ENVIRONMENTAL ASSESSMENT

EXPANDED NON-NATIVE AQUATIC SPECIES MANAGEMENT PLAN IN GLEN CANYON NATIONAL RECREATION AREA AND GRAND CANYON NATIONAL PARK BELOW GLEN CANYON DAM

National Park Service

Intermountain Region
Glen Canyon National Recreation Area
Grand Canyon National Park

September 2018

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1 INTRODUCTION

1.1 DESCRIPTION OF THE PROPOSED ACTION

The National Park Service (NPS) proposes to implement an Expanded Non-Native Aquatic Species Management Plan to control non-native aquatic species in the Colorado River and its tributaries in Grand Canyon National Park (GCNP) and Glen Canyon National Recreation Area (GCNRA) below Glen Canyon Dam. The Proposed Action would expand the tools available for managing non-natives and builds on, but does not modify, those actions identified in the 2013 NPS Comprehensive Fish Management Plan (CFMP; NPS 2013a, b) and Glen Canyon Dam Long-Term Experimental and Management Plan Environmental Impact Statement (LTEMP EIS; Department of Interior [DOI] 2016a, b). A detailed description of the Proposed Action is in Chapter 2 of this environmental assessment (EA).

The area in which the Proposed Action would occur (project area) is identical to the one identified in the CFMP, and includes all waters from Glen Canyon Dam to Lake Mead National Recreation Area (LMNRA), including the Colorado River and its tributaries in GCNP and the Glen Canyon reach (Glen Canyon Dam to the Paria River confluence) in GCNRA (Figure 1-1).

Control actions considered in this EA focus on non-flow actions including physical, mechanical, biological, chemical, and harvest-based actions. Flow-based control options are outside NPS jurisdiction. The NPS has coordinated closely with the Bureau of Reclamation (Reclamation) as a Cooperating Agency on this EA. At this time, Reclamation has not identified any additional applicable actions under their jurisdiction and nothing in this document would preclude Reclamation from exploring future additional actions separately to manage for non-native species.

Control actions considered in this EA will comply with the Law of the River and will not modify anything with respect to water allocation, uses, releases, appropriation, development, or exportation of water within or between the Upper and Lower Colorado River Basins. Accordingly, consistent with the Grand Canyon Protection Act, the Proposed Action is intended to remain 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 Supreme Court in Arizona v. California, and the provisions of the Colorado River Storage Project Act of 1956 and the Colorado River Basin Project Act of 1968 that govern allocation, appropriation, development, and exportation of the waters of the Colorado River Basin, and 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.

1.2 PURPOSE OF AND NEED FOR ACTION

The purpose of taking action is to provide additional tools beyond what is available under the CFMP and the LTEMP to allow the NPS to prevent, control, minimize, or eradicate potentially harmful non-native aquatic species, and the risk associated with their presence or expansion, in the project area. Action may be needed due to an increase in green sunfish (*Lepomis cyanellus*) and brown trout (*Salmo trutta*) and potential expansion or invasion of other non-native aquatic species that threaten downstream native aquatic species, including listed species, or the Lees Ferry recreational rainbow trout (*Oncorhynchus mykiss*) fishery. Non-native species have become an increasing threat due to changing conditions since completion of the CFMP and LTEMP. Existing measures identified in the CFMP and the LTEMP may be inadequate to address harmful non-native aquatic species.

Recent increases in the non-native green sunfish and brown trout in the Glen Canyon reach have prompted concerns about risks to humpback chub (*Gila cypha*) and razorback sucker (*Xyrauchen texanus*)

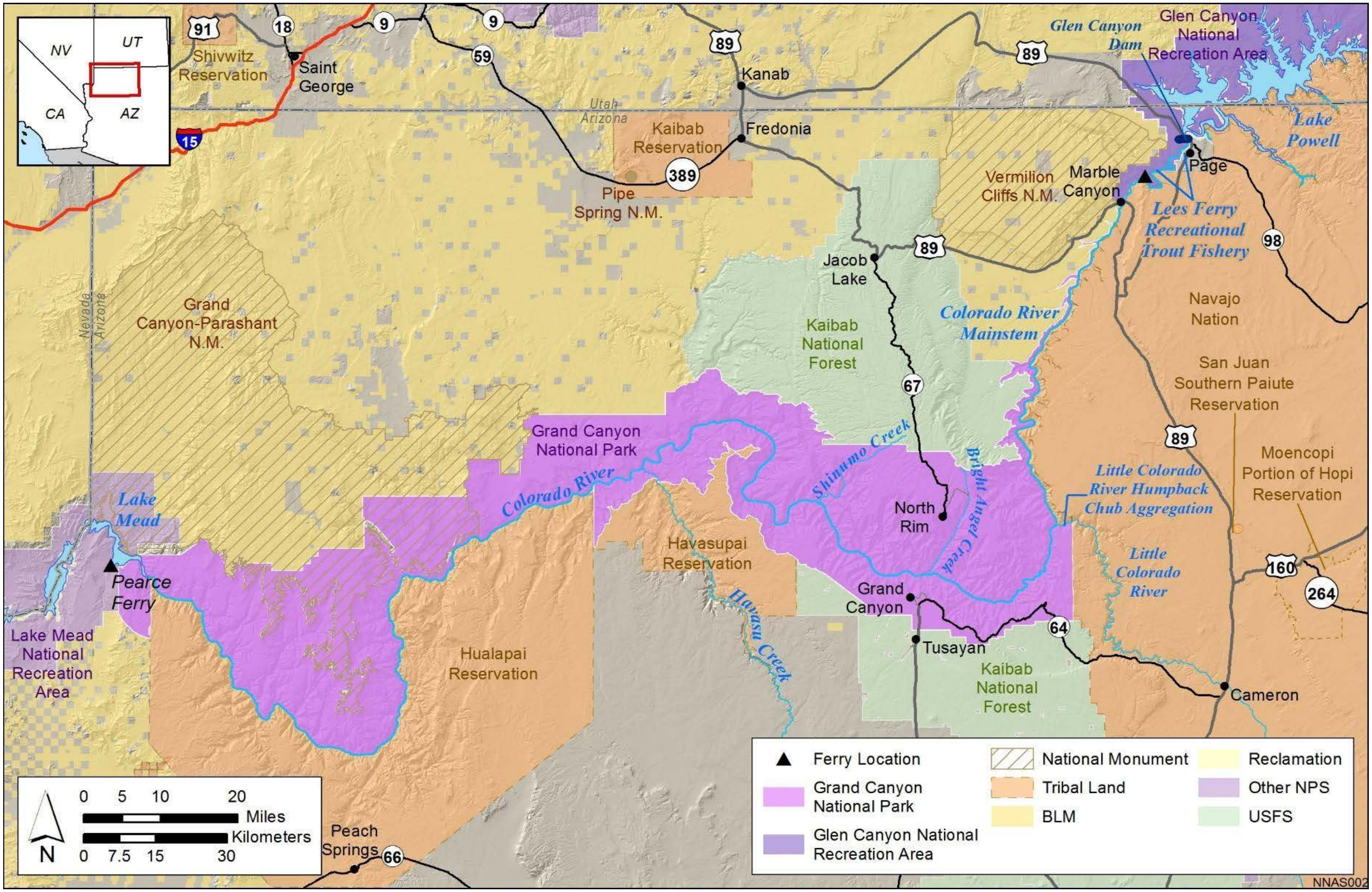

FIGURE 1-1 General Project Area for the Expanded Non-Native Aquatic Species Management Plan

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in downstream areas (Runge et al. 2018; Ward 2015). These two non-native fish species had been observed in small numbers, but have recently been reproducing in larger numbers in this reach. Both species have high predation rates on native fish (Yard et al. 2011; Runge et al. 2018; Marsh and Langhorst 1988; Whiting et al. 2014, Ward 2015), raising concerns that large populations of these species in the Glen Canyon reach could lead to large numbers of individuals migrating downstream where they could negatively impact the endangered humpback chub population. The challenges posed by these species have prompted the NPS to consider the need for additional tools and new approaches for controlling non-native aquatic species. In addition, the appearance and increase of these species suggests changes in the aquatic ecosystem are occurring that may lead to increases in other potentially harmful non-native species that also could threaten native and endangered fish or the rainbow trout fishery. This EA seeks to identify adaptive approaches to manage these threats as they appear over time.

1.3 IMPACT TOPICS CONSIDERED

1.3.1 Impact Topics Retained for Detailed Analysis

NPS determined which issues to analyze in the EA using scoping input from Cooperating Agencies, traditionally associated Tribes, other stakeholders, and the public. Based on that input, the following resources are analyzed in detail: aquatic resources, including aquatic habitats, non-native aquatic species, and native aquatic species; water quality, terrestrial resources, including wetland and riparian vegetation, and wildlife; cultural resources; Tribal resources and Indian Trust Assets and trust responsibility; socioeconomics and environmental justice; human health and safety; and recreation, visitor use, and experience, including wilderness.

1.3.2 Impact Topics Dismissed from Detailed Analysis

Impact topics dismissed include air quality, visual/scenic resources, paleontological and geological resources, and soils. Soundscapes were dismissed as a standalone topic, but sound impacts to wildlife and visitor use and experience were considered. Flow-based actions were addressed under the LTEMP EIS and the scope of this action did not include any changes to the LTEMP. Because water delivery and hydropower alterations were not considered as control actions in this EA, potential impacts of the Proposed Action on hydropower resources (e.g., electricity generation and hydropower value) were not carried forward to detailed analysis.

2 ALTERNATIVES

This EA evaluates two alternatives, the No-Action Alternative and the Proposed Action. Both alternatives would continue the implementation of existing NPS policies and programs, and, thus, include the tools identified in the CFMP Finding of No Significant Impacts (FONSI; NPS 2013b) and the LTEMP Record of Decision (ROD; 2016b) for managing potentially harmful non-native aquatic species in the Colorado River and its tributaries. Changes to the CFMP or LTEMP are outside the scope of this EA. Nothing in this EA would transfer, change, or interfere with the responsibilities of NPS or Reclamation under past biological opinions and programmatic agreements. Under both alternatives, the NPS and Arizona Game and Fish Department (AGFD) will continue to work cooperatively to manage fish and wildlife resources on NPS lands as articulated in the CFMP and the 2013 "*Master Memorandum of Understanding between United States Department of the Interior National Park Service Intermountain Regional Office and State of Arizona Game and Fish Commission*." Nothing in this EA would change anything in that relationship or any understanding of the jurisdiction or cooperation related to the fishery.

2.1 NO-ACTION ALTERNATIVE

The Council on Environmental Quality (CEQ) requires inclusion of an "alternative of no action" (Title 40, *Code of Federal Regulations*, Part 1502.14(d) [40 CFR 1502.14(d)]). For this EA, the No-

Action Alternative represents a situation in which the NPS would not add any additional tools to those currently available under existing decisions related to fishery management in GCNRA and GCNP. The No-Action Alternative continues the use of fishery management tools in the CFMP and LTEMP. LTEMP experimental actions would continue and be adaptively modified as specified in the LTEMP ROD (DOI 2016b). LTEMP actions related to non-native aquatic species control include (1) mechanical removal of brown and rainbow trout with beneficial use in the mainstem Colorado River near the confluence with the Little Colorado River; and (2) trout management flows. CFMP actions include: (1) rapid response to new non-native aquatic species using mechanical removal; (2) comprehensive brown trout control, including placement of a weir at the Bright Angel Creek confluence, incidental removal during monitoring, backpack electrofishing, and other mechanical removal with beneficial use; (3) targeted angling; and (4) removal of incidental captures (NPS 2013a).

NPS also has in place several measures that address prevention and containment of non-native aquatic species including requirements for concessionaire and staff boat washing, angler boot/wader wash stations at the Lees Ferry launch ramp, and signage and outreach to discourage movement of non-natives.

In GCNRA, prevention of introducing or spreading non-native aquatic species in the river involves regulations and public education. Regulations include prohibitions on the use of live bait, releasing plants or animals, and the transport of caught live fish, and requirements for regular cleaning of equipment. At Lees Ferry, signs and bulletin boards have been used to inform anglers that in using the river, they are being exposed to high-priority non-natives, including New Zealand mudsnails (*Potamopyrgus antipodarum*), quagga mussels (*Dreissena bugensis*), and whirling disease (*Myxobolus cerebralis*). Messaging includes steps for decontamination of equipment, boot-cleaning stations near the fish-cleaning station, and other strategic locations in the walk-in fishery near the Paria River mouth. Bulletins are posted at each angler access point, the dock, campground, and fish-cleaning/boot-cleaning station. Additionally, stand-alone signs are posted at each angler access point. Some non-native aquatic species educational messages are posted upstream of the park at river access points such as in Canyonlands National Park (NPS) and at Sand Island (Bureau of Land Management).

Generally, stream monitoring for non-native aquatic species in GCNRA is anecdotal, except for quagga mussels where several artificial substrates have been placed. GCNRA formed a quagga mussel interagency containment coordination working group with non-native aquatic species program staff from the states of Arizona and Utah in 2014. This group meets quarterly to share information and coordinate each agency's respective role and authority related to the management of quagga mussels at GCNRA both above and below the dam. A memorandum of understanding was signed between GCNRA, the Utah Department of Wildlife Resources (UDWR), and AGFD in 2018. Agency coordination to manage non-natives involves coordinating with neighboring land managers to support their non-native aquatic species management programs.

In GCNP, commercial boaters (concessioners) must comply with applicable state non-native aquatic species laws, available at http://www.azgfd.gov/. Further guidance is given in the Commercial Operating Requirements presented in the GCNP Colorado River Management Plan (NPS 2006a). Per Arizona state law, and NPS regulations, commercial boats are required to be decontaminated prior to launching for downstream travel from Lees Ferry but decontamination is not required for upstream travel. Boats used exclusively between Lees Ferry and Pearce Ferry have less stringent requirements than boats that may be used in other waters. Private boaters and upstream angling guides are encouraged to "Clean, Drain, and Dry" and make sure their boats do not harbor invasive species before launching. GCNP is expanding their education and public outreach via development and placement of signs at public access points (such as Diamond Creek), website development, interpretive talks, and other materials or practices that will be expanded to prevent accidental or purposeful introduction of new non-native aquatic species in the project area. Outreach efforts would also encourage harvest of all non-native fish species by anglers when appropriate (NPS 2013b). In addition, the park regularly presents information on non-native aquatic species prevention at the annual river guides training seminar. Monitoring also occurs below Lava Falls to

Pearce Ferry for small-bodied fish. Sampling is conducted using seines primarily for razorback sucker monitoring; however, small-bodied non-native species are also captured, identified, and recorded. This sampling is believed to serve as monitoring for initial detection of new non-native species. During this sampling, staff incidentally check for quagga and zebra mussels in the vicinity of Diamond Creek. This monitoring is co-led and funded by the Reclamation and NPS and sampling is led by contractors (Healy 2015).

2.2 PROPOSED ACTION

The Proposed Action includes all of the tools available under the No-Action Alternative plus additional non-native aquatic species management tools that could be used downstream of Glen Canyon Dam in GCNRA and in GCNP to achieve the purpose of and need for the Proposed Action (see Section 2.2.2). This alternative was originally generated through internal scoping and coordination with Cooperating Agencies. It was refined after public scoping based on comments from the public, and with additional input from Cooperating Agencies, representatives from Tribes, and Glen Canyon Dam Adaptive Management Program (GCDAMP) Technical Work Group (TWG) and Adaptive Management Work Group (AMWG) members. Refinements were also made based on assessments in a U.S. Geological Survey (USGS) report on the recent increases in brown trout in the Glen Canyon reach (Runge et al. 2018) and a Reclamation analysis of options for the river mile (RM) -12 sloughs (Greimann and Sixta 2018).

For the purposes of this Proposed Action, potentially harmful non-natives are defined as those fish, aquatic plants, or aquatic invertebrate species that are not native to the project area and that may pose a threat to native species (including federally or state-listed aquatic species), or may pose a threat to the Lees Ferry recreational rainbow trout fishery. The list of potentially harmful non-natives includes, but is not limited to brown trout, catfish species (Ictaluridae), bass and sunfish (Centrarchidae), striped bass (*Morone saxatilis*), cichlids (Cichlidae), perch and walleye (Percidae), new carp species (Cyprinidae), northern pike (*Esox lucius*), Asian clam (*Corbicula fluminea*), quagga mussel, didymo (*Didymosphenia geminata*),[1] Eurasian watermilfoil (*Myriophyllum spicatum*), hydrilla (*Hydrilla verticillata*), and other non-native aquatic species detected in GCNRA or GCNP.

Management of rainbow trout under this Proposed Action would be consistent with the CFMP and the LTEMP and their goal to maintain "a healthy high-quality recreational rainbow trout fishery in Glen Canyon National Recreation Area and reduce or eliminate downstream trout migration consistent with NPS fish management and Endangered Species Act compliance." Under the CFMP FONSI, non-native brown trout and rainbow trout within the boundaries of GCNP are managed to minimize their threat to native and endangered fish, by reductions or eradications, where possible (NPS 2013B). Under the LTEMP, trout management flows may be used to reduce rainbow or brown trout migration and downstream effects on endangered fish. The NPS and AGFD manage for a quality recreational rainbow trout fishery within the 15-mile Glen Canyon reach of GCNRA between Glen Canyon Dam and the Paria River (NPS 2013a, b; AGFD 2015).

The Proposed Action has been identified by the NPS as the preferred alternative in this EA. It was developed by the NPS based on collaboration with Cooperating Agencies and the USGS Grand Canyon Research and Monitoring Center (GCMRC), consultations with the Pueblo of Zuni and Hopi Tribes, public scoping input, a thorough review of scientific data and literature, modeling performed by Argonne National Laboratory, the USGS open file report on possible causes of and interventions to control brown trout increases in the Glen Canyon reach (Runge et al. 2018), and Reclamation's evaluation of options at the RM-12 sloughs (Greimann and Sixta 2018). The Proposed Action provides additional tools that are expected to provide better control of non-native aquatic species with little risk to other resources. The

[1] Didymo is a native diatom found throughout North America (Taylor and Bothwell 2014), but had not been found in the project area until recently and can have potentially harmful effects on the aquatic food base.

tiered and adaptive approach of the Proposed Action identifies safeguards for adjusting or stopping actions if unacceptable adverse impacts are observed or projected to occur.

2.2.1 Implementation Approach for the Proposed Action

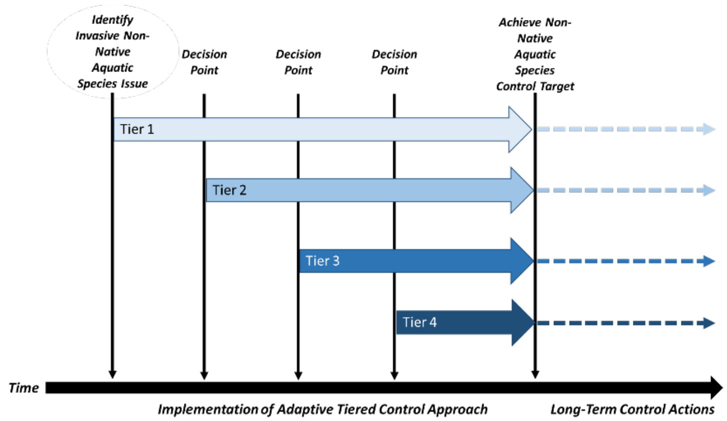

FIGURE 2-1. Conceptual Diagram of the Tiered Implementation Approach of the Proposed Action

Implementation of control actions under the Proposed Action would be sequenced using a tiered approach (Figure 2-1), considering the conditions and applications where actions are most appropriate and the risk or threat that potentially harmful non-native species pose to the aquatic ecosystem. Where possible, the actions include explicit on-triggers (population size or conditions that would result in implementation of an action) and off-triggers (population size or conditions that would result in the action stopping). The Proposed Action also includes monitoring for unintended and unacceptable adverse effects (see Appendix G), "off-ramps" that would be used to determine when control actions should stop permanently or until conditions change. Off-ramps are generally based on either the ineffectiveness or adverse effects of the control action. Mitigation would be applied if adverse impacts occur or are anticipated. Information gathered during monitoring would be used to adapt implementation approaches to improve effectiveness and minimize impacts on other resources such as the recreational rainbow trout fishery in the Glen Canyon reach or to address concerns from Tribes regarding the taking of life of non-native animals.

Tier 1 actions would be the first actions considered for implementation, and would use the least intensive management approaches. Tier 1 actions focus on non-lethal or beneficial use methods when possible for controlling or reducing harmful non-natives. They are intended to result in little alteration of habitat, and are generally lower cost than higher tier actions. Triggers (e.g., population size of potentially used to determine if a switch to higher tier actions is appropriate (see Section 2.2.2, Table 2-1). Triggers would be specific where possible, and based on the threat posed by the non-native species, the locations where the actions are being considered, and the size of the population to be controlled. In other situations, triggers may be more general, such as for rapid response to new non-native species, since the species may not be present in high numbers yet. Triggers may be reviewed at least annually and adjusted based on new information as needed. This review would include NPS communication with the GCMRC, U.S. Fish and Wildlife Service (FWS), Reclamation, AGFD, Tribes, and members of the TWG.

If lower tier actions are determined to be ineffective or triggers for implementation of higher tiers are reached, NPS would implement higher tier actions that may require more intensive management. Higher tier actions may be more effective in controlling non-native aquatic species, but rely more on lethal methods (with beneficial use when possible), have potentially greater effects on habitats or non-target organisms, and generally have higher costs in terms of labor, equipment needs, and operational expenses. When a higher tier is triggered, lower tiered actions may continue to be used (Figure 2-1). Several actions either within or among tiers may be used in combination to increase their effectiveness. Actions within the same tier level may be used separately or in combination depending on the situation. In some cases, conditions may change rapidly, and actions may be elevated through several tiers within the same season if triggers are reached. Some tiers may be skipped if actions or methods are not yet available or determined to be inappropriate for a particular control need.

The Proposed Action considers the risk or threat associated with potentially harmful non-native species as defined at the beginning of Section 2.2 and as listed in Appendix F, Table F-1. Threat levels were identified for a list of non-native aquatic species based on their potential for predation, competition, or other adverse interactions with native and federally listed species as well as to the recreational rainbow trout fishery. Threat levels were evaluated and assigned by NPS technical staff with input from GCMRC, Cooperating Agencies, and stakeholders, and were based on their current abundance and distribution, and published literature on their potential for adverse impact. Threat level assessments may change with new information, and would be reviewed annually and updated as needed. The annual review of threat levels would be coordinated with GCMRC, FWS, Reclamation, AGFD, Tribes, and TWG members.

The Proposed Action includes monitoring activities to detect new non-native species, determine if triggers are reached, determine the effectiveness of control actions, and determine if adverse effects to other resources occur that may require off-ramps or adaptations (see Appendix G). Most monitoring would be covered under existing compliance, however the Proposed Action may require additional monitoring to address trigger conditions and to monitor for unintended adverse impacts. Monitoring that may be performed more frequently or at additional locations on the river could include localized electrofishing, netting, trapping, and tagging (e.g., PIT tags or sonic tags; Zale et al. 2012, Bonar et al. 2009, Skalski et al. 2009). There could be additional administrative motorized or non-motorized river trips and helicopter flights associated with the logistics of certain management or monitoring actions in GCNRA and GCNP.

It is estimated that, under the Proposed Action, there may be up to 20 additional helicopter flight hours and 8 additional motorized boat trips per year in GCNP, and up to 12 additional motorized boat trips per year in GCNRA. When triggered in a year, mechanical removal in GCNRA could add 8 annual removal trips using two boats over a period of up to five days each.

2.2.2 Control Actions Under the Proposed Action

Control actions that could be applied under the Proposed Action, and their respective tiers, triggers, off-ramps, and mitigation actions are presented in Table 2-1 and described in the narrative below. Control actions are separated into the following five categories:

- Targeted harvest: changing harvest rates to increase removal of non-native aquatic species
- Physical controls: habitat modification or exclusion of specific areas less than 5 ac in size that are identified as source areas for harmful non-native aquatic species;
- Mechanical controls: physical removal of non-native aquatic species from habitats;
- Biological controls: introduction of organisms to control populations of non-native aquatic species;
- Chemical controls: limited application of chemicals to control populations of non-native aquatic species.

Each action is identified in Table 2-1 and in the narrative below using an alphanumeric designator that specifies the category of action (H, P, M, B, and C for the categories above) and its sequence of first appearance in Table 2-1.

Some actions would be considered for rapid response to a new threat. The CFMP allows for rapid response using mechanical removal in the project area, and the Proposed Action includes rapid response using chemical controls under certain conditions. Under the Proposed Action, a rapid response could be applied when a new non-native aquatic species is discovered that is potentially harmful. In this context, a “new” non-native aquatic species is one that previously was not observed in the project area or was only present in small numbers. See Appendix F, Table F-1 for a list of species that are currently considered candidates for rapid response. Rapid response actions could be applied for up to 3 years in sequence or up to 6 years if non-sequential application was necessary due to condition changes or abundance changes during the treatment period. National Environmental Policy Act (NEPA) compliance for non-native aquatic species control in the Little Colorado River confluence area (defined as from RM 56 to RM 66) is provided in the LTEMP Record of Decision and Biological Opinion. Reclamation is responsible for funding non-native fish control in this area.

Avoidance, minimization, and mitigation actions would be implemented under the Proposed Action to limit impacts on important resources (see Appendix C, Section C.4 for additional detail). These actions would be developed and modified adaptively as the Proposed Action is implemented. Prior to any action being conducted, the potential for impacting important resources, including special status and Endangered Species Act- (ESA; 16 USC 1531, as amended) listed species, cultural resources, resources of importance to Tribes, important recreation areas, and wilderness would be considered, and specific aspects of the action adjusted to avoid or minimize impacts. If considered necessary, surveys would be conducted for important resources prior to initiation of the action.

Beneficial use would be considered for all actions involving non-chemical lethal removal of fish from habitats (incentivized harvest, dewatering, placement of weirs and barriers, mechanical removal, sonic concussion, and tributary renovation) where nonlethal relocation is not feasible. Mechanical removal with salvage of non-native fish for beneficial use may be conducted prior to other actions (e.g., chemical control, sonic concussion) as a partial mitigation to the concerns of some Tribes regarding the taking of life (Section 3.6 for more detail on Tribal concerns). Beneficial use would be performed by placing collected non-native fish into coolers or freezers, and transporting them to Tribes for human consumption, to Tribal aviaries, or for distribution to others for human consumption.

Under the Proposed Action, some control actions would not be allowed in certain locations to minimize impacts on important resources. The Proposed Action does not include mechanical removal of rainbow trout in the Glen Canyon reach where NPS and AGFD are managing for a recreational rainbow trout fishery. However, under existing management practices, electrofishing may be used as a monitoring technique to inform decisions to improve the rainbow trout fishery. In addition, rainbow trout could be affected incidentally during actions targeting other species. Actions would be designed to minimize the incidental mortality of rainbow trout while still achieving objectives, and adaptive improvements would be considered to further minimize effects to rainbow trout.

There are some areas where NPS would not conduct electrofishing or chemical treatments under the Proposed Action because, based on past consultations, they are known areas of spiritual significance to Tribes (e.g., Ribbon Falls Creek and Deer Creek). Areas where cultural resource sites (e.g., the Spencer Steamboat) are known to occur would be avoided. Similarly specific avoidance measures would be taken for special status species including the Kanab ambersnail (*Oxyloma haydeni kanabensis*), California condor (*Gymnogyps californianus*), Mexican spotted owl (*Strix occidentalis lucida*), bald eagles (*Haliaeetus leucocephalus*), and golden eagles (*Aquila chrysaetos*).

Mitigation could be needed in areas of surface disturbance, and involve restoration of locations after the action is complete (Table 2-1). For instance, cofferdams, water control structures, weirs, or other physical barriers would be removed once no longer needed, and this would necessitate minor restoration activities such as regrading mechanically or by hand and placement of cobble to stabilize areas of disturbance. Mechanical disruption of early life stage habitats may require regrading of habitats to restore original contours.

2.2.2.1 Targeted Harvest Control

Incentivized Harvest (Action H1; Tier 1). Incentivized harvest would be used only in the Glen Canyon reach. Under this Tier 1 action, incentives would be provided to anglers to remove target non-native fish and encourage human consumption of the fish. Incentivized harvest could include

TABLE 2-1 Control Actions That Could Be Implemented under the Proposed Action

Action No.[a]	Actions, Triggers, Off-Ramps, and Mitigations[b]	Tier[c]	Target Non-Native Aquatic Species	Target Habitats
Glen Canyon National Recreation Area: Specific Actions for Brown Trout in Glen Canyon Reach				
H1[d]	Incentivized harvest methods which may include a combination of Tribal and volunteer guided fishing, tournaments, prize fish, restoration rewards for target fish harvested and removed, or similar tools to specifically remove and reduce numbers of brown trout from the Glen Canyon reach (timing and other methods may be used to restrict activities) Trigger: Presence Off-Ramp: Control action is ineffective in controlling brown trout, adequate funding is not available, or long-term unacceptable adverse effects on native fish, rainbow trout, or other important resources are expected or observed Mitigation: Cessation of activity	1	Brown trout	All
M1[d]	Mechanical disruption of early life stage habitats at specific spawning sites, including high-pressure water flushing and mechanical gravel displacement Trigger: Number of brown trout adults (>350 mm long) in Glen Canyon reach >5,000. If brown trout adults decrease to below 2,500, then mechanical disruption would cease until the population increases to the initiation trigger of 5,000 adults. Off-Ramp: Control action is ineffective in controlling brown trout, adequate funding is not available, or long-term unacceptable adverse effects on native fish, rainbow trout (including an unexpected severe reduction in rainbow trout spawning), or other important resources are expected or observed Mitigation: Cessation of activity, and restoration of affected habitats by regrading gravel substrates, if appropriate	2	Brown trout	Spawning areas only
M2[d]	Mechanical removal: Species selective electrofishing and trapping, with beneficial use, for long-term control (designed to maximize take of brown trout and minimize incidental take of rainbow trout) Trigger: LTEMP triggers for mechanical removal of trout at the Little Colorado River confluence have been exceeded and mechanical removal is being implemented there or has been proposed for the following year, AND Brown trout are a contributing proportion of the fish predators in the Little Colorado River area (e.g., 6 adult brown trout [≥350 mm] caught in the current or previous year in the Juvenile Chub Monitoring [JCM] reach [RM 63.5-65.2]),	3	Brown trout	All

Table 2-1 (Continued)

Action No.[a]	Actions, Triggers, Off-Ramps, and Mitigations[b]	Tier[c]	Target Non-Native Aquatic Species	Target Habitats
	AND Brown trout production in the Glen Canyon reach is an important contributor to the number of adults in the Little Colorado River reach (i.e., the number of adult brown trout in the Glen Canyon reach is > 5,000), OR LTEMP triggers for mechanical removal of trout in the Little Colorado River reach have not been met, but monitoring data and modeling indicate the number of adult brown trout is > 20,000 in the Glen Canyon reach, which using conservative modeling parameters indicates that the population of adult brown trout would reach 47 in the JCM reach, the threshold above which mechanical removal at the Little Colorado River confluence would be ineffective in controlling further increases. If mechanical removal has ceased at the Little Colorado River confluence and if brown trout adults in the Glen Canyon reach have decreased to below 10,000 then mechanical removal would cease until the initiation trigger of > 20,000 is reached again. Off-Ramp: Control action is ineffective in controlling brown trout, adequate funding is not available, or long-term unacceptable adverse effects on native fish, rainbow trout, or other important resources are expected or observed Mitigation: Cessation of activity			
B1	Introduction of YY male brown trout (may be considered if brood stock exists) Trigger: Experimental evidence and modeling indicate the action may be effective and other actions are shown or projected to be ineffective. Would be considered if the number of brown trout adults (≥350 mm long) is more than 500. Annual stocking would be limited initially to a maximum of 5,000 adult YY-male brown trout, or an equivalent number of juveniles (estimated to be 10,000 based on assumed juvenile survival rates). This number represents a conservative level of risk to humpback chub if survival, movement, and predation rates are at high-risk levels. This maximum number could be adjusted adaptively by ± 4,000 adults (or equivalent juveniles) based on additional modeling or data. If wild brown trout adults in the Glen Canyon reach decrease to below measurable levels for 3 years, then YY-male introduction would cease unless the population increases to above 500 adults. Off-Ramp: Control action is ineffective in controlling brown trout, adequate funding is not available, or long-term unacceptable adverse effects on native fish, rainbow trout, or other important resources are expected or observed Mitigation: Cessation of activity	Experimental (outside of tiers)	Brown trout	All

Table 2-1 (Continued)

Action No.[a]	Actions, Triggers, Off-Ramps, and Mitigations[b]	Tier[c]	Target Non-Native Aquatic Species	Target Habitats
Glen Canyon National Recreation Area: Specific Actions in RM -12 Sloughs in Glen Canyon Reach				
P1	Dewatering using high-volume portable pumps. Prior to dewatering, NPS would remove fish from target habitats, move native fish to the main channel, and explore non-lethal relocation of netted green sunfish to Lake Powell including obtaining state permits and sampling/laboratory analysis requirements to ensure only fish free of diseases, pathogens, and parasites are relocated. NPS would plan for beneficial use of all other fish. Trigger: If non-native fish are found during regular monitoring and after anytime flow is >23,000 ft^3/s [cfs]), exclusion screens would be replaced, then pump-out would be initiated within 3 weeks and the Upper Slough would be dewatered for a period between 2 days (pump to refill) to 2 weeks (naturally refills). Monitoring may lead to adaptation of time periods or triggers, especially if young fish or eggs are present. Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity, and restoration of affected habitats by refilling using pumps and screened water intakes within specified time period	1	Any harmful non-native aquatic species	RM -12 Upper Slough only
P2	Placement of selective weirs for specific time periods to disrupt spawning or new invasions Trigger: Presence Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Removal of weir with restoration of small areas disturbed during removal actions, if appropriate	1	Any harmful non-native aquatic species	Both RM -12 sloughs
P3	Placement of non-selective barriers to restrict non-native aquatic species access to tributaries, backwaters, and off-channel habitat areas, and to restrict out-migration Trigger: Presence Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Removal of barrier with restoration of small areas disturbed during removal actions, if appropriate	1	Any harmful non-native aquatic species	Both RM -12 sloughs
M2	Mechanical removal: Species selective electrofishing and trapping, (with either beneficial use or live transport/relocation if permitted), for long-term control Trigger: Presence	1	Any harmful non-native aquatic species	Both RM -12 sloughs

Table 2-1 (Continued)

Action No.[a]	Actions, Triggers, Off-Ramps, and Mitigations[b]	Tier[c]	Target Non-Native Aquatic Species	Target Habitats
	Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed. Mitigation: Cessation of activity			
M1	Mechanical disruption of early life stage habitats at specific spawning sites, including high-pressure water flushing and mechanical gravel displacement Trigger: Tier 1 actions are shown or projected to be ineffective and there is a threat of dispersal or increase Off-Ramp: Control action is ineffective in controlling non-native fish, if adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity, and restoration of affected habitats by regrading gravel substrates, if appropriate	2	Any harmful non-native aquatic species	RM -12 Lower Slough only
C1[e]	Overwhelm ecosystem-cycling capabilities of Upper Slough area (ammonia, oxygen, carbon dioxide, pH, etc.) Trigger: Tier 1 and 2 actions are shown or projected to be ineffective and there is a threat of dispersal or continued increase Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity	3	Any harmful non-native aquatic species	RM -12 Upper Slough and possibly Lower Slough
C2[f]	Rapid response application of registered piscicides for new invasive non-native fish that begin to reproduce in either slough Trigger: Tier 1 or 2 methods are shown or projected to be ineffective and there is a threat of dispersal or increase of new non-native aquatic species that is medium to very high risk Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity	3	Any new harmful non-native aquatic species rated medium to very high risk	Both RM -12 sloughs
P4	Dredging to connect Upper Slough to Lower Slough, facilitate installation of a water control structure, and allow complete draining of Upper Slough to remove all undesirable non-native aquatic species including green sunfish (Reclamation report Option 6.2; Greimann and Sixta 2018) Trigger: Tier 1, 2, or 3 actions are shown to be ineffective at eliminating non-native aquatic species in the Upper Slough Off-Ramp: One-time action without an off-ramp but subject to availability of funding	4	Any harmful non-native aquatic species	RM -12 Upper Slough only

Table 2-1 (Continued)

Action No.[a]	Actions, Triggers, Off-Ramps, and Mitigations[b]	Tier[c]	Target Non-Native Aquatic Species	Target Habitats
	Mitigation: Dredging may require a Clean Water Act Section 404 permit from the U.S. Army Corps of Engineers (USACE), and mitigation, if needed, would be stipulated in permit.			
M3	Sonic concussion devices used in backwater and off-channel habitat areas Trigger: Presence of medium to very high risk species Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity	4	Any harmful non-native aquatic species rated medium to very high risk	Both RM -12 sloughs
C3[e]	Application of registered piscicides for control of high and very high risk species Trigger: Tier 1, 2, and 3 actions are shown or projected to be ineffective and there is a threat of dispersal or increase Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observe. Mitigation: Cessation of activity	4	Any harmful non-native aquatic species rated high to very high risk	Lower Slough only due to inability to exclude or remove all fish
Glen Canyon National Recreation Area: Actions for All Other Areas in Glen Canyon Reach and All Other Non-Native Aquatic Species (Does Not Include Targeting Brown Trout or Actions at RM-12 Sloughs)				
H1	Incentivized harvest methods which may include a combination of Tribal and volunteer guided fishing, tournaments, prize fish, restoration rewards for target fish harvested and removed or similar actions to specifically remove fish from the Glen Canyon reach (timing and other methods may be used to restrict activities) Trigger: Presence or potential presence Off-Ramp: Control action is ineffective in controlling non-native aquatic species, adequate funding is not available, or long-term unacceptable adverse effects on native fish, rainbow trout, or other important resources are expected or observed Mitigation: Cessation of activity	1	Any harmful non-native aquatic species	All
P1	Dewatering off-channel ponds or small backwaters using high-volume portable pumps Trigger: Presence Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed	1	Any harmful non-native aquatic species	Small backwaters, off-channel ponds, and low velocity

Table 2-1 (Continued)

Action No.[a]	Actions, Triggers, Off-Ramps, and Mitigations[b]	Tier[c]	Target Non-Native Aquatic Species	Target Habitats
	Mitigation: Cessation of activity, and restoration of affected habitats by refilling using pumps and screened water intakes within specified time period			areas < 0.5 ac in size
P2	Placement of selective weirs for specific time periods to disrupt spawning or new invasions of tributaries, backwaters, and off-channel areas Trigger: Presence Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Removal of weir with restoration of small areas disturbed during removal actions, if appropriate	1	Any harmful non-native aquatic species	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size; tributaries
P3	Placement of non-selective barriers restricting non-native aquatic species access to tributaries, backwaters, and off-channel habitat areas and out-migration Trigger: Presence Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Removal of barrier with restoration of small areas disturbed during removal actions, if appropriate	1	Any harmful non-native aquatic species	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size; tributaries
M1	Mechanical disruption of early life stage habitats at specific spawning sites, including high-pressure water flushing and mechanical gravel displacement Trigger: Tier 1 methods are shown or projected to be ineffective and there is a threat of dispersal or increase Off-Ramp: Control action is ineffective in controlling non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity, and restoration of affected habitats by regrading gravel substrates, if appropriate	2	Any harmful non-native aquatic species	Identified spawning areas only
M2	Mechanical removal: Species selective electrofishing and trapping, (with either beneficial use or live transport/relocation if permitted), for long-term control (designed to minimize incidental take of rainbow trout) Trigger: Tier 1 methods are shown or projected to be ineffective and there is a threat of dispersal or increase Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity	2	Any harmful non-native aquatic species	Spawning and congregation areas only

Table 2-1 (Continued)

Action No.[a]	Actions, Triggers, Off-Ramps, and Mitigations[b]	Tier[c]	Target Non-Native Aquatic Species	Target Habitats
C1[e]	Overwhelm ecosystem-cycling capabilities of small backwaters and off-channel areas (ammonia, oxygen, carbon dioxide, pH, etc.) Trigger: Tier 1 and 2 methods are shown or projected to be ineffective and there is a threat of dispersal or increase Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity	3	Any harmful non-native aquatic species	Small backwaters, off-channel ponds, and low velocity areas < 0.5 ac in size
C2[f]	Rapid response application of piscicides for new invasive non-native fish (medium to very high risk) that begin to reproduce in very localized, and primarily backwater or off-channel areas Trigger: Tier 1 or 2 methods are shown or projected to be ineffective and there is a threat of dispersal or increase of new NNAS that is medium to very high risk Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity	3	Any new harmful non-native aquatic species rated medium to very high risk	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size
M3	Sonic concussion devices used in backwaters and off-channel habitat areas Trigger: Presence of medium to very high risk species Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity	4	Any harmful non-native aquatic species rated medium to very high risk	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size
C3[e]	Application of registered piscicides for control in backwaters and off-channel areas for high or very high risk species only Trigger: Tier 1, 2, and 3 actions are shown or projected to be ineffective and there is a threat of dispersal or increase for high to very high risk species only Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity	4	Any harmful non-native aquatic species rated high to very high risk	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size

Table 2-1 (Continued)

Action No.[a]	Actions, Triggers, Off-Ramps, and Mitigations[b]	Tier[c]	Target Non-Native Aquatic Species	Target Habitats
B1	Introduction of YY male green sunfish or YY males of other medium to very high risk species (may be considered if brood stock exists) Trigger: Experimental evidence and modeling indicates the action may be effective and if other actions are shown or projected to be ineffective for medium to very high-risk species Off-Ramp: Control action is ineffective in controlling non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish, rainbow trout, or other important resources are expected or observed Mitigation: Cessation of activity	Experimental (outside of tiers)	Any harmful non-native aquatic species rated medium to very high risk	All
Grand Canyon National Park: Actions Specific to Colorado River Mainstem and Tributaries				
P1	Dewatering off-channel ponds or backwaters using high-volume portable pumps Trigger: Presence Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity, and restoration of affected habitats by refilling using pumps and screened water intakes within specified time period	1	Any harmful non-native aquatic species	Small backwaters, off-channel ponds, and low velocity areas < 0.5 ac in size
P2	Placement of selective weirs to collect or restrict non-native aquatic species passage to tributaries, backwaters, and off-channel areas Trigger: Presence Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Removal of weir with restoration of small areas disturbed during removal actions, if appropriate	1	Any harmful non-native aquatic species	Small backwaters, off-channel ponds, and low velocity areas < 0.5 ac in size; tributaries
P3	Placement of non-selective barriers restricting non-native aquatic species access to tributaries, backwaters, and off-channel habitat areas and out-migration Trigger: Presence Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are observed Mitigation: Removal of barrier with restoration of small areas disturbed during removal actions, if appropriate	1	Any harmful non-native aquatic species	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size; tributaries
M2	Mechanical removal: Species selective electrofishing and trapping, with beneficial use where possible, for long-term control (live capture and relocation would not be logistically practical in this location),	1	Any harmful non-native	Small localized

Table 2-1 (Continued)

Action No.[a]	Actions, Triggers, Off-Ramps, and Mitigations[b]	Tier[c]	Target Non-Native Aquatic Species	Target Habitats
	Trigger: Presence Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity		aquatic species	spawning and congregation areas
M1	Mechanical disruption of early life stage habitats at specific spawning sites, including high-pressure water flushing and mechanical gravel displacement Trigger: Tier 1 methods are shown or projected to be ineffective and there is a threat of dispersal or increase Off-Ramp: Control action is ineffective in controlling non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity, and restoration of affected habitats by regrading gravel substrates, if appropriate	2	Any harmful non-native aquatic species	Spawning areas only
C4	Application of registered piscicides for fishery renovation of tributary streams with natural barriers (with mechanical removal and beneficial use in advance) Trigger: Tier 1 actions or CFMP actions (such as backpack electrofishing) are shown or projected to be ineffective. Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity	2:	Any harmful non-native aquatic species	Tributaries with natural barriers only
C1[e]	Overwhelm ecosystem-cycling capabilities of small backwaters and off-channel areas (ammonia, oxygen, carbon dioxide, pH etc.) Trigger: Tier 1 or 2 methods are shown or projected to be ineffective and there is a risk of dispersal or increase Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity	3	Any harmful non-native aquatic species	Small backwaters, off-channel ponds, and low velocity areas < 0.5 ac in size

Table 2-1 (Continued)

Action No.[a]	Actions, Triggers, Off-Ramps, and Mitigations[b]	Tier[c]	Target Non-Native Aquatic Species	Target Habitats
C2[f]	Rapid response application of piscicides for new invasive non-native aquatic species (medium to very high risk) that begin to reproduce in very localized, and primarily backwater or off-channel areas Trigger: Tier 1 or 2 methods are shown or projected to be ineffective and there is a risk of dispersal or increase of new non-native aquatic species that is medium to very high risk Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity	3	Any new harmful non-native aquatic species rated medium to very high risk	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size
M3	Sonic concussion devices used in backwater and off-channel habitat areas Trigger: Presence of medium to very high risk species Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity	4	Any harmful non-native aquatic species rated medium to very high risk	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size
C3[e]	Application of registered piscicides for long-term control in backwaters and off-channel areas for high or very high risk species only Trigger: Tier 1, 2, and 3 actions are shown or projected to be ineffective and there is a risk of dispersal or increase for high to very high risk species only Off-Ramp: Control action is ineffective in removing or controlling all non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity	4	Any harmful non-native aquatic species rated high to very high risk	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size
B1	Introduction of YY males of medium to very high risk species (may be considered if brood stock exists) Trigger: Experimental evidence and modeling indicates the action may be effective and if other actions are shown or projected to be ineffective for medium to very high-risk species. Off-Ramp: Control action is ineffective in controlling non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity	Experimental (outside of tiers)	Any harmful non-native aquatic species rated medium to very high risk	Tributaries only

Table 2-1 (Continued)

Action No.[a]	Actions, Triggers, Off-Ramps, and Mitigations[b]	Tier[c]	Target Non-Native Aquatic Species	Target Habitats
P5	Produce small scale temperature changes using a propane heater to adversely affect coldwater non-native fish Trigger: Presence Off-Ramp: Control action is ineffective in controlling non-native fish, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity	Experimental (outside of tiers)	Any harmful coldwater non-native aquatic species	Tributaries
Glen Canyon National Recreation Area and Grand Canyon National Park: Control Actions for Plants, Algae, and Mollusks				
M4	Mechanical harvesting of non-native aquatic plants and algae Trigger: Presence Off-Ramp: Control action is ineffective in controlling non-native plants, adequate funding is not available, or algae or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity, and restoration of affected habitats by regrading gravel substrates, if appropriate	1	Harmful non-native plants or algae	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size; tributaries
C5[e]	Application of herbicides and non-toxic dyes to backwaters and off-channel areas Trigger: Presence of high to very high risk aquatic plants or algae Off-Ramp: Control action is ineffective in controlling non-native plants or algae, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are observed Mitigation: Cessation of activity	1	Harmful non-native plants or algae with high to very high risk	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size; tributaries
C6	Application of mollusk repellents and non-toxic anti-fouling paints on boats, equipment used in the river, and NPS water intakes Trigger: Presence Off-Ramp: Control action is ineffective in controlling non-native mollusks, adequate funding is not available, or long-term unacceptable adverse effects on native fish or other important resources are expected or observed Mitigation: Cessation of activity	1	Harmful non-native mollusks	To be used only on boat hulls, equipment and water infrastructure.

Footnotes on next page

Table 2-1 (Continued)

[a] Actions are labelled with an alphanumeric designator. The initial letter indicates the control type (H= harvest, P=physical control, M=mechanical control, C=chemical control, B=biological control). Numbers are assigned in the order of first appearance within each category in the table.

[b] NPS may adjust triggers over time, and will review at least every 3 years.

[c] NPS is proposing an adaptive tiered approach to non-native aquatic species control. The first actions (Tier 1), would use the least intensive management approach. Tier 1 tools focus on non-lethal and beneficial use methods of controlling or reducing harmful non-natives, result in little alteration of habitat, and are generally lower cost. If lower tier actions are determined to be ineffective or population thresholds (triggers) are reached, NPS would implement higher tier actions that may require more intensive management. Higher tier actions may be more effective in controlling non-native aquatic species, but rely more on lethal methods with beneficial use when possible, have potentially greater effects on habitats or non-target organisms, and generally have higher costs. Several actions either within or among tiers may be used in combination to increase their effectiveness.

[d] NPS would plan to implement incentivized harvest for three winters prior to activating the triggers for other brown trout actions in this area. If triggered, other brown trout actions in the Glen Canyon reach would become available after October 31, 2021. If budget constraints, rapid and/or major changes in populations of brown trout or humpback chub, or other unexpected changes were identified, NPS would consult with AGFD and traditionally associated Tribes, communicate with the AWMG and TWG, and discuss if implementation of other actions are necessary sooner. As the action agency, NPS retains final decision–making authority.

[e] NPS would not implement this action in the same location for more than 5 consecutive years. If this action is not effective as a long-term solution when implemented over a 5-year period, NPS would pursue additional planning and compliance for any subsequent actions not included within this EA.

[f] A “new” non-native aquatic species is one that previously was not observed in the project area or was only present in small numbers.

(1) scheduled and funded guided angling trips for Tribal youth, members, or volunteers; (2) providing incentives for guides to increase the number of targeted fish harvested during fishing trips; (3) Restoration Rewards (i.e., monetary award paid to fishermen for catching and consuming targeted non-native fish and providing information on captured fish); and (4) awards for tagged target fish, and other tournament incentives during angling organization-sponsored events. Incentivized harvests might only be scheduled during periods when target fish are most susceptible to harvest to reduce administrative costs. NPS or partners may provide informational brochures that include mapped locations of prime areas to collect target fish, approved fishing techniques, and optimum angling time periods to further enhance the take of undesirable species. The administration and/or funding of these actions could be federal, state, or from a third party. Funding and administration of this program could change over time to increase efficiencies and to include new non-native aquatic species that are considered a medium to very high risk to the rainbow trout or endangered and native species downriver. NPS would plan to implement incentivized harvest for three winters prior to implementing other brown trout actions in the Glen Canyon reach. If triggered, other brown trout actions in the Glen Canyon reach would become available after October 31, 2021. If budget constraints, rapid and/or major changes in populations of brown trout or humpback chub, or other unexpected changes were identified, NPS would consult with AGFD and traditionally associated Tribes, communicate with the AWMG and TWG, and discuss if implementation of other actions are necessary sooner. As the action agency, NPS retains final decision–making authority.

