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Draft Environmental Assessment

Non-native Fish Control Downstream from Glen Canyon Dam

U.S. Department of the Interior
Bureau of Reclamation
Upper Colorado Region
Salt Lake City, Utah

Draft
July 5, 2011

Mission Statements

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American Public

Non-native Fish Control Downstream from Glen Canyon Dam

Proposed agency action:	Implementation of non-native fish control downstream from Glen Canyon Dam, Arizona, 2011-2020
Type of statement:	Environmental Assessment
Lead agency:	Bureau of Reclamation, Upper Colorado Region
Cooperating agencies:	Federal: National Park Service, Intermountain Region Bureau of Indian Affairs U.S. Fish and Wildlife Service, Southwest Region U.S. Geological Survey, Pacific Southwest Area Western Area Power Administration State: Arizona Game and Fish Department Tribal: Hualapai Tribe Pueblo of Zuni
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Executive Summary

The Bureau of Reclamation (Reclamation), Upper Colorado Region, proposes to control non-native fish in the Colorado River downstream from Glen Canyon Dam in an effort to help conserve native fish. The non-native fish control efforts would be located within Glen Canyon National Recreation Area (GCNRA) and Grand Canyon National Park (GCNP), Coconino County, Arizona. The purpose of the action is to minimize the negative impacts of competition and predation on an endangered fish, the humpback chub (*Gila cypha*) in Grand Canyon. The action is needed because competition and predation by non-native fishes, and in particular rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*), are reducing survival and recruitment of young humpback chub and threatening the potential recovery of the species. Rainbow trout and brown trout are not native to the Colorado River Basin and have been introduced into the region as sport fish. The action also addresses the concerns of American Indian tribes over the taking of life associated with non-native fish control.

Because non-native fish, particularly rainbow and brown trout, are known to prey on the endangered humpback chub, the U.S. Fish and Wildlife Service (USFWS) 2008 Biological Opinion included a conservation measure that addressed non-native fish control. That conservation measure provided that Reclamation would continue non-native fish control efforts through the Glen Canyon Dam Adaptive Management Program (GCDAMP) and anticipated removal of non-native trout at the confluence of the Colorado River mainstem and the Little Colorado River (LCR), as well as other control methods. The conservation measure was further guided by the USFWS 2009 Supplemental Biological Opinion and 2010 Reissuance of the Incidental Take Statement.

Concerns have been expressed by several of the American Indian tribes that are represented on the Adaptive Management Work Group (AMWG), particularly the Pueblo of Zuni, about the taking of life within a place that is sacred to the tribes and fundamental in several creation stories. Reclamation worked with the U.S. Geological Survey (USGS) USGS Patuxent Wildlife Research Center to conduct a Structured Decision Making (SDM) Project to evaluate various potential methods of controlling non-native fish in the Grand Canyon (SDM Project) for this Environmental Assessment (EA). The purpose of the SDM Project was to use a structured approach to develop and provide substantive input to Reclamation for use in preparation of this EA concerning management of non-native fish below the Glen Canyon Dam. The project served to enlist the cooperating agencies and GCDAMP Tribes in alternative development and analysis. The final report is provided as an appendix to this EA (Appendix A) and has been used to formulate, analyze, and select alternatives in this EA.

The proposed action is to reduce numbers of rainbow trout and brown trout near the confluence of the Colorado and Little Colorado rivers, if necessary, by reducing the numbers of trout

emigrating from population sources in Lees Ferry and reducing numbers of trout at the Little Colorado River confluence. The area near the confluence of the Colorado and Little Colorado rivers is occupied by a large portion of the humpback chub population in Grand Canyon, and nearshore areas in this part of Grand Canyon are used as nursery habitat by young humpback chub.

The proposed action would likely increase survival of young humpback chub as well as the three other native fish species that occur in the action area, the flannelmouth sucker (*Catostomus latipinnis*), bluehead sucker (*Catostomus discobolus*), and the speckled dace (*Rhinichthys osculus*). The flannelmouth and bluehead suckers are species that are declining throughout their range and are part of a Rangewide Conservation Plan for native fishes among six western states. Modeling conducted during the SDM Project indicated that the Proposed Action would have no effect on the Lees Ferry trout population. However, if the proposed action were to reduce total numbers of adult rainbow trout in Lees Ferry, it could result in a healthier, more sustainable population of rainbow trout, with a more balanced age-structure and larger trout of better condition.

Non-native fish control treatments evaluated in the SDM Project and EA processes included flow and non-flow actions to control non-native fish. Although all of these treatments could have desirable effects, based on similar prior actions, there is some uncertainty about the outcome of each treatment if applied individually or in combination with others. The SDM Project was used to identify this uncertainty and analyze the performance of potential actions in reducing non-native fish predation on humpback chub and other objectives, such as cultural resources, hydropower, and recreation. Through the SDM process, and through further analysis in this EA, the proposed action was selected because it best meets the purpose and need to reduce non-native fish predation on humpback chub, reduce uncertainty on aspects of non-native fish control, limit costs of implementing non-native fish control, address concerns by GCDAMP Tribes about the taking of life, and provide the least impact to other resources. To ensure that this action best serves the GCDAMP or the public through adaptive management design, a draft Science Plan to evaluate the proposed action, including a strategy for long-term application and monitoring, is included as an Appendix to this EA.

This Environmental Assessment evaluated the no action and the proposed action relative to the purpose and need for the action. The proposed action was chosen based on its performance in the SDM Project, as will be explained further in “Description of Alternatives” and “Affected Environment and Environmental Consequences” sections. The proposed action is to utilize boat-mounted electrofishing to remove non-native fishes. Up to 10 non-native fish removal trips would be conducted in the Colorado River below Lees Ferry from the Paria River to Badger Creek Rapid and up to 6 removal trips would be conducted in the Colorado River near the Little Colorado River from Kwagunt Rapid to Lava Chuar Rapid in each year of the proposed action. Removal in the vicinity of the Little Colorado River would only be conducted if monitoring and modeling data indicate that the adult humpback chub population in the Little Colorado River dropped below 7,000 fish. The period of the proposed action is up to 10 years, from 2011-2020. The proposed action would be implemented in accordance with a Science Plan designed to utilize adaptive management to learn from implementing non-native fish control actions. Reclamation would continue to evaluate non-native fish control actions through the GCDAMP during the proposed action. Additional flow and non-flow actions not analyzed here would continue to be evaluated and may be added through adaptive management, such as flow actions to suppress recruitment of rainbow trout in Lees Ferry. These actions may require additional environmental compliance.

1.0 Introduction

1.1 *Organization*

The Bureau of Reclamation, Upper Colorado Region (Reclamation) has prepared this environmental assessment (EA) to analyze and disclose the environmental consequences of specific actions designed to control non-native fish in the Colorado River as part of the Glen Canyon Dam Adaptive Management Program (GCDAMP) downstream from Glen Canyon Dam within Glen Canyon National Recreation Area (GCNRA) and Grand Canyon National Park (GCNP), Coconino County, Arizona (Figure 1). This EA analyzes potential effects of implementing the proposed action or alternatives to that action.

This EA describes the current environmental conditions in Glen, Marble, and Grand Canyons downstream from Glen Canyon Dam, and discloses the direct, indirect, and cumulative environmental impacts that could result from the proposed action and alternatives. It describes how the proposed action is designed to control non-native fish species, in particular rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*), that have been found to prey on native aquatic species, in the Colorado River in GCNP and GCNRA, and the impacts that would result from the proposed action.

This EA assists in ensuring compliance with the National Environmental Policy Act (NEPA) and in determining whether significant impacts would result from the proposed action or alternatives, in compliance with the National Environmental Policy Act of 1969 (42 U.S.C. 4321 *et seq.*), the Council on Environmental Quality regulations for implementing NEPA (40 CFR 1500-1508), and the Department of the Interior regulations implementing NEPA (43 CFR Part 46). If the responsible official determines that there are significant impacts to the human environment based on the analysis presented in this EA, then an environmental impact statement (EIS) may be prepared for the project. If not, a finding of no significant impact (FONSI) may be signed for the EA approving an alternative that may be the proposed action or another alternative. The EA is organized into five chapters.

- *Introduction:* The section includes information on the purpose of and need for the project, the history of the project, and the agency's proposal for achieving the purpose and need. This section also details how the public was notified of the proposal.

- *Description of Alternatives:* This section provides a detailed description of the proposal. One action alternative was developed based on issues raised by the public, other agencies and tribes, and through a Structured Decision Making (SDM) Project to evaluate various potential methods of controlling non-native fish in the Grand Canyon (SDM Project). This section also describes mitigation relative to the proposed action, and monitoring that may be required by Reclamation or the cooperating agencies.

- *Affected Environment and Environmental Consequences:* This section describes the environmental effects of implementing the proposed action compared to the effects of taking no action.

- *Consultation and Coordination:* This section describes agencies consulted during the development of the EA and meetings to facilitate consultation and coordination.

- *References Cited and Appendices:* The appendices provide more detailed information to support the analyses presented in the EA: Appendix A: Non-Native Fish Management below the Glen Canyon Dam, Report from a Structured Decision Making Project; Appendix B: Preliminary Research and Monitoring Plan in Support of the Draft Environmental Assessment Non-Native Fish Control Downstream from Glen Canyon Dam; and Appendix C: Biological Assessment for Non-native Fish Control Downstream from Glen Canyon Dam.

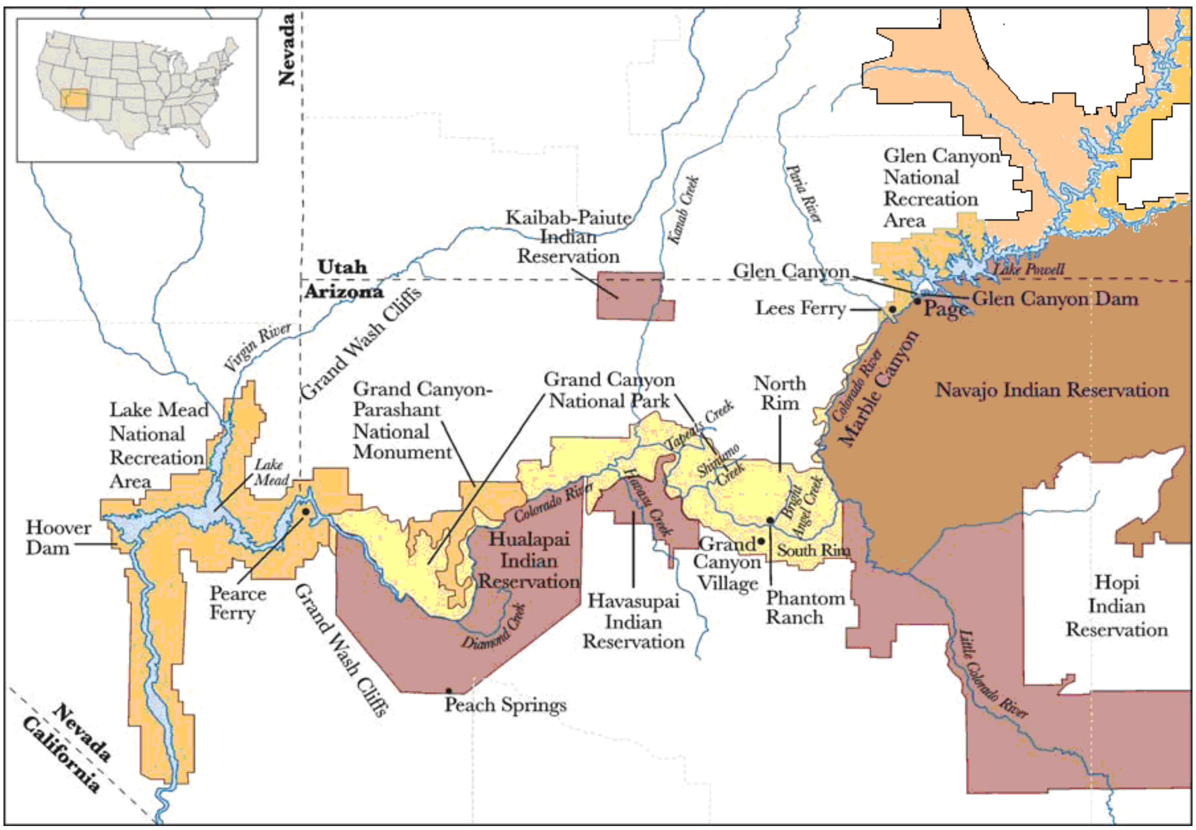


Figure 1. Map of the Action Area (courtesy of the U.S. Geological Survey).

