitat reduction, degradation, and elimination as a result of agricultural and urban development. Other reasons for the decline/vulnerability of the flycatcher include the fragmented distribution and low numbers of the current population; predation; and other events such as fires and floods that are naturally occurring, but have become more frequent and intense as a result of the proliferation of exotic vegetation and degraded watersheds, respectively.

The Grand Canyon does not provide extensive stands of dense riparian habitat suited for breeding southwestern willow flycatchers. The majority of habitat patches in the Grand Canyon lack a consistent, dependable source of water for maintaining moist/saturated soil conditions and/or slow-moving or standing surface water (Stroud-Settles et al. 2013). As a result, the majority of flycatcher habitats in the Grand Canyon are marginal and, unless current hydrological conditions change, these patches will likely continue to decline. Furthermore, the recent arrival of the tamarisk leaf beetle has transformed and will continue to transform the patches of dense tamarisk into unpredictable, diminished patches (Stroud-Settles et al. 2013). Effects of climate change and continued dry basin hydrology may further diminish habitat for the flycatcher due primarily to lower water levels within riparian areas.

2.1.5 Yuma Ridgway’s Rail

2.1.5.1 Legal Status

The Yuma Ridgway’s rail (*Rallus obsoletus yumaensis*) was listed as endangered on March 11, 1967 (32 FR 4001). A 5-year review of the species was completed in 2006, and currently the 1983 Recovery Plan is in the revision process; a draft was released in 2010 for public review (FWS 2009b), and finalization is expected in 2016. It is categorized as a subspecies with a high degree of threat and low recovery potential due to habitat loss.

2.1.5.2 Recovery Goals and Status

Recovery goals and objectives for Yuma Ridgway's rail are based on the need to achieve and maintain a viable population level and to protect and maintain a sufficient amount of core and other habitats to support the population. The primary threat to the species is that water sources supporting its habitat are not managed and protected, and as a result, habitat may be lost. The draft recovery goal is "To achieve population stability and habitat protection sufficient to downlist and/or delist the Yuma Ridgway's rail" (FWS 2009b).

The 5-year status review for Yuma Ridgway's rail was completed in 2006 (FWS 2006). Based on the review, it was determined that the population in the United States is small, and limited information is available to determine the species' demographic status. Habitat loss in a Mexican population's range and accumulation of selenium in the environment remain significant threats, and thus no change in status was warranted.

2.1.5.3 Historic and Current Range

The Yuma Ridgway's rail occurs along the lower Colorado River and tributaries (Muddy, Virgin, Bill Williams, Lower Gila and Salt Rivers) in Arizona, California, Nevada, and Utah; the Salton Sea in California; and the Cienega de Santa Clara and Colorado River Delta in Mexico (FWS 2009b). Significant breeding areas in the United States include Mittry Lake (Arizona), Imperial Reservoir, Imperial National Wildlife Refuge, Bill Williams River National Wildlife Refuge, Topock Gorge and Topock Marsh in Havasu National Wildlife Refuge, Cibola National Wildlife Refuge along the lower Colorado River and Imperial Wildlife Area, Sonny Bono Salton Sea National Wildlife Refuge at the Salton Sea in California, and the Cienega de Santa Clara in Mexico. There is a small population in southern Nevada/northwest Arizona on the Muddy and Virgin Rivers.

2.1.5.4 Population within the Action Area

McKernan and Braden (1999) reported the presence of Yuma Ridgway's rails between Spencer (RM 246) and the boundary of the Grand Canyon (RM 277); these observations were made while conducting southwestern willow flycatcher surveys in the area. Specifically, McKernan and Braden (1999) report at least one rail observed between May 26, 1996, and June 30, 1996, and they indicate that nesting was confirmed. They report at least one rail observed between May 14, 1997, and June 17, 1997, but indicate that nesting was not confirmed (McKernan and Braden 1999). Surveys for the southwestern willow flycatcher in the lower Grand Canyon from 2003 to 2008 under the Lower Colorado River Multi-Species Conservation Program (LCRMSCP) did not record any incidental detections of Yuma Ridgway's rails (LCRMSCP 2008). GCNP surveys for southwestern willow flycatchers in the lower Grand Canyon in 2010 to 2012 did not have any incidental detection; however, the method of surveying used would be unlikely to pick up rail vocalizations.

The LCRMSCP mapped marsh habitat in the lower Grand Canyon/upper Lake Mead from aerial imagery taken in 2004; that mapping extended from RM 249 (401 km) to RM 277 (446 km), all within the boundary of GCNP. Koronkiewicz et al. (2004) and LCRMSCP (2004) report the presence of live cattails at Spencer Canyon (RM 246) and Burnt Springs (RM 259.5). The persistence of the cattail patches identified in the 2004 imagery and as documented in 2004 and 2005 is unknown. The continuing fall in Lake Mead elevation (60 ft to 18 m from 2004–2015) results in a longer reach of the river, and shallow bays or coves along the channel have become dewatered. Further, within the full-pool of Lake Mead, sediments have built up over time during higher lake elevations forming a delta. The retreating lake flows allows the erosive action of the river to cut through those sediments and move them downstream. The result can be steep eroding banks with riparian and marsh vegetation on top beginning to dry out as the water recedes with the lowered channel as more and more sediment is removed. With these changes, it is not known if cattail marsh habitat is present in sufficient quantity to allow for nesting.

Because of the limited information about the Yuma Ridgway's rail and its habitat in the Grand Canyon, managers must rely heavily upon the limited information available. Given that Yuma Ridgway's rails have been recorded historically at the Grand Canyon but have not been surveyed consistently or recently, managers presume that the Yuma Ridgway's rail may be present in the lower Grand Canyon during the lifetime of the LTEMP.

2.1.5.5 Habitat and Life History

The Yuma Ridgway's rail is a secretive species and is not often seen in the wild; however, it does have a series of distinctive calls and is most often identified by those. This bird inhabits freshwater or brackish stream sides and marshes under 4,500 ft (1,372 m) in elevation. It is associated with dense riparian and marsh vegetation, dominated by cattails (*Typha sp.*) and bulrush (*Scirpus ssp*.) with a mix of riparian tree and shrub species. Yuma Ridgway's rails may climb into a shrub or tree, but overall, they do not perch above the ground (FWS 2009b). Rails are capable of swimming and are also known to dive underwater, and may hold onto submerged vegetation to avoid threats or use its wings to "swim" (Todd 1986; Ripley 1977 cited in Eddleman and Conway 1998). The rail requires a wet substrate such as a mudflat, sandbar, or slough bottom that supports cattail stands of moderate to high density adjacent to shorelines. Other important factors are the presence of vegetated edges between marshes and shrubby riparian habitat (tamarisk or willow thickets) and the amount and rate of water-level fluctuations. Nests are built 3 to 6 in. (8 to 16 cm) above the surface in sloughs and backwaters that support dense stands of bulrush and cattails, and breeding occurs from March to early July. Along the lower Colorado River, males begin calling in February and pair bonding occurs shortly after. Nonnative crayfish provide the primary food base for the rail today; prior to the introduction of crayfish, isopods, aquatic and terrestrial insects, clams, plant seeds, and small fish likely dominated their diet (LCRMSCP 2008).

Eddleman (1989) determined that vocalizations are significantly reduced in winter, and telemetry data indicated that the majority of rails do not migrate. There is evidence that some populations may be more migratory than others, and this could be based on habitat and a stable food source (Eddleman 1989; Corman and Wise-Gervais 2005). Very little is known about the dispersal of adult or juvenile birds, but the expansion of the population northward along the lower Colorado River (to Lake Mead, the Salton Sea, and up the Gila and Salt Rivers in central Arizona over the last 80 years) indicates that dispersal does occur (FWS 2009b).

2.1.5.6 Factors Affecting Distribution and Abundance in the Grand Canyon

Historically, the primary concentrations of Yuma Ridgway's rails were likely to be found in cattail/bulrush marshes in the Colorado River Delta. Unfortunately, due to diversions from the river for agriculture and municipal uses, the freshwater flows down the lower Colorado River, necessary to maintain marsh habitat, have virtually been eliminated (FWS 2009b). The majority of Yuma Ridgway's rail habitats that exists today are mostly human-made, such as the managed ponds at the Salton Sea (FWS 2009b). Without active management and protection of water resources to address land use changes in floodplains, human activities, environmental contaminants, and reductions in connectivity between core habitat areas, these habitats will be permanently lost to the Yuma Ridgway's rail (FWS 2009b). Effects of climate change and continued dry basin hydrology may further diminish habitat for the Yuma Ridgway's rail due primarily to lower water levels within riparian areas.

Another specific threat to the Yuma Ridgway's rail includes selenium in crayfish, the major prey item of the species. Selenium levels in crayfish collected in Yuma Ridgway's rail habitat were high enough to cause concern for the rail's reproductive success (FWS 2009b). No adverse effects from selenium have been observed; however, due to the rail's secretive nature, nests are very difficult to find and young birds difficult to observe (FWS 2009b).

2.2 BASELINE TAKE RESULTING FROM HANDLING AND GCDAMP RESEARCH

2.2.1 Humpback Chub

Fisheries monitoring and research are important aspects of ongoing research in the Grand Canyon that assesses the impacts of adaptive management and experimental treatments upon humpback chub and other resources. An extensive fisheries monitoring and research program is being implemented by the GCDAMP through the USGS and GCRMC throughout the project area, which will continue under the LTEMP proposed action. While stress upon individual humpback chub may result in occasional fatality, an objective of monitoring is to gather information in order to ensure that LTEMP goals for humpback chub are met.

Stress upon individual humpback chub related to sampling using netting and electro-fishing gears, as well as handling by researchers, is also a potential source of injury or mortality to individuals. No immediate mortality of humpback chub has been documented during tempering prior to release, hoop-netting, or electro-fishing during monitoring associated with NPS translocation projects in Shinumo and Havasu Creeks. Humpback chub were captured and handled 1,068 times between June 2010 and September 2012 in Shinumo and Havasu Creeks (Healy et al. 2014), for example. However, some minimal mortality has occurred during juvenile collection efforts at the Little Colorado River for translocations and refuge development, although it is generally less than 5% (Van Haverbeke 2012). Five to 10 fish out of 500 to 800 generally die during transport in route to hatchery rearing facilities and during parasite and disease treatments; however, approximately 60 (10%) were lost at a hatchery facility during disease treatments and tagging prior to translocations in 2011. In 2014, approximately 30 out of 600 died during transport to the hatchery facility due to excessive cooling. Mortality of humpback chub captured during monitoring by all management agencies and researchers is reported to the FWS annually.

Incidental fatality was reported to the FWS by the USGS and GCMRC biology program manager (S. VanderKooi) and is summarized here. In 2012, 22 incidental fatalities out of 7,755 total humpback chub captures (0.28% mortality rate from capture) were associated with fish monitoring in the Colorado River using a variety of gear types. Another 4 humpback chub were lost out of 725 captures in the lower sections of the Little Colorado River (0.55%). Incidental mortalities of subadult or juvenile humpback chub (< 200 mm TL) included 88 in 2013 and 36 in 2014. The highest mortality rate was associated with experimental collections and rearing of larval humpback chub to be used in translocations (close to 30% of fish captured). Larval humpback chub collections may continue, or potentially increase slightly, to support translocations and Tier 1-triggered conservation actions included in the proposed action; however, the number collected would be similar to baseline conditions due to hatchery capacity constraints. Larval fish have an extremely low survival rate, and the risk to the humpback chub population of collecting several hundred larval fish is low (Pine. 2013). Nevertheless, collections for translocations or refuge development would be guided by FWS guidance documents (Translocation Framework, Van Haverbeke et al. 2016) and population viability modelling (Pine 2013). While inter-annual variability in incidental fatality due to handling occurs, the research program is not expected to change substantially through the LTEMP, and thus no change in impacts relative to the baseline condition is expected.

2.2.2 Razorback Sucker

Research designed to determine the status of razorback sucker in the lower Grand Canyon has resulted in mortality of larval razorback sucker and other native fish. While the mortality of up to several hundred individual razorback sucker larvae would be expected under the proposed action through collection and sacrifice of larval razorback suckers, with continued monitoring, the population-level impact would be minimal. For example, a single female razorback sucker could produce more than 100,000 larvae. While a final science plan for monitoring razorback sucker has not been developed, given the interest in determining and monitoring the impacts of TMFs and other actions included in the preferred alternative, mortality of larval fish and handling of juvenile fish (if present) may be expected to increase. However, these impacts would not likely impact the population, and monitoring would assist managers in determining the extent of impacts of flows on the species, potentially leading to adjustments in operations to benefit the species, or minimize large-scale impacts on habitat.

3 EFFECTS ANALYSIS OF PROPOSED ACTION

3.1 EFFECTS OF THE PROPOSED ACTION ON KANAB AMBERSNAIL

3.1.1 Direct and Indirect Effects

Aspects of the proposed action that have the potential to affect Kanab ambersnail individuals and habitat include sediment-related experiments (HFEs) and nonnative vegetation management. Other experiments or changes in dam operations included in the proposed action—such as changes in base operations, trout management flows, nonnative fish control, low summer flows, and sustained low flows for invertebrate production—would have no impact on the Kanab ambersnail, because these activities would not occur in locations known to contain populations or habitat. The impacts 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 habitat or individuals 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. No fish control would occur in off-channel springs.

3.1.1.1 Effects of Sediment-Related Experiments

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 (FWS 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. Some Kanab ambersnail habitat could be adversely affected by scouring at Colorado River flows exceeding 17,000 cfs (Kennedy and Ralston 2011). The HFE may reach flows of up to 45,000 cfs. These flows will inundate Kanab ambersnail habitat up to that stage and likely scour the vegetation and carry some snails downstream.

Very little Kanab ambersnail habitat and only a few individuals occur below the 25,000 cfs stage (Meretsky and Wegner 2000; Sorensen 2009). Most Kanab ambersnail habitat is located above the 33,000 cfs stage (Reclamation 2011b). HFEs may scour or inundate portions of Kanab ambersnail habitat. Surveys conducted after HFEs revealed no substantial declines in the Kanab ambersnail population (Kennedy and Ralston 2011). Kanab ambersnails can survive up to 32 hours underwater in cold, well-oxygenated water (FWS 2011a), so as long as they are not washed away, they 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 (FWS 2011a). Under the proposed action, HFEs would occur more frequently than they would under baseline conditions. Based on modeling results, only five HFEs would occur under the baseline condition, due to the expiration of the HFE protocol (Reclamation 2011b), but an

HFE would be expected to occur almost every year under the proposed action (19.3 HFEs over the LTEMP period). Loss of habitat due to scouring could extend several years beyond the LTEMP period. In addition, impacts on individuals, including fatality, could occur during HFEs, if the individuals are dislodged from habitat and swept into the river. Depending on the elevation of maximum dam discharge during trout management flows, temporary scouring of habitat may occur, but it is unlikely to reach Kanab ambersnail habitat that is above the 30,000 cfs elevation. However, the snail population at Vasey's Paradise survived and persisted through natural pre-dam floods and the 1983 flood, which were much larger in magnitude and longer in duration than the HFEs proposed under the LTEMP (Reclamation 1995; Kennedy and Ralston 2011).The amount of habitat and number of snails that would be unaffected by the proposed action are sufficient to maintain the population.

3.1.1.2 Effects of Vegetation Management

It is possible that vegetation management may occur, on rare occasions, near or within habitat at Vasey's Paradise, which may disturb individuals in small areas. Some nonnative vegetation may encroach on the spring, in which case careful manual removal of the vegetation would occur. To mitigate potential impacts on individual Kanab ambersnails, vegetation biologists would complete surveys and relocate any individuals detected on nonnative vegetation within the treatment areas. It is possible that some individuals could be killed during the treatment, but pre-treatment surveys would minimize this risk.

3.1.1.3 Effects of Climate Change

Climate change has the potential to affect the Kanab ambersnail habitat. The water source at Vasey's Paradise consists of waterfalls emanating from groundwater and emerging from the cliff face. In 2014 and 2015 the flow was noticeably reduced, likely as a result of basin-wide drought. Consequently, the usually dense vegetation at Vasey's Paradise is notably diminished. Climate change and drought will likely diminish the water source supporting Vasey's Paradise and consequently the vegetation and habitat available to the Kanab ambersnail.

Consequently, Reclamation has concluded the proposed action **may affect and is likely to adversely affect the Kanab ambersnail**.

3.2 EFFECTS OF THE PROPOSED ACTION ON HUMPBACK CHUB

The evaluation of potential impacts of the proposed action on humpback chub included consideration of the results of previous investigations conducted below Glen Canyon Dam that examined the status and abundance of native fish (e.g., Coggins and Walters 2009; Albrecht et al. 2014; Gerig et al. 2014; Kegerries et al. 2015), as well as studies of the effects of nonnative fish (Coggins et al. 2011; Yard et al. 2011; Whiting et al. 2014), experimental flows (such as HFEs and other flows), and water temperature on native fish (e.g., Grams et al. 2010;

Makinster et al. 2011; Trammell et al. 2002; Ward 2011; Ward and Morton-Starner 2015; Valdez and Speas 2007).

Several aspects of the proposed action may affect humpback chub directly or indirectly through direct impacts on individuals or habitat; or indirectly by influencing the abundance and distribution of nonnative predators and competitors, or by influencing macroinvertebrate production. Dam operations have the potential to influence river temperatures, the quantity and quality of nearshore rearing habitats (e.g., backwaters), aquatic insects that are food for humpback chub, and nonnative species abundance. These operations may also result in direct fatality to juvenile humpback chub through stranding. Flow-related actions that are analyzed below, which may impact humpback chub, include base operations, operational flexibility incorporated into base operations, sediment-related experiments, and aquatic resource experiments including trout management flows, low summer flows, and sustained low flows for benthic invertebrate production. Other non-flow actions that may impact humpback chub directly or indirectly, and that are analyzed below, include triggered humpback chub conservation actions (Appendix D), mechanical removal of nonnative fish, conservation measures, and continued fisheries research and monitoring under the GCDAMP. Some actions may have negative impacts on individuals, but beneficial effects at a population level.