2.2.2.2 Physical Controls[2]

Dewatering with Pumps (Action P1; Tier 1). Under this action, small off-channel ponds or backwaters would be dewatered to remove habitat for breeding non-native aquatic species and to remove all of the non-natives captured by mechanical removal, netting, or in the pump-filtration system. This Tier 1 action would be considered for use in small off-channel ponds and backwaters up to 0.5 ac in size. Use of one or more portable pumps with, for example, 3 in. to 4 in. discharge pipes capable of pumping up to 500 gallons per minute (gal/min) would be considered. Estimated time to drain a backwater would be 8 hr or less to reduce the effects of engine noise on wildlife and visitors and would not occur near sensitive areas (e.g., nesting raptors). If needed, the pumps would be used in conjunction with a temporary cofferdam in small backwater or off-channel areas connected to the river to quickly remove all of the non-native species. Water pumped from the target area would be discharged to an adjoining backwater or other low-velocity area prior to the water re-entering the river main channel. Drying time may need to be adjusted if recent egg laying has occurred to fully desiccate any eggs remaining in the pond sediments. A treatment using a minimal amount of soda ash or other naturally occurring chemical may also be used if a small volume of water cannot be completely removed due to inflows from springs or the river to raise the pH above species-specific tolerance thresholds and ensure that no live fish or eggs remain. Prior to dewatering, NPS would remove fish from target habitats, relocate native fish to the main channel, and, in GCNRA only, evaluate potential non-lethal relocation of netted green sunfish to Lake Powell. NPS would plan for beneficial use of all other fish. In GCNRA, relocation of green sunfish to Lake Powell could occur if the fish to be removed are tested and found to be free of diseases, pathogens, and parasites; and state fish transport permits can be obtained. See Appendix C, Section C.2.2 for additional detail on live removal and relocation.

Placement of Weirs or Barriers (Actions P2, P3; Tier 1). Selective weirs (Figure 2-2) may be put in place for specific time periods to disrupt spawning or restrict new invasions in backwaters and off-channel areas (< 5 ac in size), and tributaries. Selective weirs allow fish to be trapped and sorted. Weirs allow passage of water, but prevent fish movement. Fish are guided into a trap where they can be sorted

[2] If structures such as cofferdams, weirs, or barriers are placed within jurisdictional waters of the United States and below the ordinary high water mark, NPS would consult with the U.S. Army Corps of Engineers and would obtain necessary permits prior to installations

by biologists; target non-native fish may be removed (and beneficial use would be pursued with Tribes) while non-target fish are released back into the target area. Non-selective barriers, including but not limited to nets, metal fish screens, or temporary cofferdams may be used to restrict non-native aquatic species access to backwaters and off-channel habitat areas. Barriers may also be used to restrict out-migration in areas where successful non-native spawning or congregating has already occurred and is found during monitoring efforts. In some circumstances, fish may not be captured, but movement is restricted while other actions are implemented.

FIGURE 2-2. Example Weir at Bright Angel Creek to Intercept Spawning Non-Native Fish

Dredging to Connect the Upper Slough to the Lower Slough at RM -12 (Action P4; Tier 4). Under this Tier 4 action, a small drainage channel would be excavated between the Upper and Lower Sloughs (0.34 and 4.5 ac in size, respectively). Sediment from the cut channel would be placed on the large cobble bar adjacent to the Upper Slough. A prefabricated water-control headgate structure with flashboards would be placed and anchored between the two sloughs (Figure 2-3), and would allow for periodic, but complete, draining of the Upper Slough, act as a fish barrier, and allow the existing aquatic habitat in the Upper Slough to function once refilling occurs (Greimann and Sixta 2018). The intention of this action is the same as pumping to dewater (Action P1; Tier 1), i.e., to facilitate removal of undesirable non-native aquatic species, including green sunfish, from the Upper Slough. Draining would likely be necessary after the Upper Slough is overtopped by high flows (e.g., high-flow experiments [HFEs], balancing, or equalization flows), which may allow warmwater non-native species to recolonize and reproduce in the Upper Slough. Because this action would not include use of a pump filter as in Action P1, it would necessitate a screen system at the headgate outflow to prevent movement of young non-native fish into the Lower Slough and Colorado River as the slough was drained. Additional pumping would likely be needed to fully drain the Upper Slough.

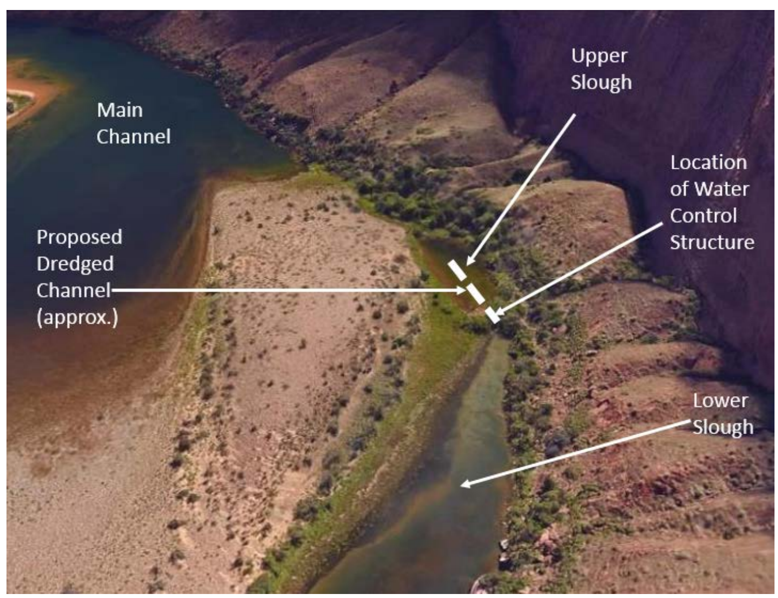

FIGURE 2-3. Aerial view of the Upper and Lower Sloughs at RM -12 Showing Proposed Location of Dredged Channel and Water Control Structure

This Tier 4 action would result in permanent habitat alteration, and would be used only if dewatering with pumps and Tier 2 and 3 actions are shown to be ineffective at controlling non-native aquatic species in the Upper Slough. Flows over approximately 21,000-23,000 cfs and up to 45,000 cfs may fill the small dredged channel with sediment or displace the headgate, thus, requiring periodic maintenance. Some mechanical removal would occur prior to draining to remove and relocate a majority of any non-target organisms present. Individuals of the target species would be collected previous to and during the treatment, where possible, for beneficial use to partially address Tribal concerns regarding the taking of life. Permitting through the U.S. Army Corps of Engineers (USACE) under Section 404 of the Clean Water Act may be required for dredging of the channel and installation of the water-control structure.

Produce Small Scale Temperature Changes to Adversely Affect Coldwater Non-Native Fish (Action P5; Experimental Outside of Tiers). This experimental action involves heating water using pool heaters or other methods to disadvantage coldwater non-native aquatic species (Hogg and Williams 1996; Canhoto et al. 2013). This action would be considered for application only in GCNP and only in headwaters of streams such as Bright Angel Creek or smaller tributaries. The action could be applied to streams where warmwater and coldwater non-native fish overlap in distribution, with the goal of excluding or disadvantaging non-native coldwater fish (mainly trout) by raising water temperature. An initial experiment would be conducted on a small tributary (i.e., less than 10 cfs) prior to scaling up to Bright Angel Creek or other similar-size stream (approx. 25 cfs baseflow). This initial experiment would take place in summer, when warm air temperatures would help meet heating targets, and would elevate the water temperature for several weeks in a treatment reach from approximately 15°C (based on summer water temperature in upper Bright Angel Creek) to at least 22°C, which may be a critical threshold for young-of-year (YOY) brown trout. A target of as high as 29°C, a lethal threshold for adult brown trout (>350 mm total length), would be the maximum attempted temperature target. Initial experiments would target heating a 1,500 ft (457 m) stream segment. Should this small-scale experiment prove successful at eliminating trout (without harming native fishes and aquatic invertebrates), and if heating a larger volume of water is deemed feasible, it could be expanded to treat larger tributaries.

2.2.2.3 Mechanical Controls

Mechanical Disruption of Early Life Stage Habitats (Action M1; Tier 2). This Tier 2 action would use ongoing and new technologies to limit the success of spawning of high to very high risk species in known or suspected spawning beds. Mechanical disruption of spawning beds in shallow areas may include use of high-pressure water flushing, vacuum devices, or other mechanical gravel displacement to disturb the eggs and force them into the water column where they would be subject to higher predation rates. If a vacuum or suction device was used, NPS would only retain the eggs collected, with all gravels returned to their original location since these gravel beds may also be important to rainbow trout. NPS would consult with the USACE to determine the need for Clean Water Act Section 404 permits for application of this method. For spawning beds found in deeper river areas or backwaters, measures that impede the development of eggs and larvae such as electrical grids, physical coverings (e.g., mats), or other measures that disrupted the amount of oxygen available to the eggs may be considered. Additional documentation of the risk posed by the target species, possible impacts of the proposed control action to non-target species, and Tribal consultations would occur prior to their selection and use. Additional details on the triggers to be used for this action are provided in Appendix C, Section C.1.1.

Mechanical Removal (Action M2; Tiers 1, 2, or 3). Mechanical removal, primarily through electrofishing and trapping, is a widely used fishery tool that is species-selective with low incidental mortality (Zale et al. 2012). Under the Proposed Action, both active and passive fish collection methods may be used including electrofishing, trapping, sweep netting (seines), and entanglement netting such as trammel or gill nets. Additional description of mechanical removal and the triggers to be used for this action are provided in Appendix C, Section C.2.1.

Electrofishing is used by biologists to monitor fish populations in freshwater (Guy et al. 2009; Curry et al. 2009). Electrofishing uses electricity to stun and catch fish. Biologists use this method to determine species composition, age distribution, and the presence of non-native species. This technique is regularly used by agencies to assess sportfish populations, native fish, and endangered fish. Most stunned fish can be returned to water unharmed after biologists acquire the information desired. (Bonar et al. 2009; O'Riordan 2007; American Sportfish 2016; FFWCC 2018). Biologists use either small backpack units, small-sled mounted units, or electrofishing boats or rafts. Each type uses either a battery or a generator to produce an electric field in the water between positive and negative electrodes. Biologists use long-handled nets to collect fish temporarily stunned by the electric current. When done properly, the electric field does not kill fish but temporarily stuns or impairs those that swim within the electric field. The fish can then be scooped up and handled with little stress or injury.

Electrofishing has been used regularly in the Colorado River and its tributaries in Grand Canyon for over 25 years. Electrofishing is a preferred method for capturing fish because the mortality rate is lower than other methods (typically < 1%; Ainslie et al. 1998), and target non-native fish can be removed without harm to other fish populations (Bonar et al. 2009, Zale et al. 2012). Other removal methods such as chemicals or netting can have more harmful effects and do not allow for safe return of non-target species to the river. Other methods are used in situations where electrofishing has limitations, such as in very deep-water habitats, or habitats with dense vegetation where fish can hide. Electrofishing is less effective on smaller fish (Saunders et al. 2011) or eggs than other control methods. The effects to non-target species, such as rainbow trout, can be reduced further by using equipment settings designed to minimize impacts to that species (Sharber et al. 1994).

Mechanical removal would be implemented as (1) a Tier 1 action in the RM -12 sloughs and in GCNP; (2) as a Tier 2 action for non-native fish other than brown trout in all other locations in GCNRA; and (3) as a Tier 3 action for brown trout in GCNRA. NPS would evaluate the potential for live relocation of fish captured in GCNRA. During discussions with AGFD and FWS, concerns were raised regarding the spread of disease or pathogens or unintended consequences of live relocation. Therefore, the NPS is currently considering only the relocation of green sunfish to Lake Powell because any green sunfish in GCNRA likely originated as escapees from Lake Powell. NPS would seek state permits for relocation including the testing of fish prior to release to ensure they are free of diseases, pathogens, and parasites. NPS may continue to explore this option to determine if other suitable sites for relocation can be identified. See Appendix C, Section C.2.2 for additional detail on live removal and relocation. For all mechanical removal actions where live relocation is not considered an option, beneficial use of removed fish would be pursued to partially address Tribal taking of life concerns.

Use of Sonic Concussion Devices (Action M3; Tier 4). This Tier 4 action could be used on medium to very high-threat species in backwater and off-channel habitat areas that are < 5 ac in size. This would be an experimental action as has been described in Gross et al. (2013), and would be implemented as a Tier 4 action. The equipment considered for this technique would be a pressure pulse cannon, or sonic cannon, which is not readily available commercially. Generally, the technique works by pulsing compressed gas (air) through the water column. This could be useful in smaller backwaters such as the Upper and Lower Sloughs at RM -12 to fully remove reproducing non-native aquatic species. It would be non-selective and could kill amphibians and non-target fish in the backwater. NPS would conduct mechanical removal prior to a treatment to remove and relocate as many of the non-target individuals as possible. Individuals of the target species would be collected pre- and post-treatment, where possible, for beneficial use to partially address Tribal taking of life concerns. No sonic concussive treatments would occur within 330 ft (100 m) of known locations of the endangered Kanab ambersnail.

Mechanical Harvesting of Non-Native Plants and Algae (Action M4; Tier 1). Various methods to physically remove emergent, rooted floating, submerged, and/or free floating non-native plants and algae may be used in backwaters and off-channel areas that are < 5 ac in size. These methods would include hand removal, rakes, hooks, hand tools, boat rakes, vacuums, underwater weed cutters, nets, shade coverings, covering mats, dyes, or other physical tools for removal. If a vacuum or suction device was used, NPS would consult with the USACE to determine the need for Section 404 permits. Where feasible, water drawdown and drying may be considered with refilling occurring once the target species are controlled. Some non-native aquatic plants and algae can become re-established from dislodged pieces so care must be taken to not allow dispersal of pieces and to remove the entire organism. Plants and algae that are removed would be disposed of either in compost piles on upland sites or in landfills. No mechanical harvesting of aquatic plants and algae would occur within 330 ft (100 m) of known locations of Kanab ambersnail.

2.2.2.4 Biological Controls

Introduction of YY-Male Fish (Action B1; Experimental Action Outside of Tiers). Introduction of YY-male fish is a new approach to non-native fish management that has been used experimentally on brook trout (*Salvelinus fontinalis*) in Idaho (Schill et al. 2017). This tool is intended to reduce or eliminate the population of non-native fish by skewing the sex ratio of the population toward almost all males. With this technique, males with two Y chromosomes are produced in hatcheries or fish farms from hormonally treated brood stock with techniques that have been used in commercial fish farms for many years. The second generation of untreated YY males are then stocked into the wild population. All of the offspring of wild females and YY males are normal XY males. Over a few generations, reproductive output in the population declines and nearly stops as the proportion of YY males increases relative to the proportion of XY males, and the number of females that are produced decreases (Schill et al. 2017). This control method is most effective when used in combination with removal of wild target adult fish to reduce the total number of reproducing fish (Schill et al 2017). In GCNRA, that removal would be accomplished with incentivized harvest occurring concurrently with the release of YY males. All stocked YY-male fish would be marked, and public education for which fish should be released (i.e., marked YY males) and which should be kept and consumed (unmarked females and XY males). In GCNP, mechanical removal may be used concurrently with a YY-male experiment. Immigration of wild females from other sources could delay the effectiveness of this method.

NPS is considering using this alternative for brown trout and green sunfish or other medium to very high-risk species if brood stock exists. Currently brood stock is expected to become available for brown trout and walleye in 5-8 years (Schill 2018) and green sunfish are currently being researched and could become available over the same time period (Bonar and Teal 2018).

Because this is an experimental method for which there may be a long delay (5 to 8 years) before stock becomes available, the latest scientific and field studies and any other new information regarding effectiveness and negative or unintended impacts would be reviewed prior to implementation. Additional planning and compliance may be considered if there was new information regarding potential impacts. Prior to implementation of this experiment, NPS would present any new information as well as details of the experimental implementation to relevant stakeholders and Tribes, through the AMWG and TWG, and seek consensus. The life expectancy of brown trout and other target species should be considered prior to selecting this tool because it works best on short-lived species. Brown trout are known to live 10 to 20 years in the wild.

2.2.2.5 Chemical Controls

Overwhelm Ecosystem Cycling Capabilities of Small Areas (Action C1; Tier 3). This Tier 3 action includes the possible use of ammonia, carbon dioxide, pH alteration, or oxygen super-saturation treatments and would be considered for small backwater and other off-channel areas (< 0.5 ac in size) where Tier 1 or 2 efforts have not been successful, periodic re-infestations and new spawning events continue to occur, use of Tier 3 and 4 tools like rotenone are a concern, and where environmental conditions are such that the use of these naturally occurring chemicals are expected to be successful in removing target non-native aquatic species. Prior to use, efforts would be made to remove a majority of the non-target species, especially natives, and to remove as many individuals of the target species so they could be relocated or provided for beneficial use. Use of approved methods to administer the chemicals and overwhelm the natural cycling or capacity of the small target area would be detailed in a treatment plan prepared prior to implementation. Depending on the amount of scientific literature on the treatment selected, the initial use of some of these tools may be conducted under research permits in conjunction with GCMRC staff or other scientists. Chemicals selected, efficacy whether in liquid or dry form, amounts used, application methods and timing, and monitoring would all be detailed in the treatment plan. A report on the results, including impacts on non-target species would also be made available to the TWG. NPS would consult with AGFD and other state agencies and seek state permits for implementation of this action as appropriate. NPS would not implement this action in the same location for more than five consecutive years. If this action is not effective as a long-term solution when implemented over a 5-year period, NPS would pursue additional planning and compliance for any subsequent actions not included within this EA. All chemical use would be subject to NPS approval processes in strict adherence to applicable regulations and guidelines.

Application of Piscicides (Actions C2, C3, C4; Tier 3, 4, and 2, respectively). There are three situations when piscicides (i.e., chemicals that kill fish) could be used: (1) rapid response to invasion or sudden expansion of new species in backwaters and off-channel areas < 5 ac in size (Action C2, Tier 3); (2) control of high and very high-risk species in backwaters and off-channel areas < 5 ac in size (Action C3, Tier 4); and (3) tributary renovation (Action C4, Tier 2). NPS would not implement Action C3 in the same location for more than five consecutive years. If this action is not effective as a long-term solution when implemented over a 5-year period, NPS would pursue additional planning and compliance for any subsequent actions not included within this EA.

Under these actions, only U.S. Environmental Protection Agency (EPA)-registered piscicides would be used. The only currently registered piscicides are rotenone and antimycin, but only rotenone is available commercially. If other chemicals become registered or available and have comparable or lower environmental effects, then they could be used under the compliance provided by this EA. If environmental effects of a newly registered piscicide differ substantively, additional compliance may be needed. All piscicide use would be subject to NPS approval processes in strict adherence to applicable regulations and guidelines. NPS would consult with AGFD and other state agencies and seek state permits for implementation of this action as appropriate.

The environmental effects of rotenone have been well studied and described (Finlayson et al. 2018). Chemical controls would not be used in the mainstem Colorado River; therefore effects would be limited to backwaters and off-channel areas where treatments are applied. Adverse effects on non-target organisms and areas would be further limited by the use of temporary barriers and neutralization methods. The process for application and monitoring of rotenone in small relatively isolated habitats were described and followed in the Green Sunfish Plan for the RM -12 sloughs in 2015 (Trammell et al. 2015). Implementation of chemical control under this action in backwaters and off-channel ponds would be similar to those used in 2015. Application would depend on target species, size of area to be treated, likelihood of success, and other considerations. For tributary renovation applications, efforts to salvage native fish for restocking, and non-native fish for beneficial use will take additional time and effort, including helicopter support, advance camps, generators to run equipment, backpack electrofishing, and several crews to apply, monitor, and neutralize the chemical. NPS would conduct mechanical removal with beneficial use (Action M2) prior to using chemical controls to partially address Tribal taking of life concerns.

Application of Herbicides (Action C5; Tier 1). Various registered herbicides may be used in backwater or off-channel areas < 5 ac in size to control highly invasive non-native aquatic plants and algae including weeds such as Eurasian watermilfoil, hydrilla, didymo, giant salvinia (*Salvinia molesta*), and Brazilian waterweed (*Egeria densa*). Non-toxic dyes may be used in combination with herbicide treatments to mark the areas treated. Chemicals would be used in compliance with NPS, federal, and state regulations, the manufacturer's label, safety data sheets, chemical transport and handling guidelines, and applicator certification requirements. The use of herbicides would be on a very limited basis and only when the threat was high for the targeted species to continue to spread and impact other critical aquatic habitat areas along the Colorado River. NPS would not implement this action in the same location for more than five consecutive years. If this action is not effective as a long-term solution when implemented over a 5-year period, NPS would pursue additional planning and compliance for any subsequent actions not included within this EA. All herbicide use would be subject to NPS approval processes in strict adherence to applicable regulations and guidelines.

Application of Mollusk Repellents and Non-Toxic Antifouling Paints (Action C6; Tier 1). Repellents and antifouling paints would be applied to the exterior of boats, equipment used in the river, and NPS water intakes to reduce the threats and impacts from non-native aquatic mussels such as quagga mussels and Asian clam. NPS will carefully consider the use of any of these treatments and will ensure that they have also been approved by the state of Arizona. Current repellent treatments include the use of hot pepper capsaicin in a wax-based application. Approved anti-fouling paints for boat and equipment surfaces that do not utilize copper derivatives, which are toxic to aquatic organisms, or other toxic additives will be considered as new options are developed. All use of repellent and anti-fouling paint would be subject to NPS approval processes in strict adherence to applicable regulations and guidelines.

2.2.3 Details of Tiers for Specific Locations and Species

The specific actions, tiers, and triggers to be used in four situations are discussed in this section. These situations include: 1) control of brown trout in the Glen Canyon reach; 2) control of non-native aquatic species in the RM -12 sloughs; 3) control of other species in other parts of Glen Canyon reach; and 4) control of non-native aquatic species in the Colorado River mainstem and tributaries through GCNP. Table 2-1 is organized according to these situations. See Section 2.2.1 for a description of the overall tiered implementation approach for the Proposed Action.

2.2.3.1 Control of Brown Trout in the Glen Canyon Reach

Control actions for brown trout in the Glen Canyon reach that are included under the Proposed Action are shown in Table 2-1. NPS would consult with and seek consensus with AGFD regarding the development and adaptation of triggers for these actions (see Appendix C, Sections C.1, C.2, and C.3 for additional details on triggers). At a minimum, NPS and AGFD would meet every 3 years to review triggers. This level of coordination is consistent with the 2013 Memorandum of Understanding between NPS and AGFD regarding cooperative management of the Lees Ferry fishery.

Incentivized harvest (Action H1) is the Tier 1 action for brown trout control in the Glen Canyon reach as described in Section 2.2.2.1. The goal of incentive harvest programs would be to remove 25% to 50% of adult brown trout ($\geq$350 mm) and some juveniles from the population each year. As discussed in Section 2.2.2.1, NPS would plan to implement incentivized harvest for three winters prior to implementing other brown trout actions in the Glen Canyon reach. If triggered, other brown trout actions in the Glen Canyon reach would become available after October 31, 2021.

Mechanical disruption of early life stage habitats at specific spawning sites (Action M1) is the Tier 2 action for brown trout control in the Glen Canyon reach as described in Section 2.2.2.3. Options for mechanical disruption include high-pressure water flushing and mechanical gravel displacement. Mechanical disruption for brown trout primarily would occur during spawning between November 1 and February 28 outside of the peak demand period for recreational fishing. This time period could be adjusted adaptively based on monitoring data or new research.

Mechanical removal (Action M2) is the Tier 3 action for long-term control of brown trout in the Glen Canyon reach as described in Section 2.2.2.3. This action would be designed to maximize take of brown trout and minimize incidental take of rainbow trout, and would be triggered using the criteria in Table 2-1. This action would be considered as a “last resort,” and conducted only if brown trout are threatening downstream humpback chub, either because they are already part of what is triggering mechanical removal downstream, or are projected (using modeling presented in Runge et al. 2018; Yackulic 2018a and 2018b, or subsequent models based on new information) to reach a population size in the Glen Canyon reach that would result in an immigration rate from the Glen Canyon reach that would not be controllable using mechanical removal at the Little Colorado River confluence. Mechanical removal may never be needed in the Glen Canyon reach if actions in lower tiers effectively control brown trout. The specifics of implementation would be similar to what was analyzed in Runge et al. (2018), as described in the next paragraph. Should conditions approach the brown trout mechanical removal trigger, NPS would consult with AGFD and seek consensus prior to initiating mechanical removal.

In the Glen Canyon reach, electrofishing for mechanical removal of brown trout could be applied throughout the reach when the specific triggers are met, or in specific locations known as, or suspected of being spawning locations for brown trout or other target species. Reach-wide electrofishing for brown trout would be implemented similarly to the rainbow trout fishery monitoring work conducted by AGFD (Rogowski et al. 2015a, 2017). Up to eight complete electrofishing passes of the Glen Canyon reach would be conducted primarily between November 1 and February 28. Each pass could take up to 5 days to complete. The number, and location, of electrofishing passes may be modified through adaptive management. During each pass, two electrofishing boats would be used to fish both shorelines. Additional boat and crew support may be needed to process fish. Rainbow trout would be released back into the river, although some handling will be required to identify fish and examine for tags to supplement other scientific studies. All, or most, brown trout would be removed, euthanized, examined for tags and other information, and kept in coolers for beneficial use. Some tagged brown trout may be released if needed to inform movement or abundance studies. Brown trout will not be moved live and transported to other waters due to the presence of whirling disease in Lees Ferry. Live transportation carries the risk of spreading whirling disease, which is harmful to other salmonids, including rainbow trout. Other non-native fish (excluding rainbow trout in the Glen Canyon reach, which would be released to the river, and green sunfish, which may be relocated to Lake Powell) would be removed opportunistically and kept for beneficial use.

The introduction of YY-male brown trout (Action B1) is an experimental action (outside of tiers) that may be considered in the Glen Canyon reach, as described in Section 2.2.2.4. The goal of this action is to reduce or eliminate the population of brown trout in this area over a period of 10-20 years. This action has not been field-tested on brown trout, and brood stock does not currently exist. Brown trout characteristics, including their predation rates, longevity, and migration rate need to be considered further prior to implementation because these factors may influence the effectiveness of the action. Brown trout YY-male brood stock may be available in the next 5-8 years (Schill 2018). Prior to implementation, NPS would review new modeling and field studies to determine if additional compliance was needed, and would consult with AGFD, GCMRC, FWS, Reclamation, Tribes, and relevant stakeholders, through the AMWG and TWG, to seek consensus. NPS retains decision-making authority as the action agency.

NPS proposes a trigger level of $\geq$ 500 adult brown trout (>350 mm) to begin stocking of YY-male brown trout in the Glen Canyon reach, and an initial annual stocking rate of 5,000 adult YY-male brown trout or 10,000 juveniles, which would, based on assumed juvenile survival rates, result in 5,000 adults after several years. Stocking at this rate would continue for 10 years concurrently with continued incentivized harvest. These proposed trigger levels and stocking rates were set to limit the potential for outmigration and impacts on humpback chub, taking into account a range of concurrent removal rates and mortality rates for the stocked fish. Based on additional modeling or data, the annual stocking level could be adjusted adaptively by ± 4,000 adults (or equivalent number of juveniles). To evaluate effectiveness, wild age-0 brown trout would be tested for the presence of DNA from the stocked YY males. See Appendix C, Section C.3 for additional information on stocking YY-male brown trout in the Glen Canyon reach.

2.2.3.2 Control of Harmful Non-Native Aquatic Species in RM -12 Sloughs in the Glen Canyon Reach

In the past several years, green sunfish, a warmwater species, has reproduced in the sloughs at RM -12 in the Glen Canyon reach. They are prolific and compete with and prey on native fish and amphibians (Fuller et al. 2018a). Reclamation assisted NPS with a technical evaluation of options to address the sloughs at RM -12 (Greimann and Sixta 2018). Two options from that report (Options 4 and 6.2) were incorporated into the Proposed Action (Actions P1 and P4, respectively). Actions to control non-native aquatic species in RM -12 sloughs under the Proposed Action are presented in Table 2-1.

Dewatering the Upper Slough periodically using high-volume portable pumps (Action P1) is one of the primary Tier 1 actions in the RM -12 sloughs as described in Section 2.2.2.2. The Upper Slough is a perched spring-fed pond above the elevation of the Lower Slough with refill rates of 3 to 8 gal/min). Prior to and during pumping, all non-target fish would be removed either with mechanical harvest or dip netting, and an attempt to collect and remove a majority of the target species would be made. Filters on pumps would collect any remaining target fish during the pumping. This method has advantages over other options because it is cost-effective, retains the spring-fed slough and related wetlands, and should be very effective for removing all targeted non-natives. To address Tribal concerns regarding the taking of life, NPS would attempt non-lethal removal and relocation of netted fish (only green sunfish transport and release to Lake Powell is currently being considered; see Section 2.2.2.3). If relocation were not possible, NPS would, to the extent possible, provide for beneficial use of removed fish (Section 2.2.2.3). Estimated refill times could be up to 2 weeks, which ensures that any eggs from spawning are dried out before the slough refills. It would also be possible to refill the slough more quickly by pumping water back into the slough from the river or Lower Slough should a concern or need arise to limit the impacts to the drained Upper Slough.

Other Tier 1 actions that may be used in the RM-12 sloughs include placement of selective weirs (Action P2) and non-selective barriers (Action P3) as well as mechanical removal with beneficial use or possibly live relocation (Action M2). Under Action P2 and P3, a weir or barrier screen, respectively, would be placed between the Upper and Lower Sloughs and a barrier or net may be placed within the Lower Slough. These would be used to prevent migration or dispersal of targeted non-native fish from the Upper Slough.

Tier 2 actions in the RM-12 sloughs include mechanical disruption of early life stage habitats at specific spawning sites (Action M1) and species selective electrofishing and trapping, with beneficial use, for long-term control as described in Section 2.2.2.3. These actions are most likely to be employed at the 4.5-ac Lower Slough, which is connected to the river at its downstream end and which experiences daily water level fluctuations of 2 to 4 ft. It also receives a small inflow of 3 to 5 gal/min (or more during monsoonal rains) of very warm water (>80ºF) from the Upper Slough. Native fish (primarily flannelmouth suckers, *Catostomus latipinnis*) and rainbow trout also use these sloughs, which are unique backwater habitats in GCNRA, and control actions must be carefully applied to minimize impacts on these non-target species. Currently the threat of walleye (*Sander vitreus*) and smallmouth bass (*Micropterus dolomieu*) finding suitable spawning habitat in this backwater area with a wide range of flows, substrates, and temperatures is an important concern. Mechanical removal would include beneficial use as described in Section 2.2.2.3.

Tier 3 actions in the RM-12 sloughs include overwhelming ecosystem cycling capabilities of the Upper Slough and possibly the much larger Lower Slough (Action C1) and rapid response application of registered piscicides for new invasive non-native fish that reproduce in either slough (Action C2) as described in Section 2.2.2.5 (Table 2-1). Action C2 would apply to any new harmful non-native aquatic species that is rated medium to very high risk, but would not apply to green sunfish in the Upper Slough, as they are no longer new in this area.

Tier 4 actions in the RM-12 sloughs include dredging to re-connect the Upper Slough to Lower Slough (Action P4), sonic concussion treatment (Action M3), and application of experimental or registered piscicides for long-term control of high and very high-risk species (Actions C1 and C3) as described in Sections 2.2.2.2, 2.2.2.3, and 2.2.2.5, respectively. Long-term chemical control would be considered one of the last resorts and would be applied in the Lower Slough only for control of high and very high-risk species if lower tier approaches failed. NPS would not implement Actions C1 or C3 in the same location for more than five consecutive years. If this action is not effective as a long-term solution when implemented over a 5-year period, NPS would pursue additional planning and compliance for any subsequent actions not included within this EA.

2.2.3.3 Control of Other Harmful Non-Native Aquatic Species in the Glen Canyon Reach

Actions that would be applied to non-native aquatic species other than brown trout that occur in the Glen Canyon reach outside of the RM -12 sloughs include most of the actions that could be applied to those sloughs (Table 2-1; Section 2.2.3.2). Due to the large size of the Colorado River, the daily and monthly fluctuations in that volume, and the management goal to maintain this reach as a rainbow trout fishery, some of the tools would have limited application in the main channel, but would be valuable in scattered small backwater and off-channel areas or concentration areas.

The use of incentivized harvest (Action H1; Tier 1) would be considered for non-native sport fish that begin to establish populations in the Glen Canyon reach as a result of reproduction in or migration to the reach. As for brown trout, incentivized harvest may be an important method for controlling population increases of walleye, smallmouth bass, or other large sport fish that would be of particular concern for the management of the rainbow trout fishery or downriver humpback chub populations.

The introduction of YY-male green sunfish or other medium to very high-risk species is included as an experimental action (Action B1) in GCNRA. Brood stock does not currently exist for green sunfish, walleye, smallmouth bass, or other species. Green sunfish have shorter life spans and may be particularly well-suited to control using this method if brood stock becomes available. NPS would consider this option if and when brood stock becomes available, and would follow the stocking approach and decision process described in Sections 2.2.2.4 and 2.2.3.1, respectively.

2.2.3.4 Control of Harmful Non-Native Aquatic Species in Grand Canyon National Park

Many of the actions described in Sections 2.2.3.1, 2.2.3.2, and 2.2.3.3 could also be used to control non-native aquatic species in GCNP. Mechanical removal actions at and in the vicinity of the confluence of the Colorado River and the Little Colorado River are allowed under the LTEMP ROD (DOI 2016b). In addition, as noted in Section 2.2.3.1, the CFMP allows for actions to address new source areas of brown trout within Marble and Grand Canyon.

Two actions that are unique to GCNP are:

- Small scale temperature changes using propane heaters to adversely affect coldwater non-native fish (Action P5) described in Section 2.2.2.2); and
- Application of piscicides for fishery renovation of tributary streams with natural barriers (Action C4), such as Shinumo Creek, or above “Split Rock Falls” in Bright Angel Creek. This action would be applied proactively for complete restoration of the native fish community (e.g., Shinumo Creek), which would be followed by reintroduction of native and/or endangered species. Any piscicide treatment would be preceded by mechanical salvage efforts using nets and/or electrofishing to remove as many fish as possible for beneficial use (non-native fish), and

for native fish, for release following neutralization of the piscicide. Piscicide use would be limited to situations where mechanical methods have been tried and have failed to eradicate non-native fish, or when literature or professional judgement indicates that those methods would fail.

The introduction of YY male brown trout may be included in tributaries in Grand Canyon as an experimental action (Action B1). A description of the YY male stocking approach is provided in Section 2.2.2.4.

3 AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

3.1 PROJECT AREA

The project area for this EA is identical to the one identified in the CFMP and includes all waters from the Glen Canyon Dam to Lake Mead, including the Colorado River and its tributaries (primarily Little Colorado River, Bright Angel, Shinumo and Havasu creeks) in GCNP, and the Glen Canyon reach of the Colorado and the Paria River in GCNRA (Figure 1-1).

A detailed description of resources in the project area is presented in the affected environment sections of the CFMP EA (NPS 2013a) and the LTEMP EIS (DOI 2016a), which are hereby incorporated by reference. As described in the LTEMP EIS (DOI 2016a), virtually all of the resources in the project area are associated with or dependent upon water and sediment. Glen Canyon Dam upstream of the project area collects and stores water for beneficial purposes, and, in the process, traps sediment and associated nutrients that previously traveled down the Colorado River. Regulated releases from Glen Canyon Dam and Lake Powell have resulted in an altered aquatic and terrestrial ecosystem compared to that which existed before Glen Canyon Dam. The LTEMP represents the most recent effort to identify operations at Glen Canyon Dam that would benefit downstream resources while providing for hydropower generation.

Summary descriptions of the affected environment and the environmental consequences of the No-Action Alternative and the Proposed Action are provided in resource-specific sections of this chapter.

3.2 WATER QUALITY

3.2.1 Water Quality—Affected Environment

Glen Canyon Dam and releases from Lake Powell affect water quality of the Colorado River in the project area. Water temperature in the Colorado River fluctuates annually reflecting seasonal variations in the temperature of Lake Powell at the penstock depth of Glen Canyon Dam (DOI 2016a). From 1973 to 2002, Glen Canyon Dam tailwater temperatures ranged from about 7 to 12°C (45 to 54°F) as measured at Lees Ferry (DOI 2016a). During the ongoing drought in the 2000s, Lake Powell levels generally declined and release temperatures began to warm, ranging from 8ºC to 16ºC (46ºF to 61ºF). Water temperatures increase slowly downstream from the dam, at a rate of about 1°C (1.8°F) for every 30 mi.; mean annual downstream river temperatures range from 9 to 18°C (48 to 64°F). Tributaries, backwaters, and off-channel areas tend to have higher temperatures than the Colorado River mainstem. Tributaries, especially the Paria River and Little Colorado River, carry large amounts of fine sediments and organic matter to the mainstem during flood events. The Little Colorado River contributes more salinity to the Colorado River than do other tributaries in the project area (DOI 2016a).

Turbidity of the Colorado River has been reduced by the presence of Glen Canyon Dam because it reduces the supply of river-borne sediment (DOI 2016a). Suspended sediment concentrations at Lees Ferry range from about 1 to 150 mg/L, compared to a pre-dam range from 1,450 to 6,140 mg/L. Suspended sediment concentration increases further downstream of the dam, and depends primarily on tributary runoff into the Colorado River.

Releases from Glen Canyon Dam and downstream Colorado River waters are relatively low in nutrients (DOI 2016a). Tributaries below the dam have somewhat higher nutrient contents than the mainstem, but contribute little to overall mainstem nutrient concentrations (DOI 2016a), at least during base-flow conditions. Dissolved oxygen (DO) concentrations at Lees Ferry typically range from a low of 6 mg/L in the fall (October–November) to a high between 9 and 11 mg/L in the spring (April–May), and increase further downstream because of aeration (Hall et al. 2012).

3.2.2 Water Quality—Environmental Consequences

3.2.2.1 Impacts of the No-Action Alternative on Water Quality

Under the No-Action Alternative, the proposed program of control actions would not occur, nor would associated water quality impacts; water quality would be unchanged from that described above in Section 3.2.1. The cumulative impacts of past, present, and reasonably foreseeable future actions on water quality have been significant and adverse (DOI 2016a; Appendix B, Table B-1). Past and present actions have reduced flow and resulted in alterations of water temperature and increases in salinity in the Colorado River. Climate change is expected to have the most significant effect on future changes in water temperature and quality. The No-Action Alternative would not contribute to cumulative impacts on water quality from past, present, and reasonably foreseeable future actions in the project area.

3.2.2.2 Impacts of the Proposed Action on Water Quality

Proposed control actions could affect water quality in several ways. Actions that involve sediment disturbance (mechanical disruption of spawning areas, Action M1; mechanical harvesting of plants and algae, Action M4), dredging (dredging to reconnect the Upper and Lower Sloughs, Action P4), or excavating (placement of weirs or barriers, Actions P2 and P3) would produce localized turbidity plumes in the immediate area and downstream of the actions. Such plumes would be episodic, localized, and occur during the action itself and potentially continuing for a few days afterward, and would not increase overall turbidity conditions in receiving waters, some of which are normally quite turbid especially in downstream areas and during HFEs.

Warming the water to >29ºC (84ºF) for coldwater species control in tributaries (Action P5) would produce temperature increases in treated areas (up to a 1,500-ft-long stream segment), but the effect is likely to be limited to that segment and decrease in a downstream direction due to dilution. No effect in areas upstream of treatment areas would be expected, and any residual warmer water entering the main channel Colorado River would be quickly dispersed.

Application of chemical controls, including use of piscicides (Actions C2 and C3), herbicides (Action C5), other chemical treatments (Action C1), and mollusk repellants on boats and other surfaces (Action C6) has the potential to affect water quality outside of application areas if these chemicals are transported through flow or diffusion out of the target treatment area. Piscicides, such as antimycin and rotenone, would be applied in strict adherence to applicable regulations and guidelines, including: NPS approval processes, AGFD's Piscicide Treatment Planning and Procedures Manual (AGFD 2012), and FWS's Rotenone SOP Manual (Finlayson et al. 2018), which would limit or eliminate the potential for effects outside of the target treatment area, and any incidental lethal or sublethal effects on non-target aquatic species and habitats. In addition, use of piscicides would require an approved Arizona Pollutant Discharge Elimination Discharge System permit under the Clean Water Act as administered by the state of Arizona. Following these regulations and guidelines would minimize downstream effects of piscicide applications by assuring that appropriate treatment quantities are used and treatments are confined to target areas. In streams and rivers, AGFD requires the oxidation of rotenone in outflows with potassium permanganate ($KMnO_4$) (AGFD 2012).

Rotenone in liquid formulations contains 90-95% of "inert" ingredients. For example, the commercial formulation Legumine™ contains 5% rotenone, 5% other associated resins, and 90% inert ingredients. Inert ingredients typically include N-methylpyrrolidone, acetone, naphthalene, and ethyl-, dimethyl-, and trimethyl benzenes (aromatic petroleum solvent) or other chemicals, which act as surfactants and cosolvents to aid dissolution in water and uptake of rotenone by fish. SERA (2008) reviewed the potential toxicity of inerts in rotenone formulations and found that studies, including those from the EPA, indicated that none of the inerts in rotenone formulations posed significant risks compared to that of rotenone itself.

Rotenone has a hydrolysis half-life in pH 7 water of 3.2 days (SERA 2008). Sunlight photolysis further hastens degradation. A typical application of a commercial formulation of 5% rotenone involves from a few to over 30 gal total, for example, in two treatments of a small 0.4 ac slough containing 0.67 ac-ft of water to achieve a rotenone concentration of 1-4 ppm (Trammell et al.2015). Permanganate added to neutralize rotenone can be toxic to fish and must be carefully controlled during application (Trammell et al. 2015). Crews would monitor rotenone deactivation effectiveness, for example using sentinel fish in live-cages placed downstream, while balancing permanganate application to the minimum required and monitoring permanganate residues to minimize collateral toxicity (Finlayson et al. 2018). Manganese, toxic to humans at high concentrations, when added to background concentrations from such treatments, would produce levels below human health concern (SERA 2008, Trammell et al.2015).

Aquatic and terrestrial application of herbicides would likewise be subject to strict guidelines and controls to protect aquatic species and water quality, including NPS approval processes in strict adherence with applicable regulations and guidelines. Herbicide formulations include inerts, surfactants, and adjuvants, which would be released to water bodies in aquatic applications. Neither the active herbicide nor these additives would have adverse effects on non-target organisms or water quality when used as directed by the manufacturer, and with strict adherence to applicable regulations and guidelines.

Mollusk repellents for use on boats and equipment used in the river contain capsaicin, an irritant and the hot spice found in chili peppers, incorporated in a wax base, which minimizes its release into water and the potential for impacts on non-target organisms. EPA notes in its pesticide reregistration summary for capsaicin that the agency relies on restrictive product label statements to minimize exposures and reduce any risks to aquatic species (EPA 1992). In addition, only non-toxic anti-fouling paints that do not contain copper and are approved for use in Arizona would be used for mollusk control. All use of repellent and anti-fouling paint would be subject to NPS approval processes in strict adherence to applicable regulations and guidelines.

Chemical treatments to overwhelm natural cycling processes in small backwaters and off-channel areas for control of non-native aquatic species, by their nature, would temporarily affect the water quality of the treated waters. Such treatments would purposely change water quality parameter values outside of their natural range to create conditions unsuitable to targeted aquatic life. Treatments could include altering pH using ammonia or carbon dioxide, or super-saturation of water with oxygen. Such treatments would require confined water bodies to reach desired conditions, and thus would have limited potential for effects outside of the target area. Any treated water moving downstream would quickly dilute to within natural levels and thus would have very short range and temporary effects likely resulting in the avoidance of the area by mobile species, and no or very low incidental mortality in non-target species. Reversing treatments and natural attenuation would quickly return affected areaas to natural conditions.

The cumulative impacts of past, present, and reasonably foreseeable future actions on water quality have been significant and adverse (DOI 2016a; Appendix B, Table B-1). Past and present actions have reduced flow and resulted in alterations of water temperature and increases in salinity in the Colorado River. Climate change is expected to have the most significant effect on future changes in water temperature and quality. The Proposed Action would result in incremental changes to water quality (mostly turbidity and some contaminants) that would be limited to the areas where control actions would occur. Interaction and accumulation of adverse impacts on water quality from multiple control actions would be limited because (1) most individual actions and their effects would persist for less than a week,

(2) most actions would occur in small (< 5 ac) habitats that are isolated from the main channel and each other, and (3) tiered implementation of actions would reduce the potential for different actions to occur simultaneously at specific locations. No change in baseline water quality conditions are expected.

3.3 AQUATIC RESOURCES

3.3.1 Aquatic Resources—Affected Environment

This section describes key aquatic habitats and biological resources in the project area that could be affected by control measures being considered under the Proposed Action. More detailed descriptions of the aquatic ecosystems within Glen Canyon, Marble Canyon and Grand Canyon, including habitat types, the aquatic food base, native fishes (including endangered and other special status species), and non-native fishes, are provided in Appendix E and also in the LTEMP EIS (DOI 2016a).

3.3.1.1 Aquatic Habitats

The control options included in the Proposed Action identify specific types of aquatic habitats for which they would be applicable. Differences in the physical (e.g., depth, substrate composition, water velocity, turbidity, and temperature) and chemical (e.g., dissolved oxygen and nutrient levels) and biological characteristics of various habitats can affect the ability to implement specific control measures, the types and life stages of aquatic species that are present, and the potential impacts from implementing control options. The categories of habitat types associated with the various control options include main channel, backwaters and sloughs, off-channel ponds, and tributaries. These habitat types are distributed throughout the project area and are primarily affected by daily, seasonal, and annual flow regimes that mobilize and deposit sediments that form and maintain the structure of these habitats and that affect water conditions (e.g., temperature, turbidity). Even though specific locations, spatial extent and conditions of these aquatic habitat features may vary from year to year in response to flow regimes the long-term availability of these features is likely to be maintained. For example, even though there was large temporal variability in the area and numbers of backwaters within Marble and Grand Canyons over the period from 1935 to 2000, there was no evidence for a progressive increase or decrease in the availability of backwater habitats (Goeking et al. 2003).

Main channel habitats include mid-channel habitats such as pools, runs, riffles, and rapids, as well as the shallow, lower velocity channel margins located along the edges of the main channel. Backwaters and sloughs are low-velocity habitats associated with sandbars or shoreline features that have limited connection to main channel areas. Off-channel ponds are small, bodies of water that within the floodplain, but not directly connected to the mainstem Colorado River; they are maintained by input from springs or seeps or by periodic inputs from the mainstem during high flows. Tributaries are smaller streams or rivers that flow into the Colorado River within the project area. Larger tributaries (e.g., the Little Colorado River and Paria River) can contribute significantly to flows during some periods of the year and can have notable effects on water condition in portions of the Colorado River downstream from Glen Canyon Dam (Section 3.2.1). Smaller tributaries within the project area (e.g., Bright Angel Creek, Shinumo Creek, Deer Creek, Tapeats Creek, Kanab Creek, and Havasu Creek) generally have little influence on water conditions in the main channel (Section 3.2.1), but do offer a range of habitat conditions that may attract or benefit non-native aquatic species. Maintaining a diversity of habitat types is important for maintaining the biodiversity of aquatic species within the Colorado River ecosystem.

3.3.1.2 Aquatic Food Base

Aquatic invertebrates, algae, rooted plants, and organic matter serve as the aquatic food base for fishes in the Colorado River ecosystem (Gloss et al. 2005). Although most of this food base is produced within the aquatic system, terrestrial inputs of organic matter (e.g., leaf litter) and terrestrial invertebrates also contribute. The composition and abundance of the aquatic food base in the mainstem are primarily driven by effects of the presence and operation of Glen Canyon Dam on flow patterns, temperature regimes, sediment transport and deposition, turbidity, and nutrient concentrations (DOI 2016a; Hall et al. 2015; Sabo et al. 2018). The diversity of aquatic macroinvertebrates in the Glen Canyon reach is low and dominated by non-native species (Kennedy et al. 2013). Compared to other western rivers, the structure of the food web in Glen Canyon is simple and energy transfer from the base (e.g., algae and diatoms) to the top of the web (e.g., rainbow trout) is relatively inefficient (Kennedy et al. 2013). In Grand Canyon, the food web is more complex than in Glen Canyon (Kennedy et al. 2013). Additional details regarding controlling factors, distribution, and abundance of the aquatic food base within the project area are provided in Appendix E and the LTEMP EIS (DOI 2016a).

Non-native algae and aquatic plants known to occur or with a potential to be present in the project area are identified in Appendix F, Table F-1. Didymo, an invasive alga, and curly-leaf pondweed (*Potamogeton crispus*), an invasive aquatic plant, which are native to the United States, but not to the Colorado River, have been observed in the project area. These species are believed to pose a medium level of threat to the aquatic ecosystem in the project area because they can compete with native aquatic plants, cause fish die-offs, clog waterways, and inhibit recreational activities (Appendix F). Invasive non-native aquatic invertebrate species that are known to occur within the project area include the northern crayfish (*Orconectes virilis*) (Trammell 2015), the New Zealand mudsnail (Benson et al. 2018a), and the quagga mussel (Benson et al. 2018b). These species are believed to pose low to medium levels of threat, due to their potential to alter ecosystem conditions, compete with native aquatic species, or affect operation of infrastructure and recreational opportunities (Appendix F).