1.2 *Purpose of and Need for Action*

The federal action analyzed in this Environmental Assessment is the control of non-native fish in the Colorado River downstream from Glen Canyon Dam within GCNRA and GCNP, Coconino County, Arizona. The purpose of the action is to reduce the negative impacts of competition and predation by rainbow trout and brown trout on the endangered humpback chub (*Gila cypha*) and its critical habitat in the Grand Canyon. The need for this action is to fulfill the conservation measures and terms and conditions of several U.S. Fish and Wildlife Service (USFWS) biological opinions, to contribute to the recovery of humpback chub by helping to maintain high juvenile survival and recruitment rates resulting in a stable adult population, and to address concerns expressed by American Indian Tribes over the killing of fish in the Grand Canyon, a location of cultural, religious, and historical importance to a number of tribes. This action is being conducted through the Glen Canyon Dam Adaptive Management Program.

Reclamation proposes that this action start in 2011 and extend to 2020. Starting the action in 2011 addresses several purposes including: the importance and need for implementing non-native fish control activities as soon as possible in order to address the ongoing threat to the humpback chub; the need to offset possible adverse effects of conducting High Flow Experiments (HFEs), described in other sections of this document; as well as a number of cultural and socioeconomic concerns and issues that are further described in other sections of this EA.

1.3 *Proposed Action*

Reclamation proposes to, if necessary, reduce the numbers of non-native fish in the Colorado River downstream from Glen Canyon Dam, Arizona that prey on and compete with endangered humpback chub to meet the requirements of several U.S. Fish and Wildlife Service Endangered Species Act (ESA) section 7 biological opinions concerning the effects of dam operations on the endangered humpback chub. The area of emphasis for reducing numbers of non-native fishes is the confluence of the Colorado and Little Colorado rivers, from river mile (RM) 56 to 66[1] because this area contains the greatest abundance of humpback chub in the lower Colorado River, and impacts from non-native trout species to humpback chub are greatest in this reach of the river. In order to achieve this reduction, the proposed action, in coordination with related actions, includes reducing emigration of rainbow trout and brown trout from source populations in Glen and Grand Canyon. Non-native fish, predominantly rainbow trout, would be removed from the Paria River to Badger Creek reach (PBR reach, RM 1 to RM 8) using boat-mounted electrofishing. Non-native fish would also be removed from the LCR reach, (RM 56 to 66) using the same methods, but only if humpback chub decline and adult abundance drops below 7,000 fish. Fish that are removed would be kept alive and stocked into waters as sport fish in areas that have approved stocking plans, or would be euthanized for later beneficial use (used for human consumption, or for feeding eagles, other raptors, or other captive wildlife, particularly those animals kept and reared by tribes), or may be used for other purposes that may be identified through continued tribal consultation. The proposed action would take place within GCNRA and GCNP, Coconino County, Arizona, for a 10-year period from 2011-2020. The 10-year length of the proposed action would allow for sufficient time to evaluate a number of research questions associated with non-native fish control, and would provide any needed mitigation for humpback chub or other native fish associated with the proposed action of

[1] River miles are as measured from Lees Ferry, which is RM 0.

implementing a High Flow Experiment Protocol, a separate but related action being evaluated in a separate EA.

1.3.1 *Operation of Glen Canyon Dam*

Implementation of non-native fish control would be done in concert with existing coordinated river operations. Since 1970, the annual volume of water released from Glen Canyon Dam has been made according to the provisions of the Criteria for Coordinated Long-Range Operations of Colorado River Reservoirs (LROC) that includes a minimum objective release of 8.23 million acre-feet (maf). The Interim Guidelines for Lower Basin Shortages and the Coordinated Reservoir Operations adopted in 2007 (2007 Colorado River Interim Guidelines) implements relevant provisions of the LROC for an interim period through 2026. The 2007 Colorado River Interim Guidelines allow Reclamation to modify operations by allowing for potential annual releases both greater than and less than the minimum objective release under certain conditions. A more thorough description of Reclamation's process for determining and implementing annual release volumes is available in the 2007 FEIS (Reclamation 2007), the 2007 ROD (U.S. Department of the Interior 2007), and the 2007 Biological Opinion (U.S. Fish and Wildlife Service 2007).

The proposed action would be implemented within the framework of continued operation of Glen Canyon Dam under the Modified Low Fluctuating Flow (MLFF; U.S. Department of the Interior 1996) and all applicable prior decisions, with the potential inclusion of a protocol for high-flow experimental releases from Glen Canyon Dam for the same 10-year period, 2011–2020. Steady flows are also scheduled for September and October 2011 and 2012. Annual[2] releases would continue in accordance with prior decisions, including the 2007 Colorado River Interim Guidelines for lower basin shortages and coordinated reservoir operations, and the steady flows as identified in the 2008 Biological Opinion and the 2009 Supplemental Biological Opinion (U.S. Fish and Wildlife Service 2008; 2009).

HFEs may also be implemented during the 10-year period of the proposed action as defined in the HFE Protocol EA (Bureau of Reclamation 2011) depending on the outcome of that NEPA analysis. The HFE Protocol under consideration allows for high flow events during fall (October-November) and spring (March-April) HFE implementation periods. HFEs could range in magnitude and duration from 31,500 cfs to 45,000 cfs and from 0 to 96 hours. The magnitude and duration of an HFE would be in part determined by a model to match existing sediment conditions to the HFE. High flow events under the HFE protocol could potentially require more water than what is scheduled for monthly release through the coordinated operating process. Such adjustments, however, would only be made to the extent they do not interfere with or impact implementation of the Colorado River Interim Guidelines as contemplated in the 2007 Record of Decision. In order to conduct these high flow events as prescribed by the HFE protocol, reallocation of monthly releases within a water year from Glen Canyon Dam may be necessary. If Reclamation determines that it is not possible to achieve the high flow event within the monthly release volume projected for October-November or March-April, Reclamation would adjust the projected monthly release

[2] 'Annual' in the context of water releases means within the water year, October 1 through September 30, rather than the calendar year.

volumes as necessary for the following December through March period, or May through August period, respectively while ensuring that the annual volume is not affected, nor are water deliveries under the Colorado River Interim Guidelines. A more complete description of these potential experiments is provided in the HFE Protocol EA.

Although not assessed in this EA, both flow and non-flow control mechanisms that target limiting recruitment of rainbow trout in Lees Ferry would continue to be evaluated through adaptive management. Flow actions might be more economical and effective over the long-term at mitigating the effects of trout on humpback chub. Both flow and non-flow experiments focused on the Lees Ferry reach may be conducted in order to experiment with these actions in reducing recruitment of trout in Lees Ferry, and ultimately the size of the Lees Ferry trout population. This could both reduce numbers of rainbow trout that move downstream into important areas for native fish, and result in improved conditions of the trout fishery in Lees Ferry (e.g. fewer, larger fish). Additional environmental compliance may be necessary for these experiments.

1.4 *Background*

Reclamation proposes to control non-native fish in the Colorado River downstream from Glen Canyon Dam to ensure that its operation of Glen Canyon Dam does not jeopardize the continued existence of endangered native humpback chub. Non-native fish have long been identified as a threat to native aquatic biota (Cambray 2003; Clarkson et al. 2005), and as a specific threat to native fish in the Colorado River and its tributaries in Grand Canyon (Marsh and Douglas 1996; Minckley 1991). Since passage of the Endangered Species Act of 1973 (ESA) and its implementing regulations at 50 CFR 402, Reclamation has consulted with the USFWS to ensure that its operations of Glen Canyon Dam do not jeopardize the continued existence of the endangered endemic Colorado River “big river” fishes, the humpback chub, razorback sucker (*Xyrauchen texanus*), Colorado pikeminnow (*Ptychocheilus lucius*), and bonytail (*Gila elegans*) or destroy or adversely modify their designated critical habitats. This analysis concentrates on the humpback chub because it is the only one of these species that currently occurs in the project area. The Colorado pikeminnow and bonytail are no longer found in this part of the Colorado River and are not included in this assessment. The razorback sucker would be unaffected by this action because it is absent from the action area and unlikely to occupy the area in the reasonably foreseeable future.

Critical habitat for the Colorado big river fishes was designated by the USFWS in 1994 (50 CFR 17) and includes areas within Marble and Grand canyons. For humpback chub, critical habitat extends for 175 miles of the Colorado River from Nautiloid Canyon (RM 34) to Granite Park (RM 209) and the lower 8 miles of the Little Colorado River (LCR). Critical habitat for razorback sucker in the action area consists of the Colorado River from the Paria River confluence (RM 1) to the Grand Wash Cliffs near Pearce Ferry (RM 277). These reaches of designated critical habitat lie within the boundaries of GCNP and are managed by the National Park Service (NPS). The reach of the Colorado River from RM 30 to RM 75 is a principal nursery area for humpback chub (Figure 2), and it is the reach of river downstream from Lees Ferry that has the highest densities of young humpback chub, and thus impacts of predation and competition by non-native fishes are greatest in this reach. The USFWS critical habitat designation did not include the reach of the Colorado River from RM 30-34, although this area is currently known to be an area of warm springs where humpback chub spawn and apparently recruit (Valdez and Ryel 1995; Andersen et al. 2010).