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. Although riparian vegetation can play an important role in small stream ecosystems, particularly in providing cover, shade, or habitat for terrestrial invertebrates for fish to feed upon, riparian vegetation is less important for providing cover, shade, or energy inputs in larger rivers (Vannote and Sweeney 1980). Thus, riparian vegetation management would have large impacts on humpback chub and the species' habitat in the Colorado River.

3.2.1 Direct and Indirect Effects

3.2.1.1 Effects of Base Operations

Base dam operations are expected to change with the implementation of the proposed action. Changes will include more consistency across months, and thus more stability throughout the year, in monthly dam release volumes. The daily fluctuation in discharge would be proportional to the 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. The daily downramp rate would be increased, compared to the current condition, by 67% (from 1,500 cfs/hr to 2,500 cfs/hr). Year-round, fluctuating flows throughout the life of the LTEMP period may continue to have detrimental, long-term direct impacts on humpback chub, humpback chub habitat, and aquatic invertebrate prey (food base).

Stranding of fish is a potential outcome of daily hydropeaking (Bunn and Arthington 2002; Nagrodski et al. 2012). Increasing downramp rates under the proposed action may increase the risk of stranding humpback chub. Stranding could include fish being temporarily (i.e., until flows come 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 juvenile humpback chub present. Factors that may influence the probability of stranding fish in a river with altered flow regimes—such as below hydroelectric plants—include the rate of flow reduction, water temperature, channel geomorphology, and substrate composition, as well as biotic factors including fish life stage and size (as reviewed in Nagrodski et al. 2012). Increasing drawdown rates under the proposed actions will increase the risk of negative impacts; however, humpback chub may be less reliant upon river margin habitats that are sensitive to flow fluctuations (e.g., backwaters; Dodrill et al. 2015) than other native fish, at least in the Little Colorado River inflow reach. The potential for, and the effect of, stranding on individual humpback chub survival has not been directly investigated; however, a summary of stranding literature indicated that fish stranding as a result of hydroelectric and irrigation projects is well documented (Nagrodski et al. 2012).

Daily fluctuating flows will continue to degrade nearshore habitats under the life of the LTEMP, 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, but also invertebrate production areas, would be dewatered daily. Generally, low catch rates of 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). Although backwaters were not found to be common in the Little Colorado River inflow aggregation reach during a low steady flow experiment, humpback chub were found at higher densities in these habitats than in others (Dodrill et al. 2015). Backwaters may be more prevalent in other areas of the canyon, outside of the Little Colorado River inflow.

Base operations have been, and will 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 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; the Grand Canyon was found to have among the lowest insect diversity and the highest hydropeaking index among 16 dammed rivers. A diverse source of invertebrates colonize the Colorado River among the Grand Canyon's tributaries (Oberlin et al. 1999; Whiting et al. 2014), but hydropeaking and an altered temperature and flow regime will continue to negatively impact the food base for humpback chub over the life of the LTEMP.

Under base operations, through the life of the implementation of the LTEMP proposed action, 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 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 cold- or coolwater nonnative fish (e.g., brown and rainbow trout); this is consistent with past surveys that have found more warmwater nonnative fish species in those areas than upstream.

Colder water temperatures restrict growth of YOY humpback chub, which prolongs the time during which individuals are vulnerable to trout predation (Yackulic et al. 2014). Essentially, juvenile humpback chub do not grow at temperatures under 12°C. Larger, older juvenile humpback chub may be able to avoid, withstand, or escape predation by rainbow trout under warmer and turbid conditions; however, temperature and size did not afford the same advantage in escaping brown trout predation (Ward and Morton-Starner 2015).

Unless the water can be warmed to above 12°C, it should be expected that the reduced water temperatures will result in increased egg incubation time (Hamman 1982), greatly reduced egg and fry survival (Hamman 1982), reduced larval-to-juvenile transition time (Clarkson and Childs 2000), and reduced growth rates of all life stages (Clarkson and Childs 2000; Coggins et al. 2011). From Glen Canyon Dam to the Little Colorado River inflow, water temperatures are generally <12°C. Consequently, there will be little or no spawning of humpback chub 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 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. Recently, temperatures have reached or exceeded 16°C at about RM 160 during September. This may provide opportunities for mainstem spawning activity and growth.

HFEs build sandbars, which can cause additional—but temporary—backwater habitats. Following the 2014 HFE, 22 sandbars and resultant backwaters throughout the Canyon became larger, 11 sites showed no change, and 5 sites became smaller. Although these sandbars erode within 6 to 12 months, they do not return to the pre-flood stage (Grams 2015). Three fall HFEs have occurred (2012, 2013 and 2014) in November; temperatures are unlikely to significantly increase in backwaters at this time, which is outside the spawning period for humpback chub. Spring HFEs may provide more thermal refuge in backwaters, particularly in the lower Canyon. However, relative densities of humpback chub, based on estimates of backwater prevalence directly after a controlled flood, showed the majority of juvenile humpback chub were found outside of backwaters. This suggests that the role of controlled floods in influencing native fish population trends may be limited (Dodrill et al. 2015).

It is possible that within the LTEMP period uncontrolled warm water releases may occur as a result of the elevation and subsequent water temperature of withdrawals from Lake Powell. Increased temperatures may benefit humpback chub spawning and growth, but would also allow numbers and species of warmwater nonnative species to expand in the system. A new conservation measure for LTEMP will explore new technologies for controlling the temperature of water discharged into the Colorado River and technologies to prevent the passage of fish through the dam.

Reclamation developed a risk assessment model to evaluate effects of a selective withdrawal structure on aquatic resources in the Grand Canyon area. It indicates there may be benefits for all native fishes from warmer water, as well as benefits for many nonnative fish species that may compete with or prey upon native species. Results also indicate that there may be more suitable conditions for warmwater fish parasites (Valdez and Speas 2007). Species that occur in the Colorado River are listed in Table 5, along with their spawning, incubation, growth, and lethal temperature tolerances.

The impacts of the proposed action on temperature suitability for coldwater nonnative trout were assessed to determine the potential for increased trout populations, and thus increased likelihood of competition or predation upon humpback chub. Using the temperature suitability model, generally, temperature regimes would be suitable—although not optimal—for brown and rainbow trout under the proposed action. Temperature suitability for brown and rainbow trout would be similar to the baseline at most locations downstream of Glen Canyon Dam. However, main channel temperatures at and downstream of RM 61 would be more suitable for trout 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 at these downstream locations.

Previous studies have shown that rainbow trout recruitment and population size within the Glen Canyon reach appear to be largely driven by dam operations (Avery et al. 2015; AZGFD 1996; McKinney and Persons 1999; McKinney et al. 2001a,b; Makinster et al. 2011; Wright and Kennedy 2011; Korman et al. 2011, 2012). Increases in abundance have been attributed to the changes in flows beginning with interim flows in 1991 and later the implementation of 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). Declines in 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, 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 trout density, trout condition, and turbidity during the rainbow trout natal origins study (Korman et al. 2015).

In summary, under base operations, continued hydropeaking flows with increased downramp rates compared to the existing condition under coldwater conditions will continue to degrade nearshore rearing habitats, prevent the establishment of aquatic invertebrates (food base), and increase the risk of stranding juvenile humpback chub over the long term (throughout the life of the LTEMP).

3.2.1.2 Effects of Dam Operational Flexibility

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. Flexibility in dam operations would not change from the current conditions. These minor operational changes are not expected to measurably impact humpback chub, because no known impacts have been identified related to the current regime.

TABLE 5 Temperature Requirements for Spawning, Incubation, Growth, and Lethality of 36 Native and Nonnative Fish Species of the Colorado River and Its Tributaries in and near the Project Area[a]

	Spawning			Incubation				Growth			Lethal	
Species	Minimum	Maximum	Optimum	Minimum	Maximum	Optimum	Days	Minimum	Maximum	Optimum	High	Low
Black bullhead	19	22	20	21	24	23	6	20	22	21	3	35
Black crappie	14	18	16	15	22	17	4	24	30	27	0	34
Bluehead sucker	15	25	18	17	23	20	7	15	21	18	0	29
Bluegill	19	27	20	20	26	20	3	15	25	23	0	35
Brown trout	7	14	10	8	20	10	41	12	20	15	0	27
Bonytail	18	22	20	18	28	21	4	18	24	20	0	35
Common carp	18	30	23	20	30	24	4	15	30	27	0	38
Channel catfish	21	29	27	20	30	27	7	21	30	28	3	38
Colorado pikeminnow	16	24	22	19	25	22	5	18	23	25	0	35
Flathead catfish	22	29	26	22	29	27	8	24	30	26	5	40
Fathead minnow	16	30	25	16	29	25	5	18	27	25	2	33
Flannelmouth sucker	14	25	19	14	23	18	6	16	22	20	0	35
Grass carp	18	24	19	18	24	19	1	18	22	20	0	35
Green sunfish	19	31	22	19	24	23	5	26	31	30	0	35
Gizzard shad	15	27	20	17	27	24	4	16	26	21	5	35
Humpback chub	16	22	18	16	27	19	3	16	22	18	0	35
Little Colorado spinedace	16	20	18	16	20	18	6	16	30	27	3	35
Largemouth bass	16	20	18	16	20	18	6	16	30	27	3	35
Mosquitofish	18	30	22	20	24	22	25	14	28	22	4	43
Plains killifish	20	30	28	20	30	28	21	20	30	25	5	40
Razorback sucker	14	22	18	14	25	19	7	18	24	20	0	30
Rainbow trout	8	13	10	7	15	10	31	12	21	16	0	25
Redside shiner	10	18	15	12	20	18	8	15	22	18	0	24
Red shiner	15	30	23	15	25	24	4	18	28	24	0	40
Roundtail chub	14	22	16	16	22	18	5	18	24	18	0	35
Smallmouth bass	13	18	17	14	18	15	9	20	26	23	0	35
Speckled dace	18	25	20	18	23	20	6	18	22	20	0	35
Sand shiner	16	30	24	18	26	24	4	18	28	24	0	38
Striped bass	14	24	18	16	26	18	3	23	30	24	5	33
Threadfin shad	20	25	21	20	27	20	5	22	35	25	5	37
Blue tilapia	21	28	23	21	28	26	5	25	32	27	8	46
Utah chub	12	20	16	14	20	18	6	16	30	23	0	35
Walleye	6	13	7	6	14	13	7	18	23	21	0	33
Yellow bullhead	19	24	20	21	24	23	7	21	23	22	3	35
Zuni bluehead sucker	10	15	13	10	15	13	6	15	21	20	0	29

[a] All temperatures are in °C. Days are provided as average time for incubation of eggs (Valdez and Speas 2007).

3.2.1.3 Overall Implementation Process for Experiments

As discussed in the preferred action section, an adaptive management approach is being taken to implement all experimental elements of the LTEMP. Prior to the implementation of any experiment, 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 risk of impacts on humpback chub as a result of the implementation of an experimental treatment. Each experiment's specific effects on humpback chub and humpback chub habitat are discussed for each set of experiments below.

3.2.1.4 Effects of Sediment-Related Experiments

Experimental flows under the proposed action include: (1) sediment-triggered spring and fall HFEs through 3.2.1.3 the entire 20-year LTEMP period; (2) 24-hr proactive spring HFEs in high volume years (≥10 maf release volume); and (3) extension of the duration of up to 45,000 cfs fall HFEs for as many as 250 hr depending on sediment availability. These experimental flows have the potential to affect humpback chub indirectly by increasing sandbar area and shoreline habitats; however, the importance of these habitats to humpback chub rearing and recruitment is uncertain. The aquatic invertebrate community may also be impacted by sediment experiments (Cross et al. 2011). Recruitment of rainbow trout in Glen Canyon may be affected by spring HFEs, which may potentially indirectly affect humpback chub by increasing competition with, and predation upon, humpback chub.

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. Sand deposits were redistributed during pre-dam annual floods, creating substrate for riparian vegetation, and sandbars and backwater habitats for native fish (reviewed in Grams et al. 2010). Slow-water habitats that may be important to native fish, including humpback chub that are dependent upon sand bar development, include backwaters and embayments. For example, relatively high densities of humpback chub were found in backwaters in the Little Colorado River inflow reach (Dodrill et al. 2015), and when 10 habitats were sampled in 2015, more larval humpback chub were caught in embayments than in most other habitat types (Kegerries et al. 2015). However, in 2014, catch rates for larval humpback chub did not differ significantly among habitats sampled in western Grand Canyon (Albrecht et al. 2014). It is uncertain how the availability of these habitats influences juvenile humpback chub survival and recruitment to adult life stages.

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 in the summer (Albrecht et al. 2014; Kegerries et al. 2015). However, 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. Beaches and backwaters are not common in the Little Colorado River reach and, although young chub occurred in higher densities in backwaters, their overall abundance in the Little Colorado River reach was higher in talus (Dodrill et al. 2015). Although talus slopes may be important to humpback chub rearing, and are not maintained by sediment deposition expected to occur as a result of HFEs, predation risk to juvenile humpback chub may be higher in talus compared to backwaters under low- and intermediate-turbidity conditions (Dodrill et al. 2016).

Modeling of sediment resources and the impacts of the proposed action focused on areas upstream of RM 87, but literature suggested that the impacts in this area would be indicative of impacts throughout the project area. Sandbars and backwaters cannot be built or maintained without high flows, and sediment-triggered HFEs result in the largest impacts under the proposed action. Substantial improvements in the ability to build and maintain sandbars over the baseline condition are expected for the LTEMP preferred alternative, because no HFEs would occur under the baseline condition after 2020 (existing HFE experimental protocol expires; Reclamation 2011a). The maintenance of backwater, under the proposed action may therefore benefit juvenile humpback chub rearing habitat. However, depending on the frequency and intensity of impacts of TMFs, as described below, and because daily downramp rates will increase under the preferred alternative, the potential for backwater habitats to be dewatered—stranding juvenile humpback chub—remains. In addition, 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).

HFEs have the potential to affect benthic aquatic invertebrates, which comprises the primary food base for humpback chub, but spring and fall HFE effects may differ. Much of what is known related to the effect of HFEs on the aquatic food base was determined through research in Glen Canyon, but some food base studies have been initiated recently in the Little Colorado River inflow reach. Cross et al. (2011) found that a spring HFE resulted in an overall reduction in invertebrate biomass and production, mainly reflected by declines in two nonnative invertebrates (New Zealand mudsnail, *Gammaris* sp.), but an increase in rainbow trout was also observed; this corresponded with an increase in blackflies and midges, which are prey items for fish. The effects of fall HFEs are less certain, but the aquatic invertebrate community appeared to have responded differently to fall HFEs that were implemented in 2012–2014, compared to effects described in Cross et al. (2011).

Under the proposed action, we could 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; however, spring and fall HFEs may differ in their effects, so it is unclear what long-term impacts of annual (i.e., 19.3–21 out of 20 years) HFEs may have on the food base. Under the preferred alternative, up to four of the fall HFEs could be long-duration HFEs (lasting up to 250 hr). These extended-duration HFEs would be of higher magnitude and could increase benthic scouring, compared to short-duration HFEs. Drift from an extended-duration fall HFE may be elevated due to increased biomass of benthic invertebrates that may develop over the summer months The 4 to 5 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 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 considered.

Due to increased turbidity and other factors at the Little Colorado River inflow that differ from those at Glen Canyon, food base dynamics may not be comparable to those observed in Glen Canyon, and it is unclear what impacts HFEs have had upon the food base at the Little Colorado River. In terms of food base impacts upon humpback chub, recent preliminary USGS unpublished data indicate that as invertebrate drift declines (2014–2015), adult humpback chub body condition may also decline. Cross et al. (2013) found that native fish may be limited by food production, because all of the produced midges and blackflies are consumed. However, it is unclear how declining condition may be reflected in adult humpback chub survival, reproduction, and future recruitment of juveniles. It is possible that skipped spawning may be more prevalent in adults when food is limited, for example.

No current published research is available to show what factors may have correlated to the decline in invertebrate drift at the Little Colorado River in 2014 and 2015, compared to 2012–2013, but flow, temperature, and turbidity are likely factors. However, annual variation in drift since 2012 (potentially related to these factors) is likely much less detrimental to the food base for humpback chub than long-term loss of taxa that has likely resulted from hydropeaking or load-following (Kennedy et al. 2016; see base operations above). Despite the apparent impact on adult humpback chub body condition that may be correlated to food availability, humpback chub population dynamics will likely not respond to variations in food availability in a similar manner to the response shown for rainbow trout (see Cross et al. 2011). Humpback chub evolved in a system with limited autochthonous production due to high turbidity in the pre-dam Colorado River, and thus may have relied more heavily on terrestrial invertebrates or other allochthonous food items washed into the river during floods. In addition, other aspects of the species' life history, including high adult longevity, skip spawning, and higher relative fecundity compared to species in more stable environments, may moderate the effects of highly variable environment, including variation in food availability, on long-term population dynamics of the species. Many fish species evolved in variable environments, with a "boom and bust" life history strategy (see periodic life history strategy: Winemiller and Rose 1992). However, the more stable post-dam environment may also favor nonnative species (Olden et al. 2006; see discussion below). Nevertheless, spring and fall HFEs may not be tested in years when there would appear to be unacceptable risks to key resources including the aquatic food base, and the results of experimental flows will be discussed with FWS prior to implementation to minimize indirect effects on humpback chub.

Proactive spring HFEs would occur in high volume years with planned equalization releases (≥10 maf) in order to protect the sand supply from equalization releases. Fall HFEs longer than 96 hr 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 16-mi reach below the dam (Lees Ferry reach). 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 trout is expected to increase by 11%, 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 spring HFEs, TMFs would be experimentally implemented and tested for efficacy as early in the LTEMP period as possible. In addition, if a tiered trigger approach to reversing declines in possible humpback chub recruitment fails, mechanical trout control may be implemented at the Little Colorado River inflow. Although both TMFs and mechanical trout control are considered experimental actions, they are expected to offset risks of trout predation upon juvenile chub at the Little Colorado River. In addition, basin-wide drought and the low Lake Powell levels expected to occur occasionally over the next 20 years would result in warmer dam releases, which also mitigate effects of rainbow trout predation upon juvenile humpback chub (Ward and Morton-Starner 2015).