3.3.1.3 Native Fish and Special Status Fish Species

There are currently 8 species of native fish that occur, may occur, or historically have occurred within the project area (Table 3-1). Five of these species, the humpback chub, razorback sucker, bluehead sucker (*Catostomus discobolus*), flannelmouth sucker, and speckled dace (*Rhinichthys osculus*), are currently present within the mainstem and its tributaries in the project area. The remaining three species, bonytail chub (*G. elegans*), roundtail chub (*G. robusta*), and Colorado pikeminnow (*Ptychocheilus lucius*), have been extirpated from the mainstem between Glen Canyon Dam and Hoover Dam.

Four of the native fish species within the project area have special federal and/or state status designations. Two species of native fish that are listed under the ESA, the humpback chub and the razorback sucker, occur in the project area (Table 3-1). These two species are also designated as Arizona Species of Greatest Conservation Need (AZ-SGCN), along with the bluehead sucker (Table 3-1).

Introductions of non-native fish species also have affected native fish in the Colorado River and its tributaries. Brown trout in the Glen Canyon reach have increased from 2014–2016 raising concerns regarding potential impacts on native fish, especially humpback chub near the Little Colorado River (Runge et al. 2018). Details regarding the status, biology, and threats to the native fish community in the project area are provided in Appendix E and the LTEMP EIS (DOI 2016a).

3.3.1.4 Non-Native Fish

NPS policy is to restore ecosystems and manage for native species with complete suppression or eradication of non-native species where possible. Non-native species have been introduced into the Glen Canyon, Marble Canyon, and Grand Canyon and tributaries, and 22 species occur in the project area. Threats posed by these species based on their potential for competition and predation with native species have been evaluated and ranked from low to very high (Appendix F, Table F-1). Higher risk species require more intensive management to support native species conservation. Of the fish species currently known to occur within the project area, seven species (brown trout, green sunfish, smallmouth bass, largemouth bass [*Micropterus salmoides*], northern pike, striped bass, and walleye) are believed to pose a

TABLE 3-1 Native Fish of the Colorado River through Glen, Marble, and Grand Canyons

Species	Listing Status[a]	Presence in Vicinity of Project Area[b]
Humpback chub (*Gila cypha*)	ESA-E, CH; AZ-SGCN	Lake Powell, Paria River confluence to Separation Canyon, Little Colorado River, Havasu Creek, Bright Angel Creek
Bonytail chub (*Gila elegans*)	ESA-E; AZ-SGCN	Lake Powell; extirpated from the Grand Canyon
Razorback sucker (*Xyrauchen texanus*)	ESA-E, CH; AZ-SGCN	Lake Powell; Lake Mead upstream to Lava Falls
Colorado pikeminnow (*Ptychocheilus lucius)*	ESA-E; AZ-SGCN	Lake Powell; extirpated from the Grand Canyon.
Roundtail chub (*Gila robusta*)	NL	May have occurred historically; extirpated from the Grand Canyon
Bluehead sucker (*Catostomus discobolus*)	AZ-SGCN	Paria River to Lake Mead, including tributaries
Flannelmouth sucker (*Catostomus latipinnis*)	NL	Lake Powell to Lake Mead
Speckled dace (*Rhinichthys osculus*)	NL	Glen Canyon Dam to Lake Mead, including tributaries

[a] ESA = Endangered Species Act; E = listed as endangered; CH = federally designated critical habitat in project area; AZ-SGCN = Arizona Species of Greatest Conservation Need; NL = not listed.

[b] Habitat and life history information is presented in species-specific discussions in this section.

Sources: 56 FR 54957; AGFD (2001a,b; 2002a,b; 2003); Andersen (2009); Bezzerides and Bestgen (2002); Coggins and Walters (2009); Francis et al. (2017); Makinster et al. (2010); Ptacek et al. (2005); Rees et al. (2005); Rinne and Magana (2002); FWS (2002); Ward and Persons (2006); Woodbury (1959); Gloss and Coggins (2005); GCMRC (2014); Albrecht et al. (2014); Kegerries et al. (2017).

medium-high to very high level of threat and seven species (black bullhead [*Ameiurus melas*], black crappie [*Pomoxis nigromaculatus*], bluegill [*Lepomis macrochirus*], common carp [*Cyprinus carpio*], channel catfish [*Ictalurus punctatus*], yellow bullhead [*Ameiurus natalis*], and red shiner [*Cyprinella lutrensis*]) pose a medium-low to medium level of threat to native aquatic species. Rainbow trout pose a low level of threat in the Glen Canyon reach, where they are managed to support a recreational trout fishery, but are considered to pose a high-level of threat in Grand Canyon National Park where the emphasis is on native fish conservation (Table F-1).

Brown and rainbow trout make up the salmonid coldwater non-native fish community of the Colorado River in the project area. The rainbow trout is very common in the reach of the mainstem Colorado from Glen Canyon Dam to the Paria River, and this population serves as the principal basis for the recreational trout fishery (Makinster et al. 2010; Reclamation 2011). Rainbow trout are relatively abundant in Marble Canyon between the Paria River and the confluence of the Colorado River (Makinster et al. 2010; Reclamation 2011). Downstream of the Little Colorado River confluence, fewer are found, and these are associated with tributaries, including Bright Angel Creek, Shinumo Creek, Deer Creek, Tapeats Creek, Kanab Creek, and Havasu Creek (Reclamation 2011). One of the challenges of fishery management in the Colorado River downstream of Glen Canyon Dam is to effectively manage the rainbow trout population in the Glen Canyon reach to maintain the highly valued recreational rainbow trout fishery while controlling potential impacts on native fish, especially humpback chub, in reaches further downstream.

Until recently, brown trout in the project area were found primarily in and near Bright Angel Creek, which supports a spawning population (Reclamation 2011); recent control efforts have reduced their abundance (Healy et al. 2018). However, there have been notable increases in brown trout recruitment in the Glen Canyon reach since 2014 (Runge et al. 2018). Brown trout were observed to be spawning near the RM -4 gravel bar in the Glen Canyon reach during the fall of 2014 and 2015 and there has been a subsequent increase in age-1 brown trout in that reach (Runge et al. 2018). It is unclear if flow operations, including recent fall HFEs, and/or upstream migration of adult brown trout (i.e., individuals >350 mm total length) are driving the increase in brown trout in recent years (Runge et al. 2018).

The principal concern related to the presence of rainbow trout and brown trout is the potential for them to move downstream from the Glen Canyon reach to areas where they can affect native fish, especially the population of humpback chub in the vicinity of the Little Colorado River, through predation and competition. Even though the abundance of brown trout in Glen Canyon and near the Little Colorado River confluence is small relative to rainbow trout, observations and laboratory studies suggest that an individual brown trout could consume up to 17 times more native fish than an individual rainbow trout (Yard et al. 2011; Ward and Morten-Starner 2015). In addition, adult brown trout may move more than adult rainbow trout (Runge et al. 2018), and juvenile brown trout could also emigrate downstream towards the Little Colorado River at different, potentially higher, rates than juvenile rainbow trout. For this reason, the Proposed Action includes control actions to specifically address threats from brown trout.

Surveys of the project area indicate the presence of 17 non-native warmwater fish species in the project area (Trammell and Valdez 2003; Ackerman et al. 2006; Makinster et al. 2010; Coggins et al. 2011; Albrecht et al. 2014). Of those species, the common carp, fathead minnow (*Pimephales promelas*), and red shiner are generally the most common warmwater species in the mainstem and tributaries (Rogers and Makinster 2006; Ward and Rogers 2006; Ackerman et al. 2006; Makinster et al. 2010; Coggins et al. 2011). Some warmwater non-native species, such as fathead minnow, red shiner, plains killifish, and bullhead, are primarily found in tributaries (especially in the Little Colorado River), backwaters, and off-channel ponds, but may also occur in the mainstem below the Little Colorado River confluence (Johnstone and Lauretta 2007).

Warmwater non-native species have been collected in low numbers and only sporadically in the Glen Canyon reach; species collected include the common carp, channel catfish, and fathead minnow (Johnstone and Lauretta 2007; Ackerman 2008). Other species collected from this reach include green sunfish, smallmouth bass, striped bass, redside shiner (*Richardsonius balteatus*), golden shiner (*Notemigonus crysoleucas*), and walleye (FWS 2008). During July 2015, a reproducing population of green sunfish was discovered in a slough at RM -12, approximately 3 mi downstream of Glen Canyon Dam. Green sunfish are known to be prolific and are predators of small native fish and native fish eggs and larvae (Ward 2015). The AGFD, NPS, USGS, FWS, and Reclamation have determined that green sunfish pose a threat to native fish, including the humpback chub, and the Proposed Action includes control actions to specifically address threats from this species and other non-native aquatic species in the RM -12 sloughs.

Additional details regarding the non-native fish community in the project area are provided in Appendix E and the LTEMP EIS (DOI 2016a).

3.3.2 Aquatic Resources—Environmental Consequences

3.3.2.1 Impacts of the No-Action Alternative on Aquatic Resources

Under the No-Action Alternative, the NPS would not add any additional tools to those currently available under existing decisions related to fishery management in GCNRA and GCNP. Under the No-Action Alternative, it is anticipated that there will be increases in the abundance and distribution of some non-native aquatic species that are already present within the project area, as well as establishment of new non-native aquatic species. Without the ability to readily implement additional control options when needed, it is expected that some of these non-native species may increase to levels that could adversely affect the Glen, Marble, and Grand Canyon ecosystems by competing with and preying upon native aquatic species.

A number of non-native fish species already pose a medium-high to very high level of threat to the aquatic ecosystem within the project area, including brown trout, rainbow trout (in GCNP), green sunfish, smallmouth bass, and walleye (Appendix F, Table F-1). Actions that can be implemented under the LTEMP are expected to provide protections for native fish in downstream areas from rainbow trout, while maintaining the established rainbow trout recreational fishery in the Glen Canyon reach.

Population estimates based on catch-per-unit effort and mark-recapture data indicated that approximately 6,000 brown trout over 350 mm in length were present in the Glen Canyon reach in 2017 (Runge et al. 2018). Modeling conducted by Runge et al. (2018) suggests that, under the No-Action Alternative (status quo), there would be a 64% likelihood that the abundance of brown trout within the Glen Canyon reach would increase by 3 to 10 times and could reach 80,000 adults (mean of 16,000) over the next 20 years. Modeling indicated that the minimum adult humpback chub population could decrease considerably as the abundance of brown trout in the Glen Canyon reach increases. Modeling showed impacts on the humpback chub population at the Little Colorado River when there were as few as 5,000 adult brown trout, and that impacts would increase as the brown trout population increases. Modeling also indicated a sustained population of more than 25,000 adult brown trout (i.e., brown trout >350 mm total length) in the Glen Canyon reach has the potential to eliminate humpback chub from the mainstem at the confluence with the Little Colorado River (Runge et al. 2018). Although there is a considerable amount of uncertainty in the modeling assumptions and correspondingly high variability in the results, it was estimated that the median minimum adult humpback chub abundance would be reduced to approximately 4,000 fish over the next 20 years if current management actions continue (Runge et al. 2018). The most recent comprehensive population estimate for humpback chub indicated that there were approximately 11,000 adult humpback chub in the Little Colorado River population in 2012 (Yackulic et al. 2014; FWS 2017). Decreases in the modeled value for minimum adult humpback chub population indicate a potential for reducing the population viability of humpback chub.

Other non-native species such as green sunfish, smallmouth bass, and walleye, pose a threat to downstream natives, and the endangered humpback chub. Smallmouth bass and walleye, as aggressive predators, are a threat to both native fish and the rainbow trout fishery (AGFD 2009; Fuller et al. 2018b; NPS and FWS 2014). The No-Action Alternative provides limited tools for addressing these species and does not include incentivized harvest or mechanical removal actions in Glen Canyon or chemical control options in any portions of the project area. Increase and spread in the distribution of these species could lead to declines in native and endangered fish downstream and negative impacts to the recreational rainbow trout fishery.

Cumulative Impacts of the No-Action Alternative

Significant, mostly adverse cumulative impacts on aquatic resources in the project area primarily result from changes in seasonal and annual flow patterns. Past, present, and reasonably foreseeable future actions and trends have or are expected to produce increased water demand (resulting from population growth and development); decreased water supply (resulting from drought and increased water temperature attributed to climate change); and other foreseeable actions (DOI 2016a; see Appendix B, Table B-1). Decreases in runoff, reservoir volume, and river flow caused by drought and increased demand would result in lower reservoir elevations and warmer release temperatures, which could benefit native aquatic species, but also make conditions more favorable for warmwater non-native aquatic species that prey on or compete with native species. The contributions of the CFMP and LTEMP on cumulative impacts to aquatic resources are evaluated in NPS (2013a) and DOI (2016a), respectively, and are summarized in Appendix B (Table B-1). Overall, it is anticipated that there will be unaddressed increases in the abundance and distribution of some non-native aquatic species under the No-Action Alternative, resulting in negative impacts on native aquatic species within the project area.

3.3.2.2 Impacts of the Proposed Action on Aquatic Resources

Under the Proposed Action, fishery management tools adopted under the CFMP FONSI (NPS 2013b) and LTEMP ROD (DOI 2016b) would continue; the impacts of actions in the CFMP and LTEMP on aquatic resources are evaluated in NPS (2013a) and DOI (2016a), respectively. This section presents analyses of potential impacts on aquatic resources associated with each of the control actions included in the Proposed Action and summarizes the overall impacts of the Proposed Action on aquatic resources based on the impacts on physical habitat and water quality, the potential for reducing targeted non-native aquatic species, and the potential for benefitting or adversely affecting native aquatic species and rainbow trout in the Glen Canyon reach. All control measures under the Proposed Action would provide some level of suppression of non-native aquatic species. Many of the control measures would primarily address non-native species in habitats outside of the main channel Colorado River, such as tributaries, backwaters, and off-channel ponds, because it is more cost-effective and has less impact to control organisms in such habitats than to address organisms that are widely dispersed in a large riverine system. Some of the control actions, particularly incentivized harvest, mechanical removal (electrofishing) of brown trout in the Glen Canyon reach, and experimental stocking of YY-male fish to minimize reproductive success, would undertake larger-scale and potentially longer-term control actions to maximize system-wide control. The impacts of individual actions and cumulative impacts are described below. A summary presentation is provided in Appendix A, Table A-1 and Appendix B, Table B-1)

Incentivized Harvest (Action H1; Tier 1)

Incentivized harvest is intended to increase angling activities and removal for targeted species. If the incentives resulted primarily in existing anglers shifting focus to targeting some species (e.g., a shift from rainbow trout to brown trout), impacts of angling on aquatic habitats would not change compared to existing conditions under the No-Action Alternative because the numbers of anglers would not change. Alternatively, if the incentives increase the overall number of anglers within the targeted reaches, it is expected that there would be increased foot traffic (including wading) and boat traffic in the Glen Canyon reach. Although water quality would not be noticeably affected by increasing the number of anglers, increased traffic could result in an increased level of habitat disturbance, especially on terrestrial habitats along river margins. The effects of physical impacts to aquatic resources would be expected to be negligible compared to the no-action condition because changes are likely to be within the range of conditions observed during annual peak flow and base flow cycles that mobilize and deposit sediments disturbed by anglers.

It is anticipated that brown trout would be the initial focus of any incentives to increase angler harvest. Other high-risk species within specific areas, including walleye and smallmouth bass, could also be targeted. There are currently no harvest limits on brown trout in the project area. However, a large proportion of the anglers practice catch and release for both rainbow and brown trout. Incentives, such as those identified as part of this control option would likely encourage some proportion of catch-and-release anglers to retain brown trout for consumption or other beneficial use. In addition, the number of anglers targeting brown trout could increase if new anglers decide to participate as a result of incentives. It is believed that as the incentives increase, angler participation would also increase, although the nature of the relationship between incentive magnitude and angler participation is not known.

Runge et al (2018) modeled the potential for incentivized harvest to affect brown trout populations in the Glen Canyon reach by assuming a quarterly mortality rate equivalent to 15% of the angler catch rate for trout in the Glen Canyon reach. At this level of estimated removal, the median brown trout abundance over a 20-year period was reduced by about 50% compared to a status quo scenario and was estimated to be nearly as effective as concentrated mechanical removal.

The potential for benefits to native aquatic species due to implementation of incentivized harvest awards and programs would ultimately depend on its effectiveness for suppressing populations of non-native fishes. There is evidence that reducing the abundance of non-native species from specific habitat areas can result in improvements in survival and recruitment of native fishes (Healy et al. 2018). Runge et al. (2018) modeled the potential for incentivized harvest of brown trout in the Glen Canyon reach to affect humpback chub populations in downstream reaches and concluded that incentivized harvest of brown trout could slightly increase the median minimum abundance of adult humpback chub compared to the status quo (i.e., no additional brown trout control, similar to the No-Action Alternative). Based on modeling, Runge et al. (2018) also concluded that increasing removal of brown trout through incentivized harvest would have only small effects on the median abundance of rainbow trout compared to the status quo condition. Overall, using incentivized harvest to remove brown trout would have negligible effects on the population of rainbow trout or the condition of the rainbow trout fishery in Glen Canyon.

Dewatering with Pumps (Action P1; Tier 1)

Under this action, a small number of off-channel ponds and backwaters throughout the project area, each up to 0.5 acre in size, could be affected by dewatering during specific years. After dewatering most small ponds and backwaters are expected to refill naturally over a period of 10 to 30 days from seepage through the substrate, input from natural springs, reconnection to the main channel during daily high flows, or by pumping water from the main channel. Even if this control option was applied to multiple ponds or backwaters within a given year, the total amount of habitat disturbed within a specific year would be small (e.g., less than 5 acres if applied at 10 locations) relative to the amount of similar habitat available in the project area.

Initially, it is expected that this action would be applied to control non-native fishes, primarily green sunfish, in the RM -12 sloughs in the Glen Canyon reach, but it could also be used to control other non-native species (including, fishes, amphibians, or invertebrates) in other locations throughout the project area. The NPS would conduct surveys to evaluate the types, sizes, and abundance of species present in the targeted habitat and, if practical, would arrange removal and beneficial uses of non-native species prior to completely dewatering the target area. As long as the pump capacity can outpace refilling from water infiltration, it is anticipated that this action would be highly effective for eliminating non-native aquatic species from the targeted habitat for one or more seasons. For many backwaters or ponds, it is anticipated that water conditions would return to pre-treatment conditions within a few days or weeks after refilling from springs or subsurface water infiltration. For areas with no spring or subsurface water input, refilling would be delayed until the next occurrence of mainstem flows that overtop the features separating the backwater or pond from the main channel, probably within a year or less (depending on the elevation of separation features) after dewatering; aquatic habitat conditions would not be restored until refilling occurs resulting in temporary location-specific reductions in the abundance of native aquatic species. Alternatively, aquatic habitat could be restored quickly after the dewatering treatment has been completed by refilling with water pumped from the main channel. The dewatering treatment may need to be repeated in subsequent years if there is reinvasion by non-native species that pose an unacceptable risk to native aquatic species, potentially resulting in additive effects on the target area over multiple years depending on recovery times and intervals between treatments,

The Upper Slough at RM -12 has an estimated volume of 120,000 gal when full (Greimann and Sixta 2018). As an example, it would be possible to remove this volume of water from the slough in about 4 hr using 3 3-in. portable pumps, each with a nominal pumping rate of 300 gal/min and running at 50% efficiency. Refilling of the Upper Slough by spring inflow (estimated at 3 to 8 gal/min; Hyde 2018) would require approximately 10 to 30 days. Based on this, it is anticipated that application of the control action at the RM -12 sloughs would result in a lack of aquatic habitat in the Upper Slough for a period of a few days to one month.

Overall, it is anticipated that implementing the control action would benefit native aquatic species by eliminating or controlling expansion of a non-native species that could threaten populations of native aquatic species within the project area. However, there is a potential for dewatering to also kill a small number of individuals of native species, including special-status species such as humpback chub, or rainbow trout that may be present in treated backwaters or ponds. Mortality would be greatly reduced if individuals of native species could be removed if detected during pre-treatment surveys and either relocated to nearby aquatic habitats or returned to the treated location after refilling. Mortality of the small number of rainbow trout potentially affected by the control action would not have a measurable effect on the rainbow trout population or the trout fishery in the Glen Canyon reach.

Placement of Weirs or Barriers (Actions P2, P3; Tier 1)

This control action could be used at any suitable tributary, backwater, or pond habitat within the project area, including the RM -12 sloughs, when the presence of high-risk non-native aquatic species are detected. Installation of weirs and barriers would result in a small amount of habitat disturbance on the adjacent shoreline and streambed and some increase in turbidity during the installation process. In most cases, structures would be in place for one or more seasons and then be removed, although structures for supporting some weirs may be designed to remain in place for many years. If appropriate, disturbed habitat locations would be restored when barriers are removed. The amount of habitat disturbed by the installation or footprint of weirs or other barriers would be small and is expected to be no more than a few hundred square feet. Impacts to native species from changes in physical habitat conditions or water quality (Section 3.2.2) would likely be temporary during the installation process, which could last up to 5 days.

It is anticipated that this action would be effective for reducing the abundance of non-native aquatic species from the targeted habitat. For example, the weir at Bright Angel Creek (Section 2.2.2.2; Figure 2-2) that was operated in conjunction with mechanical removal (electrofishing) in other portions of the creek resulted in an overall reduction in salmonid abundance of 67% over the 2012-2017 period (Healy et al. 2018). Barriers would be removed or use would be discontinued if they were found to be ineffective at capturing or controlling movement of targeted non-native species.

Overall, it is anticipated that the use of weirs and other barriers would benefit native aquatic species by facilitating elimination or controlling expansion of non-native species that could threaten populations of native aquatic species within the project area. Barriers used to prevent ingress of non-native fishes into specific habitat areas could enhance survival and recruitment of native fishes in tributaries, backwaters, and shoreline ponds by reducing predation and competition. Removal of non-native fishes in Bright Angel Creek during 2012-2017 sufficiently suppressed trout numbers to allow for enhanced recruitment of native fishes (Healy et al. 2018). Carpenter and Terrell (2005) reviewed 49 projects that combined the use of long-term barriers and other activities to renovate native fish communities. Of those projects, they found that in nearly 39%, non-native fishes reinvaded the restored areas in less than 3 years, while 35% were effective at keeping native fish populations free of non-natives for 10 years or more. However, there is also a potential for weirs and barriers to restrict movement of native fish species, including special-status species such as humpback chub. For some species, blocking movement could prevent access to spawning or nursery areas. For weirs that are associated with fish traps, such as the weir used at Bright Angel Creek (Healy et al. 2018), there would be little potential for incidental mortality of native species because most individuals would be released on the other side of the weir while non-native fishes would be removed. For barriers that are only used for short periods (e.g., for a few hours while seining or electrofishing in backwaters) the effect of movement restrictions on native fishes would be negligible. Because the numbers of rainbow trout potentially affected by this control action would represent only a very small proportion of the overall trout population in the Glen Canyon reach, there would be no measurable effect on recruitment or other population parameters, and there should be no measurable change in the catchability of rainbow trout in this area.

Dredging to Connect the Upper Slough to the Lower Slough at RM -12 (Action P4; Tier 4)

This option is a more permanent alteration of the Upper Slough compared to periodic dewatering using pumps. Reclamation estimated that 200 yd^3 of gravel and cobble substrate would need to be excavated to create a connecting channel approximately 3 ft wide and 300 ft long (Option 6.2 in Greimann and Sixta 2018). In addition, there would be a potential for habitat disturbance from barging equipment, fuel, and personnel to and from the area from the nearest landing. Dredging would result in the disturbance of substrate supporting benthic habitats and increased turbidity in the immediate project area during the dredging period, which is expected to take up to two weeks. Recovery following completion of the action is expected to occur rapidly (within 10 to 30 days), and the composition of the substrate after completion of dredging would remain similar to pre-dredging conditions. Algae and benthic organisms displaced during dredging would likely recolonize affected areas within weeks to months, depending on season. Drying of substrate when the Upper Slough is drained may result in decreases in production of algae and aquatic invertebrates, again depending on season. However, once the headgate structure between the Upper and Lower Sloughs is closed and the slough fills, recovery of aquatic productivity would be expected.

NPS would conduct surveys to evaluate the types, sizes, and abundance of species present in the Upper Slough and, if practical, would remove these fish (using nets or other mechanical means), release native species to adjacent waters, and arrange for beneficial uses prior to dewatering. It is anticipated that this action would be highly effective for eliminating and controlling non-native aquatic species in the Upper Slough. Periodic maintenance dredging and/or dewatering of the Upper Slough may be needed, especially after HFEs or other high-flow events, if there is sediment deposition and/or reinvasion by non-native species.

Overall, it is anticipated that the treatment would benefit native aquatic species by eliminating or controlling expansion of non-native species within the project area. However, there is a potential for dewatering to also harm a small number of individuals of native species or rainbow trout that may be present in the Upper Slough. Because the numbers of rainbow trout potentially affected by this control action would represent only a very small proportion of the overall trout population in the Glen Canyon reach, there would be no measurable effect on recruitment or other population parameters, and there should be no measurable change in the catchability of rainbow trout in this area.

Produce Small Scale Temperature Changes to Adversely Affect Coldwater Non-Native Fishes (Action P5; Experimental)

This control action could result in the physical disturbance of a small area (likely less than a few hundred square feet) of shoreline and streambed where heating equipment would be placed. The length of stream that could be warmed to target temperatures is expected to be at most about 1,500 ft (457 m). Depending upon the design of experiments, water temperature in the treated stream segment could be altered for one or more seasons within a given year. Should this pilot small-scale experiment prove successful at eliminating trout (without harming native fishes and invertebrates), and if heating a larger volume of water is deemed feasible, it could be expanded to treat larger sections of tributaries.

Adverse effects, such as mortality or avoidance of the area, on some warmwater native fish species could occur if water quality parameters, including DO, which decreases as water temperature increases, were to fall outside suitable biological ranges; appropriate experimental planning and monitoring would allow the potential for negative effects to be identified and managed. Once the experimental manipulation of temperature stops, water temperature and quality would quickly return to pre-treatment levels (within hours for temperature and days for water quality parameters). Given the limited temporal and spatial scope of the experimental treatment, impacts on native aquatic species would be localized and occur only during the treatment.

Non-native species targeted by this control action would be limited to those species that occur in the small tributaries within GCNP that have base flows of 25 cfs or less (i.e., tributaries such as Bright Angel Creek or smaller). Because of the small stream size, it is anticipated that mostly trout, and small-bodied non-native fishes would be present. It is not currently known how effective temperature treatment might be for eliminating or disadvantaging non-native aquatic species, but the results may inform scientists and managers regarding the potential for using water temperature management as a means for affecting survival of non-native species within the project area.

Overall, it is anticipated that the treatment would benefit warmwater native species within the treated stream segments by reducing the survival or competitive abilities of coldwater species (primarily trout) present in the treated areas. There is a potential for adversely affecting native species if temperatures or DO levels in treated areas were to fall outside suitable ranges, although the risks of negative effects on warmwater native species can be minimized with appropriate planning and monitoring of experiments. Because the action would occur in tributaries of GCNP, rainbow trout in the Glen Canyon reach would not be affected by the experimental action.

Mechanical Disruption of Early Life Stage Habitats (Action M1; Tier 2)

Mechanical disruption of spawning substrates by flushing with high-pressure water, mechanical displacement of gravel, or placement of temporary electrical grids or substrate covers (primarily from November 1 through February 28 for brown trout) would result in localized disturbance of aquatic habitat. Although the timing would be different, it is expected that the overall amount of disturbance from flushing or mechanical displacement of substrates within treated areas would be no greater than the effects of HFEs. Potential adverse impacts on spawning native fish and rainbow trout later in the year would be reduced because gravels would be returned to their place of origin during the treatment. Substrate disturbance would be less if electrical grids or substrate covers were used. Algae and benthic organisms displaced during treatments would likely recolonize affected areas within days to months after the treatment has been completed, depending upon the season of the year.

Any non-native aquatic species that spawns on substrates in the mainstem, tributaries, backwaters, or off-channel ponds within the project area could be targeted by this control action if deemed feasible. It is not possible to fully evaluate how effective disruption of spawning beds might be for controlling recruitment of non-native aquatic species until life history attributes of target species, the spatial extent and distribution of spawning areas, and the effect of disruption on survival of eggs and larvae have been evaluated. Roberts and White (2011) reported that up to 43% of rainbow trout and brown trout eggs and pre-emergent fry in artificial redds were killed by a single wading event and up to 96% mortality resulted from twice-daily wading throughout the development period. Similarly, modeling studies indicated that trampling of redds by cattle can affect egg and fry mortality at levels sufficient to reduce trout populations if the population growth rates are sensitive to changes in egg to fry mortality rates (Peterson et al. 2010). Mechanical disruption of early life stage habitat might be effective for controlling recruitment of small populations with spatially and temporally restricted spawning areas. For larger and more widespread populations, a population-level response would only be likely if nearly all spawning areas could be identified and a large proportion of eggs or larvae were affected by treatments.

The potential for benefits to native aquatic species would depend upon the effectiveness of the control action for suppressing populations of non-native fishes. Mechanical disruption of substrate could also harm individuals or eggs of non-target species, including native species or rainbow trout, which may be present in treated habitats. Although the general timing of brown trout and rainbow trout spawning and redd use is expected to differ within the Glen Canyon reach, there may be a potential for temporal overlap to occur during the spring period (i.e., late use of redds by brown trout and early use of redds by rainbow trout). Employing mechanical disruption of redds to target brown trout during times when redds of both species are active could affect the Glen Canyon rainbow trout population by reducing survival of early life stages of rainbow trout. By limiting mechanical disruption of brown trout spawning habitat in the

Glen Canyon reach to the period between November 1 and February 28, the potential for affecting redds being used by rainbow trout would be minimized and the work would occur outside the peak rainbow trout spawning and angler demand periods. Although the substrate would be disturbed, it would not be removed, and the composition of the substrate in redds would not be appreciably altered by mechanical disruption. Therefore, disrupted areas would still be useable for rainbow trout redd construction and spawning after disruption of brown trout redds has been completed. Overall, adverse impacts of this control action on the population of rainbow trout or the rainbow trout fishery in Glen Canyon would be avoided because actions would not occur during typical spawning periods for rainbow trout, and affected areas would be available for development of rainbow trout redds and spawning after mechanical disruption was completed. If it were determined that these treatments had more impact than expected on rainbow trout spawning, the time period for treatments could be further restricted or the action could be stopped or otherwise adjusted.

Mechanical Removal (Action M2; Tiers 1, 2, or 3)

Boat electrofishing would generally not directly disturb aquatic habitats. Use of backpack electrofishing units would result in a limited amount of habitat disturbance by wading field crews. Deployment and retrieval of static nets and traps could result in a small amount of bottom disturbance in the footprint of the net or trap itself; larger areas could be affected by crews pulling seines in some habitats. Water quality changes in the immediate area of the action would result from disturbance and suspension of fine sediments, but effects would dissipate within a few hours or days after the action was complete. In low-velocity habitats (e.g. backwaters or ponds), suspended sediments would settle and water quality would recover within several hours after cessation of harvest activities. In flowing tributaries or the mainstem, sediment suspended by disturbance would be rapidly transported from the affected area and a pulse of elevated sediment would travel through downstream areas until it settles out or is diluted or dissipated by currents. These temporary changes in water conditions would likely fall within the range of conditions experienced by aquatic organisms within the project area during an annual cycle; it is anticipated that native aquatic organisms are adapted to such changes although they may respond by temporarily avoiding affected areas.

Any non-native aquatic species in mainstem, tributaries, backwaters, or off-channel ponds within the project area could be targeted for mechanical removal using a wide variety of capture methods (Zale et al. 2012). In most cases, it is anticipated that this control action would be applied to address small, localized concentrations of non-native species in discrete habitat areas such as small tributaries, backwaters, or off-channel ponds. However, as described in Sections 2.2.2.2 and 2.2.3.1, more extensive mechanical removal efforts could be applied as a long-term control measure if the population of brown trout in the Glen Canyon reach increased to trigger levels. The values of 5,000 adult brown trout in Trigger 1c and 20,000 in Trigger 2 (Table 2-1; Appendix C, Section C.2.1) were based on modeled estimates of the number of adult brown trout in the Glen Canyon reach that would result in a density of adult brown trout at the Little Colorado River confluence above which mechanical removal in the Little Colorado River reach could be ineffective for controlling further increases (Yackulic 2018a). Population modeling in Runge et al. (2018) suggested that a sustained population of adult brown trout in the Glen Canyon reach above 25,000 individuals could eliminate all humpback chub in the mainstem Little Colorado River reach over a 20-year period.

There are many examples of mechanical removal techniques being used to reduce the abundance of non-native aquatic species, with varying degrees of success (e.g., Franssen et al. 2014, Healy et al. 2018; Mueller 2005; Meronek et al. 1996; Meyer et al. 2017; Zelasko et al. 2016). Mechanical removal methods are most likely to be effective for eliminating or reducing small populations of non-native species that are concentrated in specific locations. For larger and more widespread populations, a population-level response would only be likely if a large proportion of individuals can be removed. Runge et al (2018) used modeling to evaluate the potential for mechanical removal (electrofishing) to affect brown trout populations in the Glen Canyon reach and concluded that 8 annual removal passes that targeted the largest and most reproductively successful brown trout during the spawning period could reduce median brown trout abundance over a 20-year period by about 50% compared to a status quo scenario.

The potential for benefits to native aquatic species of this action would depend on its effectiveness in suppressing populations of non-native fishes. There is evidence that reducing the abundance of non-native species from specific habitat areas can result in improvements in survival and recruitment of native fishes. Efforts to remove non-native fishes in Bright Angel Creek during 2012-2017 sufficiently suppressed trout numbers to allow for enhanced recruitment of native fishes (Healy et al. 2018). Runge et al. (2018) modeled the potential for mechanical removal of brown trout in the Glen Canyon reach (see previous paragraph) to affect humpback chub populations in downstream reaches and concluded that mechanical removal of brown trout could slightly increase the median minimum abundance of adult humpback chub.

Runge et al. (2018) also concluded that mechanical removal of brown trout using electrofishing would result in a small increase in mortality (there is some handling mortality even when captured fishes are returned to the river alive) and a small decrease (up to about 3%) in the median abundance of age 1 and older rainbow trout compared to the status quo condition. Even though mortality of rainbow trout would be small, there is a possibility that electrofishing could affect fishing success of rainbow trout anglers by interfering with fishing activities or temporarily reducing fish catchability. It is anticipated that the impact of electrofishing on rainbow trout angling activities would be limited because (1) the proposed sampling period would occur between November 1 and February 28 when angler activity is generally low, (2) electrofishing activities at a particular location would generally only occur for several hours within a day before collection activities moved to other areas, and (3) shocked rainbow trout would be expected to recommence normal activities within a few days. Overall, adverse impacts of electrofishing to remove brown trout on the population of rainbow trout or the condition of the rainbow trout fishery in Glen Canyon would be small because the effects on rainbow trout population levels and fish behavior would be spatially and temporally limited.

Use of Sonic Concussion Devices (Action M3; Tier 4)

Depending on the design of the pressure pulse cannon, fishes up to approximately 30 ft from the source of the pulses could be killed due to internal tissue damage (Gross et al. 2013). Pulsed pressure waves can be lethal to adults, eggs and larvae, although larval fishes are less sensitive than older fishes in which the swim bladder has developed (Wright 1982). The lethality of pulsed pressure waves varies with fish size, species, orientation of individual fish relative to the shock wave, intensity and frequency of pressure waves, water depth, target depth, and bottom type (Gross et al 2013; Wright 1982). Pulsed pressure waves are not expected to adversely affect substrates or other components of habitats in target areas.

Any non-native aquatic species present in backwaters, or off-channel ponds within the project area could be targeted by this control action. Gross et al (2013) found that about 96% of northern pike exposed to pulsed pressure waves in a field experiment had tissue damage that was likely to be fatal and that 31% had died within 7 days after exposure. Thus, repeated treatment of small backwaters or ponds over one or more days would likely be effective at reducing abundance of non-native species. There is a potential that a similar approach could be used to target spawning areas and reduce survival of eggs and larvae within these same habitats.

Overall, treatment with pulsed pressure waves could benefit native aquatic species by eliminating or controlling expansion of a non-native species within the project area. The potential for benefits to native aquatic species would depend upon the effectiveness of the control action for suppressing populations of targeted non-native fishes. It is likely that pulsed pressure waves would also harm individuals of non-target species, including native species or rainbow trout that may be present in treated habitats. As described in Section 2.2.2.3, pre-treatment surveys would be conducted and native aquatic species would be mechanically removed and relocated to nearby aquatic habitats or returned to the treated location after treatment has been completed. In GCNRA only, NPS would evaluate potential non-lethal relocation of green sunfish to Lake Powell and would plan for beneficial use of all other non-native fish. Relocation of green sunfish to Lake Powell could occur if the fish to be removed are tested and found to be free of diseases, pathogens, and parasites; and state fish transport permits can be obtained (Appendix C, Section C.2). Impacts on the small number of rainbow trout potentially affected by using pulsed pressure waves in the RM -12 sloughs would not have a measurable effect on the rainbow trout population or the trout fishery in the Glen Canyon reach.

Mechanical Harvesting of Non-Native Plants and Algae (Action M4; Tier 1)

Some of the removal activities that could be applied under this control action, such as use of rakes, hooks, hand tools, boat rakes, and underwater weed cutters, have a potential to physically disturb some substrate by scraping and moving gravel and cobble. Overall, the spatial extent of disturbance would be limited to specific treatment areas (e.g., individual backwaters or tributary segments) and composition of the substrate would remain similar to pre-harvest conditions. There could be water quality changes due to disturbance and suspension of fine sediments during harvesting actions, but these actions and associated effects are not expected to last for more than a few days and would be mostly limited to the immediate area with effects diminishing quickly downstream. In low-velocity habitats (e.g. backwaters or ponds), suspended sediments would settle and water quality would recover within several hours after cessation of harvest activities. In flowing tributaries, sediment suspended by disturbance would be transported from the affected area and a pulse of elevated suspended sediment would travel downstream until the sediment settled out or was dissipated by currents. These temporary changes in water conditions would likely fall within the range of conditions experienced by aquatic organisms within the project area during an annual cycle; native species are adapted to such changes although they may respond by temporarily avoiding affected areas. Removal of non-native plants and algae could result in short-term reductions in overall productivity of the food base and availability of structural refuges for some aquatic organisms. Overall, habitat impacts would be unlikely to persist for more than a single season and would be localized to the vicinity of the treated areas.

Curly-leaf pondweed is the only invasive aquatic plant currently found in the project area that is considered to pose a medium or high risk (Appendix F, Table F-1), although other invasive aquatic plant species may need to be considered in the future. Mechanical harvesting can control the within-season presence of curly-leaf pondweed, but harvesting should be completed before turions are dropped from the plants to effectively control abundance for multiple seasons (Johnson and Fieldseth 2014, McComas and Stuckert 2017).

It is anticipated that removal of non-native aquatic plants would benefit native aquatic plants by reducing competitive effects, and native fish by improving conditions for benthic macroinvertebrates; the potential for benefits to native aquatic species would depend upon the effectiveness of the control action for suppressing populations of targeted plant species.

Mechanical harvesting of dense patches of aquatic plants has a potential to harm some non-target species, including native fish species or rainbow trout that may be using the vegetation as refuge or feeding areas. Haller et al. (1980) found that mechanical harvesting of hydrilla in Florida entangled substantial numbers of fishes in the cut vegetation. Therefore, the potential presence of native aquatic species should be considered prior to harvesting aquatic plants within the project area. To the extent practicable, any native fish and rainbow trout entangled during mechanical harvesting would be returned to the waterbody, but could be injured or killed in the process. The number of fish entangled during mechanical harvesting is expected to be small because fish are more likely to avoid the area when the removal begins. The small number of rainbow trout potentially affected by mechanical harvesting of plants in the RM -12 sloughs would not have a measurable effect on the rainbow trout population or the trout fishery in the Glen Canyon reach.

Introduction of YY-Male Fish (Action B1, Experimental)

The use of YY-male fish to reduce or eliminate populations of wild fishes has not been widely field tested. Currently, YY-male stock is only available for brook trout, and has been tested in a few alpine lakes and streams. In field trials, YY-male brook trout exhibited good survival and the ability to successfully spawn with wild female brook trout (Kennedy et al. 2018). Schill et al. (2017) modeled time-to-extirpation using a range of stocking values for YY-male brook trout fingerlings (age 1) as a percentage of existing wild stocks of brook trout (from 0 to 75%), and a range of exploitation rates (removals) ranging from 0 to 50% to determine the optimum combinations of stocking and exploitation rates to reach extirpation of the wild fish population within 10 years. Results showed that stocking rates of 25% or more of wild stock combined with removal of 25% of wild stock could result in extirpation in 10 years or less with good survival of stocked YY-male fish. If survival was relatively poorer than wild fish, then both stocking and removal rates would have to be increased, to achieve extirpation within 10 years. Thus, it is anticipated that if a control option using YY-male fish is implemented in the future, stocking rates will need to be substantial and fish removal actions would need to be implemented simultaneously. YY-male brown trout brood stock could be available within the next 5-8 years (Schill 2018).

Although stocking YY-male brown trout could reduce or eliminate brown trout within the project area, there are concerns about the need to initially stock a non-native species that could affect native fishes within GCNP. In particular, there are concerns that YY-male brown trout stocked in the Glen Canyon reach would migrate to the Little Colorado River reach where they could affect humpback chub via predation and competition.

A model developed by the GCMRC and FWS to evaluate the impact of stocking rainbow trout on humpback chub was modified to estimate how stocking YY-male brown trout in the Glen Canyon reach might contribute to mortality of juvenile humpback chub in the Little Colorado River reach of the Colorado River (Appendix C, Section C.3.3). Annual stocking would be limited initially to a maximum of 5,000 adult YY-male brown trout, or an equivalent number of juveniles (estimated to be 10,000 based on assumed juvenile survival rates). This number represents a conservative level of risk to humpback chub if brown trout survival, movement, and predation rates are at high-risk levels. This maximum stocking number could be adjusted adaptively by ± 4,000 adults (or equivalent juveniles) based on additional modeling or data. Modeling indicated that annual stocking of 5,000 adult YY-male brown trout into the Glen Canyon reach for a 10-year period could result in average annual consumption over a 20-year period of 13, 169, and 3,813 juvenile humpback chub under low-, moderate-, and high-risk scenarios, respectively. Total consumption of juvenile humpback chub over the 20-year period was estimated to be 269, 3,379, and 76,259 for the low-, moderate-, and high-risk scenarios, respectively (see Appendix C, Section C.3.3). Estimated YOY humpback chub production in the Little Colorado River ranges from approximately 5,000 to 45,000 per year (Yackulic 2018b). Based on these estimates, stocked brown trout could consume the entire year’s production in some low humpback chub production years and up to 17% of the YOY humpback chub could be consumed in high production years.

If the assumed stocking rate was sufficient for successfully eliminating wild brown trout from the Glen Canyon reach over a 20-year period, the long-term benefits to humpback chub population may outweigh the expected adverse effects of the annual losses of juveniles to predation. As identified in Section 2.2.2.4, this control action is considered experimental and updated scientific information, results of field studies, and any other new information regarding effectiveness and negative or unintended impacts of stocking YY-male fish would be reviewed prior to implementation. Additional planning and compliance assessments would be considered if there were new information regarding potential impacts.

Introduction of YY-male fish via stocking would not result in habitat disturbance. As described in Section 2.2.2.4, removal of wild adults of targeted non-native fish species using incentivized harvest or mechanical removal would be used concurrent with introduction activities; the impacts of such removal efforts on habitat conditions are described above. Impacts of YY-male fish introduction on physical habitat conditions or water quality would be negligible.

Overwhelm Ecosystem Cycling Capabilities of Small Areas (Action C1; Tier 3)

The use of chemical treatments to overwhelm the ability of backwaters and off-channel ponds (< 5 ac in size) to support non-native species by altering ecosystem cycling capabilities (Section 2.2.2.5) would not disturb substrates in treated habitats, but would temporarily affect water quality (Section 3.2.2). The length of time that conditions would be toxic to aquatic organisms would depend on the nature of the treatment, buffering capabilities of the water and the substrate, and the amount of water exchange with the main channel or water recharge from other sources. Such aspects would be considered in a treatment plan and in the appropriate research permits. It is anticipated that treatments would be designed to alter water quality for a relatively limited period of time (generally a month or less) in most cases. Depending on the nature of the chemical treatment, water quality would either naturally return to normal conditions or would require actions to restore water quality to pre-treatment levels. Ward et al (2013) found that over 40 days was needed for ammonia and nitrate concentrations to return to pre-treatment levels after treatment of experimental ponds with liquid ammonia. Treanor et al (2017) described how actions such as injections of air or the addition of hydrated lime or crushed limestone could be used to increase pH and return free CO_2 to pre-treatment levels following treatment of water bodies with CO_2. NPS would not implement this action in the same location for more than five consecutive years. If this action is not effective as a long-term solution when implemented over a 5-year period, NPS would pursue additional planning and compliance for any subsequent actions not included within this EA.

There is a potential that treatments with naturally occurring chemicals could be used to control non-native invertebrate, amphibian, and fish species in targeted habitat areas (Ward et al. 2013; Ward 2015, Treanor et al. 2017). Overall, it is anticipated that such treatments would benefit native aquatic species by eliminating or controlling expansion of non-native species in the project area. However, there is a potential for treatment of backwaters and off-channel ponds with naturally occurring chemicals to also harm native species, including special-status species, or rainbow trout that may be present in treated backwaters or ponds. Native species and rainbow trout would be removed during pre-treatment surveys and relocated to nearby aquatic habitats. In GCNRA only, NPS would evaluate potential non-lethal relocation of green sunfish to Lake Powell and would plan for beneficial use of all other non-native fish. Relocation of green sunfish to Lake Powell could occur if the fish to be removed are tested and found to be free of diseases, pathogens, and parasites; and state fish transport permits can be obtained (Appendix C, Section C.2). The small number of rainbow trout potentially affected by use of this control action within the Glen Canyon reach would have a negligible effect on the rainbow trout population or the trout fishery.

Application of Piscicides (Actions C2, C3, C4; Tier 3, 4, and 2, respectively)

As described in Section 2.2.2.5, use of chemical controls, such as rotenone or antimycin, would be limited to use in tributary segments, and backwaters and off-channel ponds < 5 ac in size. In GCNP, piscicides could be applied (1) as a rapid response measure to address newly identified invasions of medium- to very high-risk non-native aquatic species that begin to reproduce in backwaters and off-channel ponds; (2) for long-term control of any high- to very high-risk non-native aquatic species in small backwaters or off-channel ponds, and (3) for renovation of native fish communities in tributaries where there are natural barriers that would prevent reinvasion by non-native fishes following treatment (e.g., Shinumo Creek or in Bright Angel Creek upstream of Split Rock Falls). In GCNRA, piscicides could be applied in the RM -12 sloughs, or in other backwaters or off-channel ponds to address medium- to very high-risk non-native aquatic species. Rotenone was applied to the RM -12 sloughs in 2015 to eradicate a reproducing population of green sunfish that had become established and to reduce the risk of the downstream spread of green sunfish into GCNP (Trammell et al. 2015). NPS would not implement this action in the same location for more than five consecutive years. If this action is not effective as a long-term solution when implemented over a 5-year period, NPS would pursue additional planning and compliance for any subsequent actions not included within this EA.

Although acute toxicity of rotenone and antimycin in the water column can be neutralized by application of appropriate concentrations of oxidizing agents such as potassium permanganate (KMnO4), there is a potential for rotenone and antimycin to persist in treated habitats for several weeks depending on water movement, water temperature, pH, and water depth (NPS 2013c; Finlayson et al. 2018). Project-specific treatment plans would be developed to detail treatment locations, identify timelines, chemical application and neutralization procedures, plans for the removal and disposition of dead fish, and post-treatment monitoring and evaluation (see Trammell et al. [2015] for an example of a recent treatment plan for the project area).Additional assessments of the potential effects of rotenone applications on aquatic ecosystems, including potential toxicity to aquatic invertebrates, species-specific sensitivities, and application guidelines) are provided in NPS (2013c) and Finlayson et al. (2018). Application of piscicides would not disturb substrates in treated habitats.

Although the intent would be to target specific non-native fish species with piscicides, both rotenone and antimycin can also be toxic to aquatic invertebrates if concentrations are high enough. Aquatic invertebrates (insects and zooplankton) have a wide range of sensitivities to rotenone and antimycin, although more is known about the response of invertebrates to rotenone than antimycin. Factors likely to affect the magnitude of impacts on invertebrates in treated areas include the concentration and duration of the piscicide treatment, life history characteristics and morphology of the invertebrate species, and proximity of non-exposed colonization sources of invertebrates to the treatment location (Vinson 2010). Because treatments would be planned to allow for recolonization of invertebrates, and recolonization would be expected to happen quickly, the impacts on invertebrate communities within the project area would be negligible.

Overall, it is anticipated that the identified piscicide treatments would benefit native aquatic species by eliminating or controlling expansion of non-native species in the project area. There is a potential for treatment with piscicides to also harm individuals of native fish species, including special-status species, or non-target species such as rainbow trout that may be present in treated areas during applications. Native species and rainbow trout would be removed if found during pre-treatment surveys and either relocated to nearby aquatic habitats or maintained and released into treated habitats once the treatment is successfully completed. In GCNRA only, NPS would evaluate potential non-lethal relocation of green sunfish to Lake Powell and would plan for beneficial use of all other non-native fish. Relocation of green sunfish to Lake Powell could occur if the fish to be removed are tested and found to be free of diseases, pathogens, and parasites; and state fish transport permits can be obtained (Appendix C, Section C.2.2). The small number of rainbow trout potentially affected by use of this control action in GCNRA, including the RM -12 sloughs, would have a negligible effect on the rainbow trout population or the trout fishery.