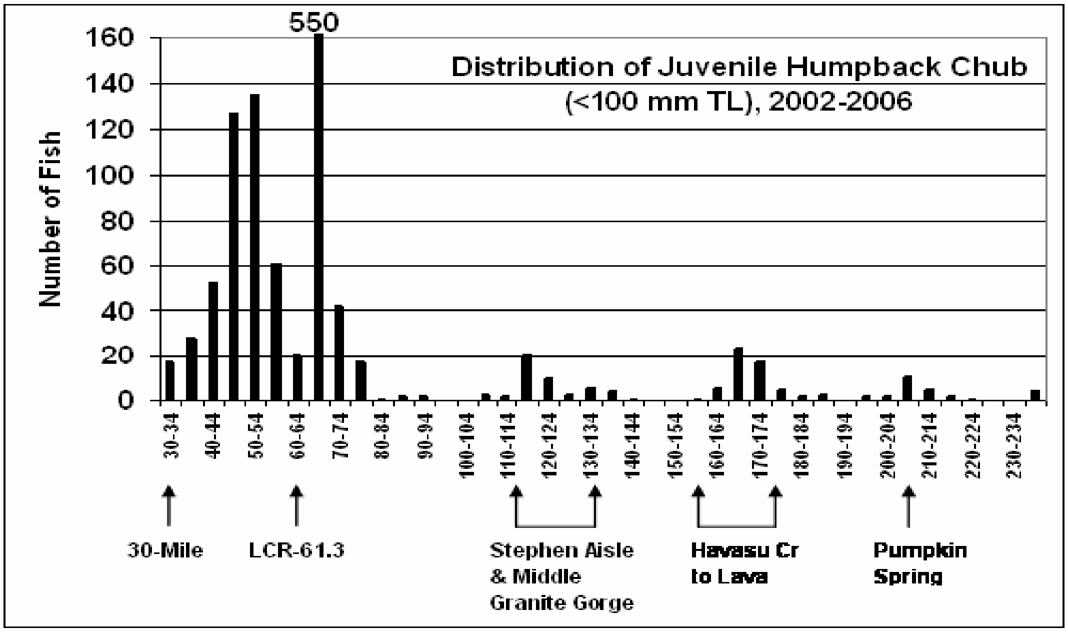


Figure 2. Distribution of juvenile humpback chub<100 mm TL caught during 2002-2006 by 5-mile increments from RM 30 to RM 240. Principal humpback chub aggregations are indicated (data from Ackerman 2008).

The USFWS identified the need for controlling non-native fish species in the recovery goals for the humpback chub (U.S. Fish and Wildlife Service 2002a)[3]. The focus of non-native fish control in the recovery goals is on controlling the proliferation and spread of non-native fish species that prey on and compete with humpback chub in the mainstem Colorado River. The Recovery Goals identify the need to develop, implement, evaluate, and revise (as necessary through adaptive management) procedures for stocking and other sport fish management actions to minimize out-migration of non-native fish species into the Colorado River and its tributaries through the Grand Canyon, and to develop and implement levels of control for rainbow trout, brown trout, and warm water non-native fish species, to minimize negative interactions between non-native fishes and humpback chub (U.S. Fish and Wildlife Service 2002a).

In prior ESA section 7 consultations on the operation of Glen Canyon Dam, Reclamation and the USFWS have agreed that controlling the numbers of non-native fish that compete with and prey on the endangered fish through the GCDAMP would serve as a conservation measure for Reclamation's dam operations planned through the year 2012. Non-native fish control was identified as a conservation measure in the February 27, 2008, Final Biological

[3] In 2006, a U.S. District Court ruling set aside the recovery goals, essentially because they lacked time and cost estimates for recovery. The court did not fault the recovery goals as deficient in any other respect. USFWS is in the process of updating the recovery plan and goals for the humpback chub.

Opinion on the Operation of Glen Canyon Dam (U.S. Fish and Wildlife Service 2008, consultation number 22410-1993-F-167R1), in the October 29, 2009, Supplement to the 2008 Final Biological Opinion for the Operation of Glen Canyon Dam (U.S. Fish and Wildlife Service 2009, consultation number 22410-1993-F-167R1), and the Reissuance of the Incidental Take Statement on the 2009 Supplemental Biological Opinion on the Operation of Glen Canyon Dam 2008-2012 (U.S. Fish and Wildlife Service 2010a, consultation number 22410-1993-F-167R1). Control of non-native fish species in Marble and Grand Canyons through the GCDAMP is also part of the conservation measures identified in the 2007 Biological Opinion for the Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (U.S. Fish and Wildlife Service 2007, consultation number 22410-2006-F-0224). A fourth biological opinion on the cancellation of non-native removal trips in 2010 was issued on November 9, 2010, and required as a term and condition that Reclamation:

> "a. Resume nonnative control at the mouth of the LCR in 2011. Attempt to implement the program in a manner compatible with the interests of Tribes and other interested stakeholders.
>
> AND/OR
>
> b. Work with interested Tribes and other parties, expeditiously, to develop options that would move nonnative removal outside of LCR confluence tribal sacred areas in 2011, with the goal that nonnative removal of trout in sacred areas will be reserved for use only to ensure the upper incidental take level is not exceeded." (U.S. Fish and Wildlife Service 2010b, consultation number 22410-1993-F-167R1).

A panel of independent scientists convened by the U.S. Geological Survey (USGS) also concluded that non-native fish control should continue to be implemented for conservation of humpback chub in Grand Canyon (U.S. Geological Survey 2008). Rainbow trout and brown trout are not native to the Colorado River Basin and were introduced into the region by federal and state agencies as sport fish before and after the 1963 completion of Glen Canyon Dam (e.g., the Arizona Game and Fish Department (AZGFD) stocked rainbow trout at Lees Ferry as recently as 1998). These trout species are the principal competitors and predators of humpback chub, as well as the other native Colorado River fishes (Douglas and Marsh 1996; Valdez and Ryel 1995; Yard et al. 2011). Other species of fish, including the channel catfish (*Ictalurus punctatus*), black bullhead (*Ameiurus melas*), and green sunfish (*Lepomis cyanellus*) also prey upon and compete with the native fishes.

Recent investigations show that negative impacts from trout on native fish are occurring near the confluence of the Colorado and Little Colorado rivers (RM 56-66), where rainbow trout and brown trout co-inhabit the area with the native fish, humpback chub, flannelmouth sucker, bluehead sucker, and speckled dace. The trout species eat juvenile humpback chub and other native fishes and also compete with them for food and space (Yard et al. 2011). This area of the Colorado River supports the largest aggregation of humpback chub in Grand Canyon, and nearshore habitats in the area (talus and vegetated shorelines and backwaters) are used as nursery areas by young humpback chub originating from the LCR. Wright and Kennedy (2011) found an apparent link between abundances of rainbow trout and humpback chub adult population numbers in Grand Canyon. When rainbow trout populations are large, humpback chub populations generally decline, potentially due to a combination of increased competition and predation, although changes in other ecosystem variables, such as water temperature or flow, could also be responsible for these trends (Coggins 2008a; Coggins and Walters 2009; Coggins and Yard 2010; Coggins et al. 2011; Wright and Kennedy 2011; Yard et al. 2011).

The source of rainbow trout in the LCR reach is not known with certainty, although available data indicate they likely originate in the Lees Ferry reach (first 15 miles below the dam). Brown trout spawn primarily in Bright Angel Creek and are most abundant in the mainstem Colorado River near this tributary (RM 88; Liebfried et al. 2003, 2006). Korman et al. (2010) noted that rainbow trout mortality in Lees Ferry and their emigration from Lees Ferry appear to be density dependent. An important aspect of this action is the need to reduce numbers of rainbow trout and brown trout near the confluence of the Colorado and Little Colorado rivers by reducing the numbers of trout emigrating from these population sources in the Lees Ferry and Bright Angel Creek.

Non-native fish control was previously tested from 2003 to 2006, and in 2009 (see Section 1.9). During this time, a removal and related mitigation program was implemented in the vicinity of the Colorado and Little Colorado rivers confluence (LCR reach). Flows from Glen Canyon Dam designed to reduce recruitment of trout in Lees Ferry were also tested from 2003-2005. Then, as now, removal of non-native fish was focused in the LCR reach because of high numbers of both non-native fishes and native fishes, including the majority of humpback chub in Grand Canyon (Valdez and Ryel 1995; Coggins and Walters 2009). No removal was conducted in the LCR (or is proposed now) because densities of non-native fish in the LCR itself are very low, too low to warrant removal efforts (Valdez and Ryel 1995; Van Haverbeke and Stone 2009). Tribes had expressed concern over non-native fish control when it was first proposed in 2002. Consultation between these tribes, Reclamation, and the USGS resulted, at that time, in the identification of a beneficial human use that served to mitigate the tribes' concerns for the experimental action. Fish removed were emulsified and used as fertilizer in the Hualapai tribal gardens. The program was effective at reducing numbers of trout and in meeting tribal concerns, although the program was conducted at a time when the trout population was undergoing a natural system-wide decline (Coggins et al. 2011).

As part of the Annual Work Plan of the GCDAMP for Fiscal Year 2010-2011, one or two river trips to remove non-native fish were included and tentatively scheduled for May-June 2010 and 2011. Some tribal representatives to the GCDAMP expressed concern and asked for government-to-government consultation regarding the killing of non-native fish in the vicinity of the confluence of the Little Colorado and Colorado rivers, a location of cultural, religious, and historical importance. The Pueblo of Zuni, in a letter dated June 30, 2009, expressed the Zuni Tribe's concerns with the "taking of life" associated with removal, and stated that the Zuni's believed that the Bureau of Reclamation and the United States Fish and Wildlife Service had failed to consult with the Zuni Tribe concerning this management action, and the Zuni Tribe's request to initiate formal consultation with the Bureau of Reclamation on this issue. After careful consideration of the issues, the Assistant Secretary of the Interior for Water and Science decided to cancel the two planned removal trips in 2010 and Reclamation reinitiated consultation with the U.S. Fish and Wildlife Service on cancelling removal. Assistant Secretary Castle and other DOI representatives have since conducted numerous meetings with tribal representatives in an effort to find suitable means of addressing the tribal concerns (see Section 1.12).

Reclamation is serving as the lead federal agency in this action because it has operational authority over Glen Canyon Dam and has agreed to address non-native fish control through the GCDAMP pursuant to the terms of the biological opinions issued by the USFWS (U.S. Fish and Wildlife Service 2007, 2008, 2009, 2010a, 2010b). However, Reclamation's legal authority does not include direct management of Colorado River fishes. That authority rests with the National Park Service, the federal agency responsible for managing natural and cultural resources within GCNRA and GCNP, and the Arizona Game and Fish Department (AGFD), the state agency responsible for managing sport fish in the state of Arizona[4].

1.5 *Structured Decision Making Project*[5]

Reclamation partnered with the USGS Patuxent Wildlife Research Center to conduct a Structured Decision Making (SDM) Project on non-native fish management below the Glen Canyon Dam as part of the process in developing this EA. The purpose of the SDM Project was to use a structured approach to develop and provide substantive input from the cooperating agencies and tribes to Reclamation in the NEPA process concerning management of non-native fish below Glen Canyon Dam. The SDM Project provided an opportunity for the cooperating agencies and tribes to participate in defining objectives for non-native fish control, as well as in developing and evaluating potential alternatives for non-native fish control with regard to their performance in meeting objectives.

Two workshops were held near Phoenix, Arizona, on October 18-20 and on November 8-10, 2010. At these workshops, a diverse set of objectives for the project were defined, a set of alternatives ("hybrid portfolios") was developed, and participants assessed alternatives against the array of objectives. Multi-criteria decision analysis methods were then employed to examine the trade-offs inherent in the problem, and allowed the participating agencies and Tribes to express their individual judgments about how those trade-offs should best be

[4] Within the two park units, federal statutes, federal regulations, and lawful federal administrative actions preempt inconsistent state law. In accordance with 43 CFR part 24, the NPS will consult with the AGFD before taking certain administrative actions to manage fish within the park units.