The impacts of spring and fall HFEs on humpback chub are incorporated into the modeling described in the LTEMP EIS. In general, HFE impacts incorporated into the model are focused on influences of the flow and temperature regime changes upon rainbow trout population dynamics and indirect effects on humpback chub as a result of competition and predation. The output of the model for the preferred alternative represents a range of potential outcomes that may occur over the next 20 years for humpback chub, including a "worst-case scenario" that may be defined as colder/coldest dam discharge and high rainbow trout abundance. However, although humpback chub declines may occur during years with cold temperatures and high trout abundance, TMFs and mechanical control of trout are expected to mitigate these negative impacts; therefore, it is unlikely that actual declines in humpback chub would cause the population to reach the low levels displayed by the model (around 1500 individuals) over the life of the LTEMP.

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 would not 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, likely as a result of spawning and recruitment in 2014, 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, caused an increase in brown trout in recent years. The YOY of fall-spawning brown trout would benefit from increased food availability, similar to rainbow trout (Cross et al. 2011), if the fall HFEs' effects on benthic invertebrates are similar to those of the spring HFE. As discussed above, an increase in blackfly and midge production following fall HFEs has not been observed; therefore, it does not appear that recent fall HFEs have resulted in conditions that facilitated increased brown trout reproduction in Glen Canyon.

Although increases in brown trout recruitment do not appear 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. Based on this assumption, and combined with expected occasional warmwater flow release periods during drought years, an increase in the likelihood of warmwater nonnative fish occurrence is expected below Glen Canyon Dam. Rapid increases in dam discharge from baseflow 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 warm water could facilitate reproduction of these species in the Grand Canyon, potentially near the Little Colorado River inflow. To offset this risk, the conservation measures discussed below were developed. These include the investigation of means to prevent warmwater species' passage through the dam, completion of planning and compliance to make a warmwater slough less hospitable to warmwater nonnative fish, and the development of a rapid response protocol that includes chemical control methods and others not included in the NPS CFMP.

In summary, sediment experiments 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 and triggered mechanical removal of nonnative fish (trout or warmwater nonnative fish) to benefit juvenile humpback chub rearing, the development of a rapid response protocol, and warmwater species' habitat modification. Further, backwaters and embayments created following HFEs may provide warm rearing habitat for juvenile humpback chub, but the benefit may be minimal for the Little Colorado River inflow aggregation. Finally, these sediment treatments will not continue to be tested if they are not effective in achieving their purpose or have unacceptable adverse impacts on the trout fishery, humpback chub population, or other resources.

3.2.1.5 Effects of Trout Management Flow Experiments

TMFs will be implemented when there is predicted high trout recruitment in the Glen Canyon reach, but tests may be implemented when trout are at low densities, early in the LTEMP period. 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 attenuation of stage changes 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 may occur, including stranding of endangered humpback chub and razorback sucker. TMFs are proposed to occur from May through August, in years when the experimental treatment would be tested or implemented, including up to three cycles per month of high steady flows to draw juvenile fish into shallow nearshore waters, followed by rapid drops in discharge to strand fish.

Modeling conducted for the LTEMP EIS evaluated the number of trout recruits in the Glen Canyon reach, and the numbers of trout and humpback chub in the Little Colorado River reach to determine when TMFs would be triggered under the proposed action. It was estimated that triggers for TMFs would be met approximately every 3 years (32% of years).

Although indirect benefits of TMFs for humpback chub at the Little Colorado River are expected under the proposed action as a result of reduced competition and predation by rainbow trout, an unknown number of YOY humpback chub may also suffer fatality as a result of being stranded during TMFs, including those at the Little Colorado River inflow and downstream in the Grand Canyon. Stranding impacts may be difficult to observe, particularly lesser studied, sublethal impacts upon growth (Nagrodski et al. 2012). However, due to the geomorphological features of the Little Colorado inflow reach, fewer shoreline habitats such as backwaters, which are susceptible to fluctuations, are present, and may support only a small portion of juvenile humpback chub in that reach (Dodrill et al. 2015). 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. Small YOY or larval fish, which already have a high mortality rate, could suffer increased mortality as a result of TMFs. 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.

The extent of humpback chub mortality due to stranding and the benefits of reduced trout recruitment in a given year as a result of repeated (every third year) TMFs in Marble and Grand Canyons over the life of the LTEMP are uncertain. These impacts may depend on the quantity of channel margin habitats and their sensitivity to flow changes, the distribution and abundance of humpback chub in sensitive habitats, the timing and number of TMFs, and the degree of attenuation of flows downstream. The beneficial effects of TMFs for humpback chub may depend on the effectiveness of flows in reducing recruitment of YOY trout and emigration to the Little Colorado reach, as well as on the strength of the interaction between humpback chub and rainbow trout, which is mediated by water temperature (see Ward and Morton-Starner 2015). Stranding has not been observed during previous flow experiments, but no studies have been completed, so the degree of stranding is uncertain. The impacts of TMFs throughout GCNP will be monitored to assess effectiveness of the action and the detrimental impacts on native fish and other resources. TMFs will not continue to be tested if there is little or no reduction in trout recruitment after at least three tests, or if there are unacceptable adverse impacts on the humpback chub population or other resources. Consultation with the FWS would be conducted prior to implementation of the experiment. Thus, with “offramps” in place, long-term negative impacts on humpback chub would not be expected.

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

Under the proposed action, mechanical removal of nonnative rainbow and brown trout (and other nonnative predators) would be implemented through a triggered, tiered approach (see Appendix D) 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 are ineffective. This approach was developed by biologists with the FWS, USGS-GCMRC, AZGFD, NPS, and Reclamation, using the best available science and professional judgement. Conservation actions designed to improve rearing and recruitment of juvenile humpback chub would be implemented when adult humpback chub abundance declines to a threshold, or if recruitment of subadult humpback chub does not meet or exceed estimated adult mortality. Conservation actions would include expanded translocations of YOY humpback chub within the Little Colorado River to grow-out areas (i.e., above Chute Falls, Big Canyon), or larval fish would be taken to a rearing facility and released in the mainstem Little Colorado River inflow area once they reach 150–200 mm. If these conservation actions fail to reverse the declining trends and adult abundance dropped below 7000, mechanical removal of nonnative fish would be implemented in the Little Colorado River inflow area to lessen the effects of competition and predation upon humpback chub by nonnative fish.

Based on a humpback chub population model, which is primarily driven by temperature and rainbow trout population dynamics, it is likely that humpback chub populations may fluctuate over the life of the implementation of LTEMP (20 years). If model assumptions are correct, adult humpback chub populations could decline as low as 1800 individuals, coinciding with cold temperatures and high rainbow trout abundance. For example, expected emigration of rainbow trout from Glen Canyon was estimated to be 11% higher than under the current dam operations. This would increase predation upon juvenile humpback chub, potentially leading to reduced recruitment.

Tier 1 conservation actions would involve collecting 300–750 larvae or YOY—age classes that are vulnerable to predation by nonnative fish and that would naturally have relatively high mortality rates (see Pine 2013)—and rearing them to less vulnerable sizes before releasing them. Alternatively, YOY would immediately be translocated for rearing to areas with few predators, such as Big Spring or above Chute Falls. In the past, fish were successfully translocated within the Little Colorado River and to tributaries; the translocated fish in these locations experienced high survival and/or growth rates (Healy et al. 2014a; Spurgeon et al. 2015; Van Haverbeke et al. 2016), and there is a high likelihood for humpback chub to benefit through augmentation of the adult population as a result of Tier 1 actions. Detrimental effects on humpback chub, including fatality, could occur during handling, transport, or tempering; however, these occurrences are generally low, see Section 2.2.

Mechanical removal of nonnative fish would be implemented at the Little Colorado River inflow if declines in adult humpback chub continued, which would help minimize mortality of juvenile humpback chub. Past studies have indicated that trout predation upon humpback chub could be significant (Yard et al. 2011), and humpback chub are particularly vulnerable to predation at cold water temperatures (Ward and Morton-Starner 2015). It is somewhat uncertain whether mechanical removal in the vicinity of the Little Colorado River would be successful in reversing declines in humpback chub, because (a) at high immigration rates into the Little Colorado River reach, mechanical removal may not be successful in reducing trout abundance (Coggins et al. 2011), and (b) other factors beyond trout predation and competition may be negatively impacting humpback chub survival and abundance. Past removal efforts appeared to be effective in controlling rainbow trout, and humpback chub recruitment increased; however, the removal effort coincided with a system-wide decline in trout abundance and warming dam discharge, which confounded results (Coggins et al. 2011). Nevertheless, TMFs designed to reduce Glen Canyon rainbow trout recruitment, and thus emigration downstream, would likely result in low immigration rates of trout to the Little Colorado River reach, thereby increasing the effectiveness of mechanical removal and benefitting humpback chub recruitment. The adaptive management approach taken to adjust trout removal targets and thresholds for action would also help ensure the effectiveness of this strategy in stemming humpback chub declines.

As designed, the tiered, adaptive approach to responding to humpback chub declines described here is expected to offset potentially negative impacts of management actions and experiments under the LTEMP. If conservation actions are ultimately successful in improving rearing success, these tools could be implemented proactively, and could potentially lead to long-term beneficial impacts on humpback chub in the Little Colorado River inflow aggregation.

3.2.1.7 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. Flows may continue to fluctuate 1000 cfs in a day, which would be less fluctuation than under base operations. The goal of the experiment is to achieve warmer river temperatures to benefit humpback chub; however, more stable shoreline habitats may also occur, which could also improve juvenile humpback chub rearing habitat. Lower flows have the potential for more warming via heat transfer from the air compared to higher flows. Low summer flows will be tested when the water temperature has been <12°C for 2 consecutive years, and a target temperature of ≥14°C can only be achieved if flows are dropped with the objective of testing the efficacy of low summer flows on warming and humpback chub growth. Low summer flows will only be tested after the first 10 years, and only under specific, rarely occurring, conditions. This test will not continue if there is no increase in growth and recruitment of humpback chub, if there is an increase in warmwater nonnative species or trout at the Little Colorado River; or if there are unacceptable adverse impacts on the trout fishery, humpback chub population, or other resources.

Under this design (1 to 2 years of testing), the effect of the low flow experiment upon humpback chub growth, rearing, and recruitment will be difficult to determine, because results are likely to be confounded by other factors (variation in annual precipitation, turbidity, etc.). In addition, the tests would be conducted only when humpback chub populations are healthy and stable; this would decrease the test's effectiveness in determining how low flows may improve humpback chub rearing during periods when the population is unhealthy or in decline.

Nevertheless, in addition to benefits associated with warming waters described in previous sections, stable nearshore habitats may benefit rearing, depending on the use of habitats that are sensitive to flow fluctuations (backwaters, embayments, cobble bars, riffles, etc.). The role of backwaters or similar habitats in humpback rearing is discussed in more detail in Section 3.2.1.4. However, reduced fluctuations under the low summer flow experiment would reduce stranding potential for humpback chub, and benefit the food base.

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 experiment (Section 1.2.12). Base operations have been, and will 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 in the Western United States (Kennedy et al. 2016). A diverse source of invertebrates to colonize the Colorado River is found among Grand Canyon's tributaries (Oberlin et al.1999; Whiting et al. 2014), but hydropeaking and an altered temperature and flow regime will continue to negatively impact the food base for humpback chub over the life of the LTEMP. Consistently more stable flows over the summer could result in successful egg-laying and reproduction by sensitive macroinvertebrate taxa (e.g., mayflies), which would also be important prey for humpback chub. However, the experiment may only be implemented 1–3 times in the second year of LTEMP, which would limit the ability of this experiment to benefit humpback chub food base over the long term. Only short-term (within the year of the test) beneficial effects on the food base would be expected.

It is possible that warming as a result of the implementation of low summer flows may increase the risk of warmwater nonnative fish establishment, threatening humpback chub populations. However, these tests are unlikely to increase the risk significantly, because they would occur infrequently (1–3 times out of 20 years), and due to low Lake Powell levels, water temperatures are already within the spawning range of warmwater nonnative species during some part of the year in the lower river (see Kegerries et al. 2015). Basin-wide hydrology that influences the Lake Powell level and dam discharge temperatures would likely overwhelm the effects of dam operations on river temperatures.

Although benefits to humpback chub may be realized as a result of this experiment on habitats and food base, the effect may be of short duration and may be insignificant over the life of the LTEMP (1–3 years out of 20). However, if the experiment has beneficial effects, it may be implemented more frequently beyond the life of the LTEMP period, if additional planning and compliance is completed.

3.2.1.8 Effects of Low Steady Weekend Flows for Macroinvertebrate Production Experiments

Experimental steady flows on weekends, in an attempt to increase invertebrate production and diversity, may benefit nearshore habitats by providing stability and some warming in habitats that are more isolated from the mainstem (low flows would be held steadier plus/minus 1000 cfs fluctuation); however, this would be limited to approximately 34 days over the summer.

This experiment will not be conducted during first 2 years of LTEMP. The goal is to replicate it two to three times to determine its effectiveness.

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 will allow for increased production and possibly diversity of aquatic invertebrates.

In addition to potential benefits of increased aquatic food base production, steady flows on weekends may help to improve the quality of nearshore habitats for juvenile humpback chub. However, it is unclear whether 2 days per week of nearshore habitat stability will result in a measureable impact on juvenile growth, rearing, and recruitment.

Sustained low flows for benthic invertebrate production may benefit humpback chub by providing additional aquatic insect prey. It may also provide stable nearshore habitats for rearing, for 2 days per week. This treatment will be discontinued if there is no observed benefit to the food base, the trout fishery, or native fish; if there is an increase in warmwater nonnative species or trout at the Little Colorado River; or if there is an unacceptable adverse impact on the trout fishery, humpback chub population, or other resources.

3.2.1.9 Effects of Ongoing Conservation Measures

Conservation measures from the 2011 Biological Opinion were evaluated and adapted for the LTEMP, where necessary, and included in the preferred alternative. Some additional conservation measures were developed specifically for the LTEMP and were incorporated into the preferred alternative. The intention of conservation measures is to mitigate or offset potential impacts on ESA-listed species that may result due to the implementation of the LTEMP preferred alternative. These conservation measures were developed in consultation with the FWS and biologists from the NPS. Effects on humpback chub are discussed for each conservation measure below.

Humpback Chub Translocations

Humpback chub translocations were included as conservation measures in the 2008 and 2011 Biological Opinions on the operation of Glen Canyon Dam and on the Nonnative Fish Control and HFE plans, respectively. The preferred alternative includes the continued implementation of humpback chub translocations from the Little Colorado River to other areas in the Little Colorado River or to other tributaries of the Colorado River in the project area in order to (a) improve rearing and growth and provide additional rearing opportunities, or (b) establish additional spawning populations. As discussed in previous sections of this document, translocations have been conducted above Chute Falls in the Little Colorado River, to Shinumo Creek, and to Havasu Creek. Translocations may result in increased growth or improved rearing and survival of juvenile humpback chub.

Translocations of juvenile humpback chub were first conducted in 2003. They involved moving fish from the lower reaches of the Little Colorado River to areas above Chute Falls (Van Haverbeke et al. 2013). These translocations have continued through recent years. Compared to juvenile humpback chub in the lower Little Colorado River, fish above Chute Falls grew much faster.

Prior to 2014, beginning in 2009, approximately 300 juvenile humpback chub per year were translocated to Shinumo Creek. Estimated growth and survival of translocated humpback chub generally was consistent with, or exceeded, growth and survival estimates of juvenile humpback chub in the Little Colorado River and Colorado River, although emigration rates exceeded 50% (Spurgeon et al. 2015; Healy et al. 2014b). In May of 2014, an NPS-managed fire started by lightning, burned approximately 10% of the Shinumo Creek watershed. Flooding and ash appeared to have extirpated the remaining humpback chub from Shinumo Creek in July and August 2014.

Havasu Creek translocations were initiated in June 2011 and have continued annually through May 2016. Approximately 300 fish were released in Havasu Creek annually. Biannual monitoring of translocated fish indicated that survival and growth objectives were met. In addition, evidence of reproduction, including ripe adult fish and untagged juveniles (age-1+), was observed annually beginning in 2013. Data collected from the May 2016 monitoring trip indicated that multiple year classes of untagged (non-translocated) humpback chub were observed (Nelson et al. 2016).

Through 2016, translocations to Havasu Creek have been limited to the lower 3.5 mi—from the Havasupai Reservation/NPS boundary to the confluence with the Colorado River—on NPS lands. A new effort will be pursued during the LTEMP to conduct initial fish surveys and complete a feasibility study to translocate humpback chub to Havasupai Reservation lands above Beaver Falls. Although the activities are subject to permission and support from the Havasupai Tribe, if habitat is suitable, translocations to this area could lead to an expanded spawning population at Havasu Creek. Larger populations would be more likely to persist in tributaries (Pine 2013).

Genetics management principles outlined in FWS guidance documents (FWS Genetics Management Plan 2010; Van Haverbeke et al. 2016) and the NPS CFMP (NPS 2013) would be followed to maintain genetic diversity and minimize detrimental genetic effects on translocated populations. For example, genetic monitoring would be conducted in tributary spawning populations established through translocations, and new migrants would be introduced occasionally (NPS 2013). As a result, no loss of genetic diversity is expected.

As part of the ongoing humpback chub translocation effort, Reclamation has committed to funding nonnative fish control in tributaries, where necessary, to maximize survival of translocated humpback chub. Control methods would vary depending on the tributary and the existing nonnative fish species. Complete eradication of a nonnative species would likely provide the most beneficial impact on humpback chub translocated to the tributary; however, no specific plans for chemical piscicides have been identified, and piscicide use would require additional planning and compliance activities.

No detrimental population-scale impacts are expected as a result of translocations. In general, as demonstrated by previous or ongoing translocations, successful rearing and potential additional spawning populations can be developed or augmented through translocation of juvenile humpback chub, thereby benefitting the population. In addition to the continuation of the Chute Falls translocations under the preferred alternative, Havasu, Shinumo, and Bright Angel (pending successful trout control) creeks would continue to be the focus of translocations efforts outside the Little Colorado River. Although translocations can result in mortality of individual juveniles during collection from the Little Colorado River, transport to rearing facilities, disease treatment, or tempering and release (thus far, Chute Falls only), no detrimental population-level impacts on the adult population in the Little Colorado River has been observed. In addition, based on population viability modeling (Pine 2013), collection methods have been further refined to mitigate this risk by targeting life stages (e.g., larval) that would have a high mortality rate in the wild.