Application of Herbicides (Action C5; Tier 1)

It is anticipated that the small-scale application of approved herbicides would not alter substrate conditions in targeted habitats. Applied herbicides and chemical breakdown products would persist and affect water quality within treated habitats for some time following application, dependent on chemical-specific characteristics and ambient water conditions (e.g., temperature, oxidation-reduction potential, and pH) (Section 3.2.2). Adherence to approved application guidelines and requirements would minimize impacts on aquatic organisms due to water quality changes. NPS would not implement this action in the same location for more than five consecutive years. If this action is not effective as a long-term solution when implemented over a 5-year period, NPS would pursue additional planning and compliance for any subsequent actions not included within this EA.

Removal of non-native plants and algae could result in short-term reductions in overall productivity of the food base and the availability of structural refuges for some aquatic organisms (e.g., macroinvertebrates and fishes) present in the treated areas. Overall, application of herbicides to control non-native aquatic plants and algae is expected to benefit native species.

Application of Mollusk Repellents and Non-Toxic Antifouling Paints (Action C6; Tier 1)

It is anticipated that the proposed applications would not result in direct physical impacts to aquatic habitat within the project area. The intent is to utilize non-toxic compounds and no degradation of water quality or toxicity to non-target organisms in aquatic habitats would be expected.

Quagga mussels, New Zealand mud snails, and Asian clams are already present within GCNRA and quagga mussels are present in GCNP. The quagga mussel is known to significantly alter aquatic ecosystems and impact water-based facilities in many areas and NPS is committed to preventing the spread, slowing the rate of infestation and determining treatment options to minimize the threat posed in currently infested waters. Currently, there are no economically feasible methods of eradication of quagga mussels once they have become established in a water body.

NPS is already encouraging and supporting actions within the project area to reduce the potential for spreading non-native mollusks, including the proper cleaning and drying of boats, trailers and equipment (see Section 2.1). Although prevention or eradication does not appear to be feasible at this time, application of repellants and antifouling paints to NPS boats and to infrastructure within the project area would further reduce the potential for transferring these species to other locations (both within and outside the project area). Educational materials, boot-cleaning stations, and periodic boat inspections are already in place. Controlling the potential spread of non-native mollusks would benefit native aquatic species by reducing competition for food resources and space.

Cumulative Impacts of the Proposed Action on Aquatic Resources

Significant, mostly adverse cumulative impacts on aquatic resources in the project area primarily result from changes in seasonal and annual flow patterns. Past, present, and reasonably foreseeable future actions and trends have or are expected to produce increased water demand (resulting from population growth and development); decreased water supply (resulting from drought and increased water temperature attributed to climate change); and other foreseeable actions (DOI 2016a; see Appendix B, Table B-1). Decreases in runoff, reservoir volume, and river flow caused by drought and increased demand would result in lower reservoir elevations and warmer release temperatures, which could benefit native aquatic species, but also make conditions more favorable for warmwater non-native aquatic species that prey on or compete with native species.

The Proposed Action is expected to benefit aquatic resources overall and decrease the magnitude of cumulative impacts by reducing existing populations of harmful non-native aquatic species and preventing the invasion and expansion of new non-native species in the project area. Because the Proposed Action includes multiple control actions, which could occur simultaneously within the project area, there is the potential for the accumulation and interaction of the adverse impacts associated with these actions. The potential for this accumulation and interaction of adverse impacts would be limited because adverse impacts would be localized and affect mostly small targeted areas (most targeted areas would be < 5 ac in size) over short periods (days to weeks) and their contribution to adverse cumulative impacts would be offset by their benefits. Only a small subset of actions is likely to take place at any particular time or location and there would be little interaction among individual actions. Implementation of actions in specific areas are likely to be separated in time under the Proposed Action due to the tiered implementation structure such that recovery of the aquatic ecosystem from actions taken at specific locations is likely to occur before actions in subsequent years take place.

3.4 TERRESTRIAL RESOURCES

3.4.1 Terrestrial and Wetland Vegetation

3.4.1.1 Terrestrial and Wetland Vegetation—Affected Environment

Plant communities along the Colorado River are strongly influenced by streamflow characteristics and have developed into distinct bands or zones of riparian vegetation based on pre-dam and post-dam flooding and disturbance frequency (DOI 2016a). Construction of Glen Canyon Dam eliminated the scouring flood flows associated with spring snowmelt and allowed riparian vegetation to increase. Mojave-Sonoran desert communities occur above the riparian vegetation zones. The uppermost portion of the riparian zone is no longer flooded, but continues to support drought-tolerant species such as netleaf hackberry (*Celtis reticulata*), catclaw acacia (*Acacia greggii*), and mesquite (*Prosopis glandulosa*) (DOI 2016a). The lower portion of the riparian zone that is inundated by post-dam high flows and normal operational flows supports communities of tamarisk (*Tamarix* spp.); seepwillow (*Baccharis* spp.); arrowweed (*Pluchea sericea*); and coyote willow (*Salix exigua*), as well as other shrub and herbaceous species.

Portions of the riparian zone that are inundated by daily fluctuations support flood-tolerant marsh species such as sedges (*Carex* spp.), rushes (*Juncus* spp.), cattail (*Typha* spp.), horsetail (*Equisetum* spp.), and common reed (*Phragmites australis*). These species occupy return current channels and successional backwaters that are inundated daily for at least part of the year (i.e., up to the elevation of the average annual daily maximum discharge of about 18,500 cfs), forming fluvial marsh wetland communities (DOI 2016a). Shrub wetland communities (predominantly coyote willow, Emory seep willow (*B. salicina*), and horsetail) occur on sandy soils that are less frequently inundated.

The two backwater sloughs at RM -12 support wet marsh communities along their margins, with willow and tamarisk on higher locations of the cobble bar or debris fans coming off the cliffs. The Upper Slough (0.34 ac) is spring-fed and typically has a relatively stable water surface elevation perched above the Lower Slough, which is connected to the river at its downstream end and has a fluctuating water surface elevation. A narrow outlet permits minor flows (approximately 3-5 gal/min) from the Upper to the Lower Slough. River flow begins to inundate the Upper Slough from the Lower Slough at a main channel discharge of approximately 19,000 to 20,000 cfs.

No plant species protected under the ESA occur in the vicinity of off-channel ponds and backwaters (DOI 2016a) where control actions under the Proposed Action would occur.

3.4.1.2 Terrestrial and Wetland Vegetation—Environmental Consequences

Impacts of the No-Action Alternative on Terrestrial and Wetland Vegetation

Under the No-Action Alternative, the continued use of fishery management tools described in the CFMP EA (NPS 2013a) and the LTEMP EIS (DOI 2016a) would represent no change in the types and magnitude of impacts on terrestrial and wetland vegetation, and a continuation of the current conditions and trends in vegetation (Appendix A, Table A-1). Impacts would primarily result from trampling of shoreline vegetation during implementation of actions, and from Glen Canyon Dam operations under the LTEMP. The implementation of those flow and non-flow actions are ongoing, and their effects are included in the baseline vegetation characteristics of the affected environment (Section 3.4.1.1).

Past and present actions have resulted in large changes in terrestrial and wetland vegetation in the project area as described in Section 3.4.1.1. The greatest contribution to these cumulative impacts are the changes in flow and sediment load that resulted from the construction of Glen Canyon Dam (DOI 2016a; see Appendix B, Table B-1). Lower regional precipitation with climate change is expected to result in a shift to more drought-tolerant species. Drought conditions would favor non-native tamarisk (which is tolerant of drought stress). However, tamarisk control efforts by the NPS and possibly the effects of non-native tamarisk beetles would increase tamarisk mortality and improve conditions for native shrubs over time. The LTEMP includes vegetation treatments that would improve vegetation conditions and could lead to a more natural riparian ecosystem. The short-term adverse impacts of actions on terrestrial and wetland vegetation under the No-Action Alternative would be a negligible and temporary increment to the effects of past, present, and reasonably foreseeable future actions.

Impacts of the Proposed Action on Terrestrial and Wetland Vegetation

Impacts of the Proposed Action on terrestrial and wetland vegetation are summarized in Appendix A, Table A-1 and described in the following paragraphs.

Several actions included in the Proposed Action, such as incentivized harvest (Action H1), mechanical removal (Action M2), mechanical disruption of habitats (Action M1), sonic concussion (Action M3), and temperature control (Action P5) could result in minimal localized impacts from trampling of shoreline vegetation by those implementing the actions. Affected vegetation would be expected to quickly recover to pre-disturbance conditions. The placement of weirs and barriers (Actions P2, P3) could result in a localized loss of vegetation where placement requires soil disturbance. YY male introduction (Action B1), chemical controls using piscicides (Actions C2, C3, C4), and mollusk repellants (C5) would have no impact on terrestrial vegetation.

Dewatering of off-channel ponds and backwaters (Action P1) would result in a reduction in soil moisture levels and subsequent desiccation of riparian vegetation along the perimeter of the pond or backwater unless water levels were restored quickly through natural recharge. Long-term or repeated dewatering could result in a loss of riparian vegetation or transition to drought-tolerant upland vegetation types, and vegetation loss could increase the potential for erosion on the margins of the pond. Ecosystem cycling control (Action C1) could result in some impact to vegetation if contacted by chemicals used.

Dredging to connect the Upper and Lower Sloughs (Action P4) to drain the Upper Slough and facilitate the use of a water-control structure at the outlet of the Upper Slough would result in disturbance of an area of approximately 3,400 ft^2. This action includes a small channel being excavated up through the slough to facilitate completely draining all of the water out the headgate. Existing vegetation in the area of the water-control structure would be removed. Installation of a water-control structure would allow draining for control of both invasive animals and plants and refilling would be through natural recharge. However, some loss of riparian vegetation may result from prolonged desiccation while refilling occurs (approximately 42 days to refill the slough at 2 gal/min or 17 days at 5 gal/min depending on spring flow and evaporation at time of treatment). Permitting through the USACE under Section 404 of the Clean Water Act may be required for dredging of a channel and installation of a water-control structure. Design details and required mitigation would be determined during the permitting process.

Mechanical harvest of non-native aquatic plants (Action M4) and application of herbicides (Action C5) would not affect terrestrial vegetation communities except for short-time periods (days or weeks) in areas trampled during implementation of the actions. Harvested plants and algae would be placed in compost piles on upland sites near the harvest area or in offsite landfills. If vegetation is allowed to remain and naturally decompose onsite there could be some impact to the terrestrial vegetation in the area of disposal. This impact would last only for a few months as the vegetation decomposes. Overall, there would be no lasting impact to the terrestrial vegetative community. Careful application of herbicides would occur to ensure that non-target riparian vegetation is not affected.

No plant species protected under the Endangered Species Act occur in the vicinity of off-channel pools and backwaters (DOI 2016a) where activities associated with the options under the Proposed Action would occur. Therefore, no impacts to special status plant species would occur.

Past and present actions have resulted in large changes in terrestrial and wetland vegetation in the project area as described in Section 3.4.1.1. The greatest contribution to these cumulative impacts on vegetation are the changes in flow and sediment load that resulted from the construction of Glen Canyon Dam (DOI 2016a; see Appendix B, Table B-1). Lower regional precipitation with climate change is expected to result in a shift to more drought-tolerant species. Drought conditions would favor non-native tamarisk (which is tolerant of drought stress). However, tamarisk control efforts by the NPS and possibly the effects of tamarisk beetles would increase tamarisk mortality and improve conditions for native shrubs over time. The LTEMP includes vegetation treatments that would improve vegetation conditions and could lead to a more natural riparian ecosystem. The Proposed Action would result in incremental adverse impacts on terrestrial and wetland vegetation that would be limited to the areas where control actions would occur, and most affected areas are expected to recover over a period of days or weeks once the action is complete. Interaction and accumulation of adverse impacts on terrestrial and wetland vegetation from multiple control actions would be limited because (1) most individual actions and their effects would persist for less than a week, (2) most actions would occur in small (< 5 ac) habitats that are isolated from the main channel and each other, and (3) tiered implementation of actions would reduce the potential for them to occur simultaneously at specific locations. No change in vegetation distribution or plant community composition, and, therefore, overall cumulative impacts, are expected to occur as a result of the Proposed Action.

3.4.2 Wildlife

3.4.2.1 Wildlife—Affected Environment

A wide variety of wildlife species are associated with riparian habitats along the Colorado River. Many of these species are habitat generalists, occurring in ecosystems from both the riparian zones and upland communities, while some species require specific vegetation composition and structural components and may only occur within specific habitats within the river corridor (DOI 2016a). Thousands of invertebrate species in the riparian corridor fill a variety of ecological roles and serve as pollinators, regulate populations of other invertebrates, and provide food resources for many terrestrial and aquatic wildlife species. In general, many wildlife species, including invertebrates, have benefited from increases in riparian vegetation in the project area (DOI 2016a).

Riparian areas nearest to the river tend to support the highest densities and diversity of amphibians and reptiles due to the presence of water, high vegetation density, and invertebrate food availability (DOI 2016a). Amphibian breeding, egg deposition, and larval development generally occur in backwaters and off-channel ponds, or on a limited basis, along the shallow water of aquatic and riparian habitats that are inundated by daily fluctuations (DOI 2016a).

Riparian areas provide habitat for birds throughout the year, including breeding habitat, migratory stopover sites, and wintering areas (Spence 2006; Spence et al. 2011; Gatlin 2013). Several species of birds that breed along the river corridor are obligate riparian species (DOI 2016a). Approximately 30 bird species are known to nest in the riparian zone of the project area (DOI 2016a), including the southwestern willow flycatcher (*Empidonax traillii extimus*), western yellow-billed cuckoo (*Coccyzus americanus occidentalis*), and Ridgway's rail (Yuma) (*Rallus obsoletus yumanensis*), which are protected under the ESA and are discussed below. A great blue heron (*Ardea herodias*) rookery is located just below Glen Canyon Dam, and included 22 active nests in May 2013. A pair of ospreys (*Pandion haliaetus*) successfully nested at the base of Glen Canyon Dam in 2014 (DOI 2016a). Peregrine falcons (*Falco peregrinus*) also frequent the canyons and a nesting pair was found in 2012 during statewide monitoring activities.

Beaver (*Castor canadensis*) occur throughout the river corridor, excavating bank dens and cutting willows, cottonwoods, tamarisk, and shrubs for food (DOI 2016a). The abundance and richness of small mammals are greatest in the higher elevation portions of riparian habitats where steeper slopes, rock falls, and canyon wall crevices provide a wider variety of habitats (NPS 2005).

The two backwater sloughs at RM-12 provide riparian habitat around their margins and along the edge of a large cobble bar, which formed the sloughs during historic floods. Although not documented, it is likely that a variety of vertebrate and invertebrate species occupy these habitats. Though they have no special status, native Arizona tiger salamanders (*Ambystoma mavortium nebulosum*) and at least one toad species (*Bufo* sp.) have been recently observed utilizing the sloughs as rearing habitat.

Wildlife species protected under the ESA or Bald and Golden Eagle Protection Act (BGEPA) that occur within the Colorado River corridor include Mexican spotted owl, California condor, southwestern willow flycatcher, Kanab ambersnail, western yellow-billed cuckoo, Ridgway's rail (Yuma), bald eagle, and golden eagle (DOI 2016a).

The Mexican spotted owl (federally listed as threatened) occurs in mixed-conifer forests, Madrean pine-oak forest, and rocky canyons. Within the latter habitat, nesting is mostly in caves or on cliff ledges in steep-walled canyons (NPS 2010).

The California condor (federally listed as endangered) occurs within GCNP and GCNRA. The beaches of the Colorado River through Grand Canyon are frequently used by condors for drinking, bathing, preening, and feeding on fish carcasses (DOI 2016a). Nest sites are often located in caves and rock crevices (NPS 2014). California condors that have been released into the wild in northern Arizona from a captive breeding program have been designated as a nonessential experimental population and exempt from ESA protections. However, individuals of this population within NPS units are protected as threatened species.

The southwestern willow flycatcher (federally listed as endangered) occurs throughout GCNP in riparian habitats, including those dominated by invasive tamarisk. Resident birds have been documented nesting in Marble Canyon and the western Grand Canyon near Lake Mead (DOI 2016a). The breeding season of the southwestern willow flycatcher is May through August (Reclamation 2007, Sogge et al. 1997, 2010).

The Kanab ambersnail (federally listed as endangered) occurs in two locations within GCNP (Vasey's Paradise and Elves Chasm), primarily above the 33,000 cfs stage elevation at Vasey's Paradise and above the 45,000 cfs stage elevation at Elves Chasm (DOI 2016a).

The western yellow-billed cuckoo (federally listed as threatened) has been known to breed at a number of sites in the western Grand Canyon near the Lake Mead delta. The riparian community at these sites is primarily willow, tamarisk, and seepwillow (DOI 2016a). The western yellow-billed cuckoo breeding season is generally June (as early as May) through August (as late as September) (Johnson et al. 2010).

The Ridgway's rail (Yuma) is a casual summer visitor to marshy riparian habitats below Separation Canyon (e.g., near RM 246 and RM 260). These occurrences are quite distant from its breeding range on the lower Colorado River (DOI 2016a). The Ridgway's rail breeding season is March through August (DOI 2016a).

The bald eagle is protected under the BGEPA, and winters in Marble Canyon and the upper half of Grand Canyon. Wintering individuals occur at tributary confluences (DOI 2016a). Breeding occurs in areas outside of the project area.

The golden eagle, also protected under BGEPA, is a rare to uncommon permanent resident and a rare fall migrant in the project area. It prefers rugged terrain with cliffs and mesas, and nests on cliff ledges. Migrants use sheer cliffs of the Glen Canyon area to hunt (DOI 2016a). Breeding does not occur in the vicinity of areas where control actions would occur.

3.4.2.2 Wildlife—Environmental Consequences

Impacts of the No-Action Alternative on Wildlife

Under the No-Action Alternative, the continued use of fishery management tools described in the CFMP EA (NPS 2013a) and the LTEMP EIS (DOI 2016a) would represent no change in the types and magnitude of adverse impacts associated with implementation of those actions on wildlife (Appendix A, Table A-1). For the most part, non-flow control actions being implemented under LTEMP also are expected to have relatively minor effects on wildlife in the project area through their effect on vegetation communities (DOI 2016a). Under the No-Action Alternative there would be fewer control actions available (relative to the Proposed Action) for managing non-native aquatic species, potentially allowing these non-natives to increase in abundance and distribution in the project area. Many of the non-native aquatic species could have adverse impacts on native amphibians either through predation (fish) or effects on habitats (algae, plants, and fungi).

In general, many wildlife species, including invertebrates, have benefited from increased riparian vegetation in the project area (DOI 2016a).The greatest contribution to cumulative impacts on wildlife relates to the changes in riparian vegetation resulting from the construction of Glen Canyon Dam (DOI 2016a; see Appendix B, Table B-1). Future increased water demand and lower flows downstream of Glen Canyon Dam, which are expected under climate change, could stress riparian and wetland vegetation, resulting in adverse impacts on wildlife habitats and the wildlife prey base. Warmer discharges (attributed to climate change) could increase algae and invertebrates, increasing the prey base for some species. The No-Action Alternative's contribution to cumulative impacts on wildlife would be much less than the effects of past, present, and reasonably foreseeable future actions. The lower level of control of non-native aquatic species that would be provided under the No-Action Alternative would result in fewer benefits to wildlife, and, therefore, would have greater adverse cumulative effect than the Proposed Action.

Impacts of the Proposed Action on Wildlife

Adverse impacts on wildlife from control actions under the Proposed Action would primarily result from noise and human disturbance. Wildlife is expected to temporarily avoid the area where and when the control actions are implemented. Habitat loss would be minimal with incentivized harvest (Action H1), mechanical removal (Action M2), temperature control (Action P5), and placement of weirs and barriers (Actions P2, P3). YY-male introduction (Action B1), chemical controls (Actions C2, C3, C4), and mollusk repellants (C5) would have no impact on wildlife habitat.

No impacts on the Kanab ambersnail are expected because this species occurs in two locations within Grand Canyon (Vasey's Paradise and Elves Chasm) that are primarily above the 33,000 cfs stage elevation at Vasey's Paradise and above the 45,000 cfs stage elevation at Elves Chasm (DOI 2016a) and mitigation measures will preclude the use of actions in close proximity that could affect this species (see Appendix C, Section C.4). No chemical, sonic concussive treatments, or mechanical harvesting of aquatic plants and algae would occur within 330 ft (100 m) of known locations of Kanab ambersnail. All piscicide or herbicide use would be subject to NPS review and approval processes in strict adherence to applicable regulations and guidelines, and would be implemented at appropriate water levels to ensure that chemicals would not come into contact with ambersnails. Before any action would occur in the vicinity of known ambersnail populations, surveys would be conducted, and ambersnails could be moved to higher locations within the habitat area if needed to avoid impacts (FWS 2011). No other control actions under the Proposed Action would be expected to have impacts on this species.

Some of the control actions under the Proposed Action could affect amphibians occupying habitat in and around ponds and backwaters where control actions are implemented. These options include mechanical disruption (Action M1), sonic concussion (Action M3), dewatering of off-channel ponds and backwaters (Action P1), ecosystem cycling control (Action C1), piscicide application (C2, C3, and C4) dredging to connect the Upper and Lower Sloughs (Action P4), mechanical harvest of non-native aquatic plants (Action M4), and application of herbicides (Action C5). These options could directly adversely impact amphibians from mortality or result in indirect impacts through loss of habitat. Any impacts, however, would not jeopardize these amphibian populations.

Rotenone generally has a greater impact on larval forms of both frogs and salamanders than on adult forms (Farringer 1972; Burress 1982; Fontenot et al. 1994; Grisak et al. 2007). However, during the larval stage, frogs undergo lung development as they approach metamorphosis and rely very little on gill respiration, whereas, toads remain gill-breathers during the entire larval period (Ultsch et al. 1999). Frog tadpoles, therefore, may be less susceptible to the negative effects of rotenone as they grow older.

It should be noted that most of the non-native fish likely to occur in the project area are predatory and would have long-term impacts on native amphibians if these fish became established. Therefore, removal of non-native fish would benefit amphibian populations by reducing predator pressure in off-channel ponds and sloughs. Stable or increasing amphibian populations would in turn benefit some bird species. Control of non-native aquatic plants and algae under the Proposed Action could also benefit native amphibian populations by helping maintain healthy native plant and algal communities.

Special status species that may occur in or near riparian areas, and, therefore, may be present near the locations where control actions are implemented include: California condor, southwestern willow flycatcher, western yellow-billed cuckoo, Ridgway's rail (Yuma), and bald eagles. Species that breed in riparian vegetation upstream of Lake Mead include the southwestern willow flycatcher, western yellow-billed cuckoo, and Ridgway's rail (Yuma). Disturbance of these species may result from any of the control actions, particularly those with appreciable noise generation, such as the operation of pumps, propane heaters, generators used during electrofishing, hydraulic pumps used during sonic concussive methods, pumps used for pressure washers for treating spawning beds, construction equipment during dredging, or additional motorized river trips. The total additional administrative boat trips that would occur under the Proposed Action would be unlikely to exceed 8 trips/year in GCNP and 12 administrative boat trips in GCNRA. When triggered in a year, mechanical removal in GCNRA would add 8 annual removal trips using 2 boats over a period of up to 5 days each. Because the pumps, generators, and motors used will conform to NPS standards of being below 60 dB at 50 ft, the impacts on riparian birds from these trips and the associated noise would be limited to the immediate area. In addition, noise-related impacts would be temporary, lasting for the duration of the activity (the hours of equipment operation), and may result in flushing but would be unlikely to result in nest abandonment or changes in significant behavioral activity or important life requirements such as nesting, roosting, foraging, rearing, and movement activities and habitat.

Helicopter flights may be utilized in the logistics of various actions, and could have impacts on birds, particularly Mexican spotted owls and California condors. Impacts would be primarily due to disturbance from noise as individuals would temporarily leave the area but would likely return following the disturbance. Equipment and staff could be flown into and out of previously established camps and landing areas, so occasional short-term (up to 1 hour) noise impacts may occur up to 20 times per year for support of control actions in GCNP. This is a small addition to the number of flights that occur in GCNP (3.5-4.5% of current total administrative helicopter flight hours). Measures that would be utilized to minimize impacts on these two species are discussed in Appendix C, Section C.4.

Based on the distance helicopters and work crews would maintain from known California condor roost and nest sites, and short-term duration of noise, the Proposed Action would result in limited and localized impacts on California condors. Disturbances would be limited to the duration and immediate vicinity of the flight. Condors are not expected to experience any reduction in foraging or nesting success. Based on the distance helicopters would maintain from Protected Activity Center boundaries (see Appendix C, Section C.4), the Proposed Action is expected to result in negligible impacts on the Mexican spotted owl, which would be limited to the duration and immediate vicinity of the flight. Helicopter flights would be expected to have only temporary impacts on bald and golden eagles, limited to the duration and immediate vicinity of the flight. Eagles would not be expected to experience any reduction in foraging or nesting success. The southwestern willow flycatcher, the western yellow-billed cuckoo, the Ridgway's rail (Yuma), and other riparian nesting birds could be temporarily displaced during the nesting season (March –September), but would be expected to experience only temporary impacts from helicopter flights. Individuals would be expected to return to their nests immediately following passage of the flight, without loss of eggs or chicks. No helicopter flights associated with this plan are expected to occur in GCNRA. Primary access to GCNRA locations would be by motor boat.

Another possible impact on birds or mammals could come from consuming fish killed by chemical treatments with rotenone and antimycin, or drinking treated water. In their risk assessments Turner et al. (2007a, b) found the acute oral LD50 for both piscicides to be many times higher than piscicide concentrations for birds and mammals and in an environmental fate study, EPA (2006) found that rotenone had a low potential for bioaccumulation and Turner et al.(2007a b) "conservatively suggest a maximum exposure concentration of about 0.7 ppm." These findings indicate that mammal and avian consumption of fish killed with either rotenone or antimycin, or consumption of treated water would have no effect on the health of these organisms.

The short-term adverse impacts of implementing control actions under the Proposed Action as described above are expected to be offset by the benefit to wildlife populations of controlling non-native aquatic species in the project area. If successful in controlling non-native aquatic species, implementation of control actions under the Proposed Action could provide a net benefit to wildlife, especially native amphibian populations and wildlife dependent on aquatic insects with terrestrial adult forms that contribute to terrestrial wildlife food webs, because the benefits of control would outweigh the mostly short-term localized adverse effects of the control actions themselves.

In general, many wildlife species, including invertebrates, have benefited from increased riparian vegetation in the project area (DOI 2016a).The greatest contribution to these cumulative impacts on wildlife relates to the changes in riparian vegetation resulting from the construction of Glen Canyon Dam (DOI 2016a; see Appendix B, Table B-1). Future increased water demand and lower flows downstream of Glen Canyon Dam, which are expected under climate change, could stress riparian and wetland vegetation, resulting in adverse impacts on wildlife habitats and the wildlife prey base. Warmer discharges (attributed to climate change) could increase algae and invertebrates, increasing the prey base for some species. Interaction and accumulation of adverse impacts on terrestrial wildlife from multiple control actions under the Proposed Action would be limited because (1) most individual actions and their effects would persist for less than a week, (2) most actions would occur in small (< 5 ac) habitats that are isolated from the main channel and each other, and (3) tiered implementation of actions would reduce the potential for them to occur simultaneously at specific locations. Benefits of control actions on wildlife, especially native amphibian populations and terrestrial wildlife food webs could reduce negative trends in cumulative impact caused by expected increases in non-native aquatic species if not adequately controlled.

3.5. TRIBAL AND CULTURAL RESOURCES

Cultural resources can be categorized as archeological resources, historic and prehistoric structures, cultural landscapes, traditional cultural properties, ethnographic resources, and museum collections. Many natural resources, such as plants and plant-gathering areas, water sources, minerals, animals, and other ecological resources, are also considered cultural resources, as they are integral to the identity of Tribes in various ways. The physical attributes of cultural resources are often non-renewable, especially archaeological sites, which often represent ancestral homes for the parks' traditionally associated Tribes.

Historic properties are defined as those cultural resources that meet the eligibility criteria for listing on the *National Register of Historic Places* (NRHP) and are considered "significant" resources that must be taken into consideration during the planning of federal projects. Historic properties are defined in the National Historic Preservation Act (NHPA) Section 106 (36 CFR 800.16(l)(1)) as any "prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the National Register of Historic Places maintained by the Secretary of the Interior. This term includes artifacts, records, and remains that are related to and located within such properties. The term includes properties of traditional religious and cultural importance to an Indian tribe or Native Hawaiian organization and that meet the National Register criteria. Historic properties can include traditional cultural properties (TCPs), certain archeological sites, or historic districts.

3.5.1 Tribal and Cultural Resources—Affected Environment

3.5.1.1 Traditional Cultural Properties

NPS Bulletin No. 38 describes a TCP as a historic property that is eligible for inclusion in the NRHP based on its associations with the cultural practices, traditions, beliefs, lifeways, arts, crafts, or social institutions of a living community. TCPs are rooted in a traditional community's history and are important in maintaining the continuing cultural identity of the community (Parker and King 1990). The cultural practices or beliefs that give a TCP its significance are still observed at the time a TCP is considered for inclusion in the NRHP.

The Colorado River, as it flows through Glen Canyon, Marble Canyon, and Grand Canyon (Canyons), has a prominent place in the history and worldview of the indigenous peoples of the Southwest and continues to have an important place in contemporary American Indian cultures, religion, and economies. The Hopi, Havasupai, Hualapai, Navajo, Pueblo of Zuni, Southern Paiute Consortium, Fort Mojave, and Yavapai-Apache Nation Tribes all have strong cultural ties to the Colorado River and the Canyons. Many see themselves as connected to the Colorado River and its Canyons and as stewards over the living world around them, including water, earth, plant life, and animal life. Many regard the Canyons as sacred space, the origin and home of their ancestors, the residence of the spirits of their dead, and the source of many culturally important resources including plants, animals, mineral sources and other resources naturally occurring in the environment. The Canyons and all within are important to the genesis of the Tribes and to their contemporary ways of life rooted in traditions engendered by those experiences.

Associated Tribes have stated that they regard the Colorado River Ecosystem, inclusive of the river and the land base from rim-to-rim within both GCNRA below Glen Canyon Dam and GCNP as a TCP. The Arizona State Historic Preservation Office has concurred with the determination as a TCP (Hopi CPO 2001; Dongoske 2011; Maldanado 2011; Coulam 2011). Within the TCP document submitted by the Pueblo of Zuni and Hopi Tribe, some of the elements of the TCPs have been disclosed and other elements are considered confidential, but all are considered important to the Tribes. A description of the importance of these elements to Tribes is provided throughout Chapter 3 in the LTEMP EIS (DOI 2016a). A description of the Tribal view of history and meaning of the Grand Canyon can be found in Section 3.9 of the LTEMP EIS (DOI 2016a).

3.5.1.2 Archaeological Sites

An archeological site or property is defined by the National Register as "a district, site, building, structure, or object. However, archeological properties are most often sites and districts." The National Register further defines an archeological site "as the place or places where the remnants of a past culture survive in a physical context that allows for the interpretation of these remains." Archeological resources identified along the Colorado River reveal the relationships between the canyon and the people who occupied the area over the past 12,000 years. For some Tribal communities, archaeological resources are considered to be markers left by their ancestors, the embodiment of those who came before, and are imbued with the spirits of the ancestors. They represent a physical link to the past.

A complete archaeological inventory of the river corridor, encompassing all traversable terrain between Glen Canyon Dam and Separation Canyon from the river up to and including pre-dam river terraces, was completed in 1991 for the 1995 Glen Canyon Dam EIS (Fairley et al. 1994). This and subsequent survey efforts have documented nearly 500 properties in the near-shore environment of the river from Glen Canyon Dam to Lake Mead (NPS 2006a). The GCNP Multiple Property Inventory National Register Determination of Eligibility considers archaeological sites within the canyon, with significance and integrity to be eligible for the National Register. These archaeological sites are frequently considered as ethnographic resources or traditional cultural properties to Tribes. A description of the types of archaeological resources and the timeframes into which they fall can be found in Section 3.8 of the LTEMP EIS (DOI 2016a).

3.5.1.3 Historic Districts

The Lonely Dell Ranch Historic District was nominated to and listed on the NRHP in 1978 (Muhn 1977); 20 years later, the district was expanded to include Lees Ferry (Hubbard 1997), creating the Lees Ferry and Lonely Dell Ranch Historic District. This is the only historic district within the project area. The district contains 26 contributing elements, including historic structures, a cemetery, irrigation ditches, and the remains of the Spencer Steamboat, which is completely submerged in the Colorado River except at low flows. Also contained within the district are numerous modern non-contributing structures including maintenance buildings, a launch ramp, and a comfort station. The significance of the district is based on its association with early Mormon settlement, early ranching and agriculture, early mining, early USGS river gaging and dam exploration activities, the exploration and development of the Colorado Plateau, and as one of the few transportation crossings of the Colorado River for over 400 miles that was first crossed by American Indians. Not included in the District, but very near it, are remnants of Puebloan architecture. Although indigenous occupation is not currently identified as a contributing element to the District's National Register eligibility, the NPS may revisit this evaluation as part of ongoing District management. Additionally, Lonely Dell Ranch has been identified as a historic vernacular landscape (See Section 3.5.1.4), significant for its association with Mormon settlement and with exploration and development of the Colorado Plateau.

3.5.1.4 Cultural Landscapes

Cultural landscapes are defined as “a geographic area, including both cultural and natural resources and the wildlife or domestic animals therein, associated with an historic event, activity, or person, or exhibiting other cultural or aesthetic values” (NPS 2009).

Glen, Marble, and Grand Canyons are significant for their human history and their ongoing roles in the lives and traditions of today’s American Indians of the Colorado Plateau and those who work and visit the canyon. On a broad scale, the entire river corridor can be viewed as a cultural landscape in which American Indians for millennia have farmed, hunted, gathered plants and minerals, and performed rituals. Ancient trails, remnants of stone structures, traces of fields, and prayer objects enshrined in travertine and salt are enduring evidence of a subtly altered landscape. Integral to this landscape are the animals, plants, and minerals traditionally used and valued by American Indians. American Indian views and traditional knowledge on a number of resources in the canyons can be found throughout Chapter 3 in the LTEMP EIS (DOI 2016a).

The historic vernacular landscape, as defined in the NPS *Cultural Resource Management Guideline* (NPS 1998), is represented at both Lees Ferry and Phantom Ranch. Both landscapes are representative of the historic exploration, settlement, and recreational activity of the Colorado River area. A short description of these landscapes can be found in Section 3.8.2.3 of the LTEMP EIS (DOI 2016a).

3.5.2 Tribal and Cultural Resources—Environmental Consequences

Impacts of the No-Action Alternative and the Proposed Action on Tribal and cultural resources are summarized in Appendix A, Table A-1 and are explained in more detail below.

3.5.2.1 Traditional Cultural Properties

Impacts of the No-Action Alternative on Traditional Cultural Properties

All mechanical removal or flow actions under the No-Action Alternative would adversely affect non-native fish, which are considered a contributing element of the documented TCP for the Pueblo of Zuni and Hopi Tribe. Under the No-Action Alternative, archaeological sites along the river could be affected by actions under the CFMP and LTEMP although impacts to archaeological sites are expected to be negligible. Potential impacts under the LTEMP and CFMP were fully evaluated and could include damage from LTEMP flow actions or unintentional trampling and potential artifact displacement if staging areas for mechanical removal experimental actions under either the LTEMP or CFMP occurred on or near these locations.

Impacts of the Proposed Action on Traditional Cultural Properties

The Proposed Action represents an increase in the type of actions that could occur under the No-Action Alternative, the locations in which those actions could occur, and their frequency of occurrence. All mechanical and chemical actions under the Proposed Action would adversely affect the non-native fish and other aquatic species, which are considered a contributing element of the documented TCP for the Pueblo of Zuni and Hopi Tribe. All archaeological sites are considered to be contributing elements to the TCP, and although impacts to sites would be avoided, if an unanticipated impact does occur, it could affect the associative value of the properties.

Several Tribes have previously expressed concerns about non-native aquatic species management in the Canyons. For those Tribes that hold the Canyons to be a sacred space, plant and animal life as well as the water itself are integral elements without which its sacredness would not be complete. An impact to one part of the ecosystem may be seen as impact to the whole. A healthy ecosystem contributes to the integrity of the Canyons as a TCP, and is characterized by a high degree of species diversity (both native and non-native) along with quality water sources (See Sections 3.2.3, 3.5, 3.6.2.1, and 3.7.4.1 of the LTEMP EIS, DOI 2016a) that are considered culturally and spiritually important to traditionally associated Tribes.

Applications of pesticides, piscicides, or other chemicals (Actions C1 through C6), mechanical control actions (Actions M1-M4), or physical control actions (P5) could affect water quality, plants, and animals. Some Tribes have expressed a preference for letting nature take its course rather than intervening to mitigate the consequences of past actions, and many Tribes have expressed confusion regarding the conflicting management goals of maintaining a native population of fish while simultaneously supporting a recreational rainbow trout fishery in the same river (DOI 2016a). Tribal viewpoints are summarized in this section; greater detail is presented in Appendix H of this EA and in Sections 3 and 4 of the LTEMP EIS (DOI 2016a).

The Zuni and Hopi in particular have been the most vocal Tribes regarding their concerns of lethal management actions applied to non-native fish and other aquatic species. Fish and other aquatic species are considered contributing elements to both Tribes' TCPs; consequently, lethal management actions would be considered an adverse effect on the TCP. The Hopi and Zuni prepared text to describe their perspective on lethal management actions, which was included in Runge et al. (2018). An excerpt of this text is presented in Appendix H and summarized briefly below.

The Zuni have consistently expressed their objection to lethal management actions. The Zuni have familial and spiritual relationships to all aquatic life, including native and non-native fish and macroinvertebrates. The taking of life without beneficial use is contrary to their cultural values and the Zuni believe these actions could have adverse impacts on their community (Runge et al. 2018).

The Hopi have similarly expressed their concerns with lethal management actions. The Hopi acknowledge and have expressed agreement with the purpose of trying to protect native species, but many believe that killing large numbers of fish without beneficial use is wrong. (See Appendix H for a more detailed description of the Hopi viewpoint). Those who support removal, state it should only be used if there is strong evidence that non-native species are a real threat to the survival of native species. Several Tribes, particularly the Hopi, Zuni, and Navajo, have expressed a preference for live removal in past agreements with Reclamation (Reclamation 2012; Runge et al. 2018).

To address these concerns, NPS has adopted a tiered adaptive implementation approach that retains the use of mechanical removal and chemical controls, but only as actions of last resort, and includes beneficial use of fish with consideration of live removal if possible as the preferred approach to removal.

Several Tribes, particularly the Zuni, Hopi, and the Southern Paiute Consortium have expressed concern about the introduction of YY-male trout or other species (Action B1) as a method of controlling target populations, because these fish are artificially modified before release. NPS considers this action experimental and is separate from the tiered approach. It would not be considered for implementation until brood stock became available (5 to 8 years in the future) and more research has been conducted on its efficacy. Prior to implementation, NPS would review new modeling and field studies to determine if additional compliance was needed; consult with AGFD, GCMRC, FWS, Reclamation, and Tribes; and discuss this option with stakeholders through the AMWG and TWG to seek consensus. NPS retains decision-making authority as the action agency.

Some controls under the Proposed Action have the potential to increase visitation in the Canyons and impact the Canyons as a TCP for most Tribes. The majority of that increase would likely be NPS staff or contractors conducting management actions. It is estimated that 8 additional boat trips would be conducted in GCNP and 12 in GCNRA. Incentivized harvest (Action H1) could encourage more recreational anglers and increase the number of visitors to the Canyons. Several Tribes have reported experiencing discomfort when performing ceremonies at certain sites within the river corridor because of the number and behavior of visitors present. Increased visitation could diminish feeling, association, settings, and materials of important places; aspects used to evaluate the integrity of a TCP. Incentivized harvest is only being considered in the Glen Canyon reach, so there should be geographic separation from the locations where most Tribal ceremonies would occur. More detail regarding the types of impacts from increased visitation and research can be found in Section 4.9.1.4 of the LTEMP EIS (DOI 2016a).

Tribes have expressed concern that fish removed for monetary gain under incentivized harvest may not be treated respectfully, in opposition to Tribal values. To address this concern, NPS has committed to providing educational materials that emphasize the respect of life and will meet with Tribes further on the wording and messaging in these programs. NPS has also developed an option for funding Tribal youth and other Tribal member trips to help harvest non-native fish. This program would offer an opportunity for Tribal elders to continue to pass down traditional knowledge from generation to generation, which in turn connects individuals with the cultural significance of the Canyons and keeps alive the community identity associated with the Colorado River Ecosystem TCP. This program would also offer a subsistence benefit to Tribal communities through the use of harvested fish.

In order to address the impacts on the Colorado River Ecosystem TCP, NPS would continue to regularly inform Tribes of intended management actions and consult on the appropriate measures for mitigation based on the management action. Examples of potential mitigations include live transport and relocation of green sunfish or beneficial use of removed non-native fish as described above. Beneficial use involves collecting fish during management actions and transporting them to Tribes for either human consumption or for use in aviaries or similar uses. Although beneficial use has been used in the past (Reclamation 2011), it should be noted that what is considered beneficial use may not be the same for all Tribes and is considered only a partial mitigation by most Tribes. What a Tribe considers beneficial use may also change over time as communities become more aware of specific management actions.

3.5.2.2 Archaeological Sites

Impacts of the No-Action Alternative on Archaeological Sites

Under the No-Action Alternative, archaeological sites along the river could be affected by actions identified in the CFMP and LTEMP, although these impacts are expected to be negligible. This could include damage from flow actions or unintentional trampling and potential artifact displacement if staging areas for mechanical removal experimental actions occurred on or near these locations. Potential impacts under the LTEMP and CFMP were fully evaluated. Because potential staging areas have recently had inventory surveys, locations of archaeological sites are known and any placement of equipment or staging would be planned to avoid potential impacts.

Impacts of the Proposed Action on Archaeological Sites

Under the Proposed Action, similar impacts to those under the No-Action Alternative are likely to occur. Although there may be up to 8 additional monitoring and control action boat trips in GCNP and up to 12 in GCRNA, it is unlikely that there will be additional impacts since the resource locations are known and implementation strategies would be designed to avoid impacts to archaeological sites. Incentivized harvest (Action H1) could increase the amount of recreational anglers on the river in GCNRA, potentially increasing the number of people on the river, but as a focused, resource management action. The number of recreational users in GCNRA is not capped and the additional number of users in both park units from the Proposed Action is within existing visitor use numbers. Increased visitation, for scientific or recreational purposes, could contribute to intentional and unintentional damage to sites if visitors were to spend time off-river exploring archaeological sites. Damage could include trailing, trampling, removal of vegetation, disturbance of artifacts, vandalism, and disruption of the sacred context through inappropriate behavior (DOI 2016a). These impacts would be minimized or avoided by ensuring the occurrence or potential occurrence of project activities and their location relative to archaeological and other types of cultural resources is determined prior to an action occurring.

3.5.2.3 Historic Districts

Impacts of the No-Action Alternative on Historic Districts

Under the No-Action Alternative, the Lees Ferry and Lonely Dell Ranch Historic District could experience intentional and unintentional damage to contributing elements if staging areas for actions occurred within the District, but these impacts would be minimized or avoided by ensuring the occurrence or potential occurrence of sites is determined prior to an action occurring. In addition, the Spencer Steamboat could be affected under flow-control actions under the LTEMP.

Impacts of the Proposed Action on Historic Districts

Under the Proposed Action, the Lees Ferry and Lonely Dell Ranch Historic District could experience intentional and unintentional damage to contributing elements if staging areas for mechanical removal occurred within the District. These impacts would be minimized or avoided by ensuring the occurrence or potential occurrence of project activities and their location relative to archaeological and other types of cultural resources is determined prior to an action occurring.

If performed near Spencer Steamboat, mechanical disruption of habitats (Action M1) and any other action that increases boat traffic could displace sediment that is beneficial for preservation of that site. Spencer Steamboat may also be adversely affected by inadvertent collision with boats being used for monitoring or non-native aquatic species control. Up to 12 additional monitoring and control action boat trips are expected under the Proposed Action in GCNRA and potential impacts from boat collision or sediment displacement are expected to be minimal. To avoid these potential impacts, mechanical removal of fish, mechanical disruption of habitats, and mechanical harvesting of aquatic plants would not be performed within 100 ft (30 m) of this site.

3.5.2.4 Cultural Landscapes

Neither the No-Action Alternative nor the Proposed Action is likely to impact the cultural landscapes of Lees Ferry and Phantom Ranch.

3.5.2.5 Cumulative Impacts on Tribal and Cultural Resources

Past and present actions have contributed to adverse cumulative impacts on cultural resources in the project area. Cultural resources (mostly archaeological sites) are in an ongoing state of deterioration due to natural erosive processes or, in some cases, human causes related to the presence and operation of Glen Canyon Dam or park visitation, including deterioration of sites exposed by erosion and intentional and unintentional damage (artifact movement, vandalism, and erosion) to archaeological sites from visitor traffic. Dam operations may affect sediment availability for site stabilization in GCNP and lowered reservoir levels resulting from climate change and changes in water demand may affect archaeological sites along shorelines in the project area contributing to exposure and erosion. These effects are somewhat mitigated through enforcement of NPS's Colorado River Management Plan (CRMP; NPS 2006a) and Backcountry Management Plan (NPS 1988) in GCNP (with similar enforcement in GCNRA). The extended-duration HFEs under the LTEMP could adversely affect terraces that support cultural resources in GCNRA, however the HFEs under the LTEMP could also provide for greater protection of sites in GCNP by providing more sand for wind transport to these sites.

Past and present actions in the project area have ongoing adverse impacts on many Tribal communities (DOI 2016a). Reclamation has entered into a Programmatic Agreement to address any potential effects to cultural and historic properties under LTEMP. The LTEMP includes mechanical removal of trout and trout management flows, both of which will have an adverse impact on the TCP because fish are a contributing element. Actions and basin-wide trends affecting aquatic life, vegetation, and wildlife (as described above) would also affect resources of value to Tribes. The LTEMP includes vegetation treatments that improve vegetation conditions and could lead to a more natural riparian ecosystem contributing to the overall better health of the Canyons, which would be considered a benefit.

The No-Action Alternative includes mechanical removal of trout in GCNP (CFMP and LTEMP) and TMFs (LTEMP) and may have an adverse impact to the Pueblo of Zuni, Hopi Tribe, and potentially other associated Tribe's TCPs. The LTEMP includes vegetation treatments that improve vegetation conditions and could lead to a more natural riparian ecosystem and provide a benefit. The No-Action Alternative is not expected to contribute to cumulative impacts on archaeological sites, historic districts, and cultural landscapes.

The Proposed Action's contribution to cumulative impacts on cultural resources would increase impacts on the Canyons as a TCP if lower tier actions are not successful and lethal methods of control cannot be conducted with beneficial use. Tribes believe the undertaking has the potential to have an adverse effect on both ethnographic and identified traditional cultural properties of importance to

American Indian Tribes. This includes impacts from lethal aquatic species management and monitoring actions and the experimental introduction of YY-male non-native fish. Chemical control actions, if used, could also adversely affect water quality and overall health of the Canyons. The Proposed Action is not expected to contribute to cumulative impacts on archaeological sites, historic districts, and cultural landscapes.

3.5.3 Indian Trust Assets and Trust Responsibility

The NPS acknowledges its federal trust responsibility and the importance of Indian trust assets within the project area. The trust responsibility consists of the highest moral obligations that the United States must meet to ensure the protection of Tribal and individual Indian lands, assets, resources, and treaty and similarly recognized rights. Secretaries of the Interior have recognized the trust responsibility repeatedly and have strongly emphasized the importance of honoring the United States' trust responsibility to federally recognized Tribes and individual Indian beneficiaries (Secretarial Order 3335; DOI 2014). Indian trust assets are legal interests in property held in trust by the U.S. Government for Indian Tribes or individuals. Examples of such resources are lands, minerals, or water rights.

The project area is bounded on the east by the Navajo Indian Reservation and on the south by the Hualapai Indian Reservation. The NPS has ongoing consultation with these Tribes regarding potential effects of NPS management action on their lands, resources, trust assets, and reserved rights. Analysis of effects on resources show that the Proposed Action is not likely to affect Indian lands, minerals, or water rights.

3.6 RECREATION, VISITOR USE, AND EXPERIENCE

3.6.1 Recreation, Visitor Use, and Experience—Affected Environment

3.6.1.1 Glen Canyon National Recreation Area

Construction of Glen Canyon Dam on the Colorado River in 1963 provided the cold-water discharges necessary for creation of the Lees Ferry rainbow trout fishery in the 15 mi Glen Canyon reach. The fishery was sustained by stocking from 1964 until 1991, and has since been self-sustaining. Fish in all waters of GCNRA and GCNP are managed by NPS, in cooperation with AGFD and FWS, and in accordance with the CFMP (NPS 2013a). The Glen Canyon reach, (Figure 1-1), is an important and frequently visited recreational region within the project area. This segment of the river includes the Lees Ferry rainbow trout fishery, as well as boat launch facilities, commercial and private boating and rafting operations, and six designated campsites spread out along the shore of the river (DOI 2016a). Visitors engage in trout fishing, from shore and boats, and in private and commercial boating and flat-water rafting, kayaking/canoeing/paddle-boarding, camping, hiking, waterfowl hunting, visiting cultural sites, and sight-seeing. The Navajo Indian Reservation extends along much of the east side of the river adjacent to the GCNRA boundary. Hiking and canyoneering access is very limited due to high, steep canyon walls.

NPS has proposed about 51% of GCNRA as wilderness under guidance provided in the 2006 NPS Management Policies and the Wilderness Act of 1964 (Act), including most of the lands on the west side of the Glen Canyon reach. NPS manages areas proposed for wilderness in a manner to preserve wilderness values and character to offer visitors opportunities for solitude and primitive recreation. The Act prohibits temporary roads, motor vehicle use, motorized equipment or motorboats, landing of aircraft, mechanical transport, structures, and installations. Section 4 (d)(1) of the Act permits the use of aircraft or motorboats where their uses have become established. *Wilderness character* is defined in the NPS Wilderness Stewardship Reference Manual 41 (NPS 2013d) as "The combination of biophysical, experiential, and symbolic ideals that distinguishes Wilderness from other lands. The five qualities of Wilderness Character are Untrammeled, Undeveloped, Natural, Solitude or a Primitive and Unconfined Type of Recreation, and Other Features of Value."