[5] The use of the phrase "Structured Decision Making" refers to a process utilized by the U.S. Geological Survey to assess and proceed through a complex set of analyses and resource considerations. In this instance the outcome of the SDM process is not a "decision" *per se*, as the SDM process in this instance was utilized as an *input* to the NEPA process. Accordingly, the SDM process does not represent a final agency action and serves in this instance as a method to ensure that the decision agency (Reclamation) had received input from the entities participating in the SDM effort. As described in Appendix A, SDM was used to "provide a forum for the diverse cooperating agencies and Tribes to discuss, expand, and articulate their respective values, to develop and evaluate a broad set of potential management alternatives, and to indicate how they would individually prefer to manage the inherent trade-offs in this management problem."

managed in selecting a preferred alternative. Subsequent work refined that analysis. The project served to enlist the cooperating agencies in alternative development and analysis. The final report is provided as an appendix to this EA (Appendix A; Runge et al. 2011) and has been utilized to formulate, analyze, and select alternatives for analysis in this EA were indicated.

The SDM Project was used to assist Reclamation and the cooperating agencies in identifying, developing, and analyzing alternatives as part of the NEPA process. The alternatives considered in the SDM Project were complex, multi-faceted approaches, some with adaptive components. The alternatives were built up from the simplest components and identified several layers of complexity. At the simplest level, the alternatives consist of action elements, which are specific and detailed aspects of on-the-ground actions. Action elements that are related can be combined into single strategies that focus on a particular method for addressing some aspect of non-native fish control (e.g. removal of non-native fish at the confluence of the Little Colorado River). The single strategies can also be combined into hybrid portfolios. These hybrid portfolios are the alternatives for long-term non-native fish control, and were evaluated in the SDM Project.

The hybrid portfolios created in the SDM Project were each evaluated by the cooperating agencies and tribes that participated in the SDM Project. These hybrid portfolios essentially serve as NEPA alternatives. The evaluation process is described in detail in the SDM Project report in Appendix A. That process used multi-criteria decision analysis methods to evaluate the performance and impacts of the proposed hybrid portfolios against objectives for the undertaking, and the objectives were derived from the perspective of the cooperating agencies and tribes in the process. At the second workshop, 20 hybrid portfolios were included in the analysis, and objective weights were elicited from the cooperating agency and tribal representatives to rate the alternatives against the objectives.

A number of portfolios were eliminated from further consideration at that point because their ability to meet objectives was poor and they did not meet the purpose and need. Others were eliminated because they were not well developed and they could not be evaluated. Two high-ranking portfolios, both of which involved sediment augmentation (Randle et al. 2007; discussed further below) were eliminated from further consideration due to cost and because they did not satisfy the purpose and need for the action because the ecological impacts require more detailed analysis than could be developed in time to be evaluated in this EA, and similarly, construction would take a number of years precluding implementation within the timeframe necessary to meet the need for this action. An additional seven hybrid portfolios were created and a total of 13 portfolios were carried forward for final analysis. The final analysis resulted in a ranking of the 5 top-performing hybrid portfolios, performance being measured against the objectives and using methods described in the "Affected Environment and Environmental Consequences" section and in the SDM Project report (Appendix A, section 6). The top-performing hybrid portfolio was selected as the proposed action. The proposed action was then analyzed in this EA against the no action alternative. The "No Action" alternative was also fully analyzed in the SDM Project, and was not in the top five hybrid portfolios at the end of the SDM evaluation. In this way, Reclamation used the SDM Project to help develop analysis of potential alternatives in the NEPA process.

1.6 *Selected Legal Authorities*

The Secretary of the Interior (Secretary) was authorized to "construct, operate, and maintain" Glen Canyon Dam by the Colorado River Storage Project Act of 1956 (CRSPA; 43 U.S.C. § 620):

> "… for the purposes, among others, of regulating the flow of the Colorado River, storing water for beneficial consumptive use, making it possible for the States of the Upper Basin to utilize, consistently with the provisions of the Colorado River Compact, the apportionments made to and among them in the Colorado River Compact and the Upper Colorado River Basin Compact, respectively, providing for the reclamation of arid and semiarid land, for the control of floods, and for the generation of hydroelectric power, as an incident of the foregoing purposes,…"

The CRSPA, as well as a number of Federal statutes and legislative authorities, affect the manner in which Glen Canyon Dam is operated and the manner in which water is apportioned to the seven basin states and Mexico. These authorities are collectively known as the "Law of the River," which is a collection of Federal and State statutes, interstate compacts, court decisions and decrees, an international treaty with Mexico, and criteria and regulations adopted by the Secretary.

In 1970, Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs Pursuant to the Colorado River Basin Project Act of September 30, 1968 (P. L. 90-537) were established to govern operation of reservoirs along the Colorado River.

An important function and purpose of Glen Canyon Dam is to generate hydroelectric power. Water released from Lake Powell through the dam's eight hydroelectric turbines generates power marketed by Western Area Power Administration (Western). From the time of the dam's completion in 1963 to 1990, the dam's daily operations were primarily undertaken to maximize generation of hydroelectric power in accordance with Section 7 of the CRSPA, which requires hydroelectric powerplants to be operated "so as to produce the greatest practicable amount of power and energy that can be sold at firm power and energy rates."

In the early 1980s, Reclamation undertook the Uprate and Rewind Program to increase powerplant capacity at Glen Canyon Dam. As part of an Environmental Assessment and Finding of No Significant Impact (FONSI; Reclamation 1982), Reclamation agreed to not use the increased capacity until completion of a more comprehensive study on the impacts of historic and current dam operations. The Glen Canyon Dam Environmental Studies (GCES) Phases I and II were conducted from 1982 to 1995 to evaluate the effect of the uprate and rewind and dam operations on downstream resources. The GCES concluded that dam operations were adversely affecting natural and recreational resources and that modified operations would better protect those resources (Reclamation 1988). These studies also brought forth concerns about the effects of dam operations on the resources of GCNP and GCNRA and highlighted the need to evaluate the effects on species listed pursuant to the

Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. § 1531 et seq.). As a result of these studies, Reclamation agreed to maximum authorized releases of 31,500 cfs, and the potential of 33,200 cfs that resulted from the uprate and rewind was not implemented.

In 1992 Congress enacted, and President George H.W. Bush signed into law, the Grand Canyon Protection Act (GCPA), title XVIII, §§ 1801-1809 of the Reclamation Projects Authorization and Adjustment Act of 1992, Pub. L. No. 102-575, 106 Stat. 4600, 4669. Congress enacted the GCPA to address the detrimental effects of dam operations on downstream resources. Section 1802(a) of the GCPA provides that:

> The Secretary shall operate Glen Canyon Dam in accordance with the additional criteria and operating plans specified in section 1804 and exercise other authorities under existing law in such a manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established, including, but not limited to natural and cultural resources and visitor use.

At the same time Congress directed the Secretary to implement the GCPA in compliance with other specified provisions of federal law applicable to the operation of Glen Canyon Dam. Section 1802(b) of the GCPA states:

> The Secretary shall implement this section in a manner 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.

Similarly, Section 1806 of GCPA states that:

> Nothing in this title [GCPA] is intended to affect in any way—
>
> (1) The allocations of water secured to the Colorado Basin States by any compact, law, or decree; or
>
> (2) Any Federal environmental law, including the Endangered Species Act (16 U.S.C. 1531 et seq.).

Finally, the GCPA emphasized the Secretary's authority and responsibility to manage and administer Grand Canyon National Park and Glen Canyon National Recreation Area in accordance with the so-called NPS Organic Act and other laws applicable to units of the national park system. Section 1802(c) states:

> Nothing in this title alters the purposes for which the Grand Canyon National Park or the Glen Canyon National Recreation Area were established or affects the authority and responsibility of the Secretary with respect to the management and administration

of the Grand Canyon National Park or the Glen Canyon National Recreation Area, including natural and cultural resources and visitor use, under laws applicable to those areas, including, but not limited to, the Act of August 25, 1916 (39 Stat. 535) as amended and supplemented.

Section 1804(a) of the GCPA required completion of an Environmental Impact Statement (EIS) evaluating alternative operating criteria, consistent with existing law, that would determine how the dam would be operated consistent with the purposes for which the dam was authorized and the goals for protection of GCNP and GCNRA. The Operation of Glen Canyon Dam Final Environmental Impact Statement was completed in March 1995 (Reclamation 1995) with the preferred alternative, called the MLFF Alternative, selected. As articulated in the Record of Decision, issued on October 9, 1996 (Department of the Interior 1996).

The goal of selecting a preferred alternative was not to maximize benefits for the most resources, but rather to find an alternative dam operating plan that would permit recovery and long-term sustainability of downstream resources while limiting hydropower capability and flexibility only to the extent necessary to achieve recovery and long-term sustainability.

The final EIS hypothesized that high flows were important for restoring ecological integrity and identified these as beach-habitat building flows and habitat maintenance flows. Additionally, the 1995 Biological Opinion (U.S. Fish and Wildlife Service [USFWS] 1995) identified a program of experimental flows as an element of the Reasonable and Prudent Alternative that included provisions for high-volume dam flows termed “beach-habitat building flows” (BHBFs) and “habitat maintenance flows” (HMFs). BHBFs were releases that exceeded the powerplant capacity and were designed to build sandbars and beaches, and HMFs were releases up to powerplant capacity designed to maintain these sand features. These actions were also discussed in the EIS and the Record of Decision. This biological opinion was replaced by a new Biological Opinion in 2008 (USFWS 2008), which was subsequently supplemented in 2009 (USFWS 2009). A more complete history of high-flow releases is provided in section 1.5 of this EA.

Section 1805 of the GCPA directs the Secretary to undertake research and monitoring to determine if dam operations are actually achieving the resource-protection objectives of the Final EIS and Record of Decision, i.e., mitigating adverse impacts and protecting and improving the natural, cultural, and recreational values for which GCNP and GCNRA were established. These provisions of the GCPA were incorporated into the 1996 Record of Decision and led to the establishment of the Glen Canyon Dam Adaptive Management Program (GCDAMP; www.gcdamp.gov). The GCDAMP includes the Adaptive Management Work Group, a chartered Federal Advisory Committee to the Secretary, and the Grand Canyon Monitoring and Research Center (GCMRC), a research branch of the GCDAMP under the U.S. Geological Survey (USGS). Monitoring and research conducted by these organizations since 1996 have improved the understanding of riverine geomorphology and how dam operations might assist in the conservation of sand and other natural and cultural resources below the dam.

Since 1999, the Colorado River Basin has experienced prolonged and historic drought conditions; this period represents the driest period in over one hundred years of streamflow recordkeeping. In response to several years of below-normal runoff and declining reservoir conditions and at the direction of the Secretary, Reclamation completed a Final EIS and Record of Decision in 2007 on the *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead* (Bureau of Reclamation 2007; U.S. Department of the Interior 2007). These 2007 Colorado River Interim Guidelines were adopted in December 2007 and are scheduled to be in effect through September 2026 to provide better operational management of Lake Powell and Lake Mead. The provisions of the 1995 EIS and 1996 Record of Decision that led to MLFF, as well as the 2007 EIS and Record of Decision that proposed adoption of interim guidelines and coordinated operations, establish the foundation for the no action and proposed action alternatives defined in this EA.

Section 7(a)(2) of the Endangered Species Act (ESA) requires federal agencies to consult with agencies designated by the Secretaries of Commerce and the Interior to insure that a proposed agency action is unlikely to jeopardize an endangered or threatened species. The USFWS and the National Marine Fisheries Service administer the ESA. Once a consultation process is complete, a written biological opinion is issued, which may suggest alternative actions to protect a jeopardized species or its critical habitat. USFWS also administers the FWCA which enables USFWS to provide planning and assistance and recommendations to support conservation of fish and wildlife resources.