Humpback Chub Refuge

A refuge population of humpback chub was established at the FWS SNARRC facility in Dexter, New Mexico. The goal of the refuge is to maintain a genetically diverse population of 1000 humpback chub to be used for propagation in the case of a catastrophic loss of the Grand Canyon population. Impacts would be similar to those described for translocations, in that a small number of larval chub may be lost during collection, transport, and disease treatment; however, no detrimental impacts on the population would be expected.

Mainstem Humpback Chub Aggregations

Conserving mainstem humpback chub aggregations was a focus of past conservation measures related to dam operations. In the LTMEP, Reclamation will continue to assist the FWS, NPS, and GCDAMP to ensure that a stable or upward trend of humpback chub mainstem aggregations can be achieved. Actions include continued monitoring of the Little Colorado River humpback chub aggregation using the juvenile chub monitoring protocol developed following the natal origins project (see Pine et al. 2011); monitoring the mainstem aggregations annually; developing a methodology for locating additional aggregations and individual humpback chub; evaluating “drivers” of recruitment, potential spawning, and natal origins; and exploring a means of expanding humpback chub populations outside the Little Colorado River inflow aggregation.

Mainstem monitoring is critical to understanding how base operations and other experiments under the LTEMP impact humpback chub. Understanding more about the ecology and population dynamics of mainstem aggregations outside the Little Colorado River, including the impacts of dam operations, may lead to improved management and conservation of those aggregations.

The impacts on individual humpback chub that may occur as a result of monitoring are covered below in Section 2.2. Monitoring under this action would be designed to assess trends in humpback chub in the mainstem Colorado River, and to assess impacts of experimental and management actions on humpback chub. Results of monitoring may allow managers to adapt actions to ensure that projects goals for humpback chub are met.

Disease and Parasite Monitoring

Reclamation intends to fund the GCDAMP to conduct disease and parasite monitoring in humpback chub and other fish in the mainstem Colorado River, in addition to ongoing disease and parasite monitoring conducted by USGS/GCMRC in the Little Colorado River.

It is unclear how this monitoring will be accomplished or how it may benefit humpback chub over the long term; however, understanding the impacts of parasites may inform future conservation actions.

Razorback Sucker Conservation Measures

Studies designed to help understand the status of the razorback sucker population in the Grand Canyon and Lake Mead would continue with the implementation of the preferred alternative. Although the focus of these studies is on razorback sucker, seining for larval and small-bodied YOY and juvenile fish may lead to an increased understanding of juvenile and larval humpback chub habitat use and spawning areas (at a course scale) in the Grand Canyon.

Fatality of individual larval humpback chub would occur as a result of this sampling regime; however, high larval mortality rates are likely in the wild, and thus, this effort would not be expected to impact the adult population. In the first 2 years of the larval and small-bodied fish study conducted from Lava Falls (RM 180) to Pearce Ferry above Lake Mead (RM 280), indicated that reproduction may be occurring (larval humpback chub with yolk sac attached).

No population-scale impacts on humpback chub would be expected, and the study may provide important information for conservation of the species in the western Grand Canyon.

Nonnative Species Conservation Measures

Nonnative fish will continue to threaten humpback chub in the Grand Canyon under the LTEMP preferred alternative. Under the continued colder temperature regimes and clear water that result from dam construction and operations, particularly in Glen and Marble Canyons, nonnative cool-/coldwater species are expected to proliferate and continue to prey upon and compete with humpback chub. Brown trout are a particular threat due to their piscivorous nature

(Yard et al. 2011; Whiting et al. 2014). However, with continued basin-wide drought, and lower Lake Powell levels, warmer water releases from Glen Canyon dam are expected occasionally. For example, in late fall 2015 (November) water released from Glen Canyon dam approached 15°C, which is within the range of suitable temperatures for smallmouth bass spawning. In addition, temperatures in western/lower Grand Canyon reached or exceeded 20°C in 2015. Warmer temperatures may allow for highly piscivorous warmwater nonnative species such as smallmouth bass to proliferate in the project area. Smallmouth bass were identified as a major threat to native fish in the Yampa River, and have caused major declines and extirpation of humpback chub there (Johnson et al. 2008).

Conservation measures that were developed to specifically address nonnative species threats to humpback chub include (a) continued nonnative trout (brown and rainbow) removal efforts at Bright Angel Creek and its inflow, or other areas where expanded populations have been found; (b) feasibility study, and planning, and compliance for chemical piscicide renovation at Bright Angel and Shinumo creeks; (c) study of efficacy of a temperature control device on the dam to address future conditions under climate change; (d) potential research and development of a means to prevent passage of warmwater nonnative fish through Glen Canyon Dam; (e) planning, compliance, and implementation of a plan to address (make less suitable) the suitability of warmwater nonnative fish habitat in a slough below Glen Canyon dam; and (f) completion of a plan for rapid response to nonnative fish invasions, using tools not approved in the NPS CFMP (e.g., chemicals). Finally, the use of flows (e.g., TMFs) to inhibit brown trout spawning and recruitment in Glen Canyon, or other mainstem locations, will be explored over the life of the LTEMP. This measure is necessary to prevent recently detected spawning of brown trout in Glen Canyon from further expanding or increasing in abundance.

Control of brown and rainbow trout in Bright Angel Creek and the Bright Angel Creek inflow reach of the Colorado River would be continued under the proposed action. In 2017, results of control efforts implemented between 2012 and 2017, including trends in abundance of both native and nonnative fish, would be reviewed, and methodology for continued control efforts may be adapted to ensure trout control objectives are met. Brown trout catch-per-unit effort in the Colorado River outside of Bright Angel Creek appears to have declined in recent years (Stewart 2016), concurrent with trout control activities, and declines of brown trout abundance and biomass in Bright Angel Creek (Nelson 2016). Brown trout are defined as high-risk nonnative predators (NPS 2013), and continued control in and around Bright Angel Creek—and in other areas where they expand—would minimize a major threat to humpback chub by reducing predation risk. Long-term beneficial impacts for humpback chub would be expected as a result of continued control of brown trout and reduced predation risk.

The other nonnative fish conservation measures could all lead to beneficial impacts on humpback chub as a result of reduced the risk of invasion and establishment of warmwater nonnative species. The outcome will depend on the effectiveness of the actions, including whether feasible options are developed to manage slough habitat and prevent the passage of warmwater nonnative fish through the dam; no technology currently exists for this.

3.2.1.10 Effects of New Conservation Measures

New conservation measures for humpback chub will explore additional tributaries for potential translocations including consulting with the Havasupai Tribe for potential translocations above Beaver Falls in Havasu Creek. Razorback sucker measures will include continued monitoring of larval and small-bodied fish; these measures will determine the extent of hybridization of flannelmouth and razorback sucker larvae from the western Grand Canyon through genetic analysis. Additional measures to address nonnative fish include evaluation of new technologies for temperature-controlled releases from the dam and methods to prevent fish passage through the dam. Reclamation will support planning and compliance for the development and implementation of a rapid response control effort for new and established nonnative invasive species. This includes modifying the backwater slough at RM 12 to prevent establishment of warmwater invasive species. Reclamation will also explore the use of flow such as TMFs to inhibit brown trout spawning and recruitment in mainstem locations.

3.2.1.11 Effects of Native and Nonnative Plant Management Experimental Actions

Under the proposed action, exotic plant species that are spread or favored by dam operations would be mechanically removed, and potentially treated with herbicides, in selected areas within the project area.

Herbicides may be poisonous to fish and aquatic species; however, standard practices for herbicide application would be followed. This would minimize any risk of impacts on humpback chub or their habitat as a result of contact with the chemicals.

3.2.1.12 Effects of Activities to Preserve and Protect Historic Properties and Cultural Sites

Under the preferred alternative, various mitigation and erosion control measures would be implanted at cultural sites along the river corridor. Sites that would be treated would generally be located above the Colorado River high water mark and outside of humpback chub habitat. Thus, these activities would be expected to have no impacts on humpback chub individuals or habitat.

3.2.1.13 Effects of Climate Change

Climate change and drought have direct influences on hydrologic patterns and water temperature, thus impacting humpback chub. In the Colorado River Basin, hydrologic impacts include lower precipitation and decreased inflow to the reservoir system, resulting in more frequent lower reservoir release volumes, which could potentially impact shoreline habitats and riparian areas. More frequent droughts and warmer atmospheric temperatures have the potential to result in warmer water being released from the dam. Although this may improve thermal suitability for humpback chub, any subsequent benefits may be offset by increased abundance and expansion of warmwater nonnative fish and aquatic fish parasites (see Section 3.6). Uncontrolled warmer water releases may occur as a result of the elevation and subsequent water temperature of withdrawals from Lake Powell. Increased temperatures may allow numbers and species of warmwater nonnative species to increase in the system.

Springs that supply the Little Colorado River within critical habitat may be vulnerable to basin-wide drought and climate change impacting overall habitat availability and the largest self-sustaining population for the species.

3.3 EFFECTS OF THE PROPOSED ACTION ON RAZORBACK SUCKER

The evaluation of potential impacts of the proposed action on razorback sucker included consideration of the results of previous investigations of the species' ecology (Albrecht et al. 2014; Kegerries et al. 2015), as well as studies of the effects of nonnative fish (Coggins et al. 2011; Yard et al. 2011; Whiting et al. 2014), experimental flows (such as HFEs and other flows) and water temperature on native fish and native fish habitat (e.g., Grams et al. 2010; Makinster et al. 2011; Trammell et al. 2002; Ward 2011; Ward and Morton-Starner 2015).

Several aspects of the proposed action may affect razorback sucker directly or indirectly through direct impacts on individuals or habitat; or indirectly by influencing the abundance and distribution of nonnative predators and competitors, or by influencing macroinvertebrate production. Dam operations have the potential to influence river temperatures, the quantity and quality of nearshore rearing habitats (e.g., backwaters), aquatic insects that are food for razorback sucker, and nonnative species abundance; operations may also result in direct mortality to larval or juvenile razorback sucker through stranding. Flow-related actions are analyzed below that may impact razorback sucker; these include base operations, sediment-related experiments, and aquatic resource experiments including trout management flows, low summer flows, and sustained low flows for benthic invertebrate production. Because identified impacts of operational flexibility under current dam operations have been identified for native fish, no effects are expected that are not considered for other dam operations. Other non-flow actions, which may impact razorback sucker directly or indirectly and are analyzed below, include mechanical removal of nonnative fish, conservation measures, and continued fisheries research and monitoring under the GCDAMP. Some actions may have negative impacts on individuals, but beneficial effects at a population level.

Efforts to manage riparian vegetation, humpback chub translocations, and sediment monitoring and research are not expected to have impacts on razorback sucker individuals or habitat. Riparian vegetation management would occur in only small, localized areas within the project area. Although riparian vegetation can play an important role in small stream ecosystems, particularly in providing cover, shade, or habitat for terrestrial invertebrates for fish to feed upon, riparian vegetation is less important in larger rivers for providing cover, shade, or energy inputs (Vannote and Sweeney 1980). Thus, riparian vegetation management would have large impacts on the razorback sucker and the species' habitat in the Colorado River.

3.3.1 Direct and Indirect Effects

3.3.1.1 Effects of Base Operations

Base dam operations are expected to change with the implementation of the proposed action. Changes will include more consistency across months, and thus more stability throughout the year, in monthly dam release volumes. The daily fluctuation in discharge would be proportional to the volume (i.e., lower fluctuations during lower flows), with a maximum discharge fluctuation range of 8,000 cfs; this would be the same as the current maximum fluctuation range. The daily downramp rate would be increased, compared to the current condition, by 67% (from 1,500 cfs/hr to 2,500 cfs/hr). Under base operations, year-round, fluctuating flows throughout the life of the LTEMP period may have detrimental, long-term direct impacts on juvenile razorback sucker and rearing habitat, razorback back sucker spawning habitat, and aquatic invertebrate prey (food base).

Stranding of fish is a potential outcome of daily hydropeaking (reviewed in Bunn and Arthington 2002; Nagrodski et al. 2012). Increasing downramp rates under the preferred alternative may increase the risk of stranding larval razorback sucker. Thus far, juvenile (older than larval) life stages of razorback sucker have not been sampled in 2 years of study in the 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, or if larvae drift to Lake Mead and rear in the lake. Thus, effects are mainly discussed for larval age classes. Stranding 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 razorback sucker present. Factors that may influence the probability of stranding fish in a river with altered flow regimes, such as below hydroelectric plants, include the rate of flow reduction, water temperature, channel geomorphology, and substrate composition, as well as biotic factors including fish life stage and size (reviewed in Nagrodski et al. 2012). Larval razorback sucker have limited swimming ability, and thus are at risk of stranding. Increasing drawdown rates under the preferred alternative will increase the risk of fatality. Larval sampling in the lower Grand Canyon found razorback sucker larvae to be distributed throughout most shoreline habitats from Lava Falls to Pearce Ferry 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, a summary of stranding literature indicated that fish stranding as a result of hydroelectric and irrigation projects is well documented (Nagrodski et al. 2012).

Razorback sucker 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, they are susceptible to flow fluctuations. Continued daily flow fluctuations combined with increased downramp rates will 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 at less risk.

Under base operations, through the life of the implementation of the LTEMP preferred alternative, 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 cold or coolwater nonnative fish (e.g., brown and rainbow trout); this is consistent with past surveys that have found more warmwater fish species in those areas than upstream.

Habitat requirements for the endangered razorback sucker, explained in detail in Section 2.1.3, are summarized here. Suitable water temperatures for spawning, egg incubation, and growth range from 14 to 25°C (FWS 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 (FWS 2002b). 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 (FWS 2002b). Razorback sucker are distributed within the project area, from the Colorado River inflow of Lake Mead and at least upstream as far as an area above Lava Falls in Grand Canyon. The upstream distribution of adult razorback sucker is unknown. During May of 2014, razorback sucker larvae were found in the Colorado River as far upstream as RM 173 (upstream of Lava Falls), which is the farthest upstream razorback sucker spawning has been documented in the Grand Canyon (Albrecht et al. 2014). Warm temperatures may be even more critical for larval razorback suckers than other native suckers to transform into juveniles (see Bestgen 2008). Therefore, continued cold temperatures under base operations during the LTEMP implementation period will continue to negatively impact razorback sucker over the long term. However, experimental stable flows may provide some benefit to offset these impacts (see the following sections).

As described for humpback chub, under base operations and fluctuating flows the food base will continue to be degraded throughout the life of the LTEMP.

In summary, under base operations and coldwater conditions, continued hydropeaking flows with increased downramp rates compared to the existing conditions will continue to degrade nearshore rearing habitats, prevent the establishment of aquatic invertebrates (food base), and increase the risk of stranding larval or juvenile razorback sucker in the long term (throughout the life of the LTEMP). In addition, daily fluctuating flows will degrade razorback sucker spawning habitat, river-wide, throughout the life of the plan.

3.3.1.2 Effects of Sediment-Related Experiments and Low Summer Flows

Base flow fluctuations may impact rearing habitat for larval or juvenile razorback sucker. Juvenile 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 have been a major focus of several investigations. For example, during and after the 2008 HFE physical scientists described the number and area of backwaters that were created during this flood disturbance, and documented how normal operations under MLFF eroded these features to pre-HFE levels within 6 months (Grams et al. 2010). 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. 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 distributed from RM 115 to 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), potentially affecting rearing habitat for larval or juvenile razorback sucker.

Although very few studies in the Grand Canyon have specifically investigated razorback sucker habitat, biologists have demonstrated that densities of juvenile native fishes were greatest in backwater habitats compared to other habitats (Dodrill et al. 2015). However, in the Little Colorado River confluence reach where these investigations occurred, backwaters represent a small percentage of available nearshore habitat. Therefore, investigators concluded that maintenance of backwater habitats was not critical to the persistence of the Little Colorado River confluence aggregation of humpback chub. Nonetheless, no studies have evaluated habitat use by larval or juvenile native fishes in downstream reaches where backwaters are larger and more persistent than in the Little Colorado River confluence aggregation (Grams et al. 2010). Few studies have investigated the use of backwaters or other shoreline habitats that may be important to native fish rearing in the western Grand Canyon, where water temperatures are not ideal, but are more suitable for native fish rearing than closer to Glen Canyon Dam. However, shoreline habitats have the potential to provide warmer rearing habitat than the mainstem under certain conditions (Grams et al. 2010; Trammell et al. 2002). It is likely that prolonging the “turnover” of water in nearshore and backwater habitats with steady flows resulted in warmer temperatures than in the mainstem (Behn et al. 2010). Given the need for warm, productive floodplain or backwater habitats for rearing larval and juvenile native fishes, and the lack or low abundance of nonnative fish found in recent backwater sampling (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. Thus, 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. However, the implementation of the experiment may occur only under rare conditions. Benefits to razorback sucker would be minimal if the experiment was implemented only once or a few times in the LTEMP period.

Due to the impact that HFEs and low summer flows have on the creation and maintenance of backwater habitats important to larval or juvenile razorback sucker, these experiments would be expected to benefit razorback sucker in a similar manner to humpback chub. Low summer flows could potentially create or maintain warm backwater habitat beneficial to razorback sucker rearing. Spring HFEs may also create backwater habitat during a time period that may coincide with spawning and emergence of larval fish.

3.3.1.3 Effects of Low Steady Weekend Flows for Macroinvertebrate Production Experiments

Experimental low steady flows on weekends to attempt to increase macroinvertebrate production and diversity may benefit nearshore habitats by providing stability and some warming in habitats that are more isolated from the mainstem (low flows would be held steadier plus/minus 1,000 cfs fluctuation); however, this would be limited to approximately 34 days over the summer. This experiment will not be conducted during first 2 years of LTEMP. The goal is to replicate it two to three times to determine its effectiveness.