In 2012, about 210,000 users visited the Glen Canyon reach, about 25% of which accessed the area via the pontoon-raft concession that departs near the dam and travels to Lees Ferry (DOI 2016a) daily. NPS hosts facilities at Lees Ferry, including a launch ramp, campground, restroom, shade pavilion, and interpretive facilities. The six designated campsites in the reach are located on sediment terraces and beaches and are accessible by boat only. A single NPS-authorized concessionaire provides river services in the Glen Canyon reach. Half-day guided trips on motorized pontoon rafts running twice daily are the most popular service. Non-motorized full-day trips are also offered. They are also authorized to back-haul kayaks, canoes, and paddleboards and the users back up to the dam allowing for single and multiple day trips down the river.

The condition of the rainbow trout fishery has varied considerably over time in response to management actions, stocking, dam release patterns, changing reservoir conditions, and food availability. Approximately 10,900 anglers used the fishery in 2014, of which 6,700 were boat anglers who accessed the boat-fishing section upriver of Lees Ferry, and 4,200 were walk-in shore anglers, mainly accessing the 1.2-mi walk-in section at Lees Ferry downstream of the launch facility. Fishing occurs year-round, with peak fishing occurring in April and May, but remaining high through October. Five commercial guided fish operations served about 50% of boat-based fishing in 2011, and served about 3,000 clients in each of the preceding 4 years (DOI 2016a).

3.6.1.2 Colorado River in Grand Canyon National Park

GCNP received 6.2 million visitors in 2017, mostly along the South Rim where most visitor facilities and services are located. Approximately 94% of GCNP, including almost 11,000 ac along the 277-mi Colorado River corridor qualifies as Wilderness under the 1964 Wilderness Act and NPS Management Policies 2006 (NPS 2006b). Under the CRMP (NPS 2006a) a 6.5-month no-motor season is in effect in GCNP to enhance wilderness experience. River trips, including rafting and boating, camping, hiking, and visiting cultural sites, are the most popular form of recreation in the river corridor.

NPS, in accordance with the CRMP (NPS 2006a), manages resources within the river corridor, including the regulation of highly sought whitewater river trips though the corridor. The CRMP established a number of just under 25,000 recreational users, who access the area on either commercial or privately guided trips that employ a variety of sizes and types of boats to run Grand Canyon river trips. Commercial trips run from April through October and private trips run year-round. Trips may run up to 25 days. Trips begin at Lees Ferry (RM 0) and end at Diamond Creek (RM 226) or Pearce Ferry (RM 280) in the Lake Mead National Recreation Area.

NPS and the Hualapai Tribe manage recreational use of the Lower Gorge, the 51-mi section of Colorado River from Diamond Creek to Pearce Ferry. The Hualapai Reservation is on the south side of the river, between RM 164.5 and RM 273. NPS permits noncommercial and educational trips launching from Diamond Creek, in addition to those launching at Lees Ferry. In addition, the Hualapai Tribe permits and operates its own commercial trips from Diamond Creek and other sites on Tribal lands. Backcountry visitors are required to have NPS permits to camp off-river in GCNP; the Hualapai Tribe requires permits for recreational or research activities on tribal land. The Tribe also authorizes helicopter-landing pads, near Whitmore (RM 187) and at RM 261, RM 262 and RM 263 to variously serve on-river and off-river activities.

A 2011 NPS inventory identified 235 river-accessed campsites between Lees Ferry and Diamond Creek, which exist mainly on sediment terraces and beaches. Campsites of various sizes accommodate a maximum group of 32. Critical campsites are those with high demand due to scarcity in a particular stretch of river, or are located near attractions or passenger exchange sites. The number and total area of campsites has been declining in recent decades due to erosion and vegetation encroachment (Hadley et al. 2018), leading to crowding at some locations (Kaplinski et al. 2010).

3.6.2 Recreation, Visitor Use, and Experience—Environmental Consequences

3.6.2.1 Impacts of the No-Action Alternative on Recreation, Visitor Use, and Experience

The impacts of implementing the control actions included under the No-Action Alternative on recreation, visitor use, and experience would result from temporary disturbance of visitors and would be limited to the area and time when actions were occurring. TMFs under the LTEMP could affect visitors, including boaters and anglers during their implementation (DOI 2016a). The No-Action Alternative would have fewer non-flow control actions than the Proposed Action, and, therefore, would have fewer of the adverse effects associated with implementing the actions. However, the No-Action Alternative would also be less effective in controlling new or expanding non-native aquatic species populations. Such an expansion of non-native species could result in the reduction or loss of native species and reduce the natural quality of the ecosystem, a component of wilderness character. Increases in non-native species could also adversely affect the rainbow trout fishery. The No-Action Alternative would therefore result in greater adverse impact on recreation, visitor use, and experience when compared to the Proposed Action.

Past and present cumulative impacts have been beneficial to visitor use and experience (see Appendix B, Table B-1 for details including the improving of camping beaches through the HFE protocol and managing visitation under the CRMP), and some reasonably foreseeable impacts would be adverse (e.g., climate change effects on flow; see Appendix B, Table B-1 for details). The No-Action Alternative would result in a slight additional adverse impact on visitor use and experience, and therefore a slightly adverse contribution to the cumulative effect on visitor use and experience overall.

3.6.2.2 Impacts of the Proposed Action on Recreation, Visitor Use, and Experience

The Proposed Action represents a potential increase in the type of actions that could be used to control non-native aquatic species, the locations in which those actions could occur, and their frequency of occurrence. These actions have the potential to affect recreation, visitor use, and experience, including wilderness characteristics. Under the Proposed Action, control actions, if successful, would prevent degradation of the rainbow trout fishery and provide benefits to recreation, mainly from expanding fishing opportunities (more than what exist under the No-Action Alternative) from incentivized harvest. Impacts of the Proposed Action are summarized in Table A-1.

Handling and removal of non-native fishes and the various mechanical and chemical control actions included under the Proposed Action are localized and temporary (typically for a less than a week in any one area) manipulations of the ecosystem that impact the untrammeled quality of wilderness, but all are directed at restoring the natural quality of wilderness by reducing the presence of non-native species. The natural and undeveloped qualities of wilderness, as well as opportunities for solitude or a primitive and unconfined type of recreation could be temporarily affected for visitors by control actions as described in the following paragraphs. To limit impacts on wilderness values, NPS would perform a Minimum Requirements Analysis (MRA) prior to implementation of any new individual control action under the Proposed Action with potential for impacts on wilderness.

Visitors seeking a wilderness experience may be disturbed by encounters with workers transporting to and from treatment sites, from boat and helicopter traffic and noise, and from temporary loss of some campsites in proposed wilderness along tributaries occupied by workers, materials, and equipment near treatment sites. These effects would reduce opportunities for solitude and unconfined recreation. Effects would be short term (typically for less than a week in any one area), but could occur over the entire length of the transport route. Similar effects would occur during dismantling and return transport of materials and equipment. Encounters on trails or on the river would be transient and brief. Transport activities would have little or no effect on recreation.

Many prospective treatment sites are downriver of fishing locations in the Glen Canyon reach. Worker and equipment transport boats would not run frequently enough to interfere with recreational rafting trips in either park unit. It would be unlikely to exceed 8 additional administrative boat trips/yr in GCNP, and 12 additional administrative day trips/year in GCNRA. These increases represent 1.6% and 2.4%, respectively, of the recent 5-yr annual average of total motorized river trips (administrative, commercial, and non-commercial) in either park. An estimated increase of 20 helicopter flight hours would be 4.4% of recent annual average flight hours. Mechanical removal in GCNRA, is considered a higher tier and would only be implemented if other, lower tier actions were shown or projected to be ineffective. When triggered, mechanical removal would add 8 trips/day for 3 boats over a period of up to 5 days. Mechanical removal, when targeting brown trout in the Glen Canyon reach, could have negative impacts on catchability of rainbow trout for a few days following the mechanical removal. However, this would primarily occur between November 1 and February 28, when fishing use is low, so would effect a smaller number of anglers. Increases in boat and helicopter traffic would have a small impact on visitor experience, as they represent a small addition to the helicopter and boat traffic that is already occurring.

Workers at treatment locations and participants in incentivized harvest activities or fishing tournaments targeting non-native species could temporarily disturb visitors near those sites through their presence and from noise and visual disruption. Such presence could diminish a wilderness experience, where solitude is a principal wilderness value, however the incentivized harvest actions will only occur in the Glen Canyon reach where the river corridor is not part of the proposed wilderness. Fishing tournaments would draw crowds and noise to the Glen Canyon reach and could result in increased litter or waste at the launch ramp or other shoreline congregation areas and along the river requiring cleanup and waste removal activities. The presence of workers would not affect boating recreation, while public participation in fishing tournaments or other incentivized harvest could briefly enhance fishing for those participants.

Equipment used to install control structures, dig trenches, or power pumps and other equipment would generate noise, both continuous and intermittent. Installation and control actions would typically occur for less than a week in any one area. Activities would generate noises of various character, from loud, percussive noise, to constant moderate noise, for example from electrical generators and pumps. In addition, odors from fuels, exhaust, and disturbed sediments would emanate from some work areas. In GCNRA, these would not occur in wilderness areas and therefore would not affect wilderness character. Equipment operation should not interfere with recreational fishing, boating, or hiking, but may have a slight negative affect on waterfowl hunting in GCNRA. Action M1 (spawning bed treatment) would not occur in wilderness areas, but the sediment and gravel displacement would generate noise from the equipment used and odors from fumes and disturbed sediments.

In GCNP, some actions such as the placement of weirs, mechanical removal, chemical treatment or the temperature experiment could be conducted on tributaries in proposed wilderness and the presence of crews and equipment, noise, and odors could temporarily detract from the wilderness qualities of untrammeled, natural, undeveloped and opportunities for solitude for any visitors nearby however this would typically only occur for less than a week in any one area. Treatment locations would be closed to camping or other visitor uses. Therefore, although effects on wilderness experience could be adverse for a few affected individuals, the number of individuals affected would be a small fraction of total visitors.

In GCNRA, structures will not be placed in wilderness. In GCNP, some actions such as P1 and P2 may require temporary structures in tributaries in proposed wilderness. These structures could impact wilderness qualities of untrammeled, natural, and undeveloped, while the control actions themselves would affect the untrammeled quality of wilderness, as such actions are meant to manipulate the ecosystem. To mitigate visual impacts, color and composition would be chosen for structures to minimize contrast and native vegetation may be re-established around structures as a visual screen. Locations would be closed to camping or other visitor uses or the short period of installation (typically less than a week in any one area). Effects on camping, waterfowl hunting, and hiking would be minimal due to the small size, isolated locations, and short duration of most treatments. In addition, control structures and actions would not affect other features of scientific, educational, scenic, or historical value in wilderness (or other) areas, because control actions would not be implemented in areas with such features, and only actions that would not affect valued features would be used where such features are present.

The Proposed Action would have beneficial effects because of the expanded fishing opportunities in GCNRA from incentivized harvest and benefits to wilderness from the retention of native species in wilderness in GCNP. However, it would also have short-term and localized adverse impacts on recreation, visitor use, and experience during implementation of control actions. These could include impacts to waterfowl hunting in GCNRA during the days when loud operations occur, or decreased catchability of rainbow trout for 2-3 days following mechanical removal. In GCNP there would be short term impacts to wilderness qualities of untrammeled, natural, undeveloped on small sections of stream (less than 1,500 ft) and impacts on opportunities for solitude for small numbers of people for short periods of times (less than a week in any one area) in GCNP during construction of structures or operation of pumps or generators.

Past and present cumulative impacts have been beneficial to visitor use and experience (see Appendix B, Table B-1 for details including the improving of camping beaches through the HFE protocol and managing visitation under the CRMP), and some reasonably foreseeable impacts would be adverse (e.g., climate change; see Appendix B, Table B-1). The Proposed Action would contribute both small adverse impacts during operations and some small benefits to recreation and wilderness from fishing opportunities and native species retention to the cumulative impacts on visitor use and experience overall. Interaction and accumulation of adverse impacts on recreation, visitor use, and experience from multiple control actions under the Proposed Action would be limited because (1) most individual actions and their effects would persist for less than a week, (2) most actions would occur in small (< 5 ac) habitats that are isolated from the main channel and each other, and (3) tiered implementation of actions would reduce the potential for them to occur simultaneously at specific locations.

3.7 SOCIOECONOMICS AND ENVIRONMENTAL JUSTICE

3.7.1 Socioeconomics

3.7.1.1 Socioeconomics—Affected Environment

People that visit the GCNRA and GCNP for river-based recreation spend large sums of money in the region on food and beverages, restaurants, fishing and boating equipment, gasoline for vehicles and boats, camping fees or motel expenses, guide services, and fishing license fees (DOI 2016a). Total estimated river-based recreational use values were estimated as $489.4 million ($20.1 million for angling and $469.2 million for boating, net present value in 2015 dollars) under current conditions and was predicted to decrease slightly to $451.4 million ($19.2 million for angling and $432.2 million for boating) with implementation of the LTEMP (DOI 2016a). Direct and indirect employment associated with river recreation was estimated to be 156 jobs and associated income was estimated to be $3.6 million, with negligible changes anticipated under the LTEMP (DOI 2016a).

3.7.1.2 Socioeconomics—Environmental Consequences

Impacts of the No-Action Alternative on Socioeconomics

The impacts of implementing control actions under the No-Action Alternative on socioeconomics are related to potential effects on the Lees Ferry rainbow trout fishery, but as described in Section 3.3, impacts on the fishery are expected to be relatively limited in area and time. The No-Action Alternative would have fewer non-flow control actions than the Proposed Action, and, therefore, would have fewer of the adverse effects associated with implementing the actions. However, the No-Action Alternative would not have available the same set of control actions as the Proposed Action, and, therefore, would be less effective in controlling new or expanding non-native aquatic species populations. The No-Action

Alternative, because it would be less effective in non-native aquatic species control, could result in greater adverse impacts on socioeconomics related to the rainbow trout fishery.

The presence and operation of Glen Canyon Dam and Lake Powell have provided benefits to recreational socioeconomics associated with angling and boating, mostly in GCNRA. However, projected future changes in reservoir levels and river flow due to increased water demand, decreased water supply, and drought attributed to climate change are the greatest contributors to adverse cumulative impacts on the recreational use values associated with fishing, day rafting, and whitewater boating (DOI 2016a; see Appendix B, Table B-1). The annual release volume from Glen Canyon Dam, as determined by the 2007 Interim Guidelines, also affects recreation economics. The impacts of the No-Action Alternative described in the preceding paragraph represent a negligible contribution to the cumulative impact of past, present, and reasonably foreseeable future actions on socioeconomics.

Impacts of the Proposed Action on Socioeconomics

The Proposed Action represents a potential increase in the type of actions that could be used to control non-native aquatic species, the locations in which those actions could occur, and their frequency of occurrence. As described in the following paragraphs, control actions under the Proposed Action could have some adverse effects on socioeconomics related to impacts on the Lees Ferry rainbow trout fishery, but as described in Section 3.3, impacts on the fishery are expected to be relatively limited in area and time. If successful, the Proposed Action could prevent degradation of the fishery and provide overall benefits to recreation economics. Impacts of the Proposed Action are summarized in Table A-1.

Because the control actions under the Proposed Action are limited in scope and scale, target isolated areas including backwaters and off-channel ponds, and are temporary and short-duration in nature, they would have only negligible effects on factors related to the local and regional economy. Actions would have negligible adverse effects on tourism, fishing, hiking, river trips, or on demands on park facilities. In addition, the actions would not affect related socioeconomic resources, such as housing, lodging, or schools. The control action with the highest likelihood to benefit anglers, the angling guides, and the local community is incentivized harvest (Action H1) to remove brown trout and possibly other species. Rewards for target fish harvested by anglers would be paid out, guided trips would be reserved for Tribal participants and may involve overnight stays in the local area, and more visitor use and traffic may occur during the off-season periods.

An action of concern to the public expressed during public scoping is the potential effect of mechanical removal of brown trout in the Glen Canyon reach on the rainbow trout fishery and the local economy. There are several factors that should reduce the potential for adverse impact of this action on the rainbow trout fishery. Mechanical removal of brown trout in the Glen Canyon reach is a Tier 3 activity, and, thus, other lower tier actions would be implemented before this action. Mechanical removal would occur during the brown trout spawning period (between November 1 and February 28), which is outside of the peak angling period (April and May). The numbers of trips associated with this effort would likely not exceed 8 multi-day boat trips per year for the entire Glen Canyon reach and the amount of time or mechanical removal effort (e.g., electrofishing) at any specific location during a sampling pass would be only a portion of each 24-hour period and would primarily occur at night. Thus, brown trout control in the Glen Canyon reach is likely to occur relatively infrequently and result in only negligible disruption of angling with little adverse economic impact, and potentially a benefit if the action successfully improves the rainbow trout fishery as intended. It should be noted that even if mechanical removal activities do not alter rainbow trout population levels or catchability, as described in Section 3.3.2.2, there could be negative impacts to the local fishery economy if anglers perceive that fishing opportunities or catch would be affected. In addition, it is expected that incentivized harvest would continue during the mechanical harvest treatments.

Although not expected, there is the potential for the collective or repeated use of some or all of the potential actions of the Proposed Action to harm the Lees Ferry rainbow trout fishery or result in a negative public perception of the fishery. If this occurred, the actions could have adverse impacts on the local economy that relies on the fishery. Regular monitoring, triggers, and off-ramps are expected to detect any such effect and allow for responsive action to prevent adverse impacts. Mitigation actions, implemented in coordination with AGFD, would also be applied as needed to maintain a high-quality fishery. NPS would work with AGFD to develop long-term approvals to mitigate any such effects on the fishery and local economy through stocking the fishery as needed.

The presence and operation of Glen Canyon Dam and Lake Powell have provided benefits to recreational socioeconomics associated with angling and boating, mostly in GCNRA. However, projected future changes in reservoir levels and river flow due to increased water demand, decreased water supply, and drought attributed to climate change are the greatest contributors to adverse cumulative impacts on the recreational use values associated with fishing, day rafting, and whitewater boating (DOI 2016a; see Appendix B, Table B-1). The annual release volume from Glen Canyon Dam, as determined by the 2007 Interim Guidelines, also affects recreation economics. Adverse impacts under the Proposed Action on the Lees Ferry trout fishery (see Section 3.3) and subsequent impacts on recreational economics are expected to be limited and outweighed by the beneficial effects on recreational economics of non-native aquatic species control. Interaction and accumulation of adverse impacts on socioeconomics from multiple control actions under the Proposed Action would be limited because (1) most individual actions and their effects would persist for less than a week, (2) most actions would occur in small (< 5 ac) habitats that are isolated from the main channel and each other, and (3) tiered implementation of actions would reduce the potential for them to occur simultaneously at specific locations. Because of limitations on adverse effects and net benefits of the Proposed Action, an overall reduction in cumulative impacts on socioeconomics is expected.

3.7.2 Environmental Justice

The potential for environmental justice impacts, i.e., high and adverse impacts on minority or low income populations, are limited to impacts on traditionally associated Tribes especially those with land within or adjacent to the project area (i.e., the Hopi, Havasupai, Hualapai, Navajo, Zuni, and the Southern Paiute Consortium).

3.7.2.1 Impacts of the No-Action Alternative on Environmental Justice

As described in preceding resource sections, the impacts of implementing the control actions included under the No-Action Alternative are not expected to represent high and adverse impacts, and, therefore would not constitute environmental justice impacts on potentially affected low-income and minority populations in the project area. Tribal members constitute the low-income and minority populations in the project area. Cumulative impacts of past, present, and reasonably foreseeable future actions, and the incremental contributions of the No-Action Alternative on cumulative impacts on Tribal resources (and, therefore, environmental justice) are presented in Section 3.5.2.5.

3.7.2.2 Impacts of the Proposed Action on Environmental Justice

Environmental justice issues are related to adverse impacts of the Proposed Action on Tribal values, especially those related to the taking of life, introduction of YY-male fish, water quality issues related to chemical controls, and potential disruption of spring flow in the Upper Slough at RM -12. These impacts represent an increase over adverse effects on Tribal values experienced under the No-Action Alternative. These impacts and their basis are discussed in greater length in Section 3.5.2.1. Tribal-based targeted harvest programs would provide economic benefit to some Tribal participants, and could increase spiritual connection to the Canyon ecosystem. The walk-in fishery at Lees Ferry is often used by Tribes, particularly the Navajo Tribe, and, if control actions are successful in improving that fishery, economic benefits to Tribal anglers and the overall Tribal community would result.

Environmental justice impacts would result from Tribal objections to taking of life of fish and impacts on water quality, if lower tier control actions are not successful (see Section 3.5.2.1 and Appendix B, Table B-1). Live removal and relocation, or beneficial use of fish may reduce environmental justice impacts. Cumulative impacts of past, present, and reasonably foreseeable future actions, and the incremental contributions of the Proposed Action on cumulative impacts on Tribal resources (and, therefore, environmental justice) are presented in Section 3.5.2.5.

3.8 HUMAN HEALTH AND SAFETY

Activities under the Proposed Action present some risks to human health and safety. Workers implementing control actions would be subject to both physical hazards and potential exposure to chemical substances. Both types of risks would be mitigated and managed to reduce risks to the lowest practical level through the implementation of project-specific health and safety plans prepared under an overarching health and safety program. Park visitors and other members of the public would be excluded from work areas where hazards are present; risks to the public, therefore, would be negligible. Risks to workers under the No-Action Alternative would be reduced commensurate with the reduced use of control actions as compared to the Proposed Action.

NPS health and safety policy for employees and others working under NPS jurisdiction is articulated in Director's Order No. 50B, *Occupational Safety and Health Program* (September 3, 2008), which requires managers, supervisors, employees, and volunteers to comply with applicable procedures in Reference Manual 50B (NPS 2008). This manual has chapters on safety program management, codes and standards, occupational health, occupational safety, safety training, motor vehicle safety, contractor safety, off-the-job safety, watercraft safety, and concessioner safety. The guidelines and requirements of these primary documents would be implemented though project-specific health and safety plans, which analyze and identify the hazards of each project and specific actions and protections to control them.

For the proposed control actions, workers would face physical hazards during transport to worksites via watercraft, helicopter flights, and hiking with gear and equipment. During the construction of weirs, barriers, and water-control structures, workers would face hazards from powered mechanical equipment, use of hand tools, trips and falls, electrical hazards, gasoline and diesel fuel-related hazards, and over-exertion and dehydration in hot working areas. Workers involved in mechanical removal using electrofishing equipment could be at risk of shock, but this would be avoided by using personal protective equipment and following NPS's health and safety policy. In addition, some of the proposed activities would involve working in remote areas with difficult transportation of injured workers. These risks would be mitigated though safe working practices, use of personal and area protective equipment, safety controls on equipment, water and rest breaks for workers, and stop-work authority by any worker who identifies an unsafe condition.

Workers could be subject to chemical exposures from substances directly or indirectly involved in control actions. The greatest potential chemical exposure hazards would be associated with the application of piscicides (Actions C2, C3, and C4) and herbicides (Action C5) and their formulation ingredients. Laboratory exposure of rats to rotenone by injection has been associated with Parkinson's disease-like symptoms. Such symptoms were not observed in studies of oral or inhalation exposure, exposure routes relevant to use in the field (SERA 2008, NPS 2013c). No studies have conclusively linked clinically diagnosed Parkinson's disease to exposure to rotenone (Trammell et al. 2015; Finlayson et al. 2018), and even if such a link was established, the toxicological studies to date showing Parkinson's disease-like symptoms used exposure routes, such as intraperitoneal or intravenous injection, that are not germane to human exposure from fishery use (Finlayson et al. 2018). In addition, $KMnO_4$ used for rotenone neutralization, is an oxidant and a corrosive chemical that presents a handling hazard.

Human exposures to piscicides and herbicides would be minimized though proper handling, use of application equipment designed to eliminate direct contact, use of application practices and formulations that minimize vapor levels, use of protective clothing, face masks and respirators by applicators, application by trained personnel, and exclusion of non-involved workers and members of the public from application areas. Other potential chemical exposure risks include exposure to hazardous ammonia vapor (Action C1), fuel vapors, and diesel exhaust from generators and other equipment in actions that employ such equipment.

4 AGENCIES AND PERSONS CONSULTED

4.1 AGENCIES AND PERSONS CONSULTED

4.1.1 Cooperating Agencies

NPS contacted 4 federal agencies, 12 state agencies, and 13 Tribes to determine their interest in participating as Cooperating Agencies in preparation of the Expanded Non-Native Aquatic Species Management Plan EA. Of these, the following ten agreed to participate as Cooperating Agencies: (1) Arizona Game and Fish Department (2) Bureau of Reclamation, (3) Colorado River Board of California, (4) Colorado River Commission of Nevada, (5) Pueblo of Zuni, (6) Southern Nevada Water Authority, (7) Upper Colorado River Commission, (8) U.S. Fish and Wildlife Service, (9) Utah Associated Municipal Power Systems, and (10) Western Area Power Administration

Monthly teleconferences were held with Cooperating Agencies to provide updates on the status of the development of the Expanded Non-Native Management Plan and EA, and to provide opportunities for discussion. In addition, several in-person meetings, teleconferences, and webinars were held with individual or groups of Cooperating Agencies to address topics and get input within their areas of expertise or jurisdiction during the alternative development process.

Reclamation developed a technical report (Greimann and Sixta 2018) that evaluated various options to reduce temperature in the RM -12 sloughs and reduce their suitability to support non-native warmwater aquatic species. One of the options was included as a control action in the Proposed Action.

4.1.2 American Indian Tribes

Although only one Tribe participated in the process as a Cooperating Agency, NPS provided opportunities for government-to-government consultations with other traditionally associated Tribes. Opportunities included participation in monthly Cooperating Agency teleconferences, an in-person meeting for Tribal representatives (April 10, 2018), and meetings with individual Tribes to seek input and discuss concerns associated with the Plan and EA (meeting with Zuni on May 24, 2018, and Hopi on June 11, 2018).

4.1.3 GCDAMP and GCMRC

In addition to meetings with Cooperating Agencies and Tribes, NPS regularly sought input from GCMRC technical staff on species population status, non-native aquatic species threats, potential control methods, and assessment approaches. The NPS EA team participated in workshops associated with development of the Runge et al. (2018) report on underlying causes of and potential interventions for recent brown trout increases in the Glen Canyon reach; several EA team members were co-authors on that report. Runge et al. (2018) provided important information and analyses that were used in development of the EA. Regular updates on the status of the Expanded Management Plan and EA were provided to the GCDAMP TWG during public meetings. These updates provided a forum for input to be provided by the GCDAMP stakeholders.

4.2 PUBLIC INVOLVEMENT

The public scoping period for the Expanded Non-Native Management Plan extended from November 15, 2017 to January 5, 2018. The NPS invited and encouraged public participation using press releases, a public website for the project, e-mail announcements, and a public newsletter. The NPS also hosted a public webinar and three in-person public meetings in November and December of 2017 to present information about the proposed plan and to invite input regarding the Proposed Action, environmental issues that should be addressed, alternatives, and sources of data. A project Web site (https://parkplanning.nps.gov/Expanded_Nonnative) was used to disseminate information about the public scoping meetings and other information during the development of the Expanded Non-Native Management Plan and EA.

A total of 427 comment documents were received from individuals, recreational groups, environmental groups, power customers or organizations, federal and state government agencies, and other organizations. Most comments (approximately 80%) expressed opposition to the removal of trout, especially mechanical removal of brown trout in the Glen Canyon reach using electrofishing. Some commenters were opposed to removal of trout in general, regardless of method or location. About 21% of comments expressed opposition to the Proposed Action overall (i.e., actions to control or remove non-native fish), while a few (1%) recognized the need for non-native aquatic species control and supported the Proposed Action. Additional details about public scoping and of the issues raised during the scoping process are provided in a public scoping report (NPS 2018a).

APPENDIX A

SUMMARY TABLE OF THE IMPACTS OF THE NO-ACTION ALTERNATIVE AND PROPOSED ACTION

A summary of the impacts of the No-Action Alternative and Proposed Action on all resource categories is presented in Table A-1. A summary of cumulative impacts is presented in Appendix B, Table B-1. More detailed descriptions of impacts are provided in Chapter 3 of this EA.

TABLE A-1 Summary Table of the Impacts of the No-Action Alternative and Proposed Action

Control Actions	Action ID	Tier	Area Action Could Be Used	Water Quality	Aquatic Resources	Terrestrial Resources	Tribal and Cultural Resources	Recreation, Visitor Use, and Experience	Socioeconomics and Environmental Justice	Human Health and Safety
No-Action Alternative										
Suite of non-flow and flow actions in the CFMP and LTEMP including: • Rapid response to new non-native aquatic species using mechanical removal (CFMP) • Comprehensive brown trout control, including placement of weir at Bright Angel Creek confluence, incidental removal during monitoring, backpack electrofishing, and other mechanical removal with beneficial use (CFMP) • Targeted angling (CFMP) • Removal of incidental captures (CFMP) • Mechanical removal of brown and rainbow trout at the Little Colorado River confluence with beneficial use (LTEMP) • Trout management flows (LTEMP)	NA	NA	All habitats in GCNRA and GCNP	Negligible impact on water quality	There is the potential for adverse impacts of control actions that would be implemented under the No-Action Alternative on non-target native species within treated habitats, but these adverse impacts would be offset by potential benefits to native biota. The limited set of available control actions may be insufficient to provide long-term control of new or expanding potentially harmful non-native aquatic species, and this expansion of non-native species could result in reductions of native aquatic species populations and adverse impacts on aquatic habitats.	Trampling of shoreline vegetation and disturbance of wildlife during actions. Impact would be similar to, but slightly less than the impacts of the Proposed Action. Potential benefits to terrestrial resources resulting from greater control of non-native aquatic species under the Proposed Action would not be realized under the No-Action Alternative.	Potential for inadvertent damage to nearby cultural resource sites during implementation of actions. Adverse impact to the TCP for Pueblo of Zuni and Hopi Tribe, and potentially other associated Tribes, resulting from taking of life of removed fish. An impact to one part of the TCP (fish as a contributing element) may be seen as an impact to the whole TCP. Impacts would be reduced in proportion to the degree to which beneficial use of removed fish could be achieved. Impact would be similar to, but slightly less than the impacts of the Proposed Action.	Adverse impacts on visitor experience, and recreation during implementation of control actions. Control actions would help prevent degradation of the fishery and provide benefits to recreation, but the limited set of available actions may be insufficient to provide long-term control of new or expanding potentially harmful non-native aquatic species resulting in long-term adverse effects on fishery.	Little potential for adverse economic impact. Control actions would help prevent degradation of the fishery and provide economic benefits, but the limited set of available actions may be insufficient to provide long-term control of new or expanding potentially harmful non-native aquatic species resulting in long-term adverse effects on socioeconomics. Environmental justice impacts would result from Tribal objections to taking of life of removed fish. Impacts may be reduced in proportion to the degree to which beneficial use of removed fish could be achieved.	Physical risks to workers implementing mechanical controls would be managed through implementation of NPS's Occupational Safety and Health Program.

TABLE A-1 (Continued)

Control Actions	Action ID	Tier	Area Action Could Be Used	Water Quality	Aquatic Resources	Terrestrial Resources	Tribal and Cultural Resources	Recreation, Visitor Use, and Experience	Socioeconomics and Environmental Justice	Human Health and Safety
Proposed Action										
Overall Impacts of the Proposed Action										
Multiple actions in the following categories: targeted harvest, physical controls, mechanical controls, biological controls, and chemical controls, implemented in a tiered approach	NA	NA	Entire project area as specified for individual control actions	Most adverse impacts of control actions on water quality would be short-lived and restricted to a limited number of small areas. Interaction and accumulation of adverse impacts from multiple control actions would be limited because (1) most individual actions and their effects would persist for less than a week, (2) most actions would occur in small (< 5 ac) habitats that are isolated from the main channel and each other, and (3) tiered implementation of actions would reduce the potential for them to occur simultaneously at specific locations.	Most adverse impacts of control actions on aquatic resources would be restricted to a limited number of small areas (< 5 ac) and for short periods (most actions would only last for a few hours or days). Interaction and accumulation of adverse impacts from multiple control actions would be limited because (1) most individual actions and their effects would persist for less than a week, (2) most actions would occur in small (< 5 ac) habitats that are isolated from the main channel and each other, and (3) tiered implementation of actions would reduce the potential for them to occur simultaneously at specific locations. Overall benefits are expected to result if non-native aquatic species control efforts are successful.	Most adverse impacts of control actions on terrestrial resources would be restricted to a limited number of small areas (< 5 ac) and for short periods (most actions would only last for a few hours or days). Interaction and accumulation of adverse impacts from multiple control actions would be limited because (1) most individual actions and their effects would persist for less than a week, (2) most actions would occur in small (< 5 ac) habitats that are isolated from the main channel and each other, and (3) tiered implementation of actions would reduce the potential for them to occur simultaneously at specific locations. Overall benefits are expected to result if non-native aquatic species control efforts are successful.	No impacts on archaeological sites. Some impacts on TCPs resulting from taking of life and effects on water quality. Some impacts would be reduced by implementing beneficial use of removed fish.	Most adverse impacts of control actions on recreation, visitor use, and experience would be restricted to a limited number of small areas (< 5 ac) and for short periods (most actions would only last for a few hours or days). Interaction and accumulation of adverse impacts from multiple control actions would be limited because (1) most individual actions and their effects would persist for less than a week, (2) most actions would occur in small (< 5 ac) habitats that are isolated from the main channel and each other, and (3) tiered implementation of actions would reduce the potential for them to occur simultaneously at specific locations. Control actions, if successful, would prevent degradation of the rainbow trout fishery and provide benefits to recreation.	Control actions under the Proposed Action could affect socioeconomics related to the rainbow trout fishery. Interaction and accumulation of adverse impacts from multiple control actions would be limited because (1) most individual actions and their effects would persist for less than a week, (2) most actions would occur in small (< 5 ac) habitats that are isolated from the main channel and each other, and (3) tiered implementation of actions would reduce the potential for them to occur simultaneously at specific locations. If successful, these actions would prevent degradation of the fishery and provide overall benefits to recreation economics. Environmental justice impacts could result from impacts related to the taking of life and short-term effects on water quality. Some impacts would be reduced by implementing beneficial use of removed fish.	Workers implementing control actions would be subject to both physical hazards and potential exposure to chemical substances. Both types of risks would be mitigated and managed to reduce risks to the lowest practical level through the implementation of project-specific health and safety plans prepared under an overarching health and safety program. Park visitors and other members of the public would be excluded from work areas where hazards are present; risks to public, therefore, would be negligible.

TABLE A-1 (Continued)

Control Actions	Action ID	Tier	Area Action Could Be Used	Water Quality	Aquatic Resources	Terrestrial Resources	Tribal and Cultural Resources	Recreation, Visitor Use, and Experience	Socioeconomics and Environmental Justice	Human Health and Safety
Targeted Harvest										
Incentivized harvest tools	H1	1	Glen Canyon reach	Negligible impact on water quality.	Beneficial effects on populations of humpback chub and other native species due to reduction in competition and predation; and reduction in abundance of targeted non-native fish species. Adverse impacts on non-target aquatic resources including rainbow trout population in Glen Canyon reach could result from incidental capture of non-target species, but this is not expected to exceed impacts from recreational angling.	Increase in angling could result in an increase in trampling of shoreline vegetation and disturbance of wildlife.	Potential increase in recreational anglers could lead to unintentional and/or intentional trailing, trampling, removal of vegetation, disturbance of artifacts, vandalism, and disruption of the sacred context to archaeological sites. Increased visitation could lead to an increase in impacts on elements of Tribe's TCPs and a disruption of the sacred context of the TCP if participants engaged in inappropriate behavior. Beneficial effect if Tribal youth and other members can visit resource, be taught Tribal traditions on harvesting, and feed families/members of community.	Adverse impacts on visitor experience during events that drew crowds. Recreational benefits for participants in fishing events and incentive program. No adverse effects on river rafting, boating, or trout fishing. If successful, action would help prevent degradation of the fishery and provide additional benefits to recreation.	Increases in visitor spending during fishing events. Direct and indirect event–related spending would temporarily contribute to local economy. Tribal-based programs could benefit Tribal communities. No high and adverse impacts on minority or low income populations.	Physical risk to workers and the public involved in incentivized harvest programs would be managed through implementation of NPS's Occupational Safety and Health Program.
Physical Controls										
Dewatering using high-volume portable pumps with beneficial use or possible relocation of netted fish	P1	1	Small backwaters, small off-channel ponds, and low velocity areas < 0.5 ac in size in GCNRA and GCNP; RM -12 Upper Slough	Impacts on water quality limited to the targeted area and the period of dewatering (several days).	Beneficial effects on populations of native species due to reduction in competition and predation; and reduction in abundance and spawning success of targeted non-native species. Adverse impacts on non-target native species, and reductions in production of benthic invertebrates and plants within treated habitats.	Trampling of shoreline vegetation and disturbance of wildlife during dewatering. Wetland vegetation in and adjacent to the dewatered area could experience short-term stress until water levels were restored after dewatering was completed; some loss of vegetation if action is prolonged or repeated. NPS restrictions on noise would limit impact on nearby wildlife.	No impact to archaeological sites. Prior to action, affected and adjacent areas would be evaluated for cultural resources, and any resources present would be avoided. Adverse impact to contributing element of TCP for Pueblo of Zuni and Hopi Tribe, and potentially other associated Tribes, resulting from taking of life of removed fish. Live removal and relocation or beneficial use of fish prior to dewatering may reduce impact.	Impacts on visitor experience and recreation during dewatering. If successful, action would help prevent degradation of the fishery and provide benefits to recreation.	Little potential for adverse economic impact. If successful, action would help prevent degradation of the fishery and provide economic benefits. Environmental justice impacts would result from Tribal objections to taking of life of entrained fish. Live removal and relocation or beneficial use of fish prior to dewatering may reduce impact.	Physical risk to workers operating pumps would be managed through implementation of NPS's Occupational Safety and Health Program.

TABLE A-1 (Continued)

Control Actions	Action ID	Tier	Area Action Could Be Used	Water Quality	Aquatic Resources	Terrestrial Resources	Tribal and Cultural Resources	Recreation, Visitor Use, and Experience	Socioeconomics and Environmental Justice	Human Health and Safety
Placement of selective weirs	P2	1	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size, and tributaries in GCNRA and GCNP; both RM -12 sloughs	Increase in turbidity during construction and placement. Turbidity would decrease to pre-disturbance levels following completion of activity.	Beneficial effects on populations of native species due to reduction in competition and predation; and reduction in abundance and recruitment of targeted non-native fish species. Adverse impacts on aquatic habitats during installation of barriers.	Impact from disturbance of vegetation and wildlife during placement; loss of vegetation in areas disturbed during placement.	No impact to archaeological sites or TCPs. Prior to installation of weirs, affected areas would be evaluated for cultural resources, and any resources present would be avoided.	Adverse impacts on visitor experience and recreation during placement, maintenance, and monitoring of weirs. If successful, action would help prevent degradation of the fishery and provide benefits to recreation.	Little potential for adverse economic impact. If successful, action would help prevent degradation of the fishery and provide economic benefits. No high and adverse impacts on minority or low-income populations.	Physical risk to workers installing weirs would be managed through implementation of NPS's Occupational Safety and Health Program.
Placement of non-selective barriers	P3	1	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size, and tributaries in GCNRA and GCNP; both RM -12 sloughs	Increase in turbidity during construction and placement. Turbidity would decrease to pre-disturbance levels following completion of activity.	Beneficial effects on populations of native species due to reduction in competition and predation; and reduction in abundance and recruitment of targeted non-native fish species. Adverse impacts on aquatic habitats during installation of structure.	Impact from disturbance of vegetation and wildlife during placement; local loss of vegetation in areas disturbed during placement..	No impact to archaeological sites or TCPs. Prior to installation of barriers, affected areas would be evaluated for cultural resources, and any resources present would be avoided.	Adverse impacts on visitor experience and recreation during placement, maintenance, and monitoring of barriers. If successful, action would help prevent degradation of the fishery and provide benefits to recreation.	Little potential for adverse economic impact. If successful, action would help prevent degradation of the fishery and provide economic benefits. No high and adverse impacts on minority or low-income populations.	Physical risk to workers installing non-selective barriers would be managed through implementation of NPS's Occupational Safety and Health Program.
Dredging to reconnect Upper Slough to Lower Slough and facilitate draining with installation of a water-control structure	P4	4	RM -12 sloughs	Increase in turbidity during dredging of channel and placement of water-control structure. Turbidity would decrease to pre-disturbance levels following completion of activity.	Beneficial effects on populations of native species due to reduction in competition and predation; and reduction in abundance and recruitment of targeted non-native species, which could serve as source populations for downstream areas. Adverse impacts on aquatic habitats during dredging and installation of structure.	Loss of vegetation and soil in area of dredged channel, water control structure, and perimeter. Disturbance of wildlife in immediate vicinity of actions during construction activities.	No impact to archaeological sites. Archaeological sites are not present on the sediment deposits that form these sloughs Potential adverse impact to contributing element of TCP for Pueblo of Zuni and Hopi Tribe, and potentially other associated Tribes, resulting from dredging-disturbed spring outflow in the Upper Slough. Adverse and potential loss of life of fish and other aquatic organisms..	Adverse impacts on visitor experience and recreation during dredging, installation of structure,, maintenance, and monitoring. If successful, action would help prevent degradation of the fishery and provide benefits to recreation.	Little potential for adverse economic impact. If successful, action would help prevent degradation of the fishery and provide economic benefits. Environmental justice impacts related to Tribal values may occur if dredging disturbed spring outflow in the Upper Slough.	Physical risk to workers performing dredging operations and installing water-control structure would be managed through implementation of NPS's Occupational Safety and Health Program.

TABLE A-1 (Continued)

Control Actions	Action ID	Tier	Area Action Could Be Used	Water Quality	Aquatic Resources	Terrestrial Resources	Tribal and Cultural Resources	Recreation, Visitor Use, and Experience	Socioeconomics and Environmental Justice	Human Health and Safety
Produce small scale temperature changes using a propane heater	P5	Experi-mental (outside of tiers)	Tributaries in GCNP	Temperature would be increased in treatment areas (up to 1,500 ft long stream segment) to up to 29°C (84°F). Temperatures would not increase in areas upstream of treatment areas and would decrease as a function of distance further downstream. No measurable effect on main channel Colorado River temperature.	Beneficial effects on populations of native species due to reduction in competition and predation; and reduction in abundance, growth, survival, and spawning success of coldwater non-native species.	Impact from trampling of vegetation and disturbance of wildlife during placement of heaters. NPS restrictions on noise would limit impact on nearby wildlife.	No impact to archaeological sites. Prior to action, areas where heaters could be placed would be evaluated for cultural resources, and any resources present would be avoided. Adverse impact to contributing element of TCP for Pueblo of Zuni and Hopi Tribe, and potentially other associated Tribes, if raising water temperature resulted in the taking of life of coldwater fish or other aquatic organisms. Beneficial use of fish prior to use of temperature experiment placement may reduce impact.	Adverse impacts on visitor experience and recreation during heater operation. If successful, action would help prevent degradation of the fishery and provide benefits to recreation.	Little potential for adverse economic impact. If successful, action would help prevent degradation of the fishery and provide economic benefits. Environmental justice impacts would result from Tribal objections to taking of life if coldwater fish or other aquatic organisms were killed as a result of the action.	Negligible physical risk to workers installing heaters. Risks would be managed through implementation of NPS's Occupational Safety and Health Program.
Mechanical Controls										
Mechanical disruption of early life stage habitats	M1	2	Spawning areas in GCNRA and GCNP, RM -12 Lower Slough	Increase in turbidity during action. Turbidity would decrease to pre-disturbance levels following completion of activity.	Beneficial effects on populations of native species due to reductions in spawning success and recruitment of targeted non-native species. Adverse impacts on non-target native species, and reductions in production of benthic invertebrates and plants within treated areas.	Impact from trampling of shoreline vegetation and disturbance of wildlife during action. NPS restrictions on noise would limit impact on nearby wildlife.	No impact to archaeological sites. Action would not occur near the submerged Spencer Steamboat to avoid impact to that site. Prior to action, areas to be used for staging of equipment would be evaluated for cultural resources, and any resources present would be avoided. Adverse impact to contributing element of TCP for Pueblo of Zuni and Hopi Tribe, and potentially other associated Tribes, resulting from taking of life of early life stages of fish.	Adverse impacts on visitor experience and recreation during action. If successful, action would help prevent degradation of the fishery and provide benefits to recreation.	Little potential for adverse economic impact. If successful, action would help prevent degradation of the fishery and provide economic benefits. Environmental justice impacts would result from Tribal objections to taking of life of early life stages of fish.	Physical risk to workers performing control action would be managed through implementation of NPS's Occupational Safety and Health Program.

TABLE A-1 (Continued)

Control Actions	Action ID	Tier	Area Action Could Be Used	Water Quality	Aquatic Resources	Terrestrial Resources	Tribal and Cultural Resources	Recreation, Visitor Use, and Experience	Socioeconomics and Environmental Justice	Human Health and Safety
Mechanical removal: Species selective electrofishing and trapping with beneficial use or live removal and trapping	M2	1 in GCNP and in RM -12 sloughs; 2 in spawning or other congrega-tion areas in GCNRA; 3 for brown trout in GCNRA	All habitats for brown trout in GCNRA; both RM -12 sloughs for any species; spawning and congregation areas for any species in GCNRA and GCNP	Increase in turbidity during some actions (e.g., seining and netting). Turbidity would decrease to pre-disturbance levels following completion of activity.	Beneficial effects on populations of native species, especially humpback chub, due to reduction in competition and predation; and reduction in abundance and recruitment of targeted non-native species. Decreases in abundance of rainbow trout and 2-3 day reductions in catchability of rainbow trout in GCNRA and non-target native species in treated areas.	Impact from trampling of shoreline vegetation and disturbance of wildlife during action.	No impact to archaeological sites. Prior to action, areas to be used for staging of equipment would be evaluated for cultural resources, and any resources present would be avoided. Adverse impact to contributing element of TCP for Pueblo of Zuni and Hopi Tribe, and potentially other associated Tribes, resulting from taking of life of removed fish. Impacts would be reduced in proportion to the degree to which beneficial use of removed fish could be achieved.	Adverse impacts on visitor experience and recreation during mechanical removal actions. If successful, action would help prevent degradation of the fishery and provide benefits to recreation.	Little potential for adverse economic impact. If successful, action would help prevent degradation of the fishery and provide economic benefits (likely minor). Environmental justice impacts would result from Tribal objections to taking of life of removed fish. Impacts would be reduced in proportion to the degree to which beneficial use of removed fish could be achieved.	Physical risk of electrical shock to workers performing electrofishing would be managed through use of personal protective equipment and implementation of NPS's Occupational Safety and Health Program. Physical risk of other mechanical removal methods also would be managed under the NPS Occupational Safety and Health Program.
Use of sonic concussion devices	M3	4	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size in GCNRA and GCNP	Negligible impact on water quality.	Beneficial effects on populations of native species due to reduction in competition and predation; and reduction in abundance of targeted non-native species. Adverse impacts on non-target native species within treated areas.	Impact from trampling of shoreline vegetation and disturbance of wildlife during action.	No impact to archaeological sites. Prior to action, areas to be used for staging of equipment would be evaluated for cultural resources, and any resources present would be avoided. Sufficient setback from Spencer Steamboat would be ensured to avoid impact on that site. Adverse impact to contributing element of TCP for Pueblo of Zuni and Hopi Tribe, and potentially other associated Tribes, resulting from loss of life of affected fish. Impacts would be reduced in proportion to the degree to which live removal and relocation or beneficial use of removed fish could be achieved prior to action	Adverse impacts on visitor experience and recreation during sonic concussion treatments. If successful, action would help prevent degradation of the fishery and provide benefits to recreation.	Little potential for adverse economic impact. If successful, action would help prevent degradation of the fishery and provide economic benefits. Environmental justice impacts would result from Tribal objections to taking of life of affected fish. Impacts would be reduced in proportion to the degree to which live removal and relocation or beneficial use of removed fish could be achieved.	Physical risk to workers performing sonic concussive treatments would be managed through implementation of NPS's Occupational Safety and Health Program.

TABLE A-1 (Continued)

Control Actions	Action ID	Tier	Area Action Could Be Used	Water Quality	Aquatic Resources	Terrestrial Resources	Tribal and Cultural Resources	Recreation, Visitor Use, and Experience	Socioeconomics and Environmental Justice	Human Health and Safety
Mechanical harvesting of non-native aquatic plants and algae	M4	1	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size and tributaries in GCNRA and GCNP	Increase in turbidity during action. Turbidity would decrease to pre-disturbance levels following completion of activity.	Beneficial effects on populations of native species, due to improved benthic conditions and food production. Adverse impacts on non-target native species within treated areas.	Impact from trampling of shoreline vegetation and disturbance of wildlife during action.	No impact to archaeological sites. Prior to action, areas to be used for staging of equipment would be evaluated for cultural resources, and any resources present would be avoided. Adverse impact to contributing element of TCP for Pueblo of Zuni and Hopi Tribe, and potentially other associated Tribes, resulting from loss of life of incidentally removed fish that may be enmeshed in the plants when removed.	Adverse impacts on visitor experience and recreation during mechanical harvesting. If successful, action would help prevent degradation of the fishery and provide benefits to recreation.	Little potential for adverse economic impact. If successful, action would help prevent degradation of the fishery and provide economic benefits. Environmental justice impacts may result to Tribes from incidental taking of life from enmeshed fish.	Physical risk to workers performing mechanical harvesting would be managed through implementation of NPS's Occupational Safety and Health Program.
Biological Controls										
Introduction of YY- male brown trout and/or other medium to very high risk species	B1	Experi-mental (outside of tiers)	All habitats in GCNRA; tributaries only in GCNP	No impact on water quality.	Potential adverse impacts for up to 20 years on humpback chub or other native species downstream of Glen Canyon reach due to increased abundance of brown trout resulting from the annual stocking of YY-males in the Glen Canyon reach; Potential benefit to natives, including humpback chub, after completion of treatment due to reduced abundance or eradication of target non-native species.	Impact from trampling of shoreline vegetation and disturbance of wildlife during action.	No impact to archaeological sites. Prior to action, areas to be used for staging of equipment would be evaluated for cultural resources, and any resources present would be avoided. Potential adverse impact to Tribal values resulting from introduction of artificially modified fish.	Adverse impacts on visitor experience and recreation during stocking events. If successful, action would help prevent degradation of the fishery and provide benefits to recreation.	Little potential for adverse economic impact. If successful, action would help prevent degradation of the fishery and provide economic benefits. Environmental justice impacts may result from Tribal objections to introduction of artificially modified fish.	Negligible physical risk to workers stocking YY-male fish. Risks would be managed through implementation of NPS's Occupational Safety and Health Program.