1.7 *Related Actions, Projects, Plans and Documents*

Related actions, projects, plans, and documents are identified in this EA in order to better understand other ongoing activities that may individually or cumulatively influence, relate to, or affect the proposed action. These actions, project, plans, and documents are related to ongoing activities of state and federal agencies, as well as American Indian Tribes.

1.7.1 *1995 Glen Canyon Dam Environmental Impact Statement and Record of Decision*

The action proposed in this EA is tiered from two Reclamation EISs and these documents are incorporated by reference: the 1995 EIS on the operation of Glen Canyon Dam (Bureau of Reclamation 1995) and the associated 1996 Record of Decision (U.S. Department of the Interior 1996); and the 2007 EIS on Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lakes Powell and Mead (Bureau of Reclamation 2007) and the associated 2007 Record of Decision (U.S. Department of the Interior 2007). The 1996 Record of Decision implemented the MLFF to govern monthly releases from Lake Powell at short time increments, down to daily and hourly releases. The 2007 Record of Decision governs annual water year releases from Lake Powell in coordination with Lake Mead. There is also an ongoing program of experimental releases from Glen Canyon Dam in effect from 2008 through 2012, under an EA and FONSI (Bureau of Reclamation 2008).

1.7.2 *High Flow Experiment Protocol Environmental Assessment*

In a concurrent NEPA process, Reclamation is preparing an EA to evaluate implementation of a protocol for conducting high flow experiments (HFEs) at Glen Canyon Dam for the purposes of sediment management in Grand Canyon. The protocol would be implemented over a period of up to 10 years, from 2011 through 2020. The HFE Protocol, if implemented, would be a multi-year, multi-experimental approach using short-duration, high-volume releases from Glen Canyon Dam in the channel of the Colorado River downstream of the dam. The purposes of the HFE Protocol are: 1) to develop and implement a protocol that determines when and under what conditions to conduct experimental high volume releases, and 2) to evaluate the effectiveness of these experimental releases in conserving sediment to benefit downstream resources in Glen, Marble, and Grand Canyons.

High-flow releases have been one mechanism that have historically been used to comply with the Grand Canyon Protection Act to restore beaches and associated resource values in Grand Canyon. However, past Spring HFEs have had demonstrated effects on some non-native fish species in Grand Canyon, and future HFEs could have similar effects (Wright and Kennedy 2010). Specifically, high flow releases may lead to increased rainbow trout populations, perhaps depending on the time of year of the HFE (Korman et al. 2010, Wright and Kennedy 2011). In turn, this may increase the threat to humpback chub from predation and competition from increased numbers of non-native fish (Wright and Kennedy 2011). Non-native fish control alternatives should be developed that would allow effective control of trout while enhancing conditions for humpback chub in consideration of the potential effects of increased HFE occurrence on trout abundance. Accordingly, this EA takes into account the potential effects of HFEs in the context of no action and the proposed action, and analyzes a 10-year period of implementation of non-native fish control to correspond with the 10-year period of the proposed action in the HFE Protocol EA.

1.7.3 *Other Agency Actions, Projects, Plans, and Documents*

The NPS actively manages resources within GCNP and GCNRA. Of importance to this EA is the GCNP and GCNRA ongoing effort related to native fish management. NPS is in the process of developing a Native Fish Plan for GCNP and the Colorado River in GCNRA. Management goals for native fisheries in Glen Canyon and Grand Canyon are being developed to achieve a "natural condition," or the condition of resources that would occur in the absence of human dominance over the landscape (NPS Management Policies 2006). In general, the NPS seeks to restore native fish communities and naturally functioning ecosystems. The overall goals of the Native Fish Plan include:

- Restore populations of native fish to a level that approximates natural conditions, and prevent adverse modification to their habitat (including critical habitat for ESA-listed species).

- Restore self-sustaining populations of extirpated fish species, including Colorado pikeminnow, razorback sucker, bonytail, and roundtail chub (*Gila robusta*), to the extent feasible within Grand Canyon National Park.

- Minimize the impacts of the recreational trout fishery in the Lees Ferry reach to downstream native fisheries in Grand Canyon National Park.

Specific actions underway include:

- Translocation of humpback chub to Shinumo Creek and Havasu Creek: juvenile humpback chub have been translocated from the Little Colorado River to Shinumo Creek. Plans are in place to make additional translocations of humpback chub to Havasu Creek. These translocations are a conservation measure of the 2008 Biological Opinion on the Operations of Glen Canyon Dam and the related 2009 Supplemental Biological Opinion (U.S. Fish and Wildlife Service 2008, 2009).

- Non-native fish are being removed from Bright Angel and Shinumo Creeks to restore and enhance the native fish community in Bright Angel Creek and to reduce predation and competition on endangered humpback chub from non-native fish. Non-native fish (rainbow and brown trout) are being removed from Shinumo Creek in conjunction with translocation to minimize predation upon newly translocated humpback chub and reduce potential competitive interactions. NPS removed from Bight Angel Creek 525 brown trout from 2006-2007, and 454 rainbow trout and 594 brown trout from 2010-2011 using a combination of a fish weir trap and electrofishing; NPS also removed 1,220 rainbow trout and one brown trout from Shinumo Creek in 2009, and 929 rainbow trout in 2010.

In addition to the above, the following are related actions identified by the NPS. The NPS is a cooperating agency in this EA and all actions identified in this document are being coordinated with that agency.

- GCNRA General Management Plan (GMP): The recreation area's 1979 GMP set an objective to manage the Lees Ferry and Colorado River corridor below the Glen Canyon Dam to "give primary emphasis to historical interpretation and access to recreational pursuits on the Colorado River" (NPS 1979).
- General Management Plan (GMP): The park's 1995 GMP set as an objective the management of the Colorado River corridor through Grand Canyon National Park to protect and preserve the resource in a wild and primitive condition (National Park Service 1995).

- Grand Canyon National Park Resource Management Plan (RMP) (1997): The RMP is the primary resource stewardship action plan that provides long-term guidance and protection for natural, cultural and recreational resources of GCNP (National Park Service 1997).

- Colorado River Management Plan (CRMP): The CRMP management objectives emphasize managing river recreation to minimize impacts to resources while providing a quality river visitor experience. The Colorado River corridor will be managed to provide a wilderness-type experience in which visitors can intimately relate to the majesty of the Grand Canyon and its natural and cultural resources. Visitors traveling through the canyon on the Colorado River will have the opportunity for a variety of personal outdoor experiences, ranging from solitary to social, with little influence from the modern world. The Colorado River corridor will be protected and preserved in a wild and primitive condition. To ensure these salient objectives are met, the NPS must determine, through a research, monitoring and mitigation program, what impacts are occurring, how these impacts alter resource condition, and how adverse impacts can be effectively mitigated. The NPS has developed a draft plan that includes individual and integrated resource-monitoring components.

- Backcountry Management Plan: This plan describes provisions for back country use, resource and wilderness management within Grand Canyon National Park. The plan is being updated in 2011.

The Arizona Game and Fish Department (AGFD) is also a cooperating agency in this EA. The following are related actions identified by that State agency.

- Changes to bag limits: the AGFD and the Arizona Game Commission changed size limits and bag limits for trout in the Lees Ferry reach in 2010. This change is designed to better manage abundance and size of trout in the Glen Canyon trout fishery, and to reduce the numbers of trout emigrating downstream to habitat occupied by humpback chub, where they prey upon and compete with this endangered fish species. Two river reaches and corresponding regulations were redefined: Paria Rifle (RM 1) to Navajo Bridge (RM 4) – 6 rainbow trout/day, 8 in possession; unlimited take of all other sport fish other than rainbow trout; and Navajo Bridge (RM 4) to Separation Canyon (RM 239.5) including all tributaries within Grand Canyon National Park – unlimited take of all sport fish.

- USFWS intra-Service consultation on Arizona Game and Fish Department stocking of sport fish in the State of Arizona outside of GCNP and the GCNRA.

1.8 *Agency Roles and Responsibilities*

Five agencies within Interior and one within the U.S. Department of Energy have responsibilities under the GCPA, and undertake operations pursuant to the GCPA. The role of each responsible agency under the GCPA is briefly addressed below.

1.8.1 *Department of the Interior*

1.8.1.1 Bureau of Indian Affairs

The Bureau of Indian Affairs' (BIA) mission, among other objectives, includes enhancing quality of life, promoting economic opportunity, and protecting and improving trust assets of American Indian Tribes and individual American Indians. This is accomplished within the framework of a government-to-government relationship in which the spirit of Indian selfdetermination is paramount. As part of the GCDAMP, BIA's Western Regional Office is committed to working hand-in-hand with interested tribes and other participating agencies to ensure that this fragile, unique, and traditionally important landscape is preserved and protected.

1.8.1.2 Bureau of Reclamation

Reclamation operates Glen Canyon Dam pursuant to applicable federal law and in accordance with the additional criteria and operating plans specified in section 1804 of the Grand Canyon Protection Act as well as in accordance with approved experimental plans. Glen Canyon Dam is also operated consistent with and subject to numerous compacts, federal laws, court decisions and decrees, contracts and regulatory guidelines commonly and collectively known as the "Law of the River."

1.8.1.3 National Park Service

The NPS manages and protects units of the national park system and administers resource-related programs under the authority of various federal statutes, regulations, and executive orders and in accordance with written policies set forth by the Secretary and the Director of the NPS, including the NPS Management Policies 2006 and the NPS Director's Orders. The NPS manages GCNP and GCNRA under the Organic Act (16 U.S.C. §§ 1 and 2-4, as amended); other acts of Congress applicable generally to units of the national park system; and the legislation specifically establishing those park units (16 U.S.C. §§ 221-228j and 16 U.S.C. §§ 460dd through 460dd-9 (2006)). The Organic Act directs the NPS to *"promote and regulate the use of . . . national parks . . . in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."* The agency emphasis is not only on preserving species and habitat, but also on maintaining natural processes and dynamics that are essential to long-term ecosystem perpetuation.

1.8.1.4 U.S. Fish and Wildlife Service

The USFWS provides Endangered Species Act (ESA) conservation and associated consultation and recovery leadership with various stakeholders primarily to benefit four ESA-listed species in Grand Canyon: humpback chub, razorback sucker, southwestern willow flycatcher (*Empidonax trailii extimus*), and Kanab ambersnail (*Oxyloma haydeni kanabensis*).

The USFWS provides Fish and Wildlife Coordination Act (FWCA) planning assistance and recommendations to support conservation of important fish and wildlife resources. Of special concern to the USFWS is the opportunity provided under the FWCA for collaborative development of recommendations to conserve non-listed native species such that the need for listing in the future under the ESA is unnecessary.

A FWCA report (June 28, 1994) provided recommendations that included timing for flows, protection of juvenile humpback chub and other native fish, and trout management, in support of preparation of the 1995 EIS. This information was provided to support conservation of fish and wildlife, including endangered species, in GCNP and GCNRA.