The scientific background for this experimental action is discussed in Section 1.2.12 (and see Kennedy et al. 2016). In addition to potential benefits of increased aquatic food base production, steady flows on weekends may help improve the quality of nearshore habitats for larval or juvenile razorback sucker. However, it is unclear whether 2 days per week of nearshore habitat stability will result in a measureable impact on juvenile growth, rearing, and recruitment. Nevertheless, it does not currently appear that razorback sucker are successfully recruiting from the larval to juvenile life stages, possibly due to cold temperatures and lack of stable rearing habitats. Because larval razorback sucker need stable, low-velocity, warm, productive habitats for rearing, a beneficial effect is expected under this experiment, combined with HFEs to build bars and backwaters.

Sustained low flows for benthic invertebrate production may benefit razorback sucker by providing additional aquatic insect prey and stable nearshore habitats for rearing 2 days per week. This treatment will be discontinued if there is no observed benefit to the food base, trout fishery, or native fish; if there is an increase in warmwater nonnative species or trout at the Little Colorado River; or if there are unacceptable adverse impacts on the trout fishery, humpback chub population, or other resources.

3.3.1.4 Effects of Trout Management Flow Experiments

The potential for TMFs to strand and cause mortality in razorback sucker would increase under the proposed action. The extent of mortality due to stranding of razorback sucker in a given year in Marble and Grand Canyons as a result of TMFs is unknown; it may depend on the quantity of channel margin habitats and their sensitivity to flow changes, the distribution and abundance of juvenile fish in sensitive habitats, the timing and number of TMFs, and the degree of flow attenuation downstream. TMFs could be implemented from May through August, which would overlap with the presence of larval razorback sucker. Given that razorback sucker spawning was documented for the first time in in the study area in 2014 (and continued in 2015; Kegerries et al. 2015) and studies are ongoing, potential impacts on the species are particularly difficult to predict. Larval or juvenile razorback sucker may be particularly sensitive to the drastic and rapid fluctuations associated with TMFs, because those life stages may be more reliant than other native species on low-velocity backwater habitats. For example, 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).

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 (reviewed in FWS 2002b), and 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 important for spawning and egg incubation may be sensitive to flow variation under the proposed action. 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 will have negative, wide-ranging impacts on razorback sucker juveniles or larvae that would continue to occur for the duration of the action. Similarly to humpback chub, risk to 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 trout management flows throughout GCNP would be implemented to assess the effectiveness of the action, as well as the detrimental impacts on native fish and other resources.

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

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) 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.

Razorback sucker have not been sampled near the Little Colorado River inflow since the 1980s or early 1990s. Although removal of nonnative fish would benefit razorback sucker, this action would likely have limited beneficial impacts on the razorback sucker. Warmer and more turbid waters characterize the lower Grand Canyon where evidence of razorback sucker spawning has been found. These areas are less suitable to trout, so removal of nonnative trout near the Little Colorado River would likely have negligible impacts on razorback sucker.

Similar, Tier 1 conservation actions developed to conserve humpback chub, including actions to enhance rearing and translocations, would have no impact on razorback sucker because actions would occur within the Little Colorado River and its inflow, and no negative impacts of humpback chub upon razorback sucker have been noted.

3.3.1.6 Effects of Conservation Measures

Conservation measures from the 2011 Biological Opinion were evaluated and adapted for the LTEMP, where necessary, and included in the preferred alternative. Some additional conservation measures were developed specifically for the LTEMP, and were incorporated into the preferred alternative. The intention of conservation measures is to mitigate or offset potential impacts on ESA-listed species that may result with the implementation of the LTEMP preferred alternative. These measures were developed in consultation with the FWS and biologists with the NPS. Effects on razorback sucker are discussed for each conservation measure below.

Humpback Chub Translocations, Disease, and Parasite Monitoring (in humpback chub), Humpback Chub Refuge, Mainstem Humpback Chub Aggregations

Humpback chub translocations may result in increased growth or improved rearing and survival of juvenile humpback chub, but would likely have minimal impacts on the razorback sucker. Although adult humpback chub may prey upon larval or juvenile native fish, it is unlikely that a population-level impact would be expected on suckers, including the razorback sucker. For example, as the translocated humpback chub population has grown in Havasu Creek, bluehead sucker have continued to recruit and possibly increase in number (Nelson et al. 2016).

Reclamation intends to fund the GCDAMP to conduct disease and parasite monitoring in humpback chub and other fish in the mainstem Colorado River, in addition to ongoing disease and parasite monitoring conducted by USGS/GCMRC in the Little Colorado River. No impacts on razorback sucker would be expected because no razorback sucker would be targeted for parasite monitoring.

A refuge population of humpback chub was established at the FWS SNARRC facility in Dexter, New Mexico. The goal of the refuge is to maintain a genetically diverse population of 1000 humpback chub to be used for propagation in the case of a catastrophic loss of the Grand Canyon population. As for disease and parasite monitoring, no effects on razorback sucker are expected because they would not be targeted for refuge development.

Conserving mainstem humpback chub aggregations was a focus of past conservation measures related to dam operations. In the LTMEP, Reclamation will continue to assist the FWS, NPS, and GDAMP to ensure that a stable or upward trend of humpback chub mainstem aggregations can be achieved. The impacts on individual razorback sucker that may occur as a result of monitoring are covered in Section 2.2.

Razorback Sucker Conservation Measures

Studies designed to understand the status of the razorback sucker population in the Grand Canyon and Lake Mead would continue with the implementation of the preferred alternative. Actions 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 trout management flows and other dam operations on the species.

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 will be critical to understanding population-level impacts on the species due to dam operations and experimental actions under the preferred alternative. 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.

Nonnative Species Conservation Measures

Nonnative fish will continue to threaten razorback sucker in the Grand Canyon under the LTEMP preferred alternative. As a result of continued colder temperature regimes and clear water from of dam construction and operations, particularly in Glen and Marble Canyons, nonnative cool-/coldwater species are expected to proliferate and continue to prey upon and compete with native fish. However, razorback sucker may be more at risk from warmwater nonnative fish that may become established because they have been primarily found in the lower river. Warmer temperatures, which have been occurring in the lower river recently, may allow for highly piscivorous warmwater nonnative species such as smallmouth bass to proliferate. Smallmouth bass were identified as a major threat to native fish in the Yampa River, and have caused major declines in native fish (Johnson et al. 2008).

Conservation measures that were developed to specifically address nonnative species threats to humpback chub and, secondarily, to benefit razorback sucker, include (a) continued nonnative trout (brown and rainbow) removal efforts at Bright Angel Creek and its inflow, or other areas where expanded populations have been found; (b) feasibility study, and planning and compliance for chemical piscicide renovation at Bright Angel and Shinumo creeks; (c) study of efficacy of a temperature control device on the dam to address future conditions under climate change; (d) potential research and development of a means to prevent passage of warmwater nonnative fish through Glen Canyon Dam; (e) planning, compliance, and implementation of a plan to address (make less suitable) the suitability of warmwater nonnative fish habitat in a slough below Glen Canyon dam; and (f) completion of a plan for rapid response to nonnative fish invasions, using tools not approved in the NPS CFMP (e.g., chemicals). Finally, the use of flows (e.g., TMFs) to inhibit brown trout spawning and recruitment in Glen Canyon or other mainstem locations will be explored over the life of the LTEMP. This measure is necessary to prevent recently detected spawning of brown trout in Glen Canyon from further expanding or increasing in abundance.

Among nonnatives present in the project area, rainbow trout recruitment and abundance would be the species most influenced by changes in dam operations. In the context of impacts on the razorback sucker, interactions between rainbow trout would be expected to be less frequent, because habitat for rainbow trout is less suitable where razorback sucker were found recently (Lava Falls to Lake Mead). Nevertheless, critical habitat for razorback sucker extends into Marble Canyon and the Paria River, where rainbow trout are abundant, and where razorback sucker were detected in the 1990s. As described above, trout emigration through Marble Canyon to the Little Colorado River reach may be higher under the proposed alternative. The magnitude of the impacts of rainbow trout on razorback sucker may depend on the extent of the current distribution of razorback sucker in upstream areas of the project area (currently relatively unknown, and habitat is less suitable), the effects of TMFs on trout recruitment, and the effectiveness of triggered mechanical removal in the vicinity of the Little Colorado River. However, TMFs may have a greater negative impact on larval or juvenile razorback sucker that prefer still, warmer, nearshore habitats in areas near Lava Falls and downstream, compared to the potential benefits of reducing rainbow trout through TMFs.

As discussed above for impacts on humpback chub, it is unclear what factors (e.g., potential flow regime changes) have influenced populations of brown trout within the project area and their expansion to Glen Canyon. Brown trout have the potential to impact razorback sucker more than rainbow trout; however, the species is primarily found near Bright Angel Creek, near Tapeats Creek, and recently expanding in Glen Canyon. The continuation of brown trout control efforts, as described under the NPS CFMP, would likely maintain low levels of brown trout near areas where their distribution overlaps with razorback sucker. In addition, because brown trout tend to be far-ranging, it is possible the reductions of brown trout at their source (Bright Angel Creek) could benefit razorback sucker in other areas of the canyon by reducing predation risk slightly. The mainstem area near Tapeats Creek is less suitable for trout due to increased turbidity, and it is unlikely that flow regime changes under the proposed action would influence brown trout in that area.

Warmwater nonnative fish are a primary threat to razorback sucker, range-wide (FWS 2002b). Since the 1990s, a shift in species composition from nonnative to native species for unknown reasons has been noted below Diamond Creek (reviewed in Kegerries et al. 2015). Nevertheless, modeled temperature suitability for warmwater nonnative species in the lower river (RM 157 or 225), where razorback sucker may be spawning, would be expected to change little compared to the baseline condition. Regardless, a response to new or expanded populations of warmwater nonnative fish may become necessary in the lower river in the future. The rapid response plan may allow for additional tools to suppress or remove warmwater nonnative fish, reducing negative impacts due to predation upon razorback sucker.

In summary, the nonnative fish conservation measures could all lead to beneficial impacts on razorback sucker by reducing the risk of invasion and establishment of warmwater nonnative species, or allowing for control of new invasions. The outcome will depend on the effectiveness of the actions, including whether feasible options are developed for management of slough habitat, and prevention of passage of warmwater nonnative fish through the dam, for which no technology currently exists.

3.3.1.7 Effects of Climate Change

More frequent droughts and warmer atmospheric temperatures as a result of climate change and warmer water being released from the dam are likely to impact razorback suckers in the Grand Canyon. Razorback suckers are currently located in the lower reaches of the canyon where backwater habitat is more available. Warmer water temperatures may create more suitable habitat for larvae and juveniles. However, these effects may be offset by increased abundance and expansion of nonnative fish and aquatic fish parasites. In addition, lower reservoir releases may result in fewer backwater habitats available for spawning and rearing of razorback sucker.

3.4 EFFECTS OF THE PROPOSED ACTION ON SOUTHWESTERN WILLOW FLYCATCHER

The southwestern willow flycatcher nests and forages in habitats ranging from dense, multi-storied riparian vegetation (such as cottonwood/willow stands with a mix of trees and shrubs) to dense tamarisk stands with little layering of vegetation. However, changes in the availability of suitable habitat may not necessarily translate into changes in the southwestern willow flycatcher populations. Despite the abundance of woody riparian vegetation (e.g., tamarisk) since construction of the Glen Canyon Dam, numbers of nesting southwestern willow flycatchers in the Grand Canyon have declined since the 1980s and no nests have been confirmed in the Grand Canyon since 2007 (Stroud-Settles et al. 2013). Consequently, the effect of the proposed action will have no effect on willow flycatchers because they do not occur in the Grand Canyon; however, the proposed action may have effects on habitat the flycatchers could potentially occupy.

The proposed action features several types of HFEs: (a) proactive spring HFEs, (b) sediment-triggered spring HFEs, and (c) sediment-triggered fall HFEs. Proactive spring HFEs in April, May, or June coincide with the nesting period of the southwestern willow flycatcher. However, these flows are only anticipated to occur approximately two times (10%) during the 20-year life of the LTEMP. These HFEs could coincide with the southwestern willow flycatcher nesting period (May and June). However, southwestern willow flycatcher nests in the Grand Canyon have typically been located above the elevation of 45,000 cfs (Gloss et al. 2005), the maximum HFE flow. The action proposes approximately <5 years (<25%) of spring HFEs triggered by sediment loading. However, these HFEs occur in March or April, prior to nest initiation for the southwestern willow flycatcher and would have no direct impact on the species. Both types of HFEs that occur in the fall (sediment triggered and extended duration) occur long after nesting and fledging dates of the southwestern willow flycatcher and would have no direct impact on the species.

This action is not expected to result in important structural changes in riparian habitat or vegetation productivity that could affect the southwestern willow flycatcher. In addition, invertebrates with only terrestrial life stages are not expected to be affected. The action should result in no impacts on the southwestern willow flycatcher's ability to forage effectively and sustain a nest.

Low summer flows, if tested, would occur for 3 months (July, August, and September). This test could overlap with the nesting period (May to August) during the months of July and August. Low summer flows have monthly average low flows of 10,000 cfs or more during the nesting period, which could sustain some inundated riparian nesting habitat, depending on the topography. Low summer flow experiments under this alternative are not expected to have long-term effects on nesting habitat.

The effects of climate change and continued dry basin hydrology may further diminish habitat for the flycatcher, due primarily to lower water levels within riparian areas.

3.5 EFFECTS OF THE PROPOSED ACTION ON YUMA RIDGWAY'S RAIL

Yuma Ridgway's rail nests can be found on small raised mud hummocks, or in the crotches of small shrubs, just above water in dense cattail and tamarisk habitat (Abbott 1940). The Grand Canyon has very little true cattail/marsh habitat, but it does contain considerable stands of dense tamarisk, both near and in the water. However, most potential habitat in the lowest portion of the Grand Canyon where Yuma Ridgway's rails have been detected is now 10 feet or more above the flowing river level; this is a result of Lake Mead water levels dropping in recent years.

Although they are only anticipated to occur approximately two times (10%) during the 20-year life of the plan, this alternative features proactive spring HFEs in April, May, or June that coincide with the nesting period of the Yuma Ridgway's rail. This alternative also proposes approximately <5 years (<25%) of spring HFEs triggered by sediment loading. There is a possibility that these HFEs, when they coincide with the Yuma Ridgway's rail nesting period (April and May), could impact nests and suitable habitat if they are along the river edge. However, it is unlikely that the nests or habitat would be close enough to the river to be impacted by HFEs because HFEs have minimal stage change in this broad floodplain habitat for the rail. Both types of HFEs that occur in the fall (sediment triggered and extended duration) occur long after nesting and fledging dates of the Yuma Ridgway's rail and would have no direct impact on the species. Low summer flows would occur under this alternative. Lower flows during the May to August nesting and fledging period could impact Yuma Ridgway's rail habitat by decreasing the density of vegetation in the marsh habitat within the rail's preferred nesting and predator avoidance areas. Low summer flow experiments under this alternative are not expected to have long-term effects on potential Yuma Ridgway's rail habitat. Designated critical habitat for the Yuma Ridgway rail does not occur in the area of the proposed action. Effects of climate change and continued dry basin hydrology may further diminish habitat for the rail, due primarily to lower water levels within riparian areas.

3.6 CUMULATIVE EFFECTS

Cumulative effects include the effects of future state, local, private, or tribal management actions that may occur in the project area during the duration of the plan (20 years). Future federal actions that have not been previously approved are not included in this section because additional ESA Section 7 consultation would be required. For example, several federal actions are being planned that would require Section 7 consultation including continued permitting of the Navajo Generating Station and the Red Gap Ranch Pipeline. Existing or previously implemented actions are discussed in Section 2. The following projects were considered when analyzing cumulative effects of the proposed action, and other non-federal actions, upon endangered species.

3.6.1 Grand Canyon Escalade

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 1.4-mi-long, eight-person tramway (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, a lodge with patio, roads, and parking for cars and recreational vehicles. It would also include a restaurant, gift shops, an amphitheater, and a riverwalk (with an elevated walkway) along the canyon floor. 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. It could also result in beneficial impacts on the local economy through increased tourism and job creation. The Little Colorado River contains critical spawning habitat for humpback chub.

The Grand Canyon Escalade Project and its associated facilities near the confluence of the Little Colorado River could cause both a localized loss of wildlife habitat and source of wildlife disturbance due to human presence. Wildlife species in the Grand Canyon are currently exposed to various sources of man-made noise ranging from human conversation to aircraft flyovers. The potential effects of noise on wildlife include acute or chronic physiological damage to the auditory system, increased energy expenditures, physical injury incurred during panicked responses, interference with normal activities (e.g., feeding), and impaired communication (AMEC Americas Limited 2005). The response of wildlife to noise would vary by species; physiological or reproductive condition; distance; and the type, intensity, and duration of the disturbance. Regular or periodic noise could cause adjacent areas to be less attractive to wildlife and result in a long-term reduction in use by wildlife in those areas. Responses of wildlife to disturbance often involve activities that are energetically costly (e.g., flying or running), altering their behavior in a way that might reduce food intake, communication, and nesting (Hockin et al. 1992; Brattstrom and Bondello 1983; Cunnington and Fahrig 2010; Francis et al. 2009; Maxell 2000).

3.6.2 Uranium Mining on State and Private Lands

Uranium mining peaked in the 1980s in the Grand Canyon region, but there is now a renewed interest due to increases in uranium prices. 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.

Aquatic biota and habitats most likely to be affected during mine development and operation are those associated with small, ephemeral, or intermittent drainages. Impacts on aquatic biota and habitats from the accidental release of regulated or hazardous materials into ephemeral drainages would be localized and small, especially if a rapid response to a release is undertaken. The accidental spill of uranium ore into a permanent stream or river such as Kanab Creek would potentially pose a localized short-term impact on the aquatic resources. However, the potential for such an event is extremely low. Most ore solids would settle in the waterbody within a short distance from a spill site (Edge Environmental, Inc. 2009). It is expected that expedient and comprehensive cleanup actions would be required under U.S. Department of Transportation regulations and that an emergency response plan would be in place for responding to accidents and cargo spills (Edge Environmental, Inc. 2009). Overall, the potential for impacts on aquatic biota from an accidental spill would be small to negligible. Spencer and Wenrich (2011) estimated that if an ore load is washed into the Colorado River and is pulverized and dissolved (a scenario that is extremely unlikely to impossible), the uranium concentration in the river would increase from the current 4.0 ppb to only 4.02 ppb (undetectable against natural variations). Predicted no-chemical-effect concentrations for aquatic vascular plants, aquatic invertebrates, and fish are ≥5.0 ppb; the lowest chronic concentrations are well above that concentration (see Hinck et al. 2010). For these reasons, the impacts from uranium mining on aquatic biota in the Colorado River or its major tributaries would be localized and would not reduce the viability of affected resources.