TABLE A-1 (Continued)

Control Actions	Action ID	Tier	Area Action Could Be Used	Water Quality	Aquatic Resources	Terrestrial Resources	Tribal and Cultural Resources	Recreation, Visitor Use, and Experience	Socioeconomics and Environmental Justice	Human Health and Safety
Chemical Controls										
Overwhelm ecosystem-cycling capabilities of small backwaters and off-channel areas	C1	3	Small backwaters, off-channel ponds, and low velocity areas < 0.5 ac in size in GCNRA and GCNP, including the RM -12 sloughs	Impacts on water quality during treatment, but effects would be limited to relatively small areas isolated from the main channel, and would dissipate quickly.	Beneficial effects on populations of native species due to reduction in competition and predation; and reduction in abundance of targeted non-native species. Adverse impacts on non-target native species within treated areas.	Impact from trampling of shoreline vegetation and disturbance of wildlife in staging areas during action; potential impact on vegetation and amphibians in treatment areas.	No impact on archaeological sites Prior to action, areas to be used for staging of equipment would be evaluated for cultural resources, and any resources present would be avoided. Adverse impact on contributing element of TCP for Pueblo of Zuni and Hopi Tribe, and potentially other associated Tribes, resulting from taking of life of affected fish and short-term impacts on water quality. Impacts would be reduced in proportion to the degree to which live removal and relocation or beneficial use of removed fish could be achieved prior to action.	Adverse impacts on visitor experience, and negligible short-term impact on recreation during treatments. If successful, action would help prevent degradation of the fishery and provide benefits to recreation.	Little potential for adverse economic impact. If successful, action would help prevent degradation of the fishery and provide economic benefits. Environmental justice impacts would result from Tribal objections to taking of life of affected fish. Impacts would be reduced in proportion to the degree to which live removal and relocation or beneficial use of removed fish could be achieved.	Physical and chemical exposure risk to workers performing chemical treatments would be managed through implementation of NPS's Occupational Safety and Health Program.
Rapid response application of registered piscicides for new invasive non-native fish considered medium to very high risk	C2	3	Backwaters, small off-channel ponds, and low velocity areas < 5 ac in size in GCNRA and GCNP, including the RM -12 sloughs	Impacts on water quality during treatment, but effects would be limited to relatively small areas isolated from the main channel, and would dissipate quickly.	Beneficial impacts to native aquatic species due to reduction in competition and predation associated with eradication of non-native species in targeted habitat area. Adverse impacts on non-target native species within treated areas.	Impact from trampling of shoreline vegetation and disturbance of wildlife in staging areas during action; potential impacts on amphibians in treated areas.	No impact on archaeological sites. Prior to action, areas to be used for staging of equipment would be evaluated for cultural resources, and any resources present would be avoided. Adverse impact on contributing element of TCP for Pueblo of Zuni and Hopi Tribe, and potentially other associated Tribes, resulting from taking of life of affected fish and short-term impacts on water quality. Impacts may be reduced in proportion to the degree to which live removal and relocation or beneficial use of removed fish could be achieved prior to action.	Adverse impacts on visitor experience and recreation during treatments. If successful, action would help prevent degradation of the fishery and provide benefits to recreation.	Little potential for adverse economic impact. If successful, action would help prevent degradation of the fishery and provide economic benefits. Environmental justice impacts may result from Tribal objections to taking of life of affected fish and short-term impacts on water quality.	Physical and chemical exposure risk to workers performing chemical treatments would be managed through implementation of NPS's Occupational Safety and Health Program.

TABLE A-1 (Continued)

Control Actions	Action ID	Tier	Area Action Could Be Used	Water Quality	Aquatic Resources	Terrestrial Resources	Tribal and Cultural Resources	Recreation, Visitor Use, and Experience	Socioeconomics and Environmental Justice	Human Health and Safety
Application of registered piscicides for long-term control of high and very high risk species	C3	4	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size in GCNRA and GCNP, Lower Slough only at RM -12	Impacts on water quality during treatment, but effects would be limited to relatively small areas isolated from the main channel, and would dissipate quickly.	Beneficial impacts on native aquatic species due to reduction in competition and predation associated with eradication of non-native species in targeted habitat area. Adverse impacts on non-target native species within treated areas.	Impact from trampling of shoreline vegetation and disturbance of wildlife during action in staging areas; potential impacts on amphibians in treated areas.	No impact on archaeological sites. Prior to action, areas to be used for staging of equipment would be evaluated for cultural resources, and any resources present would be avoided. Adverse impact on Tribal values resulting from taking of life of affected fish and short-term impacts on water quality. Impacts may be reduced in proportion to the degree to which live removal and relocation or beneficial use of removed fish could be achieved prior to action.	Adverse impacts on visitor experience and recreation during treatments. If successful, action would help prevent degradation of the fishery and provide benefits to recreation.	Little potential for adverse economic impact. If successful, action would help prevent degradation of the fishery and provide economic benefits. Environmental justice impacts may result from Tribal objections to taking of life of affected fish and short-term impacts on water quality.	Physical and chemical exposure risk to workers performing chemical treatments would be managed through implementation of NPS's Occupational Safety and Health Program.
Application of piscicides for fishery renovation of tributary streams with natural barriers	C4	2	Tributaries with natural barriers in GCNP only	Impacts on water quality during treatment, but effects would be limited to relatively small areas isolated from the main channel, and would dissipate quickly.	Beneficial effects on native aquatic species due to expansion of populations into renovated tributaries. Adverse impacts on non-target native species within treated areas.	Impact from trampling of shoreline vegetation and disturbance of wildlife in staging areas during action; potential impacts on amphibians in treated areas.	No impact on archaeological sites. Prior to action, areas to be used for staging of equipment would be evaluated for cultural resources, and any resources present would be avoided. Adverse impact on contributing element of TCP for Pueblo of Zuni and Hopi Tribe, and potentially other associated Tribes, resulting from taking of life of affected fish and short-term impacts on water quality. Impacts may be reduced in proportion to the degree to which live removal and relocation or beneficial use of removed fish could be achieved prior to action. Actions would not take place in Ribbon Falls and Deer Creek.	Adverse impacts on visitor experience during renovation. Impacts would result from helicopter flights, generators, workers and camps in tributary areas. No adverse impacts on recreation.	Little potential for adverse economic impact. If successful, action would help prevent degradation of the fishery and provide economic benefits. Environmental justice impacts may result from Tribal objections to taking of life of affected fish and short-term impacts on water quality. Actions would not take place in Ribbon Falls and Deer Creek.	Physical and chemical exposure risk to workers performing chemical treatments would be managed through implementation of NPS's Occupational Safety and Health Program.

TABLE A-1 (Continued)

Control Actions	Action ID	Tier	Area Action Could Be Used	Water Quality	Aquatic Resources	Terrestrial Resources	Tribal and Cultural Resources	Recreation, Visitor Use, and Experience	Socioeconomics and Environmental Justice	Human Health and Safety
Application of herbicides and non-toxic dyes to backwaters and off-channel areas	C5	1	Backwaters, off-channel ponds, and low velocity areas < 5 ac in size; tributaries	Impacts on water quality during treatment, but effects would be limited to relatively small areas isolated from the main channel, and would dissipate quickly.	Beneficial effects on populations of native species, due to improved benthic conditions and food production. Adverse impacts on non-target native species within treated areas.	Impact from trampling of shoreline vegetation and disturbance of wildlife in staging areas during action	No impact to archaeological sites or TCPs. Prior to action, areas to be used for staging of equipment would be evaluated for cultural resources, and any resources present would be avoided.	Short-term, localized adverse impacts on visitor experience, and negligible short-term impact on recreation during treatments. If successful, action would help prevent degradation of the fishery and provide benefits to recreation.	No impact.	Physical and chemical exposure risk to workers performing chemical treatments would be managed through implementation of NPS's Occupational Safety and Health Program.
Application of mollusk repellents and non-toxic anti-fouling paints on boats, equipment used in the river, and NPS water intakes	C6	1	To be used only on boat hulls, equipment and water infrastructure.	No impact.	No adverse impacts on native aquatic resources. Potential benefit if repellents prevent colonization and expansion of non-native mollusks in the project area.	No adverse impact. Potential benefit if repellents prevent colonization and expansion of non-native mollusks in the project area.	No impact on archaeological sites or TCPs.	No adverse impact. Potential benefit if repellents prevent colonization and expansion of non-native mollusks in the project area.	No adverse impact. Potential benefit if repellents prevent colonization and expansion of non-native mollusks in the project area.	Negligible risk applying repellents. Risks would be managed through implementation of NPS's Occupational Safety and Health Program.

APPENDIX B

SUMMARY TABLE OF THE CUMULATIVE IMPACTS OF THE PROPOSED ACTION

The CEQ defines a cumulative impact as "the impact on the environment that results from the incremental impact of [an] action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency (federal or nonfederal) or person undertakes such other actions" (40 CFR 1508.7). Table B-1 presents a summary of cumulative impacts on resources analyzed in this EA. The cumulative impact assessment presented in the LTEMP EIS (DOI 2016a) presented a summary of the past, present, and reasonably foreseeable future contributors to cumulative impacts as well as the incremental impacts of the LTEMP preferred alternative. Table B-1 includes the incremental contribution to these cumulative impacts of the Expanded Non-Native Aquatic Management Plan No-Action Alternative (as represented by impacts of flow and non-flow control actions evaluated in the LTEMP and CFMP) and the Proposed Action. Although the Proposed Action is expected to have some impacts on resources, an overall benefit, and, therefore, a reduction in cumulative impact is expected.

TABLE B-1 Summary Table of the Cumulative Impacts of the No-Action Alternative and Proposed Action[a]

Resource/System	Region of Influence	Contributions of Past, Present, and Reasonably Foreseeable Future Actions on Cumulative Impacts	Contributions to Cumulative Impacts of the LTEMP and CFMP	Contributions to Cumulative Impacts of Expanded Non-Native Aquatic Species Management Plan Proposed Action
Water Resources	Colorado River between Glen Canyon Dam and Lake Mead; Lakes Powell and Mead	Projected future changes in flow due to increased water demand (as a result of population growth and development), and decreased water supply, drought, and increased water temperature attributed to climate change could be the greatest contributors to adverse impacts on Colorado River flows, storage in Lakes Powell and Mead, and water quality (temperature and salinity). The 2007 Interim Guidelines and related water conservation efforts, should provide more predictability in water supply to users in the Basin States (especially the Lower Basin) through 2026, and may also benefit water temperature and water quality in Lakes Powell and Mead. Future water depletions from Lake Powell including those from the proposed Lake Powell Pipeline Project and Page-LeChee Project could affect availability of water for release from Glen Canyon Dam and temperatures for release from Glen Canyon Dam.	The LTEMP is consistent with the 2007 Interim Guidelines for annual water deliveries. The LTEMP would result in slightly greater summer warming and a slightly increased potential for bacteria and pathogens along shorelines. Flow- and non-flow-based control actions under the LTEMP and CFMP would not affect water quality, and, therefore would not contribute to cumulative impacts on water quality in the project area.	The Proposed Action would not affect dam operations; therefore, no impacts on flow would occur. The Proposed Action would result in incremental changes to water quality that would be limited to the areas where control actions would occur and to the time period when actions would occur (hours or several days). No change would occur to sediment or turbidity downstream or Lake Mead. No change in baseline water quality conditions would result.
Aquatic Ecology	Colorado River between Glen Canyon Dam and Lake Mead	Aquatic resources would be affected by changes in flow due to increased water demand (as a result of population growth and development); decreased water supply, drought, and increased water temperature attributed to climate change; and other foreseeable actions (related to fish management and uranium mining). The potential for urban and agricultural runoff also increases with population growth, producing adverse effects on water quality, which could ultimately affect aquatic biota and habitat. Drought conditions (and actions such as the Lake Powell pipeline project) would result in lower reservoir elevations and benefits to aquatic resources associated with warmer release temperatures. Warmer water temperatures, however, could also result in adverse effects if they increase the distribution of non-native species adapted to warm water (e.g., fish parasites). 2007 Interim Guidelines determine annual volume and equalization years may increase trout production and river temperature both of which may impact humpback chub populations. Uranium mining could also have adverse (though local) effects on aquatic biota and habitats associated with ephemeral drainages (in the event of an accidental release of hazardous materials). Translocation of native fish species (humpback chub) from the Little Colorado River to other tributaries within the Grand Canyon would have a beneficial (protective) impact on aquatic resources.	Operations and flow-based control actions under the LTEMP would result in lower trout numbers, slightly higher humpback chub numbers, and increased food base productivity. CFMP control actions would provide a limited measure of control of non-native aquatic species. The contribution to cumulative impacts would be negligible compared to the effects of past, present, and reasonably foreseeable future actions.	The Proposed Action is expected to benefit aquatic resources overall by reducing existing populations of harmful non-native aquatic species and preventing the invasion and expansion of new non-native species in the project area. Adverse impacts on conditions within aquatic habitats and populations of native fish in the project area would be minor and generally short-lived and their contribution to adverse cumulative impacts would be offset by their benefits. Contribution to cumulative impacts on humpback chub from stocking of YY-male brown trout uncertain, although long-term population benefits are anticipated due to reduction or eradication of brown trout within the project area.
Terrestrial and Wetland Vegetation	Riparian zone along the Colorado River between Glen Canyon Dam and Lake Mead	The greatest contribution to cumulative impacts to vegetation relates to the changes resulting from the construction of Glen Canyon Dam and associated changes in flow and sediment load. Lower regional precipitation with climate change would result in a shift to more drought-tolerant species in the New High Water Zone; those in the Old High Water Zone would continue to decline. Drought conditions would favor non-native tamarisk (which is tolerant of drought stress). However, tamarisk control efforts by the NPS and possibly the effects of the tamarisk leaf beetle and splendid tamarisk weevil would increase tamarisk mortality and improve conditions for native shrubs over time. Feral burros contribute to impacts on riparian vegetation in the Old High Water Zone (by reducing vegetation and decreasing species diversity); recreational visitors may also contribute to vegetation loss and the introduction of exotic plant species.	The LTEMP would result in an overall improvement in vegetation. The LTEMP includes vegetation treatments that improve vegetation conditions and could lead to a more natural riparian ecosystem and provide a benefit. LTEMP and CFMP non-flow control actions would have limited adverse impacts on shoreline vegetation. The contribution to cumulative impacts, however, would be negligible compared to the effects of past, present, and reasonably foreseeable future actions.	The Proposed Action would result in minor, short-term incremental impacts on terrestrial and wetland vegetation that would be limited to the areas where control actions would occur. No change in baseline vegetation distributions or community composition would result. The contribution to cumulative impacts, however, would be negligible compared to the effects of past, present, and reasonably foreseeable future actions.

TABLE B-1 (Continued)

Resource/System	Region of Influence	Contributions of Past, Present, and Reasonably Foreseeable Future Actions on Cumulative Impacts	Contributions to Cumulative Impacts of the LTEMP and CFMP	Contributions of Expanded Non-Native Aquatic Species Management Plan Proposed Action to Cumulative Impacts
Terrestrial Wildlife	Colorado River corridor between Glen Canyon Dam and Lake Mead	Cumulative impacts on aquatic resources and riparian vegetation (as described in the above entries) affect riparian and terrestrial wildlife. The greatest contribution to cumulative impacts to wildlife relates to the changes resulting from the construction of Glen Canyon Dam and associated changes in riparian vegetation. Wildlife may also be affected by other future actions and basin-wide trends. Increased water demand and lower flows downstream of Glen Canyon Dam could stress riparian and wetland vegetation, affecting both wildlife habitats and the wildlife prey base. Warmer discharges (attributed to climate change) would likely increase algae and invertebrates, increasing the prey base for some species. Vegetation management could adversely affect birds in the short term, but are expected to provide benefits in the long term. Wildlife disturbance could result from various actions, including uranium mining, the Grand Canyon Escalade Project, and recreational activities (hiking, rafting, fishing, and camping). Habitat loss is a concern for those projects involving the construction of roads, effluent ponds (mining), and buildings.	Flow- and non-flow-based actions under the LTEMP and CFMP would have little effect on most wildlife species and would contribute little to cumulative impacts on wildlife in the project area.	The Proposed Action would result in minor, short-term incremental impacts on terrestrial wildlife that would be limited to the areas where control actions would occur. No change in baseline wildlife distributions or community composition would result. The contribution to cumulative impacts, however, would be negligible compared to the effects of past, present, and reasonably foreseeable future actions.
Tribal and Cultural Resources	Glen, Marble, and Grand Canyons	Cultural resources (primarily archaeological sites) are in an ongoing state of deterioration due to natural erosive processes or, in some cases, human causes related to the presence and operation of Glen Canyon Dam or park visitation. Visitor traffic along the Colorado River can result in deterioration of sites as artifacts exposed by erosion are moved or removed from the site. These effects are somewhat mitigated through enforcement of NPS's Colorado River Management Plan and Backcountry Management Plan in GCNP (with similar enforcement in GCNRA). The effects of climate change on landscape features containing archaeological remains are unclear. Ongoing dam operations may affect sediment availability for site stabilization in GCNP and lowered reservoir levels may affect archaeological sites along shorelines in GCNRA and LMNRA. Many Tribes regard the Canyons as sacred space, the home of their ancestors, the residence of the spirits of their dead, and the source of many culturally important resources. Development related to projects like the Lake Powell Pipeline and uranium mining in the region, as well as fish/vegetation management practices, have ongoing adverse impacts on Tribe members. Actions and basin-wide trends affecting aquatic life, vegetation, and wildlife (as described above) would also affect resources of value to Tribes.	The extended-duration HFEs under the LTEMP could adversely impact terraces that support cultural resources in Glen Canyon, however the HFEs under the LTEMP could also provide for greater protection of sites in Grand Canyon by providing more sand for wind transport to these sites. The LTEMP's contribution to cumulative impacts, however, would be negligible compared to the effects of past, present, and reasonably foreseeable future actions. The No-Action Alternative includes mechanical removal of trout in GCNP (CFMP and LTEMP) and TMFs (LTEMP) and may have an adverse impact to the Pueblo of Zuni, Hopi Tribe, and potentially other associated Tribe's TCPs. An impact to one part of the TCP (fish as a contributing element) may be seen as an impact to the whole TCP. The LTEMP includes vegetation treatments that improve vegetation conditions and could lead to a more natural riparian ecosystem and provide a benefit. The LTEMP's contribution to cumulative impacts, however, would be negligible compared to the effects of past, present, and reasonably foreseeable future actions.	No adverse impacts on archaeological sites are anticipated. The Proposed Action's contribution to cumulative impacts on cultural resources would potentially increase impacts to the Canyons as a TCP if lower tier actions are not successful and lethal methods of control cannot be conducted with beneficial use. Chemical control actions, if used, would also negatively impact the quality of water and overall health of the canyon, which is characterized by species diversity for some associated Tribes and includes both native and non-native species.

TABLE B-1 (Continued)

Resource/System	Region of Influence	Contributions of Past, Present, and Reasonably Foreseeable Future Actions on Cumulative Impacts	Contributions to Cumulative Impacts of the LTEMP and CFMP	Contributions of Expanded Non-Native Aquatic Species Management Plan Proposed Action to Cumulative Impacts
Recreation, visitor use, and experience	Colorado River and associated recreational sites between Glen Canyon Dam and Lake Mead	The HFE protocol has had a beneficial effect on camping and beach access (and therefore visitor use and experience) because it has a direct effect on sediment transport and deposition. Other actions taken by the NPS, as described in various management plans (tamarisk management, GCNP backcountry, noise and special flight rules, fire), also benefit visitor use and experience. The CRMP (which regulates boating and rafting) and the Comprehensive Fisheries Management Plan and Non-Native Fish Control Program are protective of natural/cultural resources and also have long-term beneficial effects on recreation and visitor experience. Warming water temperatures (and reduced flows below Glen Canyon dam) attributed to climate change could affect the health of the trout fishery below the dam, thus contributing to adverse cumulative impacts on recreation related to the trout fishery.	The No-Action Alternative would result in minor short-term localized adverse impacts on visitor use and experience, and negligible short-term adverse impacts on recreation during implementation of control actions. Benefits resulting from successful control of non-native aquatic species under the Proposed Action would not be accrued under the No-Action Alternative, because of the relatively limited set of control actions available under the alternative.	The Proposed Action would result in minor short-term localized adverse impacts on visitor use and experience, and negligible short-term adverse impacts on recreation during implementation of control actions. Benefits would result from successful control of non-native aquatic species under the Proposed Action. No overall change in visitor use and experience or recreation is anticipated.
Wilderness	Colorado River and associated recreational and wilderness sites between Glen Canyon Dam and Lake Mead	The HFE protocol and other actions taken by the NPS, as described in various management plans (the CRMP, tamarisk management, GCNP backcountry, noise and special flight rules, fire) would benefit wilderness values and experience (although noise and visual effects associated with some actions diminish these values over the short term). The Grand Canyon Escalade would contribute to adverse impacts on visitors seeking solitude or a wilderness experience due to its visual and noise effects and the presence of infrastructure, all of which are incompatible with the character of GCNP. Basin-wide effects related to climate change (e.g., reduced water availability) could diminish wilderness values and experience by reducing opportunities for solitude.	Disturbance from non-flow actions under the LTEMP and CFMP would occur under all alternatives; LTEMP operations would represent an improvement in wilderness character. The program's contribution to cumulative impacts, however, would be negligible compared to the effects of past, present, and reasonably foreseeable future actions	The Proposed Action would result in some adverse impacts on wilderness characteristics, but these would last for only a few days at any one location. Benefits to wilderness character would result from successful control of non-native aquatic species under the Proposed Action.
Socioeconomics and environmental justice	Six-county region in the vicinity of the Colorado River between Lakes Powell and Mead; recreational resources, including Lake Powell, Lake Mead, and the Grand Canyon (Colorado River)	Projected future changes in reservoir levels and river flow due to increased water demand, decreased water supply, and drought attributed to climate change could be the greatest contributors to adverse impacts on the recreational use values associated with fishing, day rafting, and whitewater boating. The Grand Canyon Escalade would likely increase recreational visitation and expenditure rates along the Colorado River. The annual release volume from Glen Canyon Dam, as determined by the 2007 Interim Guidelines, also affects recreation economics. NPS regulates the number of boating trips (specified in the CRMP and the Comprehensive Fisheries Management Plan). Therefore, regional economics of these activities are not expected to change in the foreseeable future.	The No-Action Alternative would result in increments in cumulative impacts on socioeconomics that are short-term and localized during implementation of control actions. Benefits resulting from successful control of non-native aquatic species under the Proposed Action would not be accrued under the No-Action Alternative, because of the relatively limited set of control actions available under the alternative. The contribution of the No-Action Alternative to cumulative impacts would be negligible compared to the effects of past, present, and reasonably foreseeable future actions. The impacts of implementing the control actions included under the No-Action Alternative are not expected to represent high and adverse impacts, and, therefore would not constitute environmental justice impacts on potentially affected low-income and minority populations in the project area.	Implementation of the control actions under the Proposed Action would have negligible adverse economic impact, but if successful, would help prevent degradation of the fishery and provide economic benefits that would likely be minor. Although not expected, there is the potential for the collective or repeated use of some or all of the potential actions of the Proposed Action to harm the Lees Ferry rainbow trout fishery or result in a negative public perception of the fishery and damage to the local economy that relies on the fishery. Monitoring, off-ramps, and mitigation would reduce the likelihood of this impact. Environmental justice impacts would result from Tribal objections to taking of life of fish and minor short-term impacts on water quality, if lower tier control actions are not successful. Live removal and relocation or beneficial use of fish may reduce environmental justice impacts.

[a] Region of influence, contributors to cumulative impact, and contributions of LTEMP to cumulative impact are from the LTEMP EIS (DOI 2016a).

APPENDIX C

SUPPLEMENTAL DESCRIPTIONS OF CONTROL ACTIONS UNDER THE PROPOSED ACTION

This appendix provides additional supplemental descriptions of certain (but not all) control actions that would be considered for use under the Proposed Action.

C.1MECHANICAL DISRUPTION OF EARLY LIFE STAGE HABITATS (ACTION M1; TIER 2)

C.1.1 Triggers

Trigger to Initiate Action. The number of brown trout adults (i.e., fish ≥ 350 mm total length) in the Glen Canyon reach exceeds 5,000 and there is evidence that reproduction in Glen Canyon is contributing to the continued increase. This is the number above which modeling using high-risk parameters indicates the population will have reached a threshold where mechanical removal in the Little Colorado River reach would be ineffective in controlling further increases. If mechanical removal in the Little Colorado River reach has not yet been triggered under provisions of the LTEMP Biological Opinion, this population level is the point at which we would try to reduce reproduction and recruitment to slow population growth and potential out-migration. Evidence that reproduction is occurring in the Glen Canyon reach would be provided by ongoing monitoring and modeling by AGFD and GCMRC.

Trigger to Stop Action. If brown trout adults decrease to below 2,500, then mechanical disruption would cease until the population increases to the initiation trigger of 5,000 adults.

Off-Ramp. If mechanical disruption is determined to be ineffective, if adequate funding is not available, or if unacceptable impacts to other resources (such as the rainbow trout fishery, native/endangered fish, etc.) are observed then action may be suspended temporarily or permanently depending upon the evidence.

C.2 MECHANICAL REMOVAL (ACTION M2; TIERS 1, 2, OR 3)

C.2.1 Triggers

Trigger to Initiate Action. NPS would use a complex trigger that takes into account whether or not trout removal has been triggered under LTEMP at the Little Colorado River confluence and the number of brown trout in the Glen Canyon reach.

1a. LTEMP triggers for mechanical removal of trout at the Little Colorado River confluence have been exceeded and mechanical removal is being implemented or has been proposed for the following year;

and

1b. Brown trout are a contributing proportion of the fish predators in the Little Colorado River reach (e.g., 6 adult brown trout caught in the current or previous year in the Juvenile Chub Monitoring (JCM) reach (RM 63.5-65.2);[3]

and

1c. Brown trout production in the Glen Canyon reach is an important contributor to the number of adults in the Little Colorado River reach (i.e., the number of adult brown trout in the Glen Canyon reach is > 5,000; the number above which modeling using high-risk parameters indicates the population will have reached a threshold where mechanical removal in the Little Colorado River reach would be ineffective in controlling further increases).

or

2. LTEMP triggers for mechanical removal of trout at the Little Colorado River confluence have not been met, but monitoring data and modeling indicate the number of adult brown trout is > 20,000 in the Glen Canyon reach, which modeling using moderate-risk parameters indicates that the population of adult brown trout would reach 47 in the JCM reach, the threshold above which mechanical removal in the Little Colorado River reach would be ineffective in controlling further increases;

The values of 5,000 adult brown trout in Trigger 1c and 20,000 in Trigger 2 are based on modeled estimates of the number of adult brown trout in the Glen Canyon reach that would result in a density of adult brown trout at the Little Colorado River confluence above which mechanical removal in the Little Colorado River reach would be ineffective in controlling further increases, using a range of assumptions about survival, movement rates, and population growth in the Glen Canyon reach (Yackulic 2018a). Using the high risk assumptions gives a value near 5,000 (rounded to nearest 1,000), and using moderate risk assumptions gives a value near 20,000. Population modeling in Runge et al. (2018) suggested that a sustained population of adult brown trout above 25,000 could eliminate all humpback chub in the mainstem Little Colorado River reach over a 20-year period.

Trigger to Stop Action. If mechanical removal has ceased at the Little Colorado River confluence and if brown trout adults in Glen Canyon reach have decreased to below 10,000, then mechanical removal would cease until the initiation trigger is reached again. Reducing the number of adult brown trout to 10,000 would represent substantial progress in reducing the potential for out-migration of trout to the Little Colorado River reach. This value may be adjusted if monitoring shows different movement rates than expected or modeled. Modeling in Runge et al. (2018) suggested that 50% of the expected impact to HBC would occur when adult brown trout in Glen Canyon reach a sustained population of 10000 over a 20-year period (Runge et al. 2018).

Off-Ramp. If mechanical removal is determined to be ineffective, if adequate funding is not available, or if unacceptable adverse impacts to other resources (such as the rainbow trout fishery,

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[3] Includes brown trout caught in the Juvenile Chub Monitoring (JCM) reach during any kind of monitoring or mechanical removal trip. If mechanical removal is being implemented in full, and a total of 36 passes are made, we are likely to catch at least 6 and likely more than 15, if the moderate or high risk assumptions are correct; however, if we catch 6 brown trout in the JCM reach in only a few monitoring occasions, before mechanical removal is triggered at the Little Colorado River, we know the brown trout population there has increased to the point where an upstream source is likely, which must be addressed.

native/endangered fish, etc.) are expected or observed, removal may be suspended temporarily or permanently depending upon the evidence.

C.2.2 Additional Description of Mechanical Removal

Mechanical removal, primarily using electrofishing and trapping methods, is a widely used fishery tool that is species-selective with low incidental mortality (Zale et al. 2012). Under the Proposed Action, both active and passive fish collection gears may be used including electrofishing, trapping, sweep netting (seines), and entanglement netting such as trammel or gill nets. For electrofishing, biologists use either small backpack units, small-sled mounted units, or electrofishing boats or rafts. Each type uses either a battery or a generator to produce an electric field in the water between positive and negative electrodes.

The backpack unit is the smallest of the three types of electrofishing devices and can be powered by either a battery or a small generator, and is used primarily in wadeable streams, such as Bright Angel Creek, or small shallow ponds such as the sloughs in the Glen Canyon reach. Sled mounted generator-powered units are used on small ponds, and are pushed along by biologists in waders. Electrofishing boats are used in the mainstem Colorado River. An electrofishing boat uses a generator to produce electricity, which travels to the booms at the front of the boat and into the water (Arizona Game and Fish Department and Florida Fish and Wildlife Commission)

Trapping can include a wide variety of gears developed over time for both commercial and scientific purposes (Zale et al. 2012). Trap types can include minnow traps, hoop nets, fyke nets, or other designs, all of which capture fish passively. Baits or species-specific pheromones may be used to increase capture rates. Trapping is generally harmless to fish and causes little direct stress or injury. Target non-native fish can then be removed whereas non-target fish can be returned to the water. One to several traps may be set in an area to maximize captures of target species. Traps would be checked daily at a minimum to reduce stress to the fish.

Entanglement netting, such as the widely used gill nets or trammel nets are passive gears used to sample larger areas. Swimming fish encounter panels of nets which are weighted on the bottom and have floats on the top, and are usually set with one end anchored near shore and the other drifting with the current, or anchored at the downstream end. Although these gears are selective and non-target fish can be released, there can be substantial incidental mortality. Gill nets tend to be more stressful and have higher incidental mortality than trammel nets. Trammel nets have been used in Grand Canyon to monitor humpback chub, however their use has been largely discontinued due to harmful effects on humpback chub. These type of nets can be set to surround known spawning areas and capture fish moving between spawning sites and other habitats. Seines can also be used to capture fish in shallow wadeable waters. However these methods do not capture a large proportion of fish and are usually not efficient methods of removal. Large gill and trammel nets have been used in Yellowstone National Park to remove invasive lake trout with some success (Koel 2018; Koel et al. 2012, 2015).

In the Glen Canyon reach, potential relocation of fish removed prior to dewatering habitats and after mechanical removal would be considered. Live removal would be considered only for green sunfish and only for transport to Lake Powell. The NPS considers this a low risk action because these fish likely originate as escapees from Lake Powell. To meet state requirements, sampling may involve the submission of 60 or more fish/year to a qualified laboratory to ensure the population is disease and pathogen free prior to translocation. Non-native fish being considered for relocation that were found to have disease or pathogens, occurred in large numbers of large fish, or presented other conditions that would make it logistically difficult to collect and relocate would be euthanized and considered for beneficial use. It should be noted that during discussions with AGFD, concerns were raised regarding the spread of disease or pathogens or unintended consequences; therefore, this option is currently only being considered for transport of green sunfish to Lake Powell.

C.3 INTRODUCTION OF YY-MALE FISH (ACTION B1)

Introduction of YY-male fish is considered an experimental action (outside of tiers) for medium-very high risk species that may be considered if brood stock exists and if experimental evidence and modeling indicate it may be effective and other actions are shown or projected to be ineffective. Brown trout YY-male stocking would be most effective if implemented when the population is relatively small. Although it could still be effective at larger population sizes, it would take longer to reduce the wild population, and, if that population is large (e.g., >10,000 adults), a higher number of YY males must be stocked for greatest effect. Higher stocking rates could create an increased risk to downstream native and endangered fish. Based on modeling of brook trout in Idaho (Schill et al. 2017), it is expected that a removal rate of 15% (potentially achievable with incentivized harvest) and stocking of YY males at ≥ 50% of the wild population could achieve elimination of the population in 10 years; stocking at a lower percentage would extend that time.

C.3.1 Triggers

Trigger to Initiate Action. This action would be considered for brown trout if the number of wild brown trout adults (>350 mm) is more than 500. The action would be more effective if the stocking level is 25 to 50% of the existing wild population. A maximum of 5,000 adult YY-male brown trout, or equivalent number of juveniles (estimated to be 10,000 based on assumed juvenile survival rates), would be stocked into the Glen Canyon reach annually. This number represents a conservative level of risk to humpback chub if survival, movement, and predation rates are at high-risk levels (see Table C-1 for values associated with different risk levels). If survival, movement and predation rates were found to be at the lower end of the risk levels, risk to humpback chub would also be lower than modeled.

Trigger to Stop Action. If wild brown trout adults in the Glen Canyon reach have decreased to below measurable levels for 3 years, then YY-male introduction would cease unless the population increases to the initiation trigger of 500 adults. Once stocking of YY-male brown trout ceases, YY males would persist in the population for a number of years, continuing to drive the number of XY-males down to eventually eradicate the population.

Off-Ramp. YY-male introduction may be suspended temporarily or permanently if action is determined to be ineffective, if adequate funding is not available, or if unacceptable adverse impacts to other resources (such as the rainbow trout fishery, native/endangered fish, etc.) are expected or observed. Specifically, if YY males are shown to be inefficient at slowing reproduction of brown trout in the Glen Canyon reach (e.g., if mortality of YY males is too high, if reproductive success is too low, or if upstream migration of brown trout into the Glen Canyon reach is very high) or if too many YY males emigrate to the Little Colorado River reach.

C.3.2 Additional Description of YY-Male Fish Introduction

This method has not been widely field tested. Only brook trout YY-male stock is currently available, and has been tested in a few alpine lakes and streams. In those field trials, YY-male brook trout showed good survival within one year, and ability to successfully spawn with wild female brook trout (Kennedy et al. 2018).

Schill et al. (2017) modeled time-to-extirpation of brook trout after YY-male introduction, using a range of values for stocking YY-male brook trout fingerlings (age 1) as a percentage of existing wild stocks (from 0 to 75%), and exploitation rates (removals) ranging from 0 to 50% to determine the optimum stocking and exploitation rates to reach extirpation of the wild population within 10 years. Modeling showed that stocking rates should be at least 25% of wild stock, and removal rates at least 25% to reach extirpation in 10 years or less with good survival of stocked fish. An annual stocking rate of YY males equivalent to 50% of wild fingerlings coupled with removal of 25% of wild trout annually (here assumed to be from continued harvest incentives) could result in eradication in 4 to 12 years, even at a poor survival rate of stocked YY fish (20% that of wild fish) (Schill et al. (2017). If survival was relatively poorer than wild fish, then both stocking and removal rates would have to be 50% of the wild population, to achieve extirpation within 10 years. It should be noted however that there is a degree of uncertainty in applying this model (Schill et al. 2017), designed for a small stream, to the mainstem of the Colorado River below the Glen Canyon Dam.

Kennedy et al. (2018) conducted field studies using catchable brook trout in four Idaho streams. Catchable (adult) brook trout were stocked at a rate of 25% of adults in June and made up 3% of the population in October, and ultimately contributed to 3.7% of that fall’s young.

We used modeling results from Schill et al. (2017) to set the stocking value at 50%. We used the spreadsheet model developed for estimating predation effects on humpback chub of stocked triploid rainbow trout, adjusted for expected survival, movement, and predation rates of brown trout, to estimate impacts on humpback chub at the Little Colorado River confluence from stocking 5,000 additional brown trout predators into the system for 10 years.

C.3.3 Modeled Impacts of YY-Male Fish Introduction

A model developed jointly by the GCMRC and FWS to evaluate the impact of stocking rainbow trout on humpback chub was modified to estimate how stocking YY-male brown trout in the Glen Canyon reach might contribute to mortality of juvenile humpback chub in the Colorado River downstream of Glen Canyon Dam. Inputs for the model included:

- The number of YY-male brown trout to be stocked during each of the first 10 years of a 20-year period,
- An estimate of the 3-month survival rate of YY-male brown trout,
- An estimate of the proportion of stocked YY-male brown trout that would move from Lees Ferry to the 30-mile and Little Colorado River reaches during each 3-month period, and
- An estimate of the number of humpback chub that would be eaten by an individual brown trout during each 3-month period.

Using these inputs, the model calculates quarterly estimates of

- The estimated number of YY-male trout present in the Glen Canyon reach;
- The number of stocked YY-male trout that move to the 30-mile reach and the Little Colorado River confluence; and
- The estimated number of chub eaten by the stocked trout in the 30-mile and Little Colorado River reaches.

For the modeling, it was assumed that 5,000 adult YY-male brown trout would be stocked into the Glen Canyon reach during each of the first 10 years of a 20-year period (Table C-1). The estimated range of input values for 3-month brown trout survival rate, 3-month rate of brown trout movement from the Glen Canyon reach to the Little Colorado River reach, and number of humpback chub eaten by an individual brown trout over a 3-month period were used to estimate effects under low-, moderate-, and high-risk scenarios (Table C-1). The 3-month per capita predation rate of humpback chub by a rainbow trout was estimated to range from approximately 0.4 to 1.5 humpback chub per rainbow trout, with a median value of about 0.8 humpback chub per rainbow trout. Using an assumption that brown trout are approximately 17 times more piscivorous on humpback chub than a rainbow trout (Yard et al. 2011), it was estimated that the 3-month per capita predation rate of humpback chub by a brown trout could range from approximately 6.8 to 25.5 humpback chub per brown trout, with a median value of about 13.6 humpback chub per brown trout (Table C-1).

TABLE C-1 Estimated Input Parameters for Modeling Effect of Stocked YY-Male Brown Trout on Predation of Humpback Chub under Low-, Moderate-, and High-Risk Assumptions

Parameter	Low-Risk	Moderate-Risk	High-Risk
Number of YY-male brown trout stocked[a]	5,000	5,000[b]	5,000
3-month brown trout survival rate	0.38	0.62[b]	0.85
3-month proportion of stocked brown trout moving from Glen Canyon reach to Little Colorado River reach[c]	0.0008	0.0012[b]	0.0016
3-month effect on humpback chub at Little Colorado River[d]	6.8	16.15	25.5

[a] Number of YY-male brown trout stocked annually during initial 10 year period; same for all risk levels.

[b] Moderate-risk value calculated as midpoints of low- and high-risk parameter values

[c] Four times the estimated movement rate to reaches IVa and IVb (Korman et al. 2015) to represent number of brown trout within the entire Little Colorado River reach. The reaches monitored by Korman et al. (2015) represent about 28% of the entire Little Colorado River reach.

[d] Number of humpback chub eaten by an individual brown trout during a 3-month period. Calculated by multiplying low, median, and high per capita predation estimates for rainbow trout by a factor of 17.

The modeled estimates of the annual number of YY-male brown trout in the Glen Canyon and Little Colorado River reaches and humpback chub eaten by stocked YY trout in the Little Colorado River reach during the 20-year period under the various risk scenarios are presented in Figure C-1. Modeling indicated that annual stocking of 5,000 adult YY-male brown trout into the Glen Canyon reach for a 10-year period could result in average annual consumption over a 20-year period of 13, 169, and 3,813 juvenile humpback chub for low-, moderate-, and high-risk scenarios, respectively. Total consumption of juvenile humpback chub over a 20-year period was estimated to be 269, 3,379, and 76,259 for the low-, moderate-, and high-risk scenarios, respectively. The model estimated that stocked YY-male brown trout would consume fewer than 30 juvenile humpback chub in any given year under the low-risk scenario and fewer than 350 juvenile humpback chub under the medium-risk scenario (Figure C-1). Under the high-risk scenario, approximately 100-7,500 juvenile humpback chub were estimated to be consumed annually during the 20-year period by YY-male brown trout stocked in the Glen Canyon reach and emigrating to the Little Colorado River confluence (Figure C-1).

Estimated YOY humpback chub production in the Little Colorado River ranges from approximately 5,000 to 45,000 per year (Yackulic 2018b). Thus, it is estimated that stocked brown trout could consume 17-100% of the annual humpback chub production in a given year under the high-risk assumptions, 0.8-7% under the medium-risk assumptions, and 0.1 to 0.5% of humpback chub production under the low-risk assumptions.

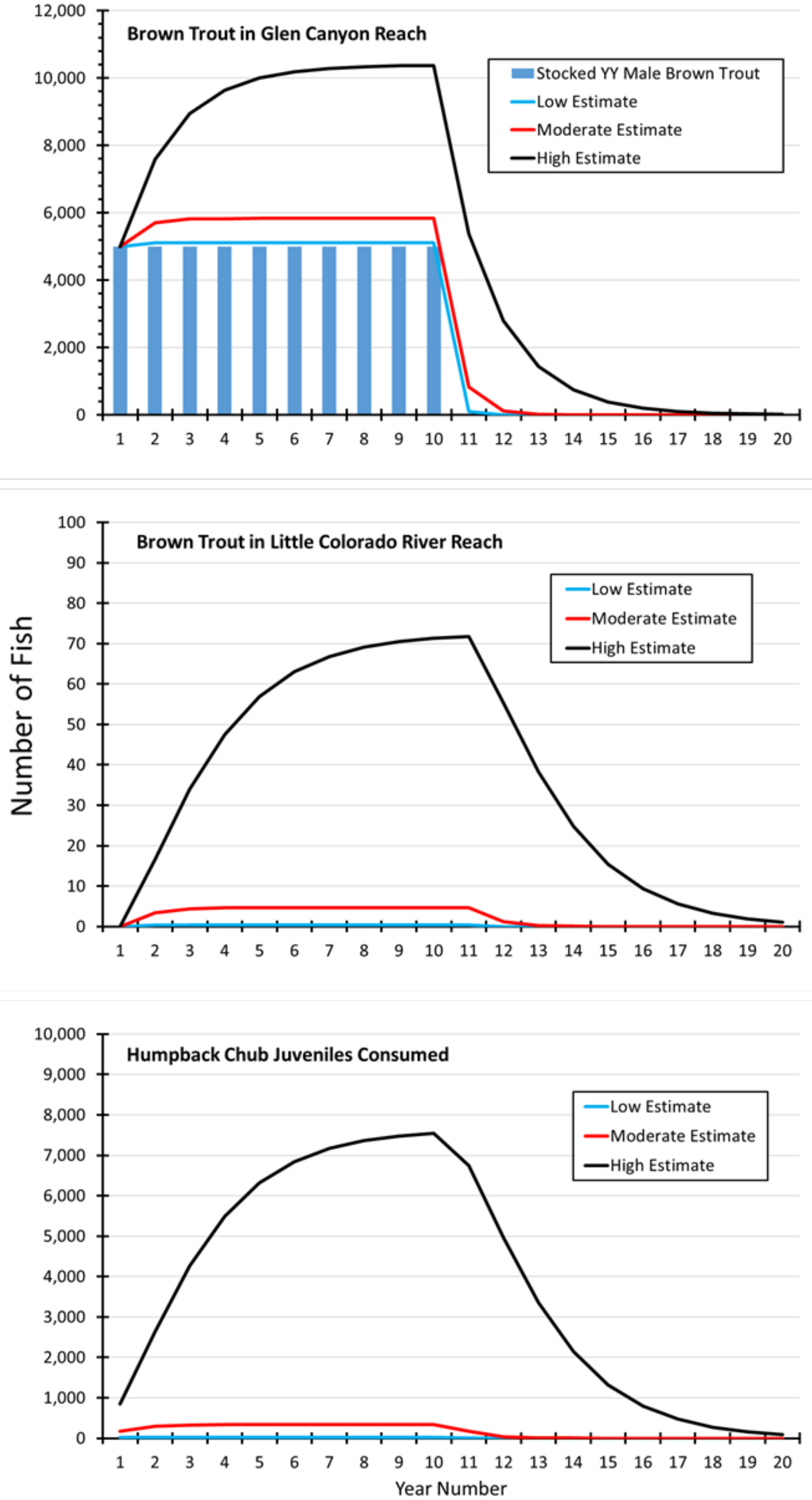

FIGURE C-1 Modeled Annual Low, Moderate, and High Estimates of YY-Male Brown Trout in Glen Canyon Reach (Upper Panel), YY-Male Brown Trout in the Little Colorado River Reach (Middle Panel), and Number of Juvenile Humpback Chub Consumed by YY-Male Trout Over a 20-Year Period (Lower Panel)

C.4 AVOIDANCE, MINIMIZATION, AND MITIGATION ACTIONS

Avoidance, minimization, and mitigation actions would be implemented under the Proposed Action to limit impacts on important resources. These actions would be developed and modified adaptively as the Proposed Action is implemented. Prior to any action being conducted, the potential for impacting important resources, including special status and ESA-listed species, cultural resources, resources of importance to Tribes, important recreation areas, and wilderness would be considered, and specific aspects of the action adjusted to avoid or minimize impacts. If necessary, surveys would be conducted for important resources prior to initiation of the action.

Under the Proposed Action, certain control actions would not be allowed a priori in some locations to avoid impacts on important resources. The Proposed Action does not include mechanical removal of rainbow trout in the Glen Canyon reach where NPS and AGFD are managing for a recreational rainbow trout fishery. However, under existing management practices, electrofishing may be used as a monitoring technique to inform decisions to improve the rainbow trout fishery. In addition, rainbow trout could be affected incidentally during actions targeting other species. Actions would be designed to minimize the incidental mortality of rainbow trout while still achieving objectives, and adaptive improvements would be considered to further minimize effects on rainbow trout.

There are some areas where NPS would not conduct electrofishing or chemical treatments under the Proposed Action because, based on past consultations, they are known areas of spiritual significance to Tribes (e.g., Ribbon Falls Creek and Deer Creek). Areas where cultural resource sites (e.g., the Spencer Steamboat) are known to occur would be avoided.

No chemical treatments, sonic concussive treatments, or mechanical harvesting of aquatic plants and algae would occur within 100 m (330 ft) of known locations of Kanab ambersnail. All piscicide or herbicide use would be subject to NPS review and approval processes in strict adherence to applicable regulations and guidelines, and would be implemented at appropriate water levels to ensure that chemicals would not come into contact with ambersnails. Before any action would occur in the vicinity of known ambersnail populations, surveys would be conducted, and ambersnails in potentially affected areas would be moved to higher locations within the habitat area if needed to avoid impacts.

Measures that would be utilized to minimize impacts on the California condor and Mexican spotted owl include:

- To reduce noise impacts on sensitive wildlife and areas with natural or wilderness characteristics when flying to and from the work area, helicopters would maintain a minimum 2,000 ft altitude where possible, per FAA Advisory Circular 91-36D Visual Flight Rules (VFR) Flight Near Noise-Sensitive Areas.
- Flights would occur prior to 10 am whenever possible because condors are less active in the morning hours
- Pilots would minimize aircraft use along the rim and cliffs to the greatest extent possible. Helicopter pilots will be encouraged to use quieter maneuvers (ones that produce less noise), wherever possible, according to the Fly Neighborly training available at https://go.usa.gov/xQPCW and https://www.rotor.org/operations/flyneighborly.aspx
- Except for authorized biologists trained in survey techniques, helicopters and fixed-wing aircraft will avoid operating within 1,000 feet of eagle nests during the breeding season, except where eagles have demonstrated tolerance for such activity. Potentially disruptive activities will be minimized in the eagles' direct flight path between their nest and roost sites and important

foraging areas. Aircraft corridors will be located no closer than 1,000 ft vertical or horizontal distance from communal roost sites, where possible.

- Aircraft associated with this project would stay at least 1 mi (1.6 km) away from active condor nest locations and vicinities except when human safety would be compromised. The active nesting season is February 1 – September 30. These dates may be modified based on the most current information regarding condor nesting activities (roosting, fledging, etc.) and coordination with GCNP's Wildlife Program Manager, Section 7 Coordinator, and FWS.
- Helicopters will stay at least 1,200 ft (366 m) away from condors in the air, or on the ground or cliffs unless safety concerns override this restriction.
- If airborne condors approach aircraft, aircraft will give up airspace to the extent possible, as long as this action does not jeopardize safety.
- In order to minimize noise disturbance within Mexican spotted owl Protected Activity Centers, helicopters will stay at least 1,200 ft (366 m) away from Protected Activity Centers between March 1 and August 31. If non-breeding is inferred or confirmed during approved-protocol surveys in a Protected Activity Center during the breeding season, restrictions on noise disturbances should be relaxed depending on the nature and extent of the proposed disturbance.
- On a case-specific basis, NPS will assess the potential for noise disturbance to nesting owls. Breeding-season restrictions will be considered if noise levels are estimated to exceed 69 dBA (A-weighted noise level; approximately 80 dBO [owl-weighted noise level, FWS 2012]) consistently (i.e., >twice/hour) or for an extended period of time (>1 hr) within 165 ft (50 m) of nesting sites (if known) or within entire Protected Activity Center if nesting sites are not known.