1.8.1.5 U.S. Geological Survey

The Grand Canyon Monitoring and Research Center (GCMRC) of the U.S. Geological Survey (USGS) was created to fulfill the mandate in the GCPA for the establishment and implementation of a long-term monitoring and research program for natural, cultural, and recreation resources of GCNP and GCNRA. The GCMRC provides independent, policy-neutral scientific information to the GCDAMP on: (a) The effects of the operation of Glen Canyon Dam and other related factors on resources of the Colorado River Ecosystem using an ecosystem approach, and (b) the flow and non-flow measures to mitigate adverse effects. GCMRC activities are focused on: (a) monitoring the status and trends in natural, cultural and recreation resources that are affected by dam operations, and (b) working with land and resource management agencies in an adaptive management framework to carry out and evaluate the effectiveness of alternative dam operations and other resource conservation actions.

1.8.2 *Department of Energy*

1.8.2.1 Western Area Power Administration

Western's mission is to market and deliver clean, renewable, reliable, cost-based federal hydroelectric power and related services. The Colorado River Storage Project (CRSP) Management Center markets power from the CRSP and its participating projects (Dolores and Seedskadee and the Collbran and Rio Grand projects). These resources are provided by 11 powerplants in Arizona, Colorado, New Mexico, Utah and Wyoming and are marketed together as the Salt Lake City Integrated Projects. CRSP staff also markets power from the Provo River Project in Utah and the Amistad-Falcon Project in Texas. Transmission service is provided on transmission facilities in Arizona, Colorado, Nevada, New Mexico, Texas, Utah and Wyoming.

1.9 *Previous Non-native Fish Control Efforts*

Non-native fish control was previously tested from 2003 to 2006, and in 2009. During this time, a removal and related mitigation program was implemented in the vicinity of the Colorado and Little Colorado rivers confluence (the LCR reach). Flows from Glen Canyon Dam, "non-native fish suppression flows," designed to reduce recruitment of trout in Lees Ferry were also tested from 2003-2005. Tribes had expressed concern over non-native fish control when it was first proposed in 2002. Consultation between these tribes, Reclamation, and the USGS resulted, at that time, in the identification of a beneficial human use that served to mitigate the tribes' concerns for the experimental action; fish removed were emulsified and used as fertilizer in the Hualapai tribal gardens. The program was effective at reducing numbers of trout and in meeting tribal concerns, although the program was conducted at a time when the trout population was undergoing a natural system-wide decline (Coggins et al. 2011).

Several key results were derived from this period of experimentation. Although the "non-native fish suppression flows" did result in a total redd loss estimate of 23% in 2003 and 33% in 2004, this increased mortality did not lead to reductions in overall recruitment due to increases in survival of rainbow trout at later life stages (Korman et al. 2005; Korman et al. 2011). Removal of non-native fish using boat-mounted electrofishing in the LCR reach was effective for both rainbow trout and brown trout removal. Of 36,500 fish captured from 2003-2006, 23,266 were non-native, including 19,020 rainbow trout and 470 brown trout. Levels of both trout species were effectively suppressed in the LCR reach using this method, especially rainbow trout, which dropped from an initial estimated abundance of 6,466 in January of 2003 to a low of 617 in February 2006 (Coggins et al. 2011). During the period of removal, the humpback chub population stabilized and increased, indicating that removal had enabled higher survival and hence, recruitment by humpback chub (Coggins 2008a; Coggins and Walters 2009; Coggins and Yard 2010). However, a system-wide decrease in rainbow trout abundance concurrent with removal and drought-induced increases in river water temperature confounded efforts to determine with certainty the causes of apparent increases in juvenile native fish survival and recruitment (Coggins et al. 2011).

Although diet content analysis indicated that rainbow trout predation rate on humpback chub was relatively low, the overall loss of young humpback chub to predation by rainbow trout was substantial due to the high density of rainbow trout in the reach. Yard et al. (in press) found that during the 12 removal trips conducted from 2003-2004, 9,326 humpback chub were eaten by trout. Therefore reducing numbers of rainbow trout in the LCR reach (19,020 rainbow trout were removed) effectively reduced predation losses of young humpback chub, a clear beneficial effect to the species, although other factors, such as warmer mainstem water temperatures in Grand Canyon during this period, confounded the overall effect of removal on humpback chub recruitment in the system (Andersen 2009; Coggins et al. 2011; Yard et al. 2011). Also during this period, rainbow trout declined system-wide, indicated both by abundance estimates from the control reach of the non-native control project and from monitoring throughout the system (Coggins et al. 2011; Makinster 2007).

The decline of rainbow trout abundance observed in the control reach may have been due to several factors. First, rainbow trout abundance in the Lees Ferry reach of the Colorado River increased during approximately 1992-2001 and then steadily fell during 2002-2006 (Makinster 2007). The 2002-2006 decrease took place during the period of removal, but upstream 60 miles in Glen Canyon. This illustrates that there was a system-wide decline in rainbow trout at the same time removal was occurring in the LCR reach. So while removal directly reduced trout numbers in the LCR reach, system-wide, rainbow trout were also declining, and it is unlikely that removal alone resulted in the decline. The decline was more likely due to other factors. Possible causes include a system-wide reduction in flow and increases in water temperature due to drought may have disadvantaged rainbow trout by reducing food base and creating less suitable conditions for growth.

One non-native removal trip was also conducted in 2009, which provided important information for consideration of non-native control efforts (Makinster et al. 2009). Results from the 2009 trip indicated that rainbow trout populations rebounded since declines in 2006-2007, a trend first documented in 2008 (Coggins 2008a). AGFD removed 1,873 rainbow trout during the 2009 removal trip. The numbers of rainbow trout in 2009 in the LCR inflow reach prior to removal are estimated to be similar to the high densities observed in 2002. Wright and Kennedy estimate that about 6-7,000 rainbow trout occupied the reach in 2002 and 2009, although these estimates are based on catch per unit effort, a less accurate measure than other methods such as catchability coefficients used by Coggins et al. (2011). By comparison, removal efforts from 2003-2006 reduced the rainbow trout population to a low of 617 in February 2006 (Coggins et al. 2011).

1.10 *Role of Adaptive Management in Non-native Fish Control*

The proposed action in this EA for non-native fish control would be conducted as a component of the ongoing Glen Canyon Dam Adaptive Management Program. The GCDAMP is administered through a designated senior Department of the Interior (DOI) official who chairs the Adaptive Management Work Group (AMWG). The AMWG provides advice and recommendations to the Secretary of the Interior relative to the operation of Glen Canyon Dam, in accordance with the additional criteria and operating plans specified in Section 1804 of the GCPA, and to the exercise of other authorities under existing laws in such a manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established, including but not limited to natural and cultural resources and visitor use, as provided in Section 1802 of the Act.

The decision to conduct non-native fish control would be based on a recommendation by scientists and federal managers that determine the need for non-native fish control based on the numbers and location of non-native fish in the system. The decision would also include consideration of the concerns expressed by American Indian Tribes and Pueblos during the NEPA process. This intersection of scientists and managers is a fundamental principle of adaptive management and uses the best available scientific information to make decisions about management of the ecosystem relative to dam operations. The AMWG would continue its role as advisor to the Secretary on this 10-year proposed action and the adaptive management process. The 10-year non-native fish control action is intended to build on prior efforts of the GCDAMP to control non-native fishes through "learning by doing," which is a fundamental principal of adaptive management.

A draft Science Plan is attached to this EA for the proposed action (see Appendix B). This plan addresses research and monitoring activities necessary to evaluate non-native fish control and the effects of both control and related actions such as experimental releases from the dam. The plan was developed by GCMRC and its cooperating scientists with consultation/coordination with the cooperating agencies. Members of the GCDAMP and the general public are afforded an opportunity to comment on the plan through the public review process for the draft EA. Key research questions that would be addressed in the Science Plan include, but are not be limited to:

- Research Question #1: Can a decrease in the abundance of rainbow trout and other cold- and warm- water non-natives in Marble and eastern Grand canyons be linked to a higher recruitment rate of juvenile humpback chub in the adult population relative to other potential sources of mortality? Or conversely, can an increase in numbers of non-native fish predators be linked to a decrease in adult humpback chub?

Rationale: The goal of the proposed action is, in part, to determine if humpback chub recruitment can be improved by controlling non-native fish species, and in particular, rainbow and brown trout.

- Research Question #2. Can removal efforts focused in the PBR reach (e.g., interception fishery) be effective in reducing downstream movement of trout such that trout levels in the LCR reach remain low? Will recolonization from tributaries, from downstream and upstream of the removal reach, or local production require that removal be an ongoing management action in the LCR reach?

  Rationale: Although previous efforts to reduce trout numbers in the LCR reach were effective, they were conducted during a period of decreasing trout abundance throughout the system. This control effort would assess whether reductions in numbers of trout, and other non-native fish species, can be sustained while also reducing effort and cost of control actions.

- Research Question #3: Can non-native fish control offset any increases in rainbow trout from multiple HFEs?

  Rationale: Ongoing research and monitoring of fish populations downstream from Glen Canyon Dam have shown that the status and trends of these populations are influenced by complex interactions of river flows, water temperature, water clarity, and tributary influences. The humpback chub population declined from about 11,000 adults in 1989 to about 5,050 adults 2001, and has subsequently stabilized and increased to 7,650 adults in 2008. Korman et al. (2010) found that the March 2008 HFE resulted in increased productivity of trout in Lees Ferry, and Makinster et al. (2010) found that this appeared to be linked to increased emigration rates, and ultimately contributed to higher numbers of trout in the LCR reach. Wright and Kennedy (2011) reported that the 2008 HFE appears to have contributed to an 800 percent increase in rainbow trout numbers in the LCR reach. Focused investigations are needed to better understand how aspects of an HFE (timing, magnitude, duration, and frequency) affect fish populations, including nearshore habitat, movement of young native fish from the Little Colorado River, recruitment of young, and food base. Due to the proposed HFE Protocol and the potential for future HFEs, non-native fish control efforts would need to be evaluated with regard to their efficacy at offsetting increases in rainbow trout that result from HFEs.

- Research Question #4: What is the importance of mainstem habitats to humpback chub recruitment relative to the LCR?

  Rationale: A long standing question of humpback chub recovery has been what is the relative importance of mainstem habitats to humpback chub recruitment? Much of the recruitment of humpback chub is thought to occur in the LCR. Non-native fish control actions would improve survivorship of humpback chub predominantly in the mainstem. However, if a vast majority of recruitment is occurring in the LCR, potential improvements in survivorship in the mainstem through non-native fish control may have relatively little effect on overall recruitment of humpback chub. Better estimates of juvenile humpback chub abundance and survivorship in both the LCR and the mainstem would be required to answer this question.

The proposed action includes both PBR reach and LCR reach removal. Removal efforts would be implemented through adaptive management. The goal of the proposed action is to reduce predation and competition from non-native fishes on humpback chub while continuing to address the concerns of American Indian tribes surrounding non-native fish removal. Through adaptive management, effort would be shifted between the two removal reaches depending on the results of removal actions and the status of native and non-native fishes reported through monitoring and modeling results.