In the past, uranium mining led to localized peregrine falcon nest failures in areas such as Kanab Canyon and its multiple side canyons, where numerous mining claims existed (Payne et al. 2010). Although 684,449 ac of federal land administered by BLM north of GCNP (North and East Parcels) and 322,096 ac of federal land administered by the USFS south of GCNP (South Parcel) was withdrawn from locatable mineral exploration and development (i.e., uranium mining), increased uranium mining on non-federal (state and private) lands remaining open to mining could locally affect wildlife habitat (e.g., habitat loss and fragmentation) and increase the amount of uranium, arsenic, and other trace elements in local surface water and groundwater flowing into the Colorado River (Alpine 2010). Edge habitat associated with uranium mines and associated access roads may provide habitat for brown-headed cowbirds (Payne et al. 2010), which are brood parasites of songbirds. In general, any impacts on wildlife from uranium mining would be localized and should not affect the viability of affected resources, especially with the use of best management practices to control mine discharges and proper mine reclamation.

3.6.3 Increased Municipal and Agricultural Water Demand

As the population in the Basin States grows and expands, municipal, industrial, and agricultural water demand continues to increase. A Reclamation study in 2012 showed that the demand for Colorado River Basin water may exceed demand before 2060 (Reclamation 2012b), which may result in lower Lake Powell levels and changes in flow, sediment, and water temperature regimes in the Grand Canyon.

Population and industrial growth, coupled with climate change, will act in concert to increase water demand in the region (Schindler 2001) and lower flows downstream of Glen Canyon Dam. This could stress existing riparian and wetland vegetation, leading to plant community alterations that would affect both wildlife habitats and the wildlife prey base. Climate change would not affect all wildlife species uniformly. Some species would experience distribution contractions and likely shrinking populations, while other species would increase in suitable areas and thus possibly experience increases in population numbers. Generally, the warmer the current range is for a species, the greater the projected distributional increase (or lower the projected loss) will be for that species due to climate change (van Riper et al. 2014).

3.6.4 Urban and Agricultural Runoff

Urban runoff, industrial releases, and municipal discharges are considered some of the leading nonpoint sources of contaminants to surface waters (EPA 2004). Areas of intensive agriculture can have an adverse effect on the water quality as a result of the salinity, nutrients, pesticides, selenium, and other trace elements that are common constituents in agricultural runoff. For example, elevated selenium found in aquatic organisms in Colorado River in Grand Canyon is thought to be partly due to agricultural runoff from areas with soils containing selenium (Walters et al. 2015). It is unclear how contamination due to agricultural and urban discharge may change in the future.

3.6.5 Nonnative Vegetation and Defoliating Nonnative Insect Expansion

The highly flammable tamarisk has created a fire hazard previously absent along the river. This threatens breeding bird populations, as well as other wildlife. In addition, if native or mixed habitat stands burn, monotypic tamarisk will likely recolonize, eliminating the crucial structure necessary for southwestern willow flycatchers and other nesting birds (e.g., thermal buffering through shading becomes insufficient and will be further exacerbated by warming climate trends) (Schell 2005). Additional factors that could affect riparian wildlife habitat include the tamarisk leaf beetle and splendid tamarisk weevil, which occur along much of the Colorado River below Glen Canyon Dam and result in defoliation and mortality of tamarisk. Widespread tamarisk mortality would likely result in a net loss in riparian habitat for at least a decade or more (Paxton et al. 2011). It seems unlikely that the effects of large-scale defoliation in areas dominated by tamarisk will be compensated for by use of tamarisk beetles as a food resource by birds (Puckett and van Riper 2014).

3.6.6 Cumulative Effects Summary

3.6.6.1 Aquatic Species – Humpback Chub, Razorback Sucker, and Kanab Ambersnail

The incremental effects of the LTEMP proposed action on razorback sucker and humpback chub are not expected to contribute significantly to cumulative impacts along the Colorado River corridor or within the basin at large. Examination of the various hydrologic traces used to model effects of the proposed action on aquatic resources indicated that hydrology (i.e., whether a 20-year trace was drier or wetter on average) had a greater influence on the model results than did the operational differences among alternatives. Similarly, climate change has the potential to have greater effects on fish resources than any of the alternatives because of its direct influences on hydrologic patterns. For example, more frequent droughts and warmer atmospheric temperatures have the potential to result in greater increases in the temperature of water being released from the dam than the operational actions being considered, and this in turn may improve thermal suitability for humpback chub, humpback chub aggregations, and native fish. However, any subsequent benefits may be offset by increased abundance and expansion of nonnative fish and aquatic fish parasites. There are a number of other actions being taken within the Colorado River Basin that could also contribute to significant cumulative effects on fish populations or fish communities. For example, actions to increase the number of self-sustaining populations of humpback chub within the basin (e.g., translocation of humpback chub from the Little Colorado River to other tributaries within the Grand Canyon) have the potential to increase overall numbers of humpback chub and could provide some level of protection against catastrophic events in the Little Colorado River that could greatly reduce or eliminate the population of humpback chub in the Grand Canyon.

3.6.6.2 Wildlife

The effects of the LTEMP proposed action on wildlife are relatively small compared to the effects of other factors, especially future hydrology, and they are not expected to contribute significantly to cumulative impacts along the Colorado River corridor or within the basin at large. The proposed action would have little effect on most wildlife species.

3.6.7 Summary of Climate-Related Changes

The general picture for climate change as it relates to Colorado River Basin hydrology includes decreased inflow to the reservoir system (e.g., lower precipitation) and greater losses (e.g., evapotranspiration associated with higher temperatures and increased demand from the growing population). Climate change is expected to result in more frequent and severe drought conditions in the Southwest. Meeting increasing water needs (e.g., the Lake Powell Pipeline project and the Page-LeChee water supply project) will likely lead to lower reservoir levels in Lake Powell, which may already be affected by increased evaporation associated with higher air temperatures. As discussed in the baseline, the decreasing the elevation of Lake Powell can lead to warmer water discharges from Glen Canyon Dam and increased water temperatures downstream.

Water discharge from springs supports the vegetative habitat upon which Kanab ambersnail relies. Changes in spring discharge due to reduced snowpack, in addition to impacts of HFEs, may further reduce habitat at Vaseys Paradise. The Southwest is already experiencing the effects of climate change (Garfin et al. 2014). The decade from 2001 to 2010 was the warmest on record, with temperatures almost 1.1°C higher than historic averages (Garfin et al. 2014; World Meteorological Organization 2014). Higher temperatures in the Colorado River Basin have resulted in less precipitation falling and being stored as snow at high elevations in the Upper Basin (the main source of runoff to the river), increased evaporative losses, and a shift in the timing of peak spring snowmelt (and high streamflow) to earlier in the year (NAS 2007; Christensen et al. 2004; Jacobs 2011). Such effects are likely to continue well into the foreseeable future (NAS 2007).

Warmer water temperatures would likely increase production rates of algae and invertebrates (Woodward et al. 2010; FWS 2011c). Lower water levels in Lake Powell may also result in increases in the composition and density of zooplankton downstream of Glen Canyon Dam, because waters would be withdrawn closer to the surface (Reclamation 1995). However, warmer temperatures, particularly in winter, may allow many invertebrate species to complete their life cycles more quickly (Schindler 2001). For example, if stream temperatures are raised by only a few degrees in winter, many aquatic insects that normally emerge in May or June may emerge in February or March and face death by freezing or be prevented from mating because they are inactivated by low air temperatures. In addition, increases in stream temperatures may cause an exaggeration in the separation of the emergence of males and females (e.g., males may emerge and die before females emerge) (Nebeker 1971). Temperatures above the optimum can lead to the production of small adults and lower fecundity (Vannote and Sweeney 1980).

Warmer water temperatures can expand the distribution of nonnative species adapted to warmer temperatures. This includes fish parasites such as the Asian tapeworm, anchor worm, and nonnative crayfish. Increased zooplankton due to climate change may increase abundance of cyclopoid copepods. All cyclopoid copepod species appear to be susceptible to infection by, and therefore serve as intermediate hosts for, the Asian tapeworm (Marcogliese and Esch 1989). Crayfish can prey on fish eggs and larvae and can diminish the abundance and structure of aquatic vegetation such as filamentous algae through grazing (FWS 2011c). Nonnative crayfish are present in Lake Powell (northern or virile crayfish [*Orconectes virilis*]) and Lake Mead (red swamp crayfish [*Procambarus clarkii*]). Warmer temperatures may allow the crayfish to expand into the mainstem of the Colorado River either downstream of Lake Powell or upstream of Lake Mead.

Higher temperatures in the Colorado River Basin have resulted in less precipitation falling and being stored as snow at high elevations in the Upper Basin (the main source of runoff to the river), increased evaporative losses, and a shift in the timing of peak spring snowmelt (and high streamflow) to earlier in the year (NAS 2007; Christensen et al. 2004; Jacobs 2011). These effects in turn have exacerbated competition among users (farmers, energy producers, urban dwellers), as well as effects on ecological systems, during a time when due to a rapidly rising population water demand has never been higher (Garfin et al. 2014). The combination of decreasing supply and increasing demand will present a challenge in meeting the water delivery commitments outlined in the Colorado River Compact of 1922 (apportioning water between the Upper and Lower Basins) and the United States–Mexico Treaty of 1944 (which guarantees an annual flow of at least 1.5 million ac-ft to Mexico). In 2007, DOI adopted interim guidelines (Reclamation 2007a) to specify modifications to the apportionments to the Lower Basin states in the event of water shortage conditions.

Changes in temperature and precipitation patterns attributed to climate change could also take a toll on the region's rich diversity of plant and animal species (e.g., widespread loss of trees due to wildfires).

As described above, depending on the extent of drought in the Colorado River basin, lower Lake Powell levels may result in the discharge of warmer than anticipated water into Glen and Grand Canyons. This could increase the likelihood that warmwater nonnative predators will become established.

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4 CONCLUSIONS AND DETERMINATIONS OF EFFECT

A summary of effects determinations for the five listed species is presented in Table 6. Analysis of effects determination are based 50 CFR 402.02, in which "[e]ffects of the action refers 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 or interdependent with that action, that will be added to the environmental baseline. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process."

4.1 LISTED SPECIES DETERMINATIONS

For the purposes of Section 7 consultation under the ESA, the following definitions are used when determining the level of anticipated effect for each listed species and its habitat (FWS and NMFS 1998a).

No effect: The proposed action will not affect listed species or designated critical habitat.

May affect, but is not likely to adversely affect: Effects of the proposed action on listed species is expected to be discountable, insignificant, or completely beneficial.

- Discountable effects are those extremely unlikely to occur. Based on best judgment, a person would not (1) be able to meaningfully measure, detect, or evaluate insignificant effects; or (2) expect discountable effects to occur.
- Insignificant effects relate to the size of the impact and should never reach the level where incidental take may occur.
- Beneficial effects are contemporaneous positive effects without any adverse effects on the species. In the event that the overall effect of the proposed action is beneficial to the listed species, but also likely to cause some adverse effects, then the proposed action "is likely to adversely affect" the listed species.

May affect, and is likely to adversely affect: Effects of the proposed action on listed species may occur as a direct or indirect result of the proposed action or its interrelated or interdependent actions, and the effect is not discountable, insignificant, or beneficial.

Jeopardize the continued existence of a species: Effects of the proposed action would be expected, directly or indirectly, to appreciably reduce the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species (50 CFR 402.02).

TABLE 6 Summary of Effects Determinations for the Five Listed Species

Determination	Basis for Determination
Humpback chub (*Gila cypha*)	
May affect, is likely to adversely affect	The stranding of young chub could occur during TMFs and downramp rates, but longer-term beneficial impacts on older age classes may result from reduced trout.
	Impacts on habitat include direct, minor, short-term reductions in nearshore habitat could occur in the vicinity of the Little Colorado River with changes in flow stage, but long-term benefit is expected from sand re-deposition that rebuilds and maintains nearshore and backwater nursery habitats. Base operations will continue to degrade the food base.
	Increased predation from expanded population of rainbow trout is expected under cold water discharge, especially with spring or multiple HFEs. Translocations, brown trout control, triggered mechanical removal, triggered proactive conservation actions, and other conservation measures may offset impacts at the population level.
Razorback sucker (*Xyrauchen texanus*)	
May affect, is likely to adversely affect	Potential for creation of warm, productive nursery habitats from increased reshaping of nearshore deposits and backwater development.
	Potential short-term dewatering of spawning areas during TMFs.
	Stranding of larval and young-of-year razorback sucker in nearshore habitats may occur as a result of TMFs and base operations (daily fluctuating flows, including increased downramp rates).
Kanab ambersnail (*Oxyloma kanabensis*)	
May affect, is likely to adversely affect	Potential habitat would be frequently inundated during HFEs that would occur almost annually.
	Proportionally less habitat area would be scoured and fewer snails would be displaced by lower magnitude HFEs.
	Sequential HFEs could re-inundate and scour primary habitat prior to full recovery from previous HFE.
Southwestern willow flycatcher (*Empidonax traillii extimus*)	
May affect, not likely to adversely affect	Not expected to be in the action area during the spring HFE release window (March–April) and high flows of 45,000 cfs or less are not likely to adversely affect their nesting and feeding sites.
Yuma Ridgway's rail (*Rallus obsoletus yumaensis*)	
May affect, not likely to adversely affect	Spring HFEs may flood nesting habitat; however, nesting habitat is rare, and likely above the level HFE effects due to dropping Lake Mead levels.

4.2 HUMPBACK CHUB

Based on the evaluation contained in this BA, Reclamation has determined that the proposed action **may affect and is likely to adversely** affect the humpback chub, and may adversely affect its designated critical habitat. This determination is based on adverse effects on habitat, related to fluctuating flows (increased downramp rates), the potential for increases in negative interactions with rainbow trout, and the potential for TMFs to impact larval and juvenile individuals occupying shallow stream margin habitats. Fluctuating flows under base operations would also continue to limit the diversity and abundance of aquatic invertebrate prey. These combined effects could result in lower survival of young fish and less recruitment to the adult population. The unintended consequence of an increased rainbow trout population that could result from HFEs, especially those in spring, would likely increase downstream dispersal of trout into the vicinity of the Little Colorado River where they could prey on and compete with young humpback chub. This effect would also reduce recruitment of humpback chub and possibly the overall population size. However, TMFs may also reduce negative effects on humpback chub related to downstream emigration and predation or competition by rainbow trout, but their effectiveness is uncertain. Mechanical control of nonnative fish would be initiated if adult or subadult humpback chub abundance declined, and proactive conservation actions to improve rearing fail to reverse population declines downstream of Glen Canyon Dam; this could reduce nonnative trout abundance and their effects on competition with and predation on humpback chub. Trout control in Bright Angel Creek and the Bright Angel inflow is also expected to reduce brown trout in the project area; however, the potential to control brown trout spawning in other areas is less certain.

The HFEs are also expected to have long-term beneficial effects on the humpback chub population. Although periodic high flows would likely temporarily affect habitat and reduce the food base, multiple HFEs would be expected to rebuild and maintain backwater habitats—so long as sufficient fine sediment was available—and stimulate productivity in backwaters and nearshore habitats. Experimental sustained low flows for benthic invertebrate production may improve the food base; however, the success of this experiment is highly uncertain. The number of consecutive HFEs that would benefit the ecosystem (e.g., rebuilding and maintenance of habitat, stimulate food base productivity) or adversely modify or alter the ecosystem from periodic scouring is unknown. In addition to the effects of low flows to benefit the food base, this will be investigated as part of the LTEMP.

Low summer flows could lead to stable, more productive nearshore habitats, increased likelihood of the establishment of a more diverse and productive food base, and warmer water temperatures in the Little Colorado River reach and further downstream, as well as contributing to enhanced growth rates of young humpback chub. However, this experimental treatment would be used only rarely, if a single test in the second 10 years of the LTEMP period proves it to be a useful tool for improving humpback chub habitat. It is thought that the potential benefit of an increase in temperature would be greatest if a water temperature of at least 14°C could be achieved, because these warmer temperatures could favor higher growth rates of humpback chub.

Finally, as described in Section 3.6.7 the potential for increased occurrence of new warmwater nonnative species' introductions may increase in the future as the likelihood of low Lake Powell levels increases with drought and expanded water use, or during LSF experiments. For example, it is likely that the establishment of green sunfish in a backwater slough in Glen Canyon was the result of fish passing through the Glen Canyon Dam (Ward 2015). There is a chance that over the life of the LTEMP, under extreme drought and low Lake Powell levels, dam release temperatures could reach temperatures suitable for reproduction of high-risk nonnative predatory species such as smallmouth bass (15°C). However, current temperatures are already suitable for many warmwater species in the lower river. The river temperature at the Lees Ferry gauge approached 15°C during the fall of 2015 (GCMRC 2016), and reached 20°C below Diamond Creek. Increases in smallmouth bass in the Yampa River have coincided with the decline of the humpback chub population; the threat smallmouth bass pose to humpback chub is thought to be 10 times greater than the threats posed by channel catfish and northern pike (Johnson et al. 2008).