Other measures to avoid and mitigate sound impacts would include:

- Where possible, pumps and generators that do not exceed 60 dBA, at 50 feet, will be selected, per the NPS Audio Disturbances rule (36 CFR 2.12).
- When possible, work will be limited to the hours of 6:00 am - 10:00 pm, to reduce disturbance during quiet hours at established campsites, marked by signs, along the Colorado River below the Glen Canyon Dam. This may not be possible for mechanical removal.
- Where possible, boats that do not exceed 75 dBA, at shoreline, will be selected, per the NPS maximum boat noise rule (36 CFR 3.15).

Mitigation could be needed in areas of surface disturbance, and involve restoration of locations after the action is complete. For instance, cofferdams, water control structures, weirs, or other physical barriers would be removed once no longer needed, and this would necessitate minor restoration activities such as regrading mechanically or by hand and placement of cobble to stabilize areas of disturbance. Mechanical disruption of early life stage habitats may require regrading of habitats to restore original contours.

APPENDIX D

ALTERNATIVES AND CONTROL ACTIONS CONSIDERED BUT DISMISSED FROM DETAILED ANALYSIS

During the scoping and analysis periods for this EA, a number of alternative concepts were considered which have been used by other river management groups, were suggested by Cooperating Agencies, or were generated by the multidisciplinary NPS team. Concepts which were presented in the NPS public scoping materials, or received from the public, Cooperating Agencies, Tribes, or members of the AMWG or TWG, which were eliminated from detailed study are listed below with explanations of why they were not included in this EA.

D.1 PRELIMINARY ALTERNATIVES FROM SCOPING

NPS identified three preliminary action alternatives at scoping: Most Expanded Control Methods (Alternative B), Moderately Expanded Control Methods (Alternative C), and Most Restrictive/Least Expanded Control Methods (Alternative D). The Proposed Action incorporates aspects of all three of these preliminary alternatives in a tiered framework. Tier 1 closely resembles Alternative D, Tier 1-3 closely resembles Alternative C, and Tier 1-4 resembles Alternative B. Using the tiered approach provides for consideration of a large set of control actions that could be applied to a wide range of potential situations, allows greater flexibility, and emphasizes the use of control actions most appropriate to the risk. These preliminary alternatives were eliminated from further analysis because they were largely duplicative with a tiered action alternative.

D.2 OPTIONS IN RECLAMATION TECHNICAL REPORT ON RM-12 SLOUGHS

Reclamation assisted NPS with a technical evaluation of options to address the sloughs at RM -12 (Greimann and Sixta 2018). Two options (#4 and #6.2) from that report were incorporated into the Proposed Action. The other options were eliminated from further analysis for the following reasons:

D.2.1 Channelization from Colorado River Main Channel to or through the Upper Slough (Reclamation Options 1.1 and 1.2)

These options evaluated the cutting of a channel from the main channel of the Colorado River into the RM -12 sloughs (Option 1.1 not filling the Upper Slough but using a deeper channel and Option 1.2 filling the Upper Slough but with a shallower channel). The size and length of channel and the amount of heavy equipment and habitat impact and permanent alteration with these options was high. Options with less extensive alterations and construction and lower costs were considered in the Proposed Action. Technical issues identified with these options included high costs and maintenance issues, continued maintenance with heavy equipment to maintain the channel following HFEs or other higher flows, impacts to the historic cobble bar, and permanent loss of the pond and related wetland habitats associated with the spring which feeds the Upper Slough. Under Option 1.1, the deeper channel would have higher initial costs and would require excavation of 1,400 yd^3 of materials, which would require heavy equipment and transport of the cut material to offsite. Option 1.2 did not require removal of as much material and would have used much of the excavated material to fill the Upper Slough. It was not expected to need as frequent or extensive channel maintenance, but there were concerns that this option could not achieve the temperature goals throughout the entire season, particularly when river water levels dropped lower in warmer months. These issues led NPS to dismiss these options from further consideration as it was duplicative of other less environmentally damaging or less expensive alternative options.

D.2.2 Piping or Pumping Cold Water into the Upper Slough (Options 2 and 3)

These two options with lower costs and less extensive construction and habitat alteration methods would move cold water from the main channel into the Upper Slough. However, both options were not carried through full analysis by Reclamation because of equipment limitations and maintenance issues (Greimann and Sixta 2018)). There were concerns regarding the size of pumps needed, the power generation and fuel delivery for large pumps, and noise impacts from the pumps. The pumps would need to operate for a very long period, from March through September each year. These issues were determined to make this an ineffective option for achieving the purpose and need of the Proposed Action.

D.2.3 Permanent Fish Barrier between the Upper and Lower Slough (Option 5)

This option was not considered further by Reclamation because they determined that a wall that could exclude all flows up to a full HFE (45,000 cfs) was not considered feasible or practical given the existing topography. Concrete is also not a very practical material given the project access limitations (Greimann and Sixta 2018)). A temporary barrier is already in place that can be removed during higher flows and replaced, so this option was determined to be duplicative of other less environmentally damaging or less expensive alternative options.

D.2.4 Create a Channel between Upper and Lower Slough (Option 6.1)

This option considered a much less extensive channel cut between the Upper and Lower Slough that would completely reconnect the two sloughs. This channel cut would have less extensive construction and habitat alteration and maintenance requirements than Options 2 and 3, but would fully drain the spring-fed Upper Slough throughout the year, not just at the times critical to address warmwater non-native species breeding concerns. Consequently, it would have had additional impacts to the associated wetlands around the Upper Slough. Option 6.2 offered a less environmentally damaging solution and was included in the Proposed Action

D.2.5 Filling in the Upper Slough

This option would eliminate the warmwater aquatic habitat of the Upper Slough and would require approximately 610 yd^3 of material to fill the slough. The material would either have to be purchased and transported to the site or excavated and moved from somewhere nearby. The continued delivery of water from the small spring and scouring during HFEs could create a series of much smaller, but warmwater ponds or wetlands that could again serve as habitat for warmwater non-native fish species resulting in the need for ongoing monitoring and maintenance (Greimann and Sixta 2018). Tribes also expressed concern with the manipulation and possible disruption of the spring. These issues led NPS to dismiss this option from further consideration.

D.3 BIOLOGICAL CONTROL OPTIONS FOR RM -12 UPPER SLOUGH

Several biocontrol options were proposed in scoping by NPS for addressing warmwater non-native aquatic species in the RM-12 Upper Slough, however preliminary analysis and comments from the public and Cooperating Agencies pointed out several problems with these options.

D.3.1 Humpback Chub or Colorado Pikeminnow Introduction to Upper Slough

This action would use native predators to prey on green sunfish or other warmwater non-native fish that might be reproducing in the Upper Slough. Preliminary evaluation indicated these options would be ineffective at removing most of the non-natives from the Upper Slough. Humpback chub or small

Colorado pikeminnow would be inefficient predators of green sunfish, and the Upper Slough would not provide adequate habitat or sustain a sufficient prey base for even a small population of native predators. Higher flows (any above approximately 21,000 to 23,000 cfs) would periodically wash out these predators from the slough. Several Cooperating Agencies expressed concerns during public scoping regarding conflict with management of the recreational trout fishery. Ultimately, NPS dismissed these options because the specific proposal to use the predators in the Upper Slough would be ineffective and would have the inability to meet the purpose of and need for the Proposed Action. The NPS received a number of comments from the public suggesting a full-scale reintroduction of the Colorado pikeminnow to this ecosystem, which is addressed, in part, in the CFMP. This was determined to be beyond the scope of this NEPA review.

D.3.2 Relocation of Common Carp from Main Channel to Upper Slough

Preliminary evaluation indicated this option would be ineffective at removing non-native aquatic species from the Upper Slough. NPS received many public comments during scoping that indicated a misperception or misunderstanding that there would be an introduction of new non-natives to the area, but the actual proposal was to gather the common carp that congregate and reproduce in the Lower Slough or in the main channel, which would reduce their population there, and move them to the Upper Slough, which would create a concentration that could overwhelm the slough's ability to cycle out the high ammonia production from a large number of relocated carp, thus, making the slough uninhabitable for a short period. If successful, both the carp and the target fish (e.g., green sunfish) would succumb to the high ammonia levels. However, the effort and cost to collect common carp and relocate them would be greater than for other tools and Tribal concerns with the taking of life of a non-target species were also voiced. NPS dismissed this option because it would likely be ineffective and would have the inability to meet the purpose of and need for the Proposed Action.

D.4 CONCUSSIVE CONTROL USING DETONATION CORD

Detonation cord has been used for fishery management in many locations. Preliminary analysis indicated concerns with using this tool in this location because of safety issues during transport and handling and the need for specialized handling permits. In addition, this method would only work in deeper water (>5 ft) so few, if any off-channel areas would meet this criteria. It would also have impacts to non-target species if used in backwater or riverine systems. Compared to other control actions, the use of detonation cord has a number of potential disadvantages including damage or destruction of benthic habitats, safety issues, and public perception. The use of sonic concussive devices may have less deleterious effects on habitats, and was retained in the Proposed Action. NPS dismissed inclusion of detonation cord from further consideration as it was duplicative of other less environmentally damaging or less expensive alternatives.

D.5 TURBIDITY MANIPULATION OPTIONS

During the scoping and analysis periods for this EA, a potential option of experimental manipulation of turbidity was considered and discussed with GCMRC. These were small-scale options involving the Paria River with sediment added to increase turbidity. Fisheries experts provided possible options and benefits, but sediment experts conducted rough calculations indicating that these options were not feasible at this time as proposed. Past evaluations on large-scale options that were produced by Reclamation (Randle et al. 2006) were also discussed, but those were considered and dismissed recently in the LTEMP EIS process (DOI 2016a).

APPENDIX E

DESCRIPTION OF AQUATIC RESOURCES IN THE PROJECT AREA

E.1 AQUATIC HABITATS

Main Channel Habitats. – Main channel habitats are those habitats associated with the main watercourse containing stream flow. Channel margin habitats are the shallow, lower velocity areas located along the edges of the main channel. Substrates in main channel and channel margin habitats are composed of a variety of sediment sizes, ranging from sands to boulders and bedrock; Aquatic vegetation is present in some areas, especially between Glen Canyon Dam and Lees Ferry. Main channel depths of up to 85 ft (26 m) occur within the Grand Canyon, with an average depth of approximately 40 ft (12 m).

Backwaters and Sloughs. – Backwaters and sloughs are low-velocity habitats associated with sandbars or shoreline features that have limited connection to main channel areas. Such habitats often form in secondary or eddy return current channels (Goeking et al. 2003) where the inlet becomes blocked by substrate as main channel water elevations subside but remain narrowly connected to the active main channel through a downstream outlet. Some of these areas are fed by water from springs. Substrates in backwaters are commonly composed of sand and silt, or cobble overlain by sand and silt due to sediment deposition under low water velocities; some backwaters may have substantial amounts of aquatic vegetation.

There are a number of backwater areas and sloughs, capable of supporting non-native aquatic species that could pose a threat to native species in the Colorado River downstream of Glen Canyon Dam. For example, in July of 2015, AGFD biologists discovered a large, reproducing population of green sunfish in large backwater slough connected to the mainstem Colorado River at RM -12, approximately 3 mi downstream of Glen Canyon Dam. Green sunfish are considered likely predators of small-bodied native fish and native fish eggs. Biologists with the AGFD, NPS, USGS, FWS, and Reclamation have determined that green sunfish pose a threat to native fish, including the humpback chub.

Off-channel Ponds. – Off-channel ponds are small, isolated bodies of water situated on shoreline areas of the mainstem Colorado River. Most of these ponds receive freshwater input from springs or seeps, with some inflows during Colorado River higher flows or HFEs. The warm, low-flow conditions that develop within these ponds could serve as suitable refuge, spawning, or nursery areas for some non-native aquatic species that enter during high flows, potentially allowing for establishment of source populations that enter and spread within the mainstem during subsequent high flows.

Tributaries. – A number of tributaries flow into the Colorado River within the project area. Larger tributaries (e.g., the Little Colorado River and Paria River) that contribute significantly to flows during some periods of the year can have notable effects on water quality of the Colorado River below Glen Canyon Dam. Many of the smaller tributaries (e.g., Bright Angel Creek, Shinumo Creek, Deer Creek, Tapeats Creek, Kanab Creek, and Havasu Creek) that enter the mainstem within the project area have different physicochemical properties than the mainstem Colorado River. Because their flows are usually low, the influence of these smaller tributaries on water quality in the main channel during base flow is generally small, however, they do offer a range of different habitat conditions that may attract or benefit non-native aquatic species. As described in the LTEMP EIS (DOI 2016a), non-native fish removal is being conducted in Shinumo and Bright Angel Creeks as part of CFMP actions (NPS 2013a, b) to restore and enhance the native fish communities and to reduce predation and competition on endangered humpback chub from non-native fishes. Past removal efforts at Shinumo Creek have used netting, angling, and electrofishing techniques while removal efforts at Bright Angel Creek included the installation and operation of a fish weir trap and backpack electrofishing in the lower portion of the creek, including the confluence of Bright Angel Creek to Phantom Creek.

E.2 AQUATIC FOODBASE

Aquatic invertebrates, algae, rooted plants, and organic matter serve as the aquatic food base for fishes in the Colorado River Ecosystem (Gloss et al. 2005). Although most of this food base is produced within the aquatic system, terrestrial inputs to the Colorado River Ecosystem of organic matter (e.g., leaf litter) and terrestrial invertebrates also contribute to the aquatic food base. Flow patterns, temperature regimes, sediment transport and deposition, and turbidity have a major influence on the food base of the Colorado River Ecosystem within the Grand Canyon. The major groups of aquatic food base organisms include (1) periphyton (e.g., algae and cyanobacteria that live attached to rocks and other surfaces) and rooted aquatic plants, (2) plankton (very small plants [phytoplankton] and animals [zooplankton] that occur in the water column), and (3) macroinvertebrates (i.e., invertebrates such as insect larvae that are visible to the naked eye). In recent years, non-native mollusks (New Zealand mudsnails and quagga mussels) have become established in the Glen Canyon reach and make up a large percentage of the living biomass. It is not known if they are being utilized by any of the aquatic organisms currently in the river. Some invasive fish species such as bluegill or green sunfish could benefit from this large food base if they were able to establish.

The aquatic flora within the project area is currently dominated by various species of algae, macrophytes, and bryophytes including filamentous green algae (mainly *Ulothrix zonata* and *Spirogyra* spp.), the stonewort *Chara contraria*, the aquatic moss *Fontinalis* spp., and the macrophyte *Potamogeton pectinatus*. *Cladophora* occurs along the entire course of the river within the project area, although its abundance decreases downstream (Blinn and Cole 1991; Shannon et al. 1994; Shaver et al. 1997; Stevens et al. 1997) due to higher suspended sediment loads contributed by major perennial tributaries(especially the Paria River and Little Colorado River) (Blinn et al. 1995). *Cladophora* is colonized by a variety of diatom species (Dodds and Gudder 1992) that are an important component of the food base in the tailwaters of Glen Canyon Dam (Blinn et al. 1992). The cyanobacteria *Oscillatoria* is co-dominant with *Cladophora* in Marble Canyon and dominates farther downstream in the Grand Canyon due to its tolerance of exposure to air and lower light levels compared to *Cladophora* (Blinn et al. 1992; Stevens, Shannon et al. 1997). Submerged macrophytes in the mainstem, backwaters, and off-channel ponds in the project area include non-native species such as horned pondweed (*Zannichellia palustris*), Canadian waterweed (*Elodea canadensis*), Brazilian waterweed, pondweed (*Potamogeton* spp.), aquatic moss (*Fontinalis* spp.), and muskgrass (*Chara* spp. [green alga]) (Carothers and Minckley 1981; Valdez and Speas 2007). Curly-leaf pondweed, which is known to be present within the Grand Canyon portion of the project area is believed to pose a medium level of threat to the aquatic ecosystem because it competes with native aquatic plants and can cause fish die-offs when algal blooms begin to die off; curly-leaf pondweed can also clog some waterways and inhibit recreational activities (Appendix F).

In general, phytoplankton productivity of the Colorado River is relatively low due to a combination of high flow rates, low temperatures, elevated turbidity (with increasing distance from the dam), and scouring action by rapids and suspended solids (Sommerfeld et al. 1976). Primary factors that regulate zooplankton in the mainstem Colorado River below Glen Canyon Dam are the distribution, species composition, and abundance of zooplankton in Lake Powell and tributaries and operations of the dam (AGFD 1996; Speas 2000). Production and densities of zooplankton in eddies, backwaters, and other low-velocity areas may be significantly higher than in the main channel in some cases (AGFD 1996; Stanford and Ward 1986; Blinn and Cole 1991). Given that waters in many backwaters are exchanged with the main channel 1.5 to 3.4 times per day even under stable flows, it is unlikely that water-column resources such as zooplankton would be substantially higher in backwaters than in the mainstem river in many cases (Behn et al. 2010). Although productivity of the food base is higher in the Glen Canyon reach, food base production in the Grand Canyon is extremely low, falling in the bottom 10% of production values for streams and rivers throughout the world (Cross et al. 2013).

The most abundant aquatic macroinvertebrates within the Glen Canyon reach include *Gammarus lacustris* (an introduced non-native amphipod), midges (order Diptera, family Chironomidae), snails (*Physella* sp. and *Fossaria obrussa*), segmented worms (especially Lumbricidae and Lumbriculidae) and other aquatic worms (Naididae and Tubificidae), fingernail clams in the family Sphaeriidae (*Pisidium variable* and *P. walkeri*), and the planarian *Dugesia* spp. (Blinn et al. 1992; Stevens, Shannon et al. 1997). Prior to 1995, snails were infrequently observed, but have since increased in abundance due to invasion by the non-native New Zealand mudsnail (*Potamopyrgus antipodarum*) (Valdez and Speas 2007; Cross et al. 2010).

There is a general decrease in standing stock of *Gammarus* with distance from Glen Canyon Dam (Blinn and Cole 1991; Blinn et al. 1992) that corresponds to a decrease in *Cladophora* biomass and associated diatoms (Hardwick et al. 1992). In the mainstem downstream of Lees Ferry, *Gammarus* is largely replaced by midges and blackflies (Blinn et al. 1992; Seegert 2010). It should be noted that even though blackflies and midges are less prevalent in Glen Canyon than further downstream, they likely support more than half of the rainbow trout production in the Glen Canyon reach (Cross et al. 2011). As indicated in Appendix F, invasive aquatic invertebrate species that are known to occur within the project area include a crayfish species (probably northern crayfish) (Trammell 2015), the New Zealand mudsnail (Benson et al. 2018a), the quagga mussel (Benson et al. 2018a), and the Asian clam. These species are currently believed to pose low to medium levels of threat, due to their potential to alter ecosystem conditions, compete with native aquatic species, or affect infrastructure and recreational opportunities.

The mainstem Colorado River in Glen and Grand Canyons supports very few species or individuals of native mayflies, stoneflies, or caddisflies because of a combination of stressors, including altered temperature regimes and a pronounced varial zone (Stevens, Shannon, et al. 1997; Kennedy et al. 2016). Cold water released from Glen Canyon Dam can prevent aquatic insect eggs from hatching and may limit successful recruitment of these orders from warmer tributaries (Oberlin et al. 1999), while a large varial zone associated with hydropower production leads to desiccation-induced mortality of insect eggs laid along river edge habitats (Kennedy et al. 2016). Some tributaries of the Colorado River, along with backwaters and off-channel ponds, have higher diversity and densities of mayflies, stoneflies, and caddisflies compared to the mainstem.

E.3 NATIVE FISH AND SPECIAL STATUS FISH SPECIES

There are currently 8 species of native fish that occur, may occur, or historically have occurred within the project area (Table 3-1). Five of these species (humpback chub, razorback sucker, bluehead sucker, flannelmouth sucker, and speckled dace) are currently present within the mainstem and its tributaries in the project area. The remaining three species (bonytail chub, roundtail chub, and Colorado pikeminnow) have been extirpated from the mainstem between Glen Canyon Dam and Hoover Dam.

Four of the native fish species within the project area have special Federal and/or State status designations. Two species of native fish that are listed under the Endangered Species Act of 1973 (ESA) (16 USC 1531, as amended), the humpback chub and the razorback sucker, occur in the potentially affected portions of the Colorado River and its tributaries between Glen Canyon Dam and the inflow to Lake Mead (Table 3-1). These two species are also designated as Arizona Species of Greatest Conservation Need (AZ-SGCN), along with the bluehead sucker (Table 3-1). Additional details regarding the status, biology, and threats to special-status native fish species within the project area are provided in the LTEMP EIS (DOI 2016a).

Construction and closure of Glen Canyon Dam altered the river downstream, created a relatively clear river with nearly constant year-round cold temperatures (<12°C [54°F]), daily flow fluctuations due to electrical demand adjustments, and seasonally modulated flows driven by tributary inflows, water storage, and electrical generation needs (Reclamation 1995; NPS 2013a). Temperatures in much of the main channel are below those suitable for spawning, egg incubation, and growth of most native fish, and successful reproduction has been largely supported only in tributaries (Reclamation 1995). Most native fish in the mainstem from the dam to the Little Colorado River are large juveniles and adults, while earlier life stages generally utilize more protected and warmer near-shore habitats and backwaters (Johnstone and Lauretta 2007; Ackerman 2008). In recent years, there has been newly documented reproduction of native fish in portions of the lower Grand Canyon, including razorback suckers (Bunch et al. 2012a; Bunch et al. 2012b; Albrecht et al. 2014; Rogowski and Wolters 2014; Rogowski et al. 2015b; Kegerries et al. 2017). Colorado River tributaries continue to exhibit natural flow and temperature regimes conducive to native fish spawning and rearing.

In addition to effects of altered mainstem physical conditions on the reproduction, growth, survival, and distribution of native fish in the Colorado River below Glen Canyon Dam, intentional and accidental introductions of non-native fish species have affected native fish in the Colorado River and its tributaries. Coldwater and/or warmwater non-native fish exist in all fish-bearing waters in GCNP and GCNRA below Glen Canyon Dam. Non-native species dominate the fish community in some locations and may threaten native species survival. Regardless, the Colorado River and its tributaries in GCNP support the largest remaining endangered humpback chub population which has been growing since the late 1990s (Coggins and Walters 2009) and was recently estimated at over 11,000 adults (Yackulic et al. 2014, FWS 2017). Over this same time period, native species have become a more dominant component of the Grand Canyon fish community near the Little Colorado River and in the lower reaches of the Grand Canyon to Lake Mead (Lauretta and Serrato 2006; Johnstone and Lauretta 2007; Ackerman 2008; Makinster et al. 2010; Kegerries et al. 2017). It is hypothesized that the shift from non-native to native fish was due, in part, to warmer than average water temperatures, a decline in rainbow trout abundance near the Little Colorado River (Ackerman 2008; Andersen 2009; Reclamation 2011; Yackulic et al. 2014). It is unclear why the shift has occurred in the lower Grand Canyon reaches but is likely also attributable to warmer temperatures as well as the low lake level of Lake Mead creating more riverine areas with warmer and more sediment-laden waters. However, brown trout numbers in the Glen Canyon reach increased over the period from 2014–2016 raising concerns regarding potential impacts on native fish, especially humpback chub near the Little Colorado River (Runge et al. 2018) and to the recreational rainbow trout fishery in the Glen Canyon reach. Additional details regarding the status, biology, and threats to the native fish community in the project area are provided in the LTEMP EIS (DOI 2016a).

E.4 NON-NATIVE FISH

As many as 25 non-native species of fish have been reported with some regularity from Lake Powell, Lake Mead, and the Colorado River and its tributaries between these reservoirs (Valdez and Speas 2007; Coggins et al. 2011; Reclamation 2011). Most of these introduced species are native to other basins in North America but not the Colorado River Basin, and a few are species from outside North America. These fish occur in the Grand Canyon as a result of intentional and unintentional introductions, especially into Lakes Powell and Mead. A number of species were stocked as game fish and others as forage fish for the stocked game fish. Among these non-native species, three are largely restricted to Lake Powell and/or Lake Mead, and occur in the Colorado River and its tributaries below Glen Canyon Dam only occasionally; these species are black crappie (*Pomoxis nigromaculatus*), bluegill (*Lepomis macrochirus*), and gizzard shad (*Dorosoma cepedianum*). Another four species—northern pike, threadfin shad (*Dorosoma petenense*), rock bass (*Ambloplites rupestris*), and yellow perch (*Perca flavescens*)—are largely restricted to the upper Little Colorado River watershed (Ward and Persons 2006; Valdez and

Speas 2007). The remaining 18 species have been reported from the mainstem Colorado River and/or its tributaries between Glen Canyon Dam and the inflow to Lake Mead. New introductions of non-native fish species continue to be documented throughout the Colorado River Basin, including several new species found by FWS in a study of ponded areas on the Little Colorado River and new introductions are likely to occur in the future (Martinez et al. 2014).

The non-native fish community changes in response to temperature and turbidity gradients in the mainstem (Makinster et al. 2010). In general, the reaches of the river just downstream of Glen Canyon Dam are dominated by coldwater non-native species (primarily rainbow trout and brown trout). Downstream reaches through the Grand Canyon are currently dominated by native species, although substantial numbers of warmwater non-native species are also present (Makinster et al. 2010). The water temperatures in the Glen Canyon reach are suitable (although colder than optimal) for rainbow trout and brown trout spawning and growth (Valdez and Speas 2007). As water temperature and turbidity increase downstream of the Little Colorado River confluence, non-native warmwater fish species such as the common carp, red shiner, and several species of catfish increase in number (Makinster et al. 2010). The warmer water temperatures in mainstem areas of Grand Canyon and in backwaters and off-channel ponds provide suitable conditions for spawning and growth for many of the warmwater non-native species, many of which are benthic feeders adapted to foraging in turbid conditions (Gloss and Coggins 2005). The annual distribution of non-native fishes in the lower portions of the Grand Canyon can also be influenced by the elevation of Lake Mead. As the elevation of Lake Mead rises, lake-like conditions suitable for many of the warmwater non-native fishes will temporarily extend farther upstream into the lower portion of the Grand Canyon.

Brown and rainbow trout make up the coldwater non-native fish community of the Colorado River between Glen Canyon Dam and the inflow to Lake Mead. The rainbow trout is common in the Glen Canyon reach and in the mainstem Colorado River between the confluence with the Paria River and the confluence with the Little Colorado River (Makinster et al. 2010; Reclamation 2011). Smaller numbers are found associated with tributaries, including Bright Angel Creek, Shinumo Creek, Deer Creek, Tapeats Creek, Kanab Creek, and Havasu Creek (Reclamation 2011). Brown trout are found primarily in and near Bright Angel Creek, which supports a spawning population (Reclamation 2011), but that population has been substantially reduced in the last six years as a result of weir operation and backpack electrofishing removals (Healy et al. 2018). They are also found throughout the upper reaches of the river corridor, including in Glen Canyon.

The rainbow trout is very common in the reach of the mainstem Colorado from Glen Canyon Dam to the Paria River, and this population serves as the principal basis for the trout fishery (Makinster et al. 2010; Reclamation 2011). This species is also found in relatively high abundance in Marble Canyon between the Paria River and the confluence of the Colorado River with the Little Colorado River (Makinster et al. 2010; Reclamation 2011). Downstream of the Little Colorado River confluence, smaller numbers are found associated with tributaries, including Bright Angel Creek, Shinumo Creek, Deer Creek, Tapeats Creek, Kanab Creek, and Havasu Creek (Reclamation 2011). Standardized annual monitoring of the population of rainbow trout in the 15-mi reach of the Colorado River between Glen Canyon Dam and Lees Ferry began in 1991. Based on catches of rainbow trout during annual monitoring surveys, the abundance of rainbow trout in Glen Canyon generally increased over the period from 1991 to 1997, remained at high levels until approximately 2001, and then declined to low levels by 2007. From 2008 through 2010, the relative abundance of rainbow trout in the Glen Canyon reach again increased to near historic high levels. Relative abundance reached all-time high levels in water years 2011 and 2012, followed by a decline in water year 2013 consistent with previous high abundance estimates (AGFD data as reported in GCMRC 2014). The relative abundance of rainbow trout in the Glen Canyon reach has continued to decline through 2016. One of the challenges of fishery management in the Colorado River downstream of Glen Canyon Dam is to effectively manage the rainbow trout population in the Glen

Canyon reach to maintain the highly valued recreational rainbow trout fishery, while controlling potential impacts on native fish, especially humpback chub, in reaches further downstream. The control actions being considered as part of the Proposed Action are not directed at managing this rainbow trout fishery.

As with rainbow trout, brown trout are not native to the Colorado River and were stocked in Grand Canyon in the first half of the 1900s; future stocking of triploid rainbow trout is currently being considered by AGFD. Brown trout are no longer stocked in the Colorado River downstream of Glen Canyon Dam and, until recently, were found primarily in and near Bright Angel Creek, which supports a spawning population (Reclamation 2011). A trout control project, using a combination of a fish weir trap and electrofishing to benefit native species in Bright Angel Creek and endangered humpback chub in the Colorado River, was implemented by the NPS during winters 2006–2007, 2010–2011, 2011–2012, 2012–2013, 2013–2014, and 2014–2015 under FONSIs (NPS 2006c; 2013b).

Overall, the abundance (based on electrofishing surveys) of brown trout in the Colorado River between Lees Ferry and Lake Mead declined from 2000 to 2006; abundance may have then increased somewhat between 2007 and 2009 (Makinster et al. 2010). Because spawning by brown trout in the Grand Canyon is believed to occur primarily in tributaries (e.g., Bright Angel Creek), recruitment rates may be less affected by conditions in the mainstem than recruitment rates of rainbow trout. However, recent increases in brown trout recruitment since 2014 have occurred in the Glen Canyon reach (Stewart 2016). Brown trout were observed to be spawning near the RM -4 le 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 again observed in the Glen Canyon reach during October and November of 2015 (Korman et al. 2015). It is unclear if flow operations, including recent fall HFEs, and/or upstream migration of adult brown trout are related to the increase in brown trout in recent years (Runge et al. 2018).

Both brown trout and rainbow trout are considered threats to humpback chub because of predation and potential competition for habitat. Although the abundance of brown trout in Glen Canyon and near the Little Colorado River confluence is small relative to rainbow trout, the brown trout is a more active predator on native fish, including humpback chub, than rainbow trout (Yard et al. 2011; Ward and Morton-Starner 2015). Estimates based on field observations and laboratory studies suggest that an individual brown trout could consume up to 17 times more humpback chub than an individual rainbow trout (Yard et al. 2011, Ward and Morten-Starner 2015). Based on various lines of evidence, Runge et al. (2018) hypothesized that the overall per capita effect of brown trout on humpback chub would be 5 to 9 times greater than the per capita effect of rainbow trout when effects of both competition and predation are taken into account. Movement of adult brown trout often increases during spawning, usually in October–November (Meyers et al. 1992; Burrell et al. 2000; Quinn and Kwak 2011). Adult brown trout may move more than adult rainbow trout based on limited recaptures within Glen and Grand canyons (Runge et al. 2018), and hypothetically, juvenile brown trout may emigrate downstream towards the Little Colorado River at higher rates than juvenile rainbow trout. For this reason, the Proposed Action includes control actions to address threats from brown trout.

Surveys of the Colorado River and its tributaries between Glen Canyon Dam and the inflow to Lake Mead, as well as experimental fish removal studies, indicate the presence of 17 non-native warmwater fish species in the project area (Trammell and Valdez 2003; Ackerman et al. 2006; Makinster et al. 2010; Coggins et al. 2011; Albrecht et al. 2014). Of those species, the common carp, fathead minnow, and red shiner are generally the most common warmwater species in the mainstem and tributaries (Rogers and Makinster 2006; Ward and Rogers 2006; Ackerman et al. 2006; Makinster et al. 2010; Coggins et al. 2011). Smaller warmwater non-native species, such as fathead minnow, red shiner, plains killifish, and bullhead, are primarily found in tributaries (especially in the

Little Colorado River), backwaters, and off-channel ponds, but may also be occur in the mainstem below the Little Colorado River confluence (Johnstone and Lauretta 2007).

Warmwater non-native species have been collected in low numbers and only sporadically in the Glen Canyon reach; species collected include the common carp, channel catfish, and fathead minnow (Johnstone and Lauretta 2007; Ackerman 2008). Other species collected from this reach include green sunfish, smallmouth bass, striped bass, redside shiner, golden shiner, and walleye (FWS 2008).

During July 2015, a large, reproducing population of green sunfish was discovered in a slough at RM -12, approximately 3 mi downstream of Glen Canyon Dam. Neither the source nor mechanism of introduction for some of these species (e.g., green sunfish, walleye, smallmouth bass, striped bass) into the Glen Canyon reach is known with certainty; however, the nearest source for large populations of these species is Lake Powell. Green sunfish are known to be prolific, with a single female capable of producing up to 10,000 eggs. Green sunfish are also considered likely predators of small native fish and native fish eggs and larvae. Therefore, AGFD, NPS, USGS, FWS, and Reclamation have determined that green sunfish pose a threat to native fish, including the humpback chub. Two removal efforts using electrofishing, seine netting, and trapping were conducted in August of 2015, but failed to deplete the population despite removing more than 3,000 fish. Biologists from the NPS and AGFD constructed and installed a large block net at the downstream end of the main slough to minimize escapement of green sunfish and treated the slough with the fish toxin rotenone. As of mid-November 2015, it appeared that the eradication effort had been successful. In August of 2016, May of 2017, and again in May of 2018 NPS biologists have discovered small numbers of adult green sunfish reproducing in the small off-channel slough in spite of chemical treatments in 2015-17 that were considered 100% effective and the placement of fish screen barriers between the sloughs in 2017. Green sunfish passage through the dam, either through the “fish friendly” turbines or during HFE events are considered the primary source of these reinvasions of the small (approximately 0.3 acre) off-channel slough.

Warmwater non-native species collected in the vicinity of the Little Colorado River confluence include smallmouth and striped bass, green sunfish, black and yellow bullhead, red shiner, and plains killifish (Trammell and Valdez 2003; Johnstone and Lauretta 2007; FWS 2008). Based on surveys conducted below Diamond Creek (RM 226–276.5) in 2005, the most abundant non-native fish species included red shiner, mosquitofish, channel catfish, and common carp (Ackerman et al. 2006). Albrecht et al. (2014) reported that native fishes composed approximately 98% of the total age-0 catch during 2014 surveys and dominated the total number of small-bodied fish captured during 2013–2014 surveys in the lower Grand Canyon (Lava Falls to Pearce Ferry); bluehead sucker, flannelmouth sucker, and speckled dace were the most common native species collected. Eight non-native species were captured during surveys in 2013–2014, including brown trout, rainbow trout, common carp, channel catfish, fathead minnow, plains killifish, western mosquitofish, and red shiner (Albrecht et al. 2014).

The Little Colorado River may represent a source for some non-native fishes found in the mainstem Colorado River (Stone et al. 2007). As many as 20 species of warmwater non-native fishes have been reported from the Little Colorado River watershed. Warmwater species collected from the Little Colorado River below Chute Falls include common carp, red shiner, fathead minnow, plains killifish, black bullhead, and channel catfish (Ward and Persons 2006; FWS 2008). Standardized monitoring from 1987 to 2005 found that non-native warmwater fish generally compose only a small percentage of the fish collected from the Little Colorado River, typically accounting for less than 10% of the total fish catch in any single year (Ward and Persons 2006). Six species of warmwater non-native fish (common carp, fathead minnow, red shiner, channel catfish, yellow bullhead, and plains killifish) are known to reproduce in the Little Colorado River (Choudhry et al. 2004).

Appendix F, identifies 22 invasive non-native fish species that are known to occur within the project area and the potential threat posed by those species to the aquatic ecosystem. Eight fish species (brown trout, green sunfish, rainbow trout, smallmouth bass, largemouth bass, northern pike, striped bass, and walleye) are believed to pose a medium-high to very high level of threat and seven species (black bullhead, black crappie, bluegill, common carp, channel catfish, and yellow bullhead, and red shiner pose a medium-low to medium level of threat to native aquatic species in within the project area, primarily due to potential for competition and predation.

APPENDIX F

RISK LEVELS OF NON-NATIVE AQUATIC SPECIES IN GLEN CANYON NATIONAL RECREATION AREA AND GRAND CANYON NATIONAL PARK

The following table presents information about non-native aquatic species known to occur or with a potential to be present in GCNRA and GCNP. It identifies the level of threat posed by each of the species to other resources, identifies potential management and control options that may be applicable and documents current information about locations of occurrence. In order keep this information up-to date, the table should be reviewed on an annual basis and revised as appropriate.

TABLE F-1 Risk or Threat Levels of Non-Native Aquatic Species in Glen Canyon National Recreation Area and Grand Canyon National Park. Intended to Be Re-evaluated Annually

Common Name	Scientific Name	Occurrence in GCNRA	Occurrence in GCNP	Level of Risk or Threat[a]	Threat to Native Species	Threat to Rainbow Trout Fishery	Preference for Warm or Cold Water	Candidate for Releasing Small Numbers if Incidentally Caught[b]	Candidate for chemical treatment[c]	Candidate for chemical rapid response	Candidate for targeted electro-fishing or trapping?	Candidate for mechanical rapid response under CFMP	Threat Notes	Location Documentation
Fish[d]														
Smallmouth bass	*Micropterus dolomieu*	Present	Present	(1) Very High	(1) Very High	Yes	Warm	No	Yes	Yes	Yes	Yes	Highly piscivorous and considered a high threat should they begin reproducing below the dam and moving downstream into endangered fish habitat. Preys upon, and competes with native fish (AGFD 2009; Fuller et al. 2018b; NPS and FWS 2014).	Present in Lake Powell and Lake Mead and small numbers discovered below Glen Canyon Dam during AIS monitoring (NPS 2016; Anderson 2015). Present in GCNP, exact locations unspecified (GCMRC 2014).
Walleye	*Sander vitreus*	Present	Present	(1) Very High	(1) Very High	Yes	Warm	No	Yes	Yes	Yes	Yes	Highly piscivorous and considered a high threat should they begin reproducing below the dam and moving downstream into endangered fish habitat. Preys upon and competes with native fish (USGS 2018; NPS and FWS 2014). Numbers increasing in Lake Powell with gizzard shad as new forage fish.	Present in Lake Powell and Lake Mead and small numbers discovered below Glen Canyon Dam during AIS monitoring (NPS 2016; Anderson 2015). Present in GCNP, exact locations unspecified (Gloss and Coggins 2005; NPS 2018b; GCMRC 2014).
Brown trout	*Salmo trutta*	Present	Present	(1) Very High	(1) Very High	Yes, via whirling disease = increased incidence and pathology	Cold	No	No in GCNRA, Yes in GCNP	No in GCNRA, yes in GCNP if a new source area)	Yes	No in GCNRA, yes in GCNP if a new source area)	Highly piscivorous and considered a very high threat. Competes with and preys on native fish (USGS 2018; NPS and FWS 2014; Yard et al. 2011; Whiting et al. 2014).	Found to be successfully reproducing in GCNRA below Glen Canyon Dam and in GCNP (Anderson 2015). In GCNP, primary spawning locations for brown trout include Bright Angel Creek, Tapeats Creek (Healy 2016).
Northern pike	*Esox lucius*	Present	Potential	(2) High	(2) High	No	Cold	No	Yes	Yes	Yes	Yes	Highly piscivorous and considered a high threat should they pass through the dam, and begin reproducing and moving downstream into endangered fish habitat	Present in Lake Powell. Not found below Glen Canyon Dam to-date (NPS 2016; Anderson 2015)
Striped bass	*Morone saxatilis*	Present	Present	(2) High	(2) High	No	Warm/Cool	No	Yes	Yes	Yes	Yes	Highly piscivorous and considered a high threat should they begin reproducing below the dam and moving downstream into endangered fish habitat, or moving up from Lake Mead in large numbers. Preys on small native fish (USGS 2018).	Present in Lake Powell and small numbers discovered below Glen Canyon Dam during AIS monitoring (NPS 2016; Anderson 2015). Present in GCNP, exact locations unspecified (NPS 2018b). Present in Lake Mead
White sucker	*Catostomus commersonii*	Potential	Potential	(2) High	(2) High	No	Cool	No	Yes	Yes	Yes	Yes	Outcompetes native suckers in impoundments (Wiltzius 1978). Hybridizes with native bluehead and flannelmouth suckers, potentially increasing native species decline (Quist et al. 2009). Pass-through possible. Lake Powell generally too warm but occurs upstream in all rivers	Documented upstream in upper basin drainages (Trammell 2015).

Table F-1 (Continued)

Common Name	Scientific Name	Occurrence in GCNRA	Occurrence in GCNP	Level of Risk or Threat[a]	Threat to Native Species	Threat to Rainbow Trout Fishery	Preference for Warm or Cold Water	Candidate for Releasing Small Numbers if Incidentally Caught[b]	Candidate for chemical treatment[c]	Candidate for chemical rapid response	Candidate for targeted electro-fishing or trapping?	Candidate for mechanical rapid response under CFMP	Threat Notes	Location Documentation
Burbot	*Lota lota*	Potential	Potential	(2) High	(2) High	Yes	Cold	No	Yes	Yes	Yes	Yes	Competes with and preys on native fish (USGS 2018, Bestgen and Jones 2015).	Present in northeast Utah, in the Flaming Gorge Reservoir and Green River below Flaming Gorge Dam (UDWR 2009; USGS 2018). Occurs upstream of Lake Powell in Flaming Gorge Reservoir (Trammell 2015).
Largemouth bass	*Micropterus salmoides*	Present	Present	(3) Medium-High	(3) Medium-High	No	Warm	No	Yes	Yes	Yes	Yes	Highly piscivorous and considered a possible threat should they begin reproducing below the dam and moving downstream into endangered fish habitat Preys upon and competes with native fish and preys upon native amphibians (USGS 2018).	Present in Lake Powell though not in large numbers. (NPS 2016; Anderson 2015). Present in GCNP, exact locations unspecified (NPS 2018b; GCMRC 2014).
Green sunfish	*Lepomis cyanellus*	Present	Present	(3) Medium-High	(3) Medium-High	No	Warm	Adults-No Juveniles (<80mm) Yes up to 20	Yes	No in RM-12, Yes in other areas	Yes	No in RM-12, Yes in other areas	Prolific and competes with and preys upon native fish and preys upon native amphibians (Fuller et al. 2018a).	Present in Lake Powell and discovered reproducing in a small backwater below Glen Canyon Dam in August 2015-2017 (NPS 2016; Anderson 2017). GCNP - Individual occurrences previously recorded in the Colorado River within GCNP (NPS 2018b; USGS 2018). Reproducing population discovered and eradicated in GCNRA below Glen Canyon Dam in 2015.
Black bullhead	*Ameiurus melas*	Present	Present	(4) Medium	(4) Medium	No	Warm	No	Yes	Yes	Yes	Yes	Competes with and preys upon native fish (USGS 2018).	Present in Lake Powell. Present in GCNP, including Little Colorado River, other exact locations unspecified (NPS 2018b; GCMRC 2014).
Yellow bullhead	*Ameiurus natalis*	Present	Present	(4) Medium	(4) Medium	No	Warm	No	Yes	Yes	Yes	Yes	Preys upon and competes with native fish (USGS 2018; NPS and FWS 2014).	Present in GCNP, exact locations unspecified (NPS 2018b; NPS 2015)
Channel catfish	*Ictalurus punctatus*	Present	Present	(4) Medium	(4) Medium	No	Warm	No	Yes	No (unless in new area as a source)	Yes	No (unless in new area as a source)	Preys upon and competes with native fish can cause death of Colorado pikeminnow that prey upon catfish (NPS and FWS 2014).	Common in the Colorado River within GCNP (NPS 2018b; GCMRC 2014; Trammell 2015).
Blue tilapia and other cichlids	*Oreochromis aureus*	Potential	Potential	(4) Medium	(4) Medium	No	Warm	No	Yes	Yes	Yes	Yes	Competes with native fish and alters aquatic ecosystems (NMAISAC 2008; USGS 2018).	Previously recorded in Arizona (Lake Havasu, Colorado River) (USGS 2018). Rare or not present in GCNP, exact locations unspecified, occurs in Lake Mead (Gloss and Coggins 2005).
Grass carp	*Ctenopharyngodon idella*	Potential	Potential	(4) Medium	(4) Medium	Possible habitat disruption	Warm	No	Yes	Yes	Yes	Yes	Competes with and disturbs habitats of native fish. May forage on moss/algae/aquatic grasses in Glen Canyon reach thereby disrupting insect reproduction	Discovered to be reproducing in the upper reaches of Lake Powell in 2016

Table F-1 (Continued)

Common Name	Scientific Name	Occurrence in GCNRA	Occurrence in GCNP	Level of Risk or Threat[a]	Threat to Native Species	Threat to Rainbow Trout Fishery	Preference for Warm or Cold Water	Candidate for Releasing Small Numbers if Incidentally Caught[b]	Candidate for chemical treatment[c]	Candidate for chemical rapid response	Candidate for targeted electro-fishing or trapping?	Candidate for mechanical rapid response under CFMP	Threat Notes	Location Documentation
Asian carps (silver carp, bighead carp.		Potential	Potential	(4) Medium	(4) Medium	Yes, competition	Cool	No	Yes	Yes	Yes	Yes	Competes with and disturbs habitats of native fish. May forage on moss/algae/aquatic grasses in Glen Canyon reach thereby disrupting insect reproduction	Not present in Utah or Arizona, listed in top 50 invasive species in the west by Western Governor's Association (WGA 2018)
Black crappie	*Pomoxis nigromaculatus*	Present	Present	(5) Medium-Low	(5) Medium-Low	No	Warm	No	Yes	Yes	Yes	Yes	Preys upon native fish (USGS 2018).	Present in Lake Powell. Present in GCNP, exact locations unspecified (Gloss and Coggins 2005; GCMRC 2014).
Redear sunfish	*Lepomis microlophus*	Potential	Potential	(5) Medium-Low	(5) Medium-Low	No	Warm	No	Yes	Yes	Yes	Yes	Prefer snails, but are opportunistic feeders eating dreisinnid mussels, aquatic insect larvae, small clams, crayfish, and fish eggs. Young redears feed exclusively on zooplankton. May compete with native fish.	Being considered by State of Utah for introduction into Lake Powell as a biocontrol for quagga mussels
Bluegill	*Lepomis macrochirus*	Present	Present	(5) Medium-Low	(5) Medium-Low	No	Warm	No	Yes	TBD	Yes	TBD	Competes with native fish and preys upon rare amphibians (USGS 2018).	Present in Lake Powell. Present in GCNP, exact locations unspecified (Gloss and Coggins 2005; NPS 2018b; GCMRC 2014).
Common carp	*Cyprinus carpio*	Present	Present	(5) Medium-Low	(5) Medium-Low	No	Warm	Yes	No	No	Yes	No	Competes with native fish and alters aquatic ecosystems (NPS and FWS 2014; Nico et al. 2014). May eat eggs and larvae of native fish (Moyle 2002).	Previously recorded in Lake Powell (USGS 2018). Common in the Colorado River within GCNP (Gloss and Coggins 2005; NPS 2018b; GCMRC 2014; Trammell 2015).
Red shiner	*Cyprinella lutrensis*	Present	Present	(5) Medium-Low	(5) Medium-Low	No	Warm	Yes	No	No	No	No	Competes with native fish (USGS 2018).	Abundant in the Colorado River in GCNP (Gloss and Coggins 2005; GCMRC 2014).
Mosquitofish	*Gambusia affinis*	Present	Present	(6) Low	(6) Low	No	Warm	Yes	Yes	Yes	No	No	Preys upon and competes with native fish and preys upon native amphibians (UDWR 2009; Nico et al. 2015).	Present in GCNRA rivers, inflows, and perennial tributaries (NPS 2016). Common in the Colorado River within GCNP (Gloss and Coggins 2005; NPS 2018b; GCMRC 2014).
Brook trout and other salmonids other than rainbow or brown	*Salvelinus fontinalis*	stocked in past but not extant	Present	(6) Low	(6) Low	No	Cold	Yes	Yes	No in mainstem, but yes in tributaries if new	Yes	No in mainstem, but yes in tributaries if new	Competes with and preys upon native fish (USGS 2018).	Previously stocked, but not currently present in park (Gloss and Coggins 2005; Trammell 2015).
Fathead minnow	*Pimephales promelas*	Present	Present	(6) Low	(6) Low	No	Warm	Yes	No	No	No	No	Preys upon native fish and amphibians (USGS 2018).	Present in GCNRA rivers, inflows, and perennial tributaries (NPS 2016). Common in the Colorado River within GCNP (Gloss and Coggins 2005; NPS 2018b; GCMRC 2014).
Gizzard shad	*Dorosoma cepedianum*	Present	Present	(6) Low	(6) Low	No	Warm	Yes	Yes	Yes	No	Yes	Competes with native fish and alters aquatic ecosystems (UDWR 2009; USGS 2018). Increasing in Lake Powell after fairly recent infestation.	Previously recorded in Lake Powell (USGS 2018). Previously recorded in the Colorado River within GCNP (USGS 2018).