In order to both address the concerns of American Indian tribes over non-native fish removal, and to better understand the relationship between predation by rainbow trout on humpback chub survivorship, removal at the LCR would only be implemented if adult humpback chub fall below 7,000 adult humpback chub as measured by the Age Structured Mark Recapture model (Coggins and Walters 2009). The last ASMR estimate of adult humpback chub in the Little Colorado River was 7,650 adults (Coggins and Walters 2009). The trigger of 7,000 adult chub is appropriate because it identifies a conservative level of loss of humpback chub from the adult population and is consistent with USFWS biological opinions. The current USFWS biological opinion on non-native fish control directs Reclamation, in the incidental take statement, to implement non-native fish control as follows: “Resume nonnative control at the mouth of the LCR in 2011. Attempt to implement the program in a manner compatible with the interests of Tribes and other interested stakeholders” and/or “Work with interested Tribes and other parties, expeditiously, to develop options that would move nonnative removal outside of LCR confluence tribal sacred areas in 2011, with the goal that nonnative removal of trout in sacred areas will be reserved for use only to ensure the upper incidental take level is not exceeded.” (U.S. Fish and Wildlife Service 2010b, consultation number 22410-1993-F-167R1). The upper incidental take level in the biological opinion is 6,000 adult humpback chub (U.S. Fish and Wildlife Service 2010b). Reclamation proposes to use 7,000 adult humpback chub as a trigger for LCR reach removal because this number is consistent with the guidance provided in the USFWS incidental take statement that “nonnative removal of trout in sacred areas will be reserved for use only to ensure the upper incidental take level is not exceeded.”

The proposed action would also include research to better understand trout movement dynamics in the action area, as well as the relative importance of habitats in the Little Colorado River and mainstem Colorado River to juvenile humpback chub. Rainbow trout would be marked with PIT tags in the Lees Ferry area, and monitoring in Marble Canyon would be increased. This additional monitoring, along with pilot testing of PBR reach removal, should assist in evaluating how and when trout move from the Lees Ferry area to downstream reaches. The proposed action would also included new research on habitat use and abundance of juvenile humpback chub in both the Little Colorado River and the mainstem Colorado River to assess the relative importance of mainstem habitats to humpback chub recruitment.

As part of the adaptive management process, Reclamation would undertake development of suppression options, with stakeholder involvement, that reduce recruitment of non-native fish at, and emigration of those fish from, Lees Ferry. Both flow and non-flow experiments focused on the Lees Ferry reach may be conducted in order to experiment with actions that would reduce the recruitment of trout in Lees Ferry, lowering emigration of trout. These actions may also serve to improve conditions of the recreational trout fishery in Lees Ferry. Additional environmental compliance may be necessary for these experiments. Utilizing actions such as Glen Canyon Dam releases to reduce recruitment and emigration rates of trout in Lees Ferry may be more economical and effective over the long-term at mitigating the effects of trout on humpback chub (Runge et al. 2011). However, flow options alone also may prove to be ineffective at reducing emigration of trout from the Lees Ferry population. Thus the goal is to use adaptive management to experiment with a variety of options to determine the extent to which non-native fish control is necessary and develop a long-term management strategy that is culturally sensitive and cost effective.

In evaluating flow options for use in non-native fish control, Reclamation would evaluate a number of research elements, including, but not limited to, the following:

- Determining if stranding flows could reduce rainbow trout recruitment by de-watering redds or stranding juvenile trout;
- Evaluating the potential for utilizing changes in down-ramp rates to strand or displace juvenile trout and reduce recruitment;
- Evaluating different types and magnitudes of stranding flows;
- Evaluating the potential to use water quality of dam releases (low oxygen levels) below Glen Canyon Dam to reduce trout survivorship.
- Determining if flow and non-flow actions are effective in improving the Lees Ferry trout fishery.

Developing and testing dam releases and other non-flow methods would require involvement of both scientists and stakeholders to adequately analyze effects of these actions. Reclamation would work with these groups to develop a proposal and science plan for implementing and evaluating these flow and non-flow actions with these groups over the next one to two years.

1.11 *Public Involvement*

Based on the previous experiments and before beginning preparation of this EA, a wide variety of people were contacted to get their ideas and concerns about the status of endangered fish in the Colorado River and possible treatments to reduce numbers of non-native fish, as well as the anticipated effects of these treatments. The Grand Canyon Monitoring and Research Center convened and conducted a Non-native Fish Workshop on March 30-31, 2010, to: (1) Describe non-native fish management in Grand Canyon, (2) identify critical issues and develop approaches to these issues, describe perspectives on management of native and non-native species, and (3) describe agency roles for non-native fish control in conservation and recovery of native fish in Grand Canyon. Two modeling workshops were also held by GCMRC on April 14-15 and on October 12-15, 2010 that helped to clarify the role of trout predation on the humpback chub and preliminarily identified possible strategies and treatments for managing trout populations in Grand Canyon.

The following cooperating agency (CA) meetings were also held:

- A cooperating agency workshop was conducted in Salt Lake City June 17-18, 2010;

- A CA and tribal meeting was held in Flagstaff on August 20, 2010; and,

- CA conference calls were conducted on July 12, September 2, 9, 16, 23, 30, and November 4 and 21, 2010, and January 5, 2011, and March 24, 2011.

- SDM Workshops were conducted on October 18-20, November 8-10, 2010.

- AZGFD also met with Marble Canyon business owners on January 28th 2011 to discuss the EAs; USGS, NPS, and Western were also in attendance.

The AZGFD with USFWS, Reclamation, NPS, USGS, and Western also met with flyfishing guides and Marble Canyon business owners to discuss their concerns regarding removal on April 16, 2010, and Reclamation met separately with the Marble Canyon business owners on August 20 and December 20, 2010.

1.12 *Consultation with American Indian Tribes*

Reclamation has a responsibility to recognize Indian Trust rights and maintain compliance with section 106 of the National Historic Preservation Act (NHPA), which forms part of the need for this EA. The Federal government holds Trust responsibilities that recognize the sovereign status and management authority of tribes, and assures the tribes that federal agencies will not knowingly compromise traditional practice and livelihoods in execution of their duties. Executive Order 13007 adds specificity to this principal in stating that federal agencies “shall avoid adversely affecting the physical integrity of sacred sites,” while Secretarial Order 3206 stipulates that within the context of the ESA the “Departments will carry out their responsibilities under the Act in a manner that harmonizes the Federal trust responsibility to tribes.” Further, the NHPA requires federal agencies to take into account the effects of their actions on historic properties, which, through the National Register of Historic Places, includes special provisions for places of cultural and religious importance.

Reclamation also has a responsibility to consult with tribes on actions it undertakes under Presidential Executive Order 13175, which was enacted on November 6, 2000, “in order to establish regular and meaningful consultation and collaboration with tribal officials in the development of Federal policies that have tribal implications, to strengthen the United States government-to-government relationships with Indian tribes, and to reduce the imposition of unfunded mandates upon Indian tribes.” President Barrack Obama also recently issued a memorandum on November 5, 2009 that further refined this responsibility, stating:

> My Administration is committed to regular and meaningful consultation and collaboration with tribal officials in policy decisions that have tribal implications including, as an initial step, through complete and consistent implementation of Executive Order 13175. Accordingly, I hereby direct each agency head to submit to the Director of the Office of Management and Budget (OMB), within 90 days after the date of this memorandum, a detailed plan of actions the agency will take to implement the policies and directives of Executive Order 13175.

Non-native fish control was first implemented through the GCDAMP beginning in 2002 with a proposal to utilize removal in the LCR reach and altered flow regimes at Glen Canyon Dam to control trout numbers in the system. At the time, several tribes expressed concern over the taking of life associated with the project in a culturally important place, both the Grand Canyon as a whole, and the confluence of the LCR and Colorado River in particular. The Hopi Tribe, the Kaibab Band of Paiute Indians, Paiute Indian Tribe of Utah, the Hualapai Tribe, and the Zuni Tribe objected to the experimental action of removal unless there was a beneficial human use for fish removed. Consultation between these tribes, Reclamation, and the USGS resulted in the identification of a beneficial human use that served to mitigate the tribes' concerns for the experimental action. Fish that were removed were emulsified and used for fertilizer at the Hualapai tribal gardens. From 2003 through 2006 and in 2009, a removal and related mitigation program was implemented in the vicinity of the Colorado and Little Colorado rivers confluence (LCR reach). The program was effective at reducing numbers of trout, although the program was conducted at a time when the trout population was undergoing system-wide decline.

As part of the Annual Work Plan of the Glen Canyon Dam Adaptive Management Program for Fiscal Year 2010-2011, one or two river trips to remove non-native fish were included and tentatively scheduled for May-June 2010 and 2011. Some tribal representatives to the program expressed concern and asked for government-to-government consultation regarding the killing of non-native fish in the vicinity of the confluence of the Little Colorado and Colorado rivers, a location of cultural, religious, and historical importance. The Pueblo of Zuni, in a letter to Larry Walkoviak, dated June 30, 2009, from Zuni Governor Norman J. Cooeyate, expressed the Zuni Tribe's concerns with the "taking of life" associated with removal, and their concern that Reclamation and the USFWS had not sufficiently consulted with the Zuni Tribe concerning this management action. The letter also requested initiation of formal tribal consultation with the Bureau of Reclamation on this issue. In response, Reclamation and other DOI representatives met with Zuni tribal leaders to hear their concerns on September 15, 2009.

A meeting of DOI and tribal representatives was held on January 12-13, 2010, where the tribes requested government-to-government consultation on the proposed removal. Tribal concerns were also expressed in February 2010, as part of a 2-day series of GCDAMP-related public meetings in Phoenix, Arizona. The Pueblo of Zuni sent a letter to Assistant Secretary of the Interior for Water and Science Anne Castle on February 19, 2010, in which the Governor of Zuni expressed his dissatisfaction with the nature and content of consultation that had occurred to date regarding non-native fish control. In response, in March 2010, Reclamation cancelled the two planned non-native fish removal trips in 2010 and reinitiated consultation with the U.S. Fish and Wildlife Service on cancelling removal.

Assistant Secretary Castle met with Pueblo of Zuni Governor Cooeyate and the Tribal Council on August 5, 2010, in Zuni, New Mexico. The Pueblo later sent Reclamation a Zuni Tribal Council Resolution (No. M70-2010-C086), a document and formal position statement generated by the Executive and Legislative Branches of the Zuni Government, that clearly stated the position of the Zuni Tribe and religious leaders concerning the adverse affects to the Pueblo from the removal of non-native fish in Grand Canyon and also explaining that the Zuni Tribe believes the Grand Canyon and Colorado River are Zuni Traditional Cultural Properties eligible for inclusion to the National Register of Historic Places. The resolution included a position statement by the Zuni Religious leaders that explained that all life and the entire environment in Grand Canyon is sacred to the Zuni people and that mechanical removal results in counterproductive energy and negative effects to the Zuni people and all life.

Government-to-government consultation was initiated with the Havasupai Tribe, Hopi Tribe, Hualapai Tribe, Kaibab Band of Paiute Indians, Paiute Indian Tribe of Utah, San Juan Southern Paiute Tribe, Las Vegas Paiute Tribe, Moapa Band of Paiutes, Navajo Nation, the Havasupai Tribe, the Yavapai Apache Nation, the Pueblo of Jemez, and Pueblo of Zuni regarding the proposed action, and consultation is continuing. The Hualapai Tribe and Pueblo of Zuni are cooperating agencies for the EA. The following government-to-government tribal consultation, informal tribal consultation, and cooperating agency (CA) meetings were held:

- Government-to-government tribal consultation meetings were held with the Zuni Tribe at the Pueblo of Zuni at Zuni, New Mexico, on September 15, 2009, and on March 24 and June 4, 2010;

- Government-to-government tribal consultation meetings were held with the Hopi Tribe (March 4 and April 22 2010, January 27, 2011), Navajo Nation (June 9, 2010, and January 26, 2011), Hualapai (March 6, 2010, and January 8, 2011), Havasupai (March 15, 2010), Kaibab Pauite Tribe (March 18, 2010, and January 20, 2011), and the Paiute Indian Tribe of Utah (December 13, 2010);

- On July 29, 2010, Reclamation served on a discussion panel discussion about this issue at the 2010 Native American Fish and Wildlife Society Southwest Conference entitled “Non-Native Fish Removal in the Grand Canyon: Cultural Considerations and Fish Management”;

- Assistant Secretary Anne Castle and other representatives from DOI and Reclamation met with the Governor of the Pueblo of Zuni, the Zuni Tribal Council, Zuni Cultural Resource Advisory Team, and the Zuni public at Zuni, New Mexico, to discuss non-native fish removal and the objection of the Zuni people to the killing of rainbow trout on August 5, 2010.