4.3 RAZORBACK SUCKER

Reclamation has also determined that the proposed action **may affect and is likely to adversely** affect the razorback sucker, and may adversely affect its designated critical habitat. This determination is based on potential adverse effects of TMFs stranding juvenile or larval razorback sucker in nearshore habitats, and long-term, river-wide effects as the result of fluctuating flows under base operations, which will continue to compromise the diversity and abundance of aquatic insect prey and degrade nearshore habitats that are important for rearing. Spawning habitat (cobble bars and riffles) is also expected to be negatively affected by base flow fluctuations (including increased downramp rates) and TMFs. TMFs will be less likely to beneficially impact razorback sucker in the western Grand Canyon by reducing trout abundance in Glen and Marble Canyons, and may result in stranding of larval or young-of-year razorback sucker during the summer months. The impacts of TMFs on razorback sucker will be investigated in the LTEMP, and ongoing razorback sucker monitoring in the western Grand Canyon will assist in this investigation. In addition, TMFs could impact spawning habitat and incubating eggs in shallow cobble areas that are most susceptible to changes in flow. Increased downramp rates could also impact razorback sucker young-of-year.

The increased frequency of HFEs could lead to improved sediment conservation and backwater habitat maintenance, benefitting razorback sucker habitat. Increases in sediment load will temporarily increase turbidity, which larvae use as cover from predators (Kegerries et al. 2009). In addition, modeling the hydrology and temperature regime expected during the life of the LTEMP indicated an improvement in temperature suitability compared to the baseline condition at areas inhabited by razorback sucker (i.e., Diamond Creek). Improved backwater habitats, in addition to stability during low summer flows and low steady weekend flows for macroinvertebrate production, could benefit young-of-year as well; however, low summer flows would be implemented only rarely, and invertebrate flows would only be in place for a total of 34 days per summer.

4.4 KANAB AMBERSNAIL

Reclamation has also determined that the proposed action **may affect and is likely to adversely affect the Kanab ambersnail**. Although impacts from the proposed action related to habitat scouring during HFEs will be limited to the habitat near the river, the impact would occur almost annually, which would exceed the rate of habitat recovery (2.5 years). This impact will be limited to one of two populations of Kanab ambersnail. Nevertheless, habitat quality or quantity may decline as a result of the proposed action, in the context of climate change.

There is no designated critical habitat for this species, and this analysis did not evaluate primary constituent elements. This determination is based on short-term adverse effects on habitat and snails located in the inundation zone at Vasey's Paradise. Habitat and snails below the high-water line are expected to be scoured and transported downstream with little or no survival of snails. The proportion of habitat and the number of snails affected would vary with the magnitude of the high release. For the past HFEs, Reclamation has removed habitat and snails from the projected inundation zone. When the habitat was relocated, the vegetation recovered within about 6 months, but when the habitat was not relocated, recovery was delayed about 2.5 years.

4.5 SOUTHWESTERN WILLOW FLYCATCHER

Reclamation has determines the proposed LTEMP **may affect, but is not likely to adversely affect** the southwestern willow flycatcher and southwestern willow flycatcher habitat. This determination is based on the fact that nesting activity, nests, or young are not expected to be in the action area during any of the HFEs except the two proactive spring HFEs. In addition, high flows of 45,000 cfs are not likely to adversely affect the species nesting and foraging habitat. Designated critical habitat for the southwestern willow flycatcher does not occur in the area of the proposed action.

4.6 YUMA RIDGWAY'S RAIL

Reclamation has determined the proposed LTEMP **may affect, but is not likely to adversely affect** the Yuma Ridgway's rail and habitat. Designated critical habitat for the Yuma Ridgway's rail does not occur in the area of the proposed action.

The volume and duration of HFEs is determined by the amount of Paria River sediment that is available. Modeling indicates that the amount of sediment required to trigger spring HFEs will occur in about 26% (5 years) of the 20 years of the LTEMP period. Spring HFEs would occur in April, May, or June and may coincide with the nesting period of the Yuma Ridgway's rail. The Grand Canyon has very little true cattail/marsh habitat and it is unlikely that the nests or habitat would be close enough to the river to be impacted by HFEs because HFEs have minimal stage change in this broad floodplain habitat. In addition, due to dropping levels of Lake Mead, most potential habitat in the lowest portion of Grand Canyon where Yuma Ridgway's rails have been detected is now raised 10 ft or more above the flowing river level, and therefore is out of reach of fluctuating flows, including HFEs. Any implementation of sediment-triggered spring HFEs will consider resource condition assessments and resource concerns using the interagency process described in Section 1.2.8.

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APPENDIX A:

SOUTHWESTERN WILLOW FLYCATCHER DETECTIONS AND NEST SITES, GRAND CANYON NATIONAL PARK, ARIZONA, 1982–2012

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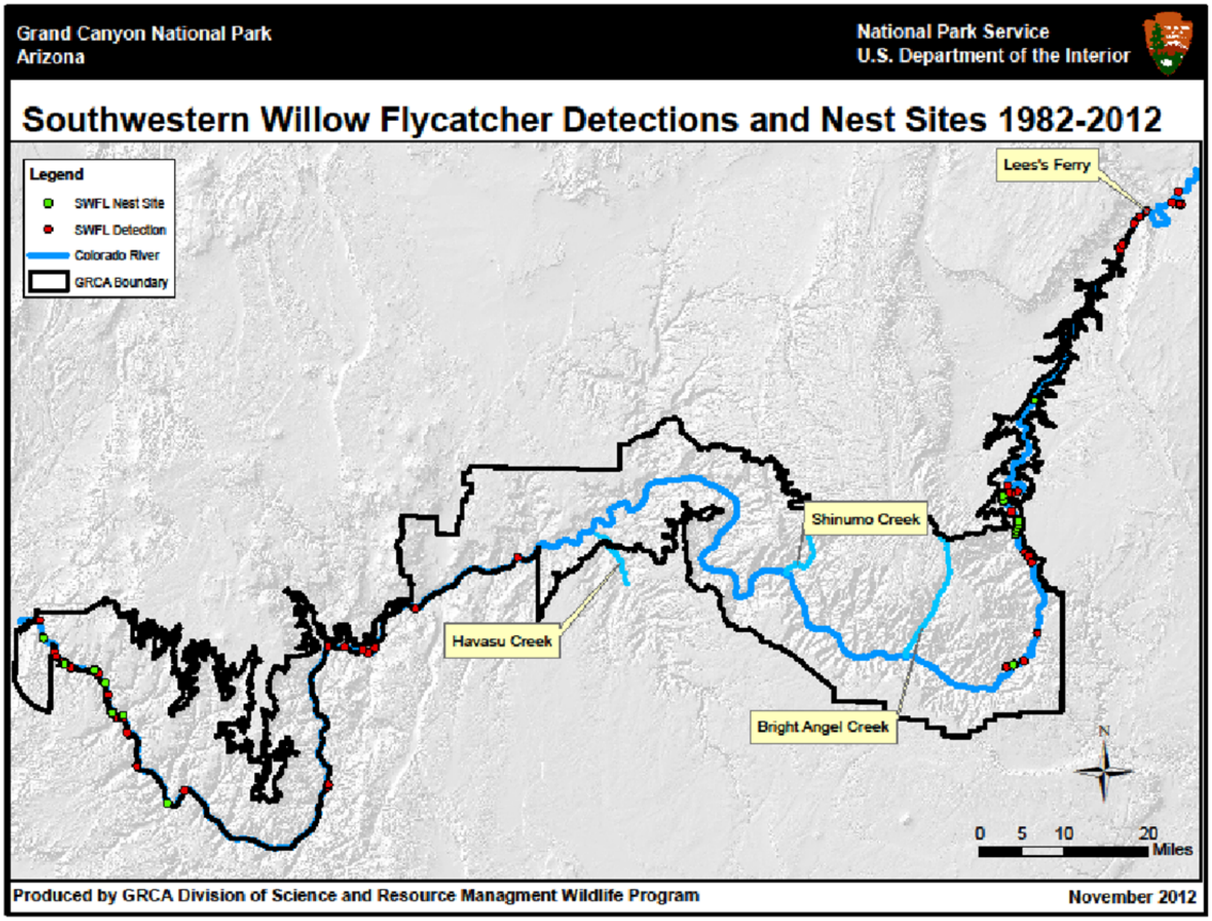
APPENDIX A:

SOUTHWESTERN WILLOW FLYCATCHER DETECTIONS AND NEST SITES, GRAND CANYON NATIONAL PARK, ARIZONA, 1982–2012



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APPENDIX B:

SOUTHWESTERN WILLOW FLYCATCHER HISTORIC AND RECENT TERRITORIES AND NESTING SITES, GRAND CANYON NATIONAL PARK, ARIZONA

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APPENDIX B:

SOUTHWESTERN WILLOW FLYCATCHER HISTORIC AND RECENT TERRITORIES AND NESTING SITES, GRAND CANYON NATIONAL PARK, ARIZONA

River Mile/Location	Year	Notes
0 (Lees Ferry)	1909	Single male collected
0	1933	Specimen collected
0	1935	Used nest collected
0	1961	2 male, 1 female, 1 unknown sex collected
Lava Canyon	1931	
Little Colorado	1953	
RM 0	1987	
RM 46	1987	
RM 51.5–50.5	1993	1 territory
RM 71.3–71	1993	1 territory
RM 277–274	1993	1 territory
RM 51.5–50.5	1994	4 territories
RM 65.3	1994	1 territory
RM 71	1994	
RM 51.5–50.5	1995	1 territory
RM 65.3	1995	1 territory
Lake Mead Delta	1995	1 territory
RM 51.5–50.5	1996	3 territories
Lake Mead Delta	1996	6 territories
RM 51.5–50.5	1997	2 territories
RM 270–168	1997	2 territories (1 presumed nesting at RM 252.9)
Lake Mead Delta	1997	6 territories/3 nesting pairs
RM 51.5–50.5	1998	1 territory
RM 246	1998	2 territories
RM 254 (Spencer Cany.)	1998	2 territories
RM 265–263.5	1998	1 territory
RM 268–264	1998	1 territory
RM 268–265	1998	5 territories
RM 270–268	1998	1 territory
RM 272–268	1998	2 territories
RM 273–270	1998	2 territories
RM 277–273	1998	1 territory
RM 51.5–50.5	1999	1 territory
RM 246	1999	3 territories
RM 254 (Spencer Cany.)	1999	2 territories, 3 yg. fledged
RM 259.5	1999	1 territory (McKernan and Braden report 2)
RM 266–262.5	1999	1 territory
RM 268–265	1999	5 territories
RM 272–268	1999	1 territory
RM 276	1999	1 territory
RM 51.5–50.5	2000	1 territory
RM 246	2000	2 territories
RM 257.5–257	2000	1 territory

River Mile/Location	Year	Notes
RM 259.5	2000	1 territory
RM 266–262.5	2000	1 territory
RM 268–265	2000	1 territory
RM 51.5–50.5	2001	1 territory
RM 246	2001	3 territories
RM 254	2001	3 pairs
RM 257.5	2001	1 pair
RM 259.5	2001	2 territories
RM 262.5–259.5	2001	1 territory/2 nests
RM 263.5–262.5	2001	1 territory
RM 268–265	2001	3 territories
RM 272–268	2001	2 territories
RM 276	2001	2 individuals, no nest confirmed
RM 51.5–50.5	2002	1 territory
RM 28–29	2003	1 pair
RM 50.5-51.5	2003	1 pair
RM 28.3	2004	1 pair
RM 50.4	2004	1 female (June)
RM 274.5	2004	1 pair nesting (+1 lone male)
RM 274.5	2005	1 unpaired male
RM 274.5	2006	1 pair nesting (+1 lone male)
RM 259.5	2007	1 pair nesting
RM 274.5	2007	3 unpaired males
RM 47	2009	1 individual
RM 49	2009	1 individual
RM 50.4–50.7	2009	1 individual
RM 28.5	2010	1 individual
RM 196.4	2010	1 individual
RM 218	2010	1 pair
RM 275	2010	2 territories
RM 51.8	2011	1 individual
RM 183.5	2011	1 individual

APPENDIX C:

RIDGWAY'S RAIL HISTORIC RECORDS AT GRAND CANYON NATIONAL PARK, ARIZONA

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APPENDIX C:

RIDGWAY'S RAIL HISTORIC RECORDS AT GRAND CANYON NATIONAL PARK, ARIZONA

TABLE C.1 Ridgway's Rail Historic Records at Grand Canyon National Park, Arizona

River Mile/Location	Year	Notes
RM 246–RM 277	1996	1 rail; nesting confirmed
RM 246–RM 277	1997	1 rail; nesting not confirmed
RM 275	1999	1 male observed
RM 276	2000	1 female observed
Burnt Springs (~RM 259.8)	2001	3 individuals detected

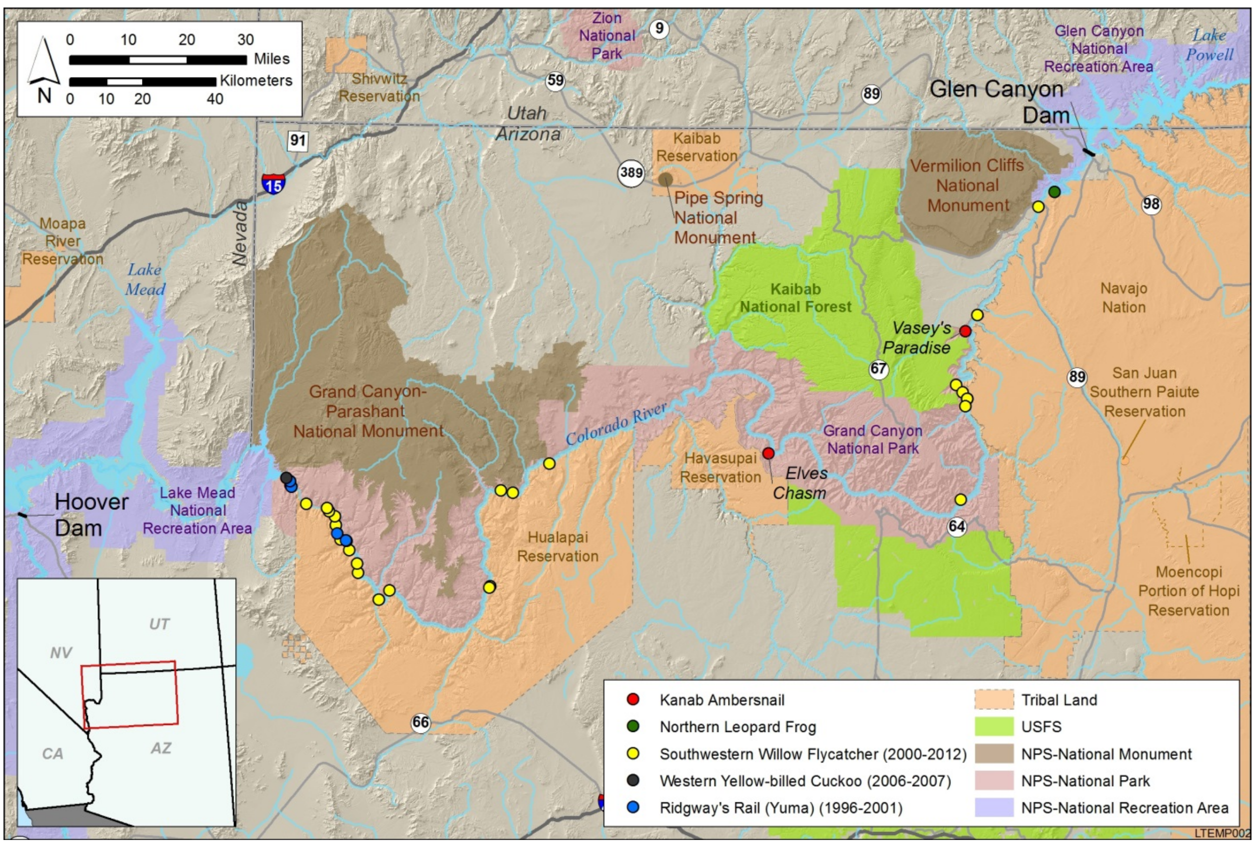

FIGURE C.1 Threatened, Endangered, and Sensitive Species Observed along the Colorado River Corridor (Sources: Drost et al. 2011; FWS 2011b; Johnson et al. 2008; NPS 2013; Stroud-Settles 2012)

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APPENDIX D:

PROPOSED ACTION TRIGGERS FOR THE MANAGEMENT OF HUMPBACK CHUB COLORADO RIVER, GRAND CANYON

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APPENDIX D

DRAFT FINAL

Proposed Action Triggers for the Management of Humpback Chub

Colorado River, Grand Canyon

November 2015

Developed by an Ad Hoc group of Grand Canyon Aquatic Biologists from USFWS, USGS-GCMRC, AZGFD, NPS, USBR (Kirk Young, David Van Haverbeke, Scott VanderKooi, David Ward, Charles Yackulic, Mike Yard, Brian Healy, Melissa Trammel, David Rogowski, Marianne Crawford)

PURPOSE
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, USFWS, AZGFD, GCMRC) to assess current trout removal triggers resulted in a concept of early conservation measure intervention to maximize conservation benefit to humpback chub (HBC) and minimize the likelihood of mechanical predator removal.

Many factors affect HBC population dynamics such as water temperature, turbidity, and water volume in the Little Colorado River (LCR). This restrains available conservation actions that can be implemented in the event of a declining population of HBC. We can translocate juveniles and young of the year to other areas within and outside the LCR system, juvenile HBC can be head-started at a hatchery, and we can attempt to remove predators. Other conservation tools may include parasite control (although this is unlikely from a population standpoint), non-native fish control in the LCR, and protect from over-utilization for scientific purposes.

Methods to actively manage temperature releases from Glen Canyon Dam sediment augmentation below the Paria River are not included in the Long-Term Experimental Management Program (LTEMP), for Glen Canyon Dam. Inclusion of infrastructure options including these were eliminated from detailed study in the LTEMP alternatives for a variety of reasons. We mention them here because these methods may still represent the most important potential conservation tools that could be used for the long term conservation of HBC in Grand Canyon and the concepts should not be lost.

While healthy wildlife populations are rarely static, trigger objectives include prescribing actions to reverse/ameliorate impacts in order to maintain the LCR HBC population within an acceptable range; and, secondarily to reduce reliance on mechanical removal of predators. For the purposes of these triggers, it is assumed that the primary drivers of HBC population dynamics are interspecific interactions with non-native species, especially rainbow trout, and low water temperature in the mainstem of the Colorado River (Kaeding and Zimmerman 1983; Douglas and Marsh 1996; USFWS 2002; Coggins et al. 2011; Yard et al. 2011). It is suspected that cold water temperatures suppress growth and thus subject young HBC to predation for extended periods of time. The approach described here puts the emphasis on managing humpback chub as opposed to managing predators. Predator removal will only occur if other conservation measures do not appear to be effective in maintaining targeted HBC population levels.