Table F-1 (Continued)

Common Name	Scientific Name	Occurrence in GCNRA	Occurrence in GCNP	Level of Risk or Threat[a]	Threat to Native Species	Threat to Rainbow Trout Fishery	Preference for Warm or Cold Water	Candidate for Releasing Small Numbers if Incidentally Caught[b]	Candidate for chemical treatment[c]	Candidate for chemical rapid response	Candidate for targeted electro-fishing or trapping?	Candidate for mechanical rapid response under CFMP	Threat Notes	Location Documentation
Golden shiner	*Notemigonus crysoleucas*	Potential	Present	(6) Low	(6) Low	No	Warm	Yes	No	No	No	No	Competes with native fish (Nico 2011).	Previously recorded in Arizona and Utah (USGS 2018). GCNP - Previously recorded, exact locations unspecified (Gloss and Coggins 2005; NPS 2018b).
Plains killifish	*Fundulus zebrinus*	Present	Present	(6) Low	(6) Low	No	Warm	Yes	No	No	No	No	Impacts to native fish are unknown (USGS 2018).	Previously recorded in the Colorado River within GCNP (Gloss and Coggins 2005; NPS 2018b; USGS 2018).
Threadfin shad	*Dorosoma petenense*	Present	Present	(6) Low	(6) Low	No	Warm	Yes	No	No	No	No	Preys upon native fish and larvae (USGS 2018).	Present in GCNP, exact locations unspecified (Gloss and Coggins 2005; NPS 2018b).
Amphibians														
American bullfrog	*Lithobates catesbeianus*	Present	Potential	(4) Medium	(4) Medium	No	Warm	Yes	Yes	TBD	No	TBD	Competes with native amphibians, preys upon native fish and amphibians (NMAISAC 2008; AGFD 2011).	Present in the Hite area (NPS 2016).
Plains leopard frog	*Lithobates blairi*	Present	Potential	(6) Low	(6) Low	No	Warm	Yes	No	No	No	No	Not native, associated with UDWR fish hatchery, rare in Wahweap Creek (Anderson 2015).	Present, but rare in Wahweap Creek (Anderson 2015).
Reptiles														
Red-eared slider	*Trachemys scripta elegans*	Potential	?	(5) Medium-Low	(5) Medium-Low	No	Warm	Yes	No	No	No	Yes	Alters aquatic ecosystems, and carries salmonella (USGS 2018; Anderson 2015).	Present in Arizona and the pet trade (Anderson 2015).
Invertebrates														
Rusty crayfish	*Orconectus rusticus*	Potential	Potential	(2) High	(2) High	Possible habitat disruption and reduced egg survival	Either	No	Yes	Yes	Yes	Yes	Alters aquatic ecosystems (UDWR 2009; Sorenson 2010). A very active crayfish that feeds on a variety of aquatic plants, benthic invertebrates (aquatic worms, snails, leeches, clams, aquatic insects, and crustaceans), detritus, fish eggs, and small fish. (UMN Sea Grant, 2008)	Present in Colorado and aquaculture (Anderson 2015).Not Present in Arizona, present upstream in the Yampa River in Colorado (Sorenson 2016).
Australian redclaw	*Cherax quadricarinatus*	Potential	Potential	(4) Medium	(4) Medium	No	Warm	No	Yes	TBD	Yes	TBD	Alters aquatic ecosystems (Anderson 2015).	Present in aquaculture trade, but not documented in Utah (USGS 2018; Anderson 2015). Present in Arizona, exact locations unspecified (AGFD 2011).

Table F-1 (Continued)

Common Name	Scientific Name	Occurrence in GCNRA	Occurrence in GCNP	Level of Risk or Threat[a]	Threat to Native Species	Threat to Rainbow Trout Fishery	Preference for Warm or Cold Water	Candidate for Releasing Small Numbers if Incidentally Caught[b]	Candidate for chemical treatment[c]	Candidate for chemical rapid response	Candidate for targeted electro-fishing or trapping?	Candidate for mechanical rapid response under CFMP	Threat Notes	Location Documentation
Red swamp Louisiana crayfish	*Procambarus clarkii*	Potential	?	(4) Medium	(4) Medium	No	Warm	No	Yes	TBD	Yes	TBD	Preys upon native aquatic fauna, vector of crayfish plague, impacts agricultural and fishing industry (UDWR 2009).	Present in Utah, in Tooele County's western basin drainage near St. John (UDWR 2009). Present in, Arizona, exact locations unspecified (Anderson 2015).
Northern crayfish	*Orconectes virilis*	Present	Present	(6) Low	(6) Low	No	Either	Yes	No	No	Yes	Yes	Alters aquatic ecosystems (NMAISAC 2008).	Present in Lake Powell (Anderson 2015). Noted that crayfish present below Diamond Creek in tributaries and in Little Colorado River drainages (Trammell 2015).
Signal crayfish	*Pacifastacus leniusculus*	Potential	?	(6) Low	(6) Low	No	Either	Yes	TBD	TBD	Yes	Yes	Competes with native fauna, reduces water resource bank stability (UDWR 2009).	Present in Utah, in Salem and Spring Ponds (UDWR 2009).
Water nymph crayfish	*Orconectes nais*	Potential	?	(6) Low	(6) Low	No	Either	Yes?	Yes	Yes	Yes	Yes	Alters aquatic ecosystems (UDWR 2009; Sorenson 2010).	Present and expanding in Colorado.
New Zealand mudsnail	*Potamopyrgus antipodarum*	Present	Present	(4) Medium	(4) Medium	Yes	Cold	Yes	TBD	TBD	No	No	Alters aquatic ecosystems and competes with native invertebrates (UDWR 2009; AGFD 2011; CPW 2016).	Currently found downstream, below Glen Canyon Dam and outside of GCNRA (NPS 2016; Anderson 2015, Benson et al. 2018a).
Red-rim melania	*Melanoides tuberculatus*	Potential	?	(4) Medium	(4) Medium	No	UNK	No	No	No	No	No	Competes with native fauna, hosts a trematode that infects native fish (NMAISAC 2008; UDWR 2009).	Present in Arizona (Anderson 2015) and Utah (UDWR 2009), exact locations unspecified.
Quagga mussel	*Dreissena bugensis*	Present	Present	(5) Medium-Low	(5) Medium-Low in river, (2) high in lake	Yes	Either	N/A	Yes	Yes	N/A	TBD	Alter aquatic ecosystems, filters much of zoo and phytoplankton from lake waters thereby reducing available foods in lake & riverine food chain, clogs pipes, reduce recreational opportunities (UDWR 2009; USGS 2018).	GCNRA - Present and has spread to all areas of Lake Powell (NPS 2016). Present below Glen Canyon Dam. GCNP - Present in GCNP, near RM 209 (Benson et al. 2018b)
Asian clam	*Corbicula fluminea*	Present	Potential	(6) Low	(6) Low	No	Either	Yes	No	No	No	No	Competes with native bivalves, alters aquatic ecosystems, clogs pipes, reduces recreational opportunities (NMAISAC 2008).	Present in Lake Powell (Anderson 2015).
Channeled golden applesnail	*Pomaceo spp.*	Potential	Potential	(6) Low	(6) Low	No	Warm	No	TBD	TBD	Yes	Yes	Alters aquatic ecosystems, competes with native aquatic fauna (NMAISAC 2008).	Present in Arizona exact locations unspecified (AGFD 2011).
Zebra mussel	*Dreissena polymorpha*	Potential	Potential	(6) Low	(6) Low in river, (2) high in lake	Yes	Either	N/A	Yes	Yes	N/A	No	Alters aquatic ecosystems, clogs pipes, reduces recreational opportunities (UDWR 2009; USGS 2018). Does not compete well with quagga mussels.	Previously recorded in Arizona, Colorado, Nevada, and Utah (USGS 2018). Previously recorded in Utah and Colorado (USGS 2018).

Table F-1 (Continued)

Common Name	Scientific Name	Occurrence in GCNRA	Occurrence in GCNP	Level of Risk or Threat[a]	Threat to Native Species	Threat to Rainbow Trout Fishery	Preference for Warm or Cold Water	Candidate for Releasing Small Numbers if Incidentally Caught[b]	Candidate for chemical treatment[c]	Candidate for chemical rapid response	Candidate for targeted electro-fishing or trapping?	Candidate for mechanical rapid response under CFMP	Threat Notes	Location Documentation
Plants														
Curly-leaf pondweed	*Potamogeton crispus*	Potential	Present	(4) Medium	(4) Medium	No	Either	N/A	TBD	TBD	N/A	TBD	Competes with native plants (UDWR 2009). Clogs waterways, inhibits aquatic recreation, and can cause algal blooms and fish die offs (USGS 2018).	Present in Arizona and Utah (UDWR 2009; Anderson 2015). Present in GCNP, exact locations unspecified (NPS 2018b).
Water hyacinth	*Eichhornia crassipes*	Potential	Potential	(6) Low	(6) Low	No	Either	N/A	TBD	TBD	N/A	TBD	Competes with native plants, clog canals and other waterways, alters aquatic ecosystems, interferes with recreation (NMAISAC 2008).	Present in Arizona, exact locations unspecified (AGFD 2011).
Water naiad	*Najas marina*	Present	?	(6) Low	(6) Low	No	Either	N/A	TBD	TBD	N/A	TBD	Has been found to compete with and replace native vegetation in the Great Lakes (USGS 2018).	Submerged aquatic – occupied new niche as lake developed (Anderson 2015).
Brazilian elodea	*Egeria densa*	Potential	Potential	(6) Low	(6) Low in river, (4) Medium in lake	No	Either	N/A	TBD	TBD	N/A	TBD	Competes with native plants, impedes fish migration, alters aquatic ecosystems (NMAISAC 2008; AGFD 2011).	Present in Glen Canyon reach.
Eurasian water-milfoil	*Myriophyllum spicatum*	Potential	Potential	(6) Low	(6) Low in river, (4) Medium in lake	No	Either	N/A	TBD	TBD	N/A	TBD	Competes with native plants, impedes fish foraging, obstruct recreational and subsistence activities, alters aquatic ecosystems (UDWR 2009).	Present in Arizona and Utah, exact locations unspecified (UDWR 2009; AGFD 2011).
Giant salvinia	*Salvinia molesta*	Potential	Potential	(6) Low	(6) Low in river, (4) Medium in lake	No	Either	N/A	TBD	TBD	N/A	TBD	Competes with native plants, impedes fish foraging, obstructs subsistence activities, alters aquatic ecosystems (NMAISAC 2008).	Present in Arizona, exact locations unspecified (AGFD 2011).
Hydrilla	*Hydrilla verticillata*	Potential	Potential	(6) Low	(6) Low in river, (4) Medium in lake	No	Either	N/A	TBD	TBD	N/A	TBD	Competes with native plants, impedes fish foraging, obstruct recreational activities, alters aquatic ecosystems (NMAISAC 2008; AGFD 2011).	Present in Arizona, exact locations unspecified (AGFD 2011).
Algae														
Didymo (rocksnot)	*Didymosphenia geminata*	Present	Potential	(4) Medium	(4) Medium	Yes	Either	N/A	N/A	N/A	N/A	N/A	Alters aquatic ecosystems, reduces recreational activities (UDWR 2009; AGFD 2011).	GCNRA - Present in Utah (NMAISAC 2008). One cell identified from the gut of *Gammarus* from below the Glen Canyon Dam (Wellard Kelly 2010).
Golden Alga	*Prymnesium parvum*	Potential	Potential	(4) Medium	(4) Medium	(4) Medium	Either	N/A	Yes	TBD	N/A	TBD	Causes fish die offs, can be particularly toxic in phosphorus and nitrogen limited systems such as Colorado River below GCD (NMSU 2018; AGFD 2011).	Present in Arizona in Apache Lake and downstream rivers and urban lakes in Phoenix (AGFD 2011).

Table F-1 (Continued)

Common Name	Scientific Name	Occurrence in GCNRA	Occurrence in GCNP	Level of Risk or Threat[a]	Threat to Native Species	Threat to Rainbow Trout Fishery	Preference for Warm or Cold Water	Candidate for Releasing Small Numbers if Incidentally Caught[b]	Candidate for chemical treatment[c]	Candidate for chemical rapid response	Candidate for targeted electro-fishing or trapping?	Candidate for mechanical rapid response under CFMP	Threat Notes	Location Documentation
Fungi														
Chytrid fungus	*Batrachochytrium dendrobatidis*	Potential	Potential	(4) Medium	None to fish, (2) High to native leopard frogs	No	Either	N/A	TBD	TBD	N/A	N/A	Causes amphibian die offs (NMAISAC 2008; UDWR 2009).	Present in Utah and Arizona, exact locations unspecified (AGFD 2011; Anderson 2015).
Parasites														
Anchor worm	*Lernaea cyprinacea*		Present	(4) Medium	(4) Medium	Yes	Either	N/A	N/A	No	N/A	No	Can directly kill native fish or cause secondary infections that irritate or kill native fish (Steckler and Yanong 2013).	Found in GCNRA, and in GCNP, primarily in Little Colorado River and possibly other unspecified locations (Trammell 2015).
Asian fish tapeworm	*Bothriocephalus acheilognathi*	Potential	Present	(4) Medium	(4) Medium	No	Warm	N/A	Yes	No	N/A	No	Can cause die-offs in young fish, reduces condition and survival (Hansen et al. 2006; NMAISAC 2008). Chemical treatment could include a veterinary treatment to treat at the Little Colorado River (praziquantel).	Present in Utah and Arizona (NMAISAC 2008). Present in GCNP and GCNRA
Whirling disease	*Myxobolus cerebralis*	Present	Present	(4) Medium	none	Yes	Cold	N/A	N/A	No	N/A	No	Causes 'Whirling Disease'. Very harmful to rainbow trout, but brown trout are resistant/carriers	Present in GCNP and GCNRA

[a] Risk or threat levels should be re-evaluated annually. Species may be added to the list or threat levels may be changed annually based on new research, new presence or abundance changes

[b] Releasing small numbers of incidentally captured fish in place rather than lethal removal in places like RM-12

[c] N/A in this column means no known chemical treatment available

[d] Rainbow trout is in a special category because NPS manages this species for a quality recreational rainbow trout fishery in GCNRA, but in GCNP, rainbow trout are controlled as an undesirable non-native fish to reduce impacts to native species, consistent with goals and objectives of the CFMP. No control actions under the Proposed Action in this EA would be applied to target rainbow trout in GCNRA, but any of the control options for any threat levels under the Proposed Action may be applied to rainbow trout in GCNP.

TBD=To be determined, N/A= Not applicable

APPENDIX G

MULTIPLE AGENCY NON-NATIVE MONITORING SCHEDULE BELOW GLEN CANYON DAM

The purpose of this monitoring plan is to provide early detection of new and expanded occurrences of non-native aquatic species, detect reproduction of new and existing high-risk species and to track the abundance of certain species in relation to trigger levels set for beginning and ending actions. Substantial monitoring for fish species already occurs in the project area. This monitoring plan relies on existing sampling where possible, and identifies gaps where monitoring is lacking or inadequate and recommends additional monitoring where needed.

The GCDAMP conducts monitoring for native and non-native aquatic species in the Colorado River below Glen Canyon Dam. The monitoring program is a collaborative effort among program partners, primarily GCMRC, AGFD, FWS, and NPS. The non-native monitoring aspect makes use of existing monitoring for native and endangered species, as well as monitoring specifically for non-native fish species. Table G-1 details the number, location, purpose and agency leads for existing monitoring in 2018. This established monitoring schedule, if continued, will help with early detection and with information related to non-native species management decisions.

All agencies will agree to report unusual or new captures of high-risk species within 5 working days after trip completion, to NPS, FWS, AGFD, and GCMRC. Incidental observations by all investigators and administrators are very helpful and may lead to more targeted sampling to verify identification of new or expanding species. Agencies also agree to share trip reports from monitoring within 2 weeks of trip completion with the agency partners, and the GCDAMP. These monitoring commitments are dependent on continued funding for the GCDAMP, Reclamation, NPS, and partner agencies, but if the GCDAMP or agency budgets change, the agencies will promptly inform the partners and this document will be revised.

G.1 EXISTING SAMPLING AND MONITORING

About 46 mainstem and Little Colorado River fish monitoring trips or surveys at the 2018 scheduled frequency and purpose are conducted jointly or individually by NPS, GCMRC, FWS, and AGFD in the Colorado River in GCNRA and GCNP, and some tributaries (Table G-1). In addition, the NPS removes non-native trout from Bright Angel Creek weekly from October through February using backpack electrofishers and a selective weir. In GCNRA the AGFD conducts a year-round creel survey of anglers, two stratified random sample electrofishing trips, and also samples known or suspected areas where warmwater non-native species are likely to be captured (i.e. ‘hot spots’). GCMRC conducts three electrofishing trips in targeted areas focusing on trout recruitment and growth dynamics. NPS has begun monthly sampling of the Upper and Lower Sloughs at RM-12 and one to two other hot spots from May to September with trap nets, and 6 additional trips covering the entire reach that focus on telemetry tracking of brown trout tagged with radio or sonic tags.

In GCNP there are four collaborative (primarily GCMRC and FWS) fish monitoring trips that cover the mainstem Colorado River from Lees Ferry to Pearce Ferry; two electrofishing, one hoop netting, and one seining trip. AGFD conducts two complete stratified random electrofishing sampling trips from Lees Ferry to Pearce Ferry, and a collaborative sampling trip combining electrofishing and hoop-netting trip that targets non-native fish from Diamond Creek to the Lake Mead inflow (currently downstream of Pearce Ferry). NPS also conducts monthly seining trips in low velocity shoreline habitat beginning below Lava Falls to Pearce Ferry, using two sizes of seine (larval and small-bodied) aimed at capturing YOY razorback sucker, and other small native and non-native fish. Sample sites were initially selected in a tessellated stratified random design and are now consistent among trips and years.

The lower 13.5 km of the Little Colorado River below Chute Falls is sampled with hoop nets four times a year by FWS. The reach above Chute Falls is sampled once, and a long-established JCM reach near the mouth is sampled one additional time by AGFD and GCMRC.

Collectively, this sampling and monitoring program is extensive and covers almost all of the monitoring needs for invasive fish species as well as some other organisms at current levels. If sampling effort and monitoring declines in response to funding or staffing levels, early detection and rapid response to new and expanding non-native aquatic species will be less effective.

Increased incidence of invasions and establishment of warmwater fish species such as green sunfish and walleye are of increasing concern due to low lake levels, which put resident fish in closer proximity to water intakes. Warmer than normal dam release temperatures, and additional downstream warming may also increase the risk of survival and reproduction of new and existing invasive species. Increased monitoring of likely habitats will improve detection probability and allow rapid response to new non-native fish.

NPS has implemented new sampling in ‘hot spots’ in the Glen Canyon reach, and in Grand Canyon in response to this concern. Additional ‘hot spots’ in the Glen Canyon reach include (1) slough at mouth of Falls Creek, RM -2.5, river left. (2) springs located at -3 mile, river left, submerged in the main channel at higher flows, (3) RM -6, river right slough and hidden pool, (4) -9 mile ‘frog ponds’ above main channel, river left, and (5) the Upper and Lower Sloughs at RM -12. Similar areas in GCNP include the mouths of warm tributaries such as Shinumo, Kanab, and Havasu creeks, warm spring areas including 30-mile, and backwaters that are relatively persistent at most flow levels and warm more than the main channel such as RM 209 (river left) and the first large backwater below Lava Falls (river right). These areas are sampled by NPS during the monthly seining trips targeting razorback sucker, and after the Shinumo Creek sampling effort.

G.2 RECOMMENDED MONITORING

Tables G-1 and G-2 describe recommended monitoring methods, locations, and frequency for GCNP and GCNRA. These are minimum recommended monitoring actions. Existing monitoring at 2018 levels usually meets or exceeds the recommended monitoring frequencies, with some exceptions, identified below. In addition to the recommended monitoring, all investigators are encouraged to report any unusual observations or captures of non-native aquatic fish, amphibians, invertebrates, plants, or alga to NPS within 5 days of trip completion.

G.3 IDENTIFIED GAPS BETWEEN EXISTING AND RECOMMENDED MONITORING

The current monitoring projects were compared with the recommended monitoring frequency to determine if and where gaps in detection might exist (Tables G-1 and G-2). Gaps were identified for grass carp, aquatic plants and invertebrates, and amphibians. No monitoring efforts target lesser known and uncommon invertebrates or amphibians such as species of crayfish and bullfrogs, or aquatic plants. These species are classified as low risk and unlikely invaders. Monitoring for presence/absence will rely on incidental observations made by all investigators. If an unusual species is detected, a more robust monitoring effort may be developed.

G.4 NEW AND ADDITIONAL MONITORING FOR NEW NON-NATIVE AQUATIC SPECIES

Recent captures of reproductively active (diploid) grass carp, and grass carp larvae in the upper Colorado River inflow to Lake Powell (Francis 2018) suggest that additional monitoring for grass carp and testing for ploidy are needed. All grass carp stocked to control algae in surrounding states are required to be triploid, non-reproductive individuals, but this system has failed as evidenced by successful reproduction in Lake Powell. While existing sampling is likely adequate to detect new adult grass carp in the project area, any such fish captured must be tested for ploidy by either a field test using blood smears (Krynak et al. 2015) or by carefully removing an eyeball, preserving in methanol and saline solution, followed by laboratory testing (Bailey 2017). The NPS shoreline-seining program for larval fishes in GCNP should be sufficient to detect grass carp larvae.

New techniques may provide ways to detect new species with less intensive monitoring efforts, such as eDNA (Keele and Hosler 2016). The use of eDNA may be explored as a way to monitor or detect rare species not present in Lake Powell (such as burbot), or of trout reinvading a tributary that has been cleared of non-native trout. However, this methodology is not suitable for species common in Lake Powell or upstream of the parks in other tributaries, as the presence of eDNA from upstream sources may produce false positive results.

G.5 MONITORING FOR BROWN TROUT TIERED ACTION TRIGGERS

Tiered actions for certain species have specific numeric triggers for on- and off-ramps. Monitoring for these species must be able to determine when a numeric trigger has been reached or exceeded (Actions M1, M2, and B1). The past capture and recapture data from AGFD and GCMRC have been analyzed and a model developed by GCMRC (Runge et al. 2018) that estimated the abundance of brown trout by size class from 2000 to 2017 (Fig. 10 in Runge et al. 2018). This modeling effort can be repeated annually and used to estimate the annual abundance of brown trout in the Glen Canyon reach using existing monitoring at current levels. No additional sampling effort is needed assuming current monitoring and funding levels persist; however, marking and releasing more brown trout will improve the accuracy of abundance and capture probability estimates, improving our ability to evaluate when triggers have been met or exceeded. NPS permits tagging and releasing of brown trout in certain reaches but may increase the number of trout that may be tagged and released to improve abundance estimates.

The incentivized harvest program will also provide information about brown trout abundance and exploitation. Anglers who participate in the program will be asked to provide information on numbers captured or harvested, and presence of marks (fin clips). These additional data may be incorporated into the future abundance estimates.

G.6 MONITORING FOR YY MALE AND PROGENY

YY-male brown trout or other species stocked to control brown trout will be marked with a PIT tag or other visible mark. Fish recaptured during monitoring efforts will be checked for the presence of the mark or tag and that information recorded before the fish is released. To determine if stocked YY fish are successfully spawning with wild females and producing young, a subsample of juvenile fish captured after spawning events will be genetically tested to determine if parentage included stocked YY-males. In addition, during the YY-male stocking experiment, a subset of fish will be euthanized and examined to determine gender. A ratio of male to female fish that is greater than 1 to 1 will indicate successful reproduction by YY males. If ratios of males to females increase over time as stocking continues, the likelihood and time needed to achieve eradication or reduction to below measurable levels can be estimated.

G.7 REFERENCES

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Francis, T., 2018, "Recent Captures of Reproductively Active (Diploid) Grass Carp, and Grass Carp Larvae in the Upper Colorado River Inflow to Lake Powell." Personal Communication Email to Melissa Trammell sent January 29, 2018.

Krynak, K.L., R.G. Oldfield, P.M. Dennis, M. Durkalec, and C. Weldon, 2015, "A Novel Field Technique to Assess Ploidy in Introduced Grass Carp (*Ctenopharyngodon idella*, Cyprinidae). *Biological Invasions* 17:1931-1939.

TABLE G-1 Existing Fish Sampling Trips in GCNRA and GCNP That Provide Monitoring for Non-Native Aquatic Fish Species

Major Reach	River Reaches/Locations	Gear	No. Trips and Trip Dates (approx.)	Agency	Primary Target	Non-Native Fish Target
GCNRA	Colorado River Mainstem; Glen Canyon	Creel survey	6 days/month, all year	AGFD	Rainbow and brown trout	Any
GCNRA	Colorado River Mainstem; Glen Canyon	Electrofishing	2 trips, July and Sept.	AGFD	Rainbow and brown trout, non-native fish	Any
GCNRA	Colorado River Mainstem; Glen Canyon	Electrofishing	4 trips, January, April, July, Oct.	GCMRC	Rainbow and brown trout	Any
GCNRA	Colorado River Mainstem; Glen Canyon	Telemetry	6 trips, monthly April through Sept.	NPS	Brown trout telemetry	Brown trout
GCNRA	Glen Canyon; RM -12 Upper Slough	Trap nets; other	3 trips, May, Aug	NPS	Green sunfish	Any
GCNRA	Glen Canyon; RM -12 Upper/Lower Slough; 1-2 hotspots	Trap nets; other	4 trips, June, July, August, Sept.	NPS	Green sunfish, smallmouth bass, striped bass, walleye	Any
GCNP	Colorado River Mainstem; Lees Ferry to Pearce Ferry	Electrofishing	2 trips, April and May	AGFD	Non-native fish	Any
GCNP	Colorado River Mainstem; Diamond Creek to Lake Mead inflow	Electrofishing, hoop nets	1 trip, Oct.	AGFD, GCMRC	Non-native fish	Any
GCNP	Colorado River Mainstem; RM 150-250	Hoop nets	3 trips, April, July, Oct.	GCMRC	Humpback chub juveniles	Any
GCNP	JCM reach in Little Colorado River	Hoop nets	1 trip, July	GCMRC	Humpback chub and Non-native fish	Any
GCNP	Colorado River Mainstem; JCM near Little Colorado River	Electrofishing, hoop nets	1 trip, Sept.-Oct.	GCMRC	Humpback chub juveniles	Any

Table G-1 (Continued)

Major Reach	River Reaches/Locations	Gear	No. Trips and Trip Dates (approx.)	Agency	Primary Target	Non-Native Fish Target
GCNP	Colorado River Mainstem; Lees Ferry to Diamond Creek or Pearce Ferry	Hoop nets	1 trip, Sept.	GCMRC, USFWS	Humpback chub	Any
GCNP	Colorado River Mainstem; Lees Ferry to Diamond Creek	Seines	1; Oct,	GCMRC, USFWS	Humpback chub juveniles	Any
GCNP	Colorado River Mainstem; shoreline	Seines	7 trips, monthly March to Sept,	NPS	Razorback sucker	Any larvae, or small-bodied NNF
GCNP	Tributary and mainstem; Shinumo Creek, Kanab Creek	Hoop nets, backpack electrofishing, seines	2 trips, June, Sept,	NPS	Humpback chub	Rainbow Trout; Any
GCNP	Tributary; Bright Angel Creek - Entire Creek	Backpack electrofishing	20 trips, Oct, to Feb,	NPS	Brown trout and rainbow trout	Any
GCNP	Tributary; Havasu Creek; Lower 4 mi within GCNP	Hoop nets, minnow traps	2 trips, May and Oct,	NPS	Humpback chub and non-native fish	Any
Little Colorado River	Tributary; Little Colorado River; lower 13.56 km	Hoop nets	4 trips, April, May, Sept,, Oct,	USFWS	Humpback chub and non-native fish	Any
Little Colorado River	Tributary; Little Colorado River above Chute Falls (13.56-17.5 km)	Hoop nets	April or May	USFWS	Humpback chub and non-native fish	Any
Little Colorado River	Tributary; Little Colorado River; upper watershed (Grand Falls, Homolovi), W. Clear, Chevelon and Silver Creeks	Hoop nets	May	USFWS	Non-native fish	Any

TABLE G-2 Recommended Monitoring for Non-Native Aquatic Species in Glen Canyon National Recreation Area

Species or Guild	Timing	Life Stage	Recommended Frequency	Gear	Habitat	Existing Sampling	Gaps
Warmwater Fish							
Green sunfish	Summer, early fall	Adult YOY, after spawning	Adult: two trips per year, stratified random; YOY: Once/month July, Aug., Sept.	Seine, minnow trap, electrofishing, barge electrofishing	Sloughs, backwaters, tributary mouths, spring inflows, frog ponds	AGFD electrofishing 2x year in July and Sept.; GCNRA 3x year in -12 sloughs and 1-2 hotspots	Not all likely sites sampled every time
Smallmouth bass; other non-native fish not listed	Summer, early fall	Adult, YOY, after spawning	Adult: two trips per year, stratified random; YOY: Once/month July, Aug., Sept.	Seine, minnow trap, electrofishing, barge electrofishing	Sloughs, backwaters, tributary mouths, spring inflows, frog ponds	AGFD electrofishing 2x year in July and Sept.; GCNRA 3x year in -12 sloughs and 1-2 hotspots	Not all likely sites sampled every time
Grass carp	All monitoring trips	Any	Adult: two trips per year, stratified random; YOY: Once/month July, Aug., Sept.	Electrofishing, trap nets	Mainstem, large backwaters, sloughs	All mainstem monitoring	No larval sampling
Catfish and bullheads	All monitoring trips	Any	Adult: two trips per year, stratified random; YOY: Once/month July, Aug., Sept.	Electrofishing, trap nets	Mainstem, large backwaters, sloughs	All mainstem monitoring	
Coolwater Fish							
Walleye	Summer, early fall	Adults, and YOY after potential spawning in early summer	Adult: two trips per year, stratified random; YOY: Once/month July, Aug., Sept.	Seine, minnow trap, electrofishing, barge electrofishing	Mainstem, sloughs, backwaters, tributary mouths, spring inflows	AGFD electrofishing 2x year in July and Sept.; GCNRA 3x year in -12 sloughs and 1-2 hotspots	Seldom sampled in restricted area just below Glen Canyon Dam where they are known to occur
Striped Bass	Any	Adults	Adult: two trips per year, stratified random; YOY: Once/month July, Aug., Sept.	Electrofishing	Mainstem, large backwaters, sloughs	AGFD electrofishing 2x year in July and Sept.; GCNRA 3x year in -12 sloughs and 1-2 hotspots	

Table G-2 (Continued)

Species or Guild	Timing	Life Stage	Recommended Frequency	Gear	Habitat	Existing Sampling	Gaps
Brown Trout	fall through early spring	Adult spawning, YOY	Adults: all existing monitoring trips	Electrofishing	Mainstem, spawning areas	All mainstem monitoring	No emergent sampling to determine timing
Burbot	All monitoring trips	Any	Adult: two trips per year, stratified random; YOY: Once/month April, May, June	Electrofishing, trap nets	Mainstem, sloughs, large backwaters	All mainstem monitoring	No larval sampling
Plants and Algae							
All non-native species	Summer	Any	GCMRC food base monitoring	Observation and collection	Mainstem, sloughs, backwaters, tributary mouths, spring inflows, frog ponds	Aquatic food base mainstem	Minimal sampling, limited identification expertise
Invertebrates and Amphibians							
Dreissenids	Any	Any	One trip per year	Artificial substrates, observation	Mainstem, sloughs, backwaters, tributary mouths, spring inflows, frog ponds	Substrate monitoring by GCNRA and Larry Stevens' studies	
Crayfish	Any	Any	One trip per year	Seine, minnow trap, electrofishing, barge electrofishing	Mainstem, sloughs, backwaters, tributary mouths, spring inflows, frog ponds	All mainstem and hotspot monitoring	Minimal sampling, limited identification expertise
Other invertebrates	Any	Any	One trip per year	Seine, minnow trap, electrofishing, barge electrofishing	Mainstem, sloughs, backwaters, tributary mouths, spring inflows, frog ponds	All mainstem and hotspot monitoring, food base monitoring	Minimal sampling, limited identification expertise
Amphibians	Any	Any	One trip per year	Seine, minnow trap, electrofishing, barge electrofishing	Mainstem, sloughs, backwaters, tributary mouths, spring inflows, frog ponds	GCNRA 3x year in - 12 sloughs and 1-2 hotspots	Minimal sampling

TABLE G-3. Recommended Monitoring for Non-Native Aquatic Species in Grand Canyon National Park

Guild/species	Timing	Life Stage	Recommended Frequency	Gear	Habitat	Existing Sampling	Gaps
Warmwater Fish							
Green sunfish	Summer, early fall	Adult YOY, after spawning	Adult: two trips per year, stratified random YOY: once per month July, Aug., Sept.	Adult: electrofishing, trap nets YOY: seines, trap nets	Sloughs, backwaters, tributary mouths, spring inflows, plunge pools	All mainstem and tributary monitoring	Not all likely sites sampled
Smallmouth bass/other non-native fish not listed	Summer, early fall	Adult YOY, after spawning	Adult: two trips per year, stratified random YOY: once per month July, Aug., Sept.	Adult: electrofishing, trap nets; YOY: seines, trap nets	Adult and YOY; sloughs, backwaters, tributary mouths, spring inflows, shoreline	All mainstem and tributary monitoring	Not all likely sites sampled
Grass carp	Any	Any	Adult: two trips per year, stratified random YOY: once per month July, Aug., Sept.	Adult: electrofishing, trap nets YOY: seines, trap nets; Larvae: light traps	mainstem, large backwaters	All mainstem and tributary monitoring	No specific effort aimed at grass carp
Catfish and bullheads	Any	Any	Adult: two trips per year, stratified random YOY: once per month July, Aug., Sept.	Electrofishing, trap nets	Mainstem, large backwaters	All mainstem and tributary monitoring	Catfish not efficiently sampled with existing gears
Coolwater Fish							
Walleye	Summer, early fall	Adults, and YOY after potential spawning in early summer	Adult: two trips per year, stratified random YOY: once per month July, Aug., Sept.	Seine, minnow trap, electrofishing, barge electrofishing	Mainstem, sloughs, backwaters, tributary mouths, spring inflows	All mainstem and tributary monitoring	
Striped bass	Any	Adults	Adult: two trips per year, stratified random	Electrofishing	Mainstem	All mainstem and tributary monitoring	
Brown trout	Any	Adult spawning, YOY	Adult: two trips per year, stratified random YOY: once per month July, Aug., Sept.	Electrofishing	Mainstem, spawning areas	All mainstem and tributary monitoring	

Table G-3 (Continued)

Guild/species	Timing	Lifestage	Recommended Frequency	Gear	Habitat	Existing Sampling	Gaps
Burbot	Any	Any	Adult: two trips per year, stratified random YOY: once per month April, May, June	Adult: electrofishing, trap nets; YOY: seines, trap nets; larvae: light traps	Mainstem, large backwaters	All mainstem monitoring	
Plants and Algae							
	Summer	Any	One trip per year	Observation and collection	Mainstem, sloughs, backwaters, tributary mouths, spring inflows, frog ponds	GCMRC; one food base monitoring trip/year	Minimal sampling, limited identification expertise
Invertebrates and Amphibians							
Dreissenids	Any	Any	One trip per year	Artificial substrates, observation	Mainstem, sloughs, backwaters, tributary mouths, spring inflows	Substrate monitoring by Larry Stevens' studies	Minimal sampling
Crayfish	Any	Any	One trip per year	Seine, minnow trap, electrofishing, barge electrofishing	Mainstem, sloughs, backwaters, tributary mouths, spring inflows	All mainstem and tributary monitoring	Minimal sampling, limited identification expertise
Other invertebrates	Any	Any	One trip per year	Seine, minnow trap, electrofishing, barge electrofishing	Mainstem, sloughs, backwaters, tributary mouths, spring inflows	GCMRC; one food base monitoring trip/year	Minimal sampling, limited identification expertise
Amphibian	Any	Any	One trip per year	Seine, minnow trap, electrofishing, barge electrofishing	Mainstem, sloughs, backwaters, tributary mouths, spring inflows		Minimal sampling

APPENDIX H

TRIBAL PERSPECTIVES ON NON-NATIVE FISH REMOVAL

(This appendix represents the perspectives of the Zuni and Hopi Tribes in their own words as prepared by their representatives and may not represent the views and opinions of the NPS, the Department of the Interior, or other agencies of the federal government).

Prepared by Kurt Dongoske, Pueblo of Zuni, and Michael Yeatts, Hopi Tribe

Participating Native American Tribes (Hopi Tribe and Pueblo of Zuni) have expressed, through government-to-government consultation, meetings with the Assistant Secretary for Water and Science, and through federal compliance processes associated with the National Environmental Policy Act and the National Historic Preservation Act, concerns to the U.S. Department of the Interior (DOI) regarding management actions described above involving fish suppression flows, mechanical removal of nonnative fish, and other lethal management actions.

In the 2002-2004 GCMRC Biennial Work Plan, a proposal was made to conduct experimental mechanical removal of trout centered on the confluence of the Colorado and Little Colorado Rivers. At the time, the Hopi Tribe expressed concern about the killing of large numbers of fish and the specter of death that would be created by such activity in a culturally significant sacred area. The Hopi Tribe also understood the scientific desire to understand the effect that the non-native trout were having on the native, endangered humpback chub and if there were management options available to control the trout numbers, particularly if they were threatening the existence of the humpback chub. To make the study more culturally acceptable, the Hopi Tribe requested that the fish removed be used for a beneficial purpose, so that the life they were sacrificing wouldn’t be trivialized. The non-native fish were viewed as a fully alive component of the ecosystem, which were there through no fault of their own, and shouldn’t be needlessly punished.

Perspectives of the Hopi Tribe have not significantly changed since the implementation of the original mechanical removal experiment. Killing large numbers of fish (or any other group of animals), unless there is an extraordinary circumstance, is fundamentally wrong! It is not the specific species of fish or the method of killing them that is at the heart of the Hopi concern; it is the view that their life is somehow less valuable and they are therefore expendable.

Since 2006, the Hopi Long-term Monitoring Program asked about the appropriateness of removing non-native fish. To date, 46% of the Hopi respondents supported removal; 37% opposed it; and 17% were not sure. Those who support removal, however, clearly state that it should only be used if there is strong evidence that the non-native species is a real threat to the survival of a native species and that other causes are not more significant. Killing just because we think it might help, and we can do it, is not suitable justification. Secondly, they view killing the non-natives as the last resort. If they can be removed alive, that is preferred. Otherwise, they should be used as food for people or possibly for some other culturally appropriate purpose.

Finally, the Hopi express puzzlement at the seemingly conflicting management goals of maintaining native fish and having a recreational trout fishery in the same river; and then fingering the trout as the threat to the native fish. While there are certainly many avenues being pursued that make managers feel that these divergent goals are possible, the simplest reading of the situation is that trying to achieve both of these goals is not appropriate.

Over the past ten years, the Pueblo of Zuni has been the most vocal of the Tribes in expressing objection to these actions because they involve the taking of life without sufficient justification. The remainder of this section focuses on the Pueblo of Zuni's objections to lethal management actions by situating those objections within the appropriate Zuni traditional cultural context. In doing so, a more informed and nuanced understanding of the Zuni position should be obtained.

For the past twenty-five (25) years, the Pueblo of Zuni has repeatedly emphasized to the Department of the Interior the important cultural, religious, and historical ties the Zuni people have to the Grand Canyon, Colorado River, and Little Colorado River. The Grand Canyon is the place of Zuni emergence into this current world at a place called *Chimik'yana'kya dey'a*, near Ribbon Falls in Bright Angel Canyon. The natural environment that Zuni people saw at Emergence became central to traditional Zuni culture. In fact, all of the plants that grow along the stream from Ribbon Falls to the Colorado River, and all the birds and other animals, springs, minerals and natural resources located in the Grand Canyon and its' tributaries, have a central place in Zuni traditional cultural practices and ceremonial activities. The confluence of the Little Colorado and Colorado Rivers is understood to be a spiritual umbilical connection between the Pueblo of Zuni and the Grand Canyon that is facilitated through the union of the Zuni River with the Little Colorado and the Colorado Rivers. The confluence is also held by the Zuni people to be an extremely important and sacred place because of its abundance of aquatic and terrestrial life that simultaneously expresses and represents the fertility of nature.

The Colorado River is a particularly important place to the Zuni people because it was the location of an important historical event. This historical event was conveyed to Frank Hamilton Cushing, an American Anthropologist, by the Zuni in the late nineteenth century and is summarized below to convey the deep, intense, and remarkable significance that the Colorado River and the aquatic life within it indelibly hold for the Zuni people.

> *Shortly after Emergence, men of the Bear, Crane, and Seed clans strode into the red waters of the Colorado River and waded across. The men of the clans all crossed successfully. The women travelling with them carried their children on their backs and they waded into the water. Their children, who were unfinished and immature (because this occurred shortly after Emergence), changed in their terror. Their skins turned cold and scaly and they grew tails. Their hands and feet became webbed and clawed for swimming. The children fell into the swift, red waters. Some of the children became lizards, others turned into frogs, turtles, newts, and fish.*
>
> *The children of these clans were lost to the waters. The mothers were able to make it to the other side of the river, where they wailed and cried for their children. The Twins heard them, returned, and advised all the mothers to cherish their children through all dangers. After listening to the Twins, those people who had yet to pass through the river took heart and clutched their children to them and safely proceeded to the opposite shore.*
>
> *The people who successfully made it out of the river rested, calmed the remaining children, and then arose and continued their journey to the plane east of the two mountains with the great water between. (Cushing 1884, 1896, 1988)*

As a consequence of this historical event, all aquatic life is recognized by present day Zunis to be descendants of those Zuni children who were lost to the waters, thus creating a strong and lasting familial bond to all aquatic life and a fundamentally important stewardship responsibility. It is precisely because of this familial bond and stewardship responsibility that the Pueblo of Zuni has for the past ten (10) years communicated to the Department of the Interior objections to any management actions (e.g., mechanical removal, trout suppression flows, piscicides) that entail the taking of aquatic life.

The implementation of lethal fish management actions is contrary to Zuni worldview and environmental ethics. Annual ceremonial activities carried out by the Zuni are performed to ensure adequate rainfall and prosperity for all life. Zuni people pray not only for Zuni lands, but for all people and all lands. Zuni prayers are especially aimed at bringing precipitation to the Southwest. In order to successfully carry out Zuni prayers, offerings, and ceremonies necessary to ensure rainfall for crops and the prosperity of all life, Zuni must maintain a balance with all parts of the interconnected universe. The animals, including all aquatic life, birds, plants, rocks, sand, minerals, and water in the Grand Canyon convey special meaning and have significant material and spiritual relationships to the Zuni people. To needlessly take life causes an imbalance in the natural world and also disturbs the harmony and health of the spiritual realm and the Zuni peoples.

Moreover, the Zuni recognize that there is a direct causal relationship between what happens in and to the Colorado River within Grand Canyon and the Pueblo of Zuni. According to Zuni religious and political leaders and illustrative of this point, when the initial mechanical removal efforts were occurring at the confluence of the Little Colorado and Colorado Rivers between 2003 and 2006, Zuni experienced an increased use of taser guns by Zuni police on Zuni community members. The increased use of tasers by Zuni police is viewed by the Zuni religious leaders as a direct adverse effect on the Zuni community that resulted from those mechanical removal efforts. To underscore this Zuni recognition of a cause/effect relationship between the Grand Canyon and Zuni, the Zuni religious leaders expressed their concern that the ongoing mechanical removal of brown trout and other non-natives from Bright Angel Creek by the National Park Service is contributing to an increase in the number of Zuni community members that are dying on a daily basis in Zuni. They emphasized that what happens on the Colorado River in Grand Canyon directly impacts Zuni – a position and recognition that has existed since the time of Emergence.

The implementation of lethal management actions to control non-native aquatic species, especially rainbow and brown trout, within the Colorado River through Glen and Grand Canyons creates a disproportionately negative impact, materially, spiritually, emotionally, and psychologically, on the Zuni people. These actions tend to emphasize strong reliance on reactionary management strategies rather than promoting proactive and productive approaches focused on identifying and controlling the antecedent environmental and structural conditions that promote or allow non-natives to enter and thrive within the system. The continued consideration of lethal management tools to address non-native aquatics demonstrates a disregard for the Zuni familial and stewardship relationship to aquatic life, a devaluation of the special relationship that the Zuni people have with the Grand Canyon and the Colorado River, and a blatant dismissal of previously expressed Zuni concerns to the U.S. Government.

The comparison of management options directed toward the control of non-native aquatics by scientists and managers must respect Zuni perspectives and knowledge sovereignty by providing it equal standing with Western forms of knowledge production. To assume that the only viable method of controlling aquatic non-natives is through lethal means changes the expression and impression of the Colorado River as a waterway of life to a river of death. It is imperative that scientists and managers respective Zuni values through the integration of Zuni perspectives with scientific analyses to make them more compassionate, caring, holistic, and ultimately, productive for all life that depends on the Colorado River. Penned over 56 years ago and directed toward unrestrained pesticide use, Rachel Carson‘s (1961:275) words expressed in *Silent Spring*, are prescient when considering the lethal management of non-native aquatics in the Colorado River. She wrote: *Life is a miracle beyond our comprehension, and we should reverence it even where we have to struggle against it.. . .The resort to weapons such as insecticides to control it is proof of insufficient knowledge and of an incapacity so to guide the processes of nature that brute force becomes unnecessary. Humbleness is in order; there is no excuse for scientific conceit.*

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APPENDIX I

ACRONYMS AND ABBREVIATIONS

ac	acre(s)
ac-ft	acre-foot (feet)
AMWG	Adaptive Management Work Group
Argonne	Argonne National Laboratory
AGFD	Arizona Game and Fish Department
AZ-SGCN	Arizona Species of Greatest Conservation Need
BGEPA	Bald and Golden Eagle Protection Act of 1940
C	Celsius
CEQ	Council on Environmental Quality
CFMP	Comprehensive Fisheries Management Plan
CFR	*Code of Federal Regulations*
cfs	cubic feet per second (ft^3/s)
CRMP	Colorado River Management Plan
dBA	A-weighted decibel
DO	dissolved oxygen
DOI	U.S. Department of the Interior
EA	Environmental Assessment
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act of 1973, as amended
F	Fahrenheit
FONSI	Finding of No Significant Impact
ft	foot (feet)
FWS	U.S. Fish and Wildlife Service
gal	gallons
gal/min	gallons per minute
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
HFE	high-flow experiment
hr	hour(s)
in.	inch(es)
JCM	Juvenile Chub Monitoring
LMNRA	Lake Mead National Recreation Area
LTEMP	Long-Term Experimental and Management Plan

mi	mile(s)
NEPA	National Environmental Policy Act of 1969, as amended
NHPA	National Historic Preservation Act
NRHP	*National Register of Historic Places*
NPS	National Park Service
ppm	parts per million
Reclamation	Bureau of Reclamation
RM	river mile
ROD	Record of Decision
TCP	traditional cultural property
TWG	Technical Working Group
USACE	U.S. Army Corps of Engineers
USC	*United States Code*
USGS	U.S. Geological Survey
YOY	young-of-year
yr	year(s)

APPENDIX J

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APPENDIX K

LIST OF PREPARERS

The following individuals contributed to preparation of the Expanded Non-Native Management Plan EA.

Name	Education/Experience	Contribution
National Park Service		
Jan Balsom	M.A., Anthropology; 34 years experience in southwestern archaeology, Tribal relations, and Park Management; Grand Canyon National Park Deputy Chief for Science and Resource Management	Project management team member; subject matter expert for Grand Canyon cultural and Tribal resources, and wilderness
Robert Billerbeck	M.S., Conservation Biology; 20 years experience in Natural Resource Management and Environmental Compliance; Intermountain Region Colorado River Coordinator	EA project manager; lead author of alternatives section (Chapter 2)
Brian Healy	M.S., Wildlife and Fisheries Science; 19 years experience in Fisheries Management	Project management team member; subject matter expert for non-native and native fishes in GCNP
Kenneth Hyde	M.S., Wildlife and Range Mngt.; 32 years experience in Natural Resource Management. with 10 years managing various fisheries.	Project management team member; subject matter expert for non-native and native fishes in GCNRA
Erin Janicki	M.S., Biology (Aquatic focus); 11 years experience in Aquatic Biology/Resource Management and Environmental Compliance (NEPA); Glen Canyon National Recreation Area Chief of Planning and Compliance	Project management team member; GCNRA NEPA specialist
Jennifer Rebenack	M.S., Fisheries Biology; 10 years experience in fisheries and wildlife ecology and environmental compliance; Intermountain Region Colorado River Program Biologist	Project management team member; subject matter expert for threatened and endangered species
Robert Schelly	Ph.D., Ecology, Evolution, and Environmental Biology; 12 years experience in systematics and field ichthyology; Grand Canyon National Park Fisheries Biologist	Subject matter expert for Grand Canyon fisheries resources

Name	Education/Experience	Contribution
Rosemary Sucec	M.A. Cultural Anthropology. 16 years as a cultural anthropologist in the NPS and working with American Indian Tribes throughout the Intermountain Region.	Subject matter expert for Glen Canyon cultural and natural Tribal resources
Melissa Trammell	M.S., Fisheries Biology; 29 years experience in Colorado River fisheries, threatened and endangered fish, and aquatic ecology	Project management team member; subject matter expert for non-native and native fishes
Argonne National Laboratory		
Jennifer Abplanalp	M.A., Anthropology; 15 years experience in cultural and Tribal resources	Lead author of cultural resources section (Section 3.5) and Tribal perspectives; subject matter expert, cultural resources, Tribal resources
Georgia Anast	B.A., Mathematics/Biology; over 20 years experience in environmental assessment	Scoping comment manager
John Hayse	Ph.D., Zoology; 29 years experience in ecological research and environmental assessment	Assistant Argonne EA project manager; lead author of introduction (Chapter 1) and aquatic resource sections (Section 3.3)
Kirk LaGory	Ph.D., Zoology; 40 years experience in ecological research; 30 years in environmental assessment	Argonne EA project manager; co-author of introduction, alternatives, and affected environment and environmental consequences sections (Chapters 1, 2, and 3, respectively); lead author of consultation and coordination sections (Chapter 4)
Kurt Picel	Ph.D., Environmental Health Sciences; 39 years experience in environmental health analysis and 24 years in environmental assessment	Lead author of recreation, visitor use, and experience section (Section 3.7) and socioeconomics and environmental justice section (Section 3.8), and human health and safety section (Section 3.9)
Robert Van Lonkhuyzen	B.A., Biology; 26 years experience in ecological research and environmental assessment	Lead author of terrestrial resource section (Section 3.4)
Emily Zvolanek	B.A., Environmental Science; 8 years experience in GIS mapping	GIS mapping and analysis