Two Tier Approach
Two tiers of sequential actions were identified; the first would emphasize conservation actions that would take place early during an adult or sub-adult HBC population decline. The second tier would serve as a backstop prescribing predator removal (Threat Reduction) if conservation measures did not mitigate a decline in HBC abundance.

ACTION TRIGGERS

Tier 1 Trigger – Early Intervention Through Conservation Actions:

1a. If the combined point estimate for adult HBC (adults defined ≥200 mm) in the Colorado River mainstem LCR aggregation; RM 57-65.9) and Little Colorado River (LCR) falls below 9,000 as estimated by the currently accepted HBC population model (e.g., ASMR, multi-state).

-OR-

1b. If recruitment of sub-adult HBC (150-199mm) does not equal or exceed estimated adult mortality such that:

1) Sub-adult abundance falls below a three-year running average of 1,250 fish in the spring LCR population estimates.

-OR-

2) Sub-adult abundance falls below a three-year running average of 810 fish in the mainstem Juvenile Chub Monitoring reach (JCM annual fall population estimate; RM 63.45-65.2).

Tier 1 Trigger Response: Tier 1 conservation actions listed below will be immediately implemented either in the LCR or in the adjacent mainstem. Conservation actions will focus on increasing growth, survival and distribution of HBC in the LCR & LCR mainstem aggregation area.

Tier 2 Trigger - Reduce threat using mechanical removal if conservation actions in Tier 1 are insufficient to arrest a population decline:

Mechanical removal of nonnative aquatic predator will ensue:
If the point abundance estimate of adult HBC decline to <7,000, as estimated by the currently accepted HBC population model.

Mechanical removal will terminate if:

Predator index (described below) is depleted to less than 60 RBT/km for at least two years in the JCM reach and immigration rate is low (the long term feasibility of using immigration rates as a metric still needs to be assessed), or

Adult HBC population estimates exceed 7,500 and recruitment of sub-adult chub exceed adult mortality for at least two years.

If immigration rate of predators into JCM reach is high, mechanical removal may need to continue. These triggers are intended to be adaptive based on ongoing and future research (e.g., Lees Ferry recruitment and emigration dynamics, effects of trout suppression flows, effects of Paria River turbidity inputs on predator survival and immigration rates, interactions between humpback chub and rainbow trout, other predation studies).

ACTION TRIGGERS BACKGROUND AND RATIONALE

Tier 1 Trigger Target

Adult Humpback Chub population target: 9,000

Using an age-structured mark-recapture (ASMR) model, Coggins and Walters (2009) estimated the adult population of the LCR aggregation of HBC in 2008 was approximately 7,650 fish (6,000-10,000 fish considering a range of assumed mortality rates and ageing error). Using a multi-state model, Yackulic et al. (2014) obtained point abundance estimates of adult HBC between ~11,000-13,000 from 2009 through 2012. This increase in adult abundances roughly coincides with the significant increase of adult HBC that first appeared in the LCR post-2006 (Van Haverbeke et al. 2013). We suggest a population estimate of 9,000 adult fish as a desired future conditions target. Estimates falling below 9,000 would trigger additional conservation actions to increase recruitment until the HBC population recovered to 9,000 adult fish. A 9,000 adult chub target is below the most recent estimate of ~11,000-13,000 individuals and would preclude conservation measures from being initiated immediately, but also provides a “buffer zone” above 7,000 adult fish, at which point mechanical removal is warranted, as prescribed in the 2011 high flow Biological Opinion (USFWS 2011).

LCR and mainstem (LCR aggregation) population targets: 2,000 and 7,000 adult HBC, respectively

We separate the 9,000 total adult target number into an LCR component (2,000 adults), and a mainstem Colorado River component (7,000 adults). It is estimated that ~82% of adult HBC reside in the mainstem Colorado River during the non-spawning season (Yackulic et al. 2014, p. 1015). This proportion was based on estimates obtained during September/October 2011, so this proportion would be expected to vary, possibly considerably, on an annual basis. Nevertheless, objectives to maintain 2,000 adults in the LCR and 7,000 adults in the mainstem during the non-spawning season (i.e., September/October) are proposed. A desired target of 2,000 adults in the LCR is reasonable because the average fall population estimate for adults was 2,380 (SE = 518) from 2007-2014, compared to the average level of 789 adults (SE = 281) from 2000-2006 (Van Haverbeke et al. 2015).

LCR Humpback Chub recruitment target

To maintain a population of 2,000 adult HBC in the LCR during the non-spawning season, there must be sufficient recruitment of sub-adult chub (150-199 mm size class). We estimate that a sub-adult chub population of 1,250 fish annually, as measured during the annual spring spawning season in the LCR is sufficient to maintain the adult HBC target population. This number is derived from an assumption that the annual adult mortality rate in the LCR is estimated at 0.35 (Yackulic et al. 2014, updates Yackulic pers. com). Hence 2,000 x 0.35 = 700 new adults needed annually to replace adult mortality. To annually recruit 700 adults, we estimate that 1,250 sub-adults are annually needed (i.e., not all sub-adults will survive into adulthood). If annual mortality for sub-adults in the LCR is 0.44 (Yackulic et al. 2014, updates Yackulic pers. com.), then 700/(1-0.44) = 1,250 sub-adults needed to offset adult mortality. Hence, if the three-year running average point population size of sub-adult chub measured during the spring season in the LCR drops below 1,250 fish, additional conservation measures would be triggered (Figure 1).

A three-year running average is used for sub-adults because production of younger life stages of HBC can be highly variable (Van Haverbeke et al. 2013). For long-lived species such as HBC, reduced recruitment of sub-adults in any one year can be compensated in subsequent years with increased recruitment. Three years is considered a reasonable timeframe from which to trigger actions to minimize large changes in adult HBC numbers.

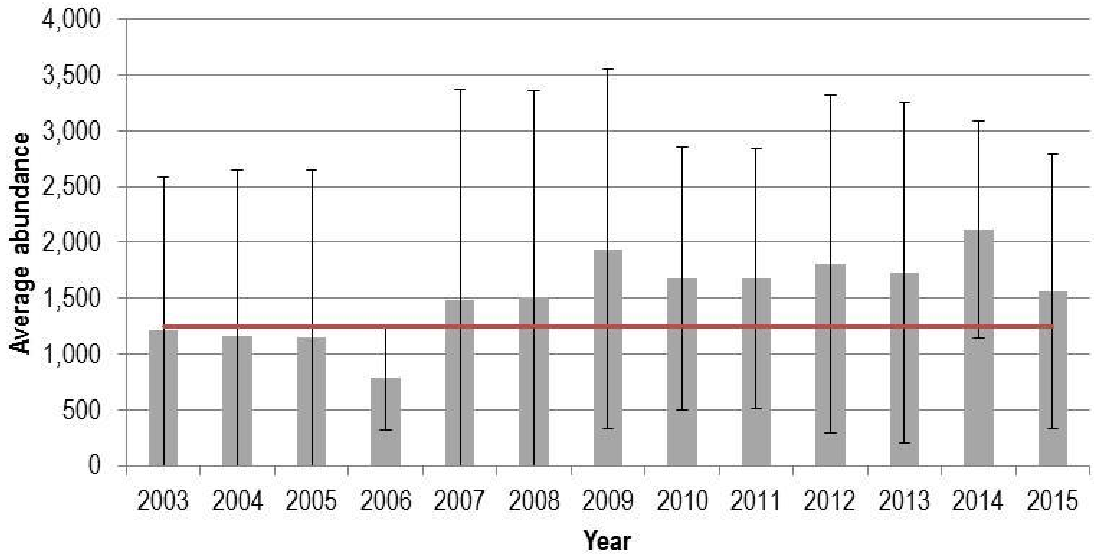

Figure 1. Running three year averages (± 95% CI) of sub-adult humpback chub abundances based on closed spring mark-recapture studies in the Little Colorado River (Van Haverbeke et al. 2013, 2015). For example, the bar for 2003 represents the average abundance of the 150-199 mm size class of humpback chub for 2001, 2002 and 2003 obtained in the Little Colorado River during spring monitoring (note: error bars are large because of typically large annual variability in the abundance of this size class). Additional conservation measures would have been triggered during 2003-2006. The red line represents a trigger value of 1,250 sub-adults, below which conservation measures would be initiated.

Mainstem LCR aggregation recruitment target

To maintain a population of 7,000 adults in the mainstem LCR aggregation reach outside of the spawning season, there must be sufficient recruitment of sub-adult fish (150-199 mm size class). The boundaries of the LCR aggregation in the mainstem traditionally extend from RM 57 (Malagosa Crest) to 65.9 (Lava-Chuar Rapid)(Valdez and Ryel 1995). Since 2009, most mainstem monitoring efforts in the LCR aggregation reach have focused in the JCM (Juvenile Chub Monitoring) reach (RM 63.45-65.2), which is below the LCR and contains ~18% of the adult HBC population found in the mainstem LCR aggregation reach (Yackulic et al. 2014). If ~18% of the population is in the JCM reach, then the desired number of adult chub to maintain in the JCM reach is 7,000 x 0.18 = 1,260 adults. Annual adult mortality in the mainstem LCR aggregation is estimated at 0.15 (Yackulic et al. 2014, updates Yackulic pers. com.). To replace the adults in the JCM reach each year would require 1,250 x 0.15 = 189 adults. Annual mortality of sub-adult chub in the mainstem is estimated at 0.3. Replacing 189 adults annually would require 189/(1-0.3) = 270 sub-adults. Approximately 1/3 of sub-adult chub grow to adult size each year, and accordingly it may take ~3 years1 for a chub in the mainstem to transition from the sub-adult to the adult size class (Yackulic et al. 2014). Therefore an acceptable target population of sub-adults in the JCM reach each year would be 810 (270 x 3 = 810). As with the LCR component, a running three year average of <810 sub-adults in the JCM reach would trigger conservation actions (Figure 2).

The above scenario assumes that population recruitment dynamics are operating more or less equally throughout the LCR aggregation reach in the mainstem, which is likely not true. Most juvenile chub exiting the LCR are displaced downriver from the confluence (Valdez and Ryel 1995). As such, we might expect that recruitment into adulthood might be more prevalent downstream of the confluence. As such, the proportional number of sub-adults measured in the JCM reach may not reflect the number actually needed to annually replace a total 7,000 adults. In other words, the JCM reach proportional calculation of 810 sub-adults could be low. For example, consider that if the JCM reach harbors a higher than average percent of the mainstem sub-adult chub that recruit into adulthood, then even more than 810 sub-adults in this reach may be needed to maintain a population of 7,000 adults.

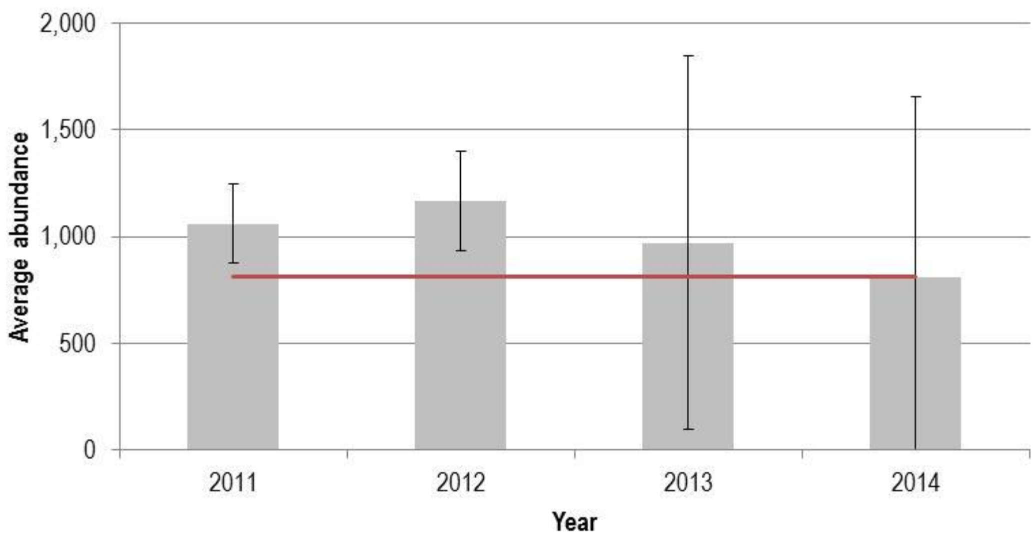

Figure 2. Running three year average abundances (± 95% CI) of sub-adult humpback chub (150-200 mm) abundances based on multi-state model in the mainstem Colorado River in the Juvenile Chub Monitoring reach (data from Yackulic pers. com.). For example, the bar for 2014 represents the average abundance of sub-adult humpback chub in the Juvenile Chub Monitoring reach during 2012, 2013, and 2014. The red line represents the approximate value of a 3-year running average of 810, below which conservation actions would be enacted.

[1]The mainstem LCR population recruitment scenario assumes temperature in the LCR mainstem reach is suitable for growth. If LCR mainstem temperatures are cold (do not exceed 11 oC during the year in the JCM reach), HBC will take longer to reach adulthood, experience greater mortality, and therefore require a larger number of sub-adults targeted to maintain the adult population objective. Target number adjustments will be made prior to implementation of LCR mainstem trigger actions if thought necessary.

Tier 1 Trigger response – HBC Conservation
It is expected that the conservation actions proposed below will assist in ameliorating HBC adult losses or recruitment failures from predation. First, ongoing translocations in the LCR above Chute Falls (~300 fish/year) as well as outside the LCR population (e.g., to Havasu Creek, etc.) will continue, regardless of Tier 1 triggers are met or not. New conservation actions will include expansion of existing activities coupled with experimental actions:

- LCR - Expand translocation actions in the LCR by collecting an additional 300-600 young of the year (YOY) HBC and move to above Chute Falls in October.

- LCR - Assess efficacy of transporting larval HBC (April/May) into Big Canyon and above Blue Springs in the LCR system. Evaluate growth and survival of these transplants;

- Mainstem LCR Aggregation - Larval fish will be removed from LCR (April/May) and head-started at Southwest Native Aquatic Resources and Recovery Center (SNARRC). Once fish reach 150-200 mm they will be translocated to the mainstem LCR reach the following year (currently grow-out space at SNARRC is limited to 750 HBC, use of fish for this purpose would reduce numbers available for other actions, e.g. Havasu, Shinumo.);

- Additional conservation actions as identified and evaluated.

Tier 2 Trigger Targets

Aquatic Predator index
A trout or aquatic predator index is proposed as a means to terminate mechanical removal should it become initiated. Essentially, this is the level (60 predator index fish/km in the JCM reach) at which mechanical removal becomes a futile exercise (i.e., very small return for a high amount of effort). The predator index concept was originally intended to serve as an index whereby mechanical removal would be initiated (e.g., mechanical removal would be initiated once trout levels reached a certain density (~760 index fish/km in the JCM reach). However, because of uncertainty of the actual predation rates of trout on HBC (at differing temperatures, densities, turbidities, etc.), and on its population level effects on HBC, determining an appropriate density of trout at which to initiate mechanical removal is highly uncertain.

A predator index will be developed in the JCM reach to weigh each probable predator by its ability to prey on HBC. The index calculates predator densities by incorporating additional species besides rainbow trout and makes assumptions about their relative predation rates compared to rainbow trout. For example, brown trout are estimated to be about 17 times more predacious on HBC than rainbow trout (Ward and Morton-Starner 2015). Additional predators (e.g., smallmouth bass) could be included through an assignment of their piscivory level relative to rainbow trout. Thus, relative piscivory can be captured in a rainbow trout equivalent predator index (Table 1). For species for which population estimates cannot be estimated with mark/recapture methods, capture probabilities or relative abundance (e.g. catch per unit effort) will be used to estimate the population and incorporate into the density matrix. Also, for certain species regarded as potentially very piscivorous and dangerous (e.g., small mouth bass, green sunfish), targeted removal efforts for these species may be initiated immediately, regardless of meeting any type of threshold. If initiated, mechanical removal would be terminated once the relative predator index declines to 60 in the JCM reach for two years or HBC recover to a target level. A predator index of 60 in the JCM reach likely represents a point at which there is very diminished return for effort expended, and is roughly equivalent to densities at which mechanical removal was deemed to be not worthwhile as an effective tool to pursue in the past (i.e., mechanical was terminated).

Table 1. Hypothetical predator index. The predator index assigns a relative piscivory rate of 17 to brown trout (Ward and Morton-Starner 2015) and to smallmouth bass (assumed at brown trout rate) and sums the hypothetical numbers of fish. If initiated, mechanical removal would be terminated once the relative predator index declines to 60 in the JCM reach for two years or HBC recover to a target level.

Species	Number	Relative predation factor	RBT equivalent
Brown Trout	21	17	357
Rainbow trout	400	1	400
Smallmouth Bass	1	17	17
Predator index total			774

HBC population level triggers
Continue to use the existing adult HBC population estimate of 7,000, as the trigger for predator removal actions, as stated in the 2011 Biological Opinion (USFWS 2011). Population estimates of sub-adults are not incorporated in Tier 2 triggers, as in Tier 1 triggers.

Tier 2 Trigger response – Threat Reduction.
Mechanical removal of predators from the LCR aggregation reach (& immediate vicinity) will be conducted.

TRIGGER CAVEATS

- If HBC decline and the identified actions are not working, USFWS, in coordination with action agencies and traditionally associated Tribes, will identify future appropriate actions;
- Triggers will be reviewed and modified as necessary (evaluated; new information considered and included; etc.), but no less than every five years;
- Actions and triggers will need to adapt if HBC are found to be impacted by other factors;
- If estimating abundances of small size classes of chub becomes problematic because of population decline (i.e., if numbers get so low capture probability cannot be estimated for

each trip), catch divided by the best estimate of capture probability will be used to estimate abundance.

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