- The Pueblo of Zuni sent Reclamation the Zuni Tribal Council Resolution No. M70-2010-C086 on September 27, 2010, regarding their concerns with mechanical removal and the request that Grand Canyon be included as a TCP eligible for listing on the National Register. This resolution included a signed position statement of the Zuni religious leaders that was given to Assistant Secretary Castle at the August 5, 2010 meeting.

- A CA and tribal meeting was held in Flagstaff on August 20, 2010.

- CA conference calls were conducted on September 2, 9, 16, 23, 30, and November 4 and 21, 2010, and on January 5, 2011, and March 24, 2011. These often included the tribes that participated as cooperating agencies, the Pueblo of Zuni and Hualapai Tribe.

- SDM Workshops were conducted on October 18-20, November 8-10, 2010, and representatives from three of the five tribes (the Navajo, Hopi, and Zuni tribes) participated in these.

- A tribal consultation meeting with the Pueblo of Zuni was held on January 25, 2011.

Reclamation, along with the USFWS, NPS, BIA, and USGS, is committed to ongoing consultation with these and any other concerned American Indian tribes. Additional meetings will be held with tribes as necessary to define and resolve effects of the proposed action under NHPA section 106.

1.13 *Relevant Resources and Issues*

Reclamation has utilized the scoping results from prior NEPA analyses (e.g. U.S. Department of the Interior 2002), as well as knowledge gained from prior experiments (e.g. Coggins 2008a; Coggins and Yard 2010; Coggins et al. 2011; Gloss et al. 2005; Korman et al. 2010; Makinster et al. 2009b, 2010; Rosi-Marshall et al. 2010; Wright and Kennedy 2011; Yard et al. 2011) to determine the relevant resources and issues for analysis in this environmental assessment. Table 1 presents the list of relevant resources considered for analysis in this EA. Resources in bold were analyzed for effects from the no action and proposed action alternatives. Resources not in bold were considered but not affected by the alternatives.

Table 1. List of resources and issues evaluated.

NATURAL RESOURCES	CULTURAL RESOURCES	SOCIOECONOMIC RESOURCES
Water Resources	**Historic Properties**	Hydropower
Water Quality	**Traditional Cultural Properties**	**Recreation (including Public Safety and Sport Fishing)**
Air Quality		
Sediment		
Vegetation	**Sacred Sites**	
Terrestrial Invertebrates and Herptofauna		
Aquatic Food Base		
Fish		
• **Humpback chub**		
• **Razorback sucker**		
• **Other native fishes**		
• **Trout**		
• **Other non-native fishes**		
• **Fish habitat**		
Birds		
Mammals		

1.14 *Authorizing Actions, Permits or Licenses*

Implementation of the proposed action would require a number of authorizations or permits from various federal and state agencies and American Indian tribal governments. Any field work within the boundaries of GCNP or GCNRA would require permits from the NPS. Tribal permits from the Hualapai Tribe or Navajo Nation would be needed for any field work within reservation boundaries. Researchers working with threatened or endangered species would need to obtain a permit from the USFWS. The proposed action could cause effects to the endangered humpback chub through electrofishing and handling that could require a USFWS ESA section 10(a)(1)(A) permit. Researchers working with resident fish may also need an Arizona Game and Fish Department (AGFD) permit. No other permits are known to be required at this time.

In addition, implementing this action will require additional ESA section 7 consultation with the USFWS. A biological assessment has been prepared and is attached to the EA as Appendix C, which has been submitted to the USFWS with a request for consultation.

1.15 *Decision Framework*

Reclamation's responsible official must decide whether to implement either the proposed action, an alternative action, or take no action. As the manager of the affected portion of the

Colorado River, the NPS would determine whether the proposed action comports with their management plans and policies. The mission of the NPS is to "to conserve the scenery and the natural and historic objects and the wild life therein and…leave them unimpaired for future generations" (1916 NPS Organic Act). The proposed action complies with the overall NPS mission and with NPS Management Policies (National Park Service 2006a, §4.4.4.2) which direct that all exotic (i.e., non-native) species that are not maintained to meet an identified park purpose will be managed—up to and including eradication—if: (1) Control is prudent and feasible; and (2) the non-native species interferes with natural processes and the perpetuation of natural features, native species, or natural habitats. This action is also consistent with the humpback chub recovery goals (U.S. Fish and Wildlife Service 2002a) in which "Brown trout and rainbow trout control programs [shall be] developed and implemented to identify levels of control that will minimize negative interactions on humpback chub in the Colorado River through Grand Canyon." Further, it is the intent of this decision framework to be consistent with the Strategic Plan for the Glen Canyon Adaptive Management Program (Final Draft, August 17, 2001) that was prepared by the AMWG.

1.16 *Relationship between EAs for Non-native Fish Control and High-Flow Protocol*

Reclamation is in the process of concurrently preparing two EAs related to the ongoing implementation of the Glen Canyon Dam Adaptive Management Program. In addition to this EA that addresses non-native fish control, the other EA addresses the development and implementation of a protocol for high-flow experimental releases from Glen Canyon Dam. Both efforts are designed to include important research components, with the expectation that the undertakings would improve resource conditions, and thereby provide important additional information for future decision-making within the GCDAMP. Although both EAs relate to and are part of the overall GCDAMP, Reclamation has considered the content of both efforts and believes that it is appropriate to maintain separate NEPA processes because each activity under consideration serves a different and independent purpose, has independent utility, and includes very different on the ground activities and actions (rate, duration and timing of water releases as compared with non-native fish research, management and control actions).

The HFE Protocol would evaluate the use of short-duration, high-volume dam releases during sediment-enriched conditions for a 10-year period, 2011–2020, to determine how multiple events can be used to better conserve sand over a long time period in the Colorado River corridor within GCNP. Under the concept of HFEs, sand stored in the river channel is suspended by these dam releases and a portion of the sand is redeposited downstream as sandbars and beaches, while another portion are transported downstream by river flows. These sand features and associated backwater habitats can provide key wildlife habitat, protect archaeological sites, enhance riparian vegetation, and provide camping opportunities along the Colorado River in GCNP. Additional attention would be given to ensure that other resources would not be unduly or unacceptably impacted or that any such impacts could be sufficiently mitigated.

The Non-native Fish Control EA is designed to control non-native fish in the Colorado River downstream from Glen Canyon Dam in an effort to help conserve native fish in GCNP and meet requirements and obligations of several USFWS biological opinions on the operation of Glen Canyon Dam. The proposed action would minimize the negative impacts of competition and predation on an endangered fish, the humpback chub in Grand Canyon. Competition and predation by non-native fishes, and in particular rainbow trout and brown trout, are reducing survival and recruitment of young humpback chub and threatening the potential recovery of the species. The action also addresses the concerns of American Indian tribes over the taking of life associated with non-native fish control.

During the first round of public review and comment on the HFE Protocol and Non-Native Fish Control EAs, several comments from the public suggested that these high-flow dam release and fish control activities are “connected actions” or “similar actions” for NEPA purposes and therefore must be combined into a single NEPA document. The primary basis for this concern appears to be that, notwithstanding the differing nature of the experimental actions, based on a previous high-flow release, there is a concern that high-flow events during certain times of the year have the potential to increase the number of non-native trout that have been documented to feed upon native, endangered humpback chub.

Reclamation reviewed and considered these comments and has added this discussion to this updated draft EA in order to provide the public with additional information with respect to the basis for the NEPA processes that are being utilized for the development of these two actions.

As an initial matter, the HFE Protocol and the Non-Native Fish Control efforts are not portions of a single action. The protocol would address multiple projected experimental operations (i.e., variable, high-flow water releases) from Glen Canyon Dam that would link high-volume releases to sediment availability in reaches downstream of Glen Canyon Dam. The high-flow releases would be conducted over a period of years and on multiple occasions to assess the ability to reduce the erosion of beach habitat in the Grand Canyon and potentially to enhance and retain beach habitat over multiple years.

Separately, the non-native research and control efforts are designed to enhance understanding of the life-cycle, movement and impacts of non-native fish on the native species in areas of the Colorado River downstream of Glen Canyon Dam. The non-native control actions are likely to address methods to reduce the population of predatory non-native trout in areas where young-of-year native fish are located. Predation by non-native fish (both warm water and cold water species) has been identified as a primary threat to native fish in the Colorado River Basin.

Reclamation has considered the most appropriate approach to NEPA compliance for these actions and has reached a conclusion at this stage of analysis that it is not necessary to combine the EAs into a single NEPA document under the applicable NEPA regulations. Under NEPA’s implementing regulations, the question of whether the two actions must be analyzed in a single compliance document turns on whether the two actions are considered “connected actions,” “cumulative actions,” or “similar actions.” Pursuant to 40 C.F.R. §

1508.25(a)(1), connected actions are "closely related and therefore should be discussed in the same impact statement." The regulations go on to provide that: "Actions are connected if they: (i) Automatically trigger other actions which may require environmental impact statements. (ii) Cannot or will not proceed unless other actions are taken previously or simultaneously. (iii) Are interdependent parts of a larger action and depend on the larger action for their justification." 40 C.F.R. § 1508.25(a)(1).

The EAs do not meet the regulatory standard for connected actions. Neither activity under consideration will automatically trigger other actions which may require environmental impact statements as part of the Glen Canyon Adaptive Management Program. Implementation of both the high flow and non-native fish control actions are designed and expected to advance scientific knowledge and inform future GCDAMP decision-making, and may lead to adjustments in release patterns and/or strategies to control the size and location of predatory non-native fish. However, Reclamation cannot conclude at this time that such information will automatically trigger other actions which may require EISs. Secondly, the non-native fish control process is not dependent on other actions being taken previously our simultaneously. Rather, the timing and manner of nonnative control will depend, in part, upon the results of monitoring efforts determining the number of trout, their location and movement, etc. While the implementation of spring high-flows has been raised as a issue, given the post-2008 monitoring results, it is clear that both warm and cold-water non-native fish control actions will be necessary regardless of high flow implementation. There are no other actions that are conditions precedent to the efforts proceeding, and neither action depends on a larger action for their justification.

There are some obvious relationships and linkages between the two proposed actions, but those similarities do not rise to the standard of requiring preparation of a single NEPA document as "connected actions" for NEPA purposes. Both actions are part of the overall GCDAMP, and they share a common overall geographic area (primarily focused on the mainstem of the Colorado River below Glen Canyon Dam). In addition, there are some overlapping impact analysis issues that are discussed herein, as it is possible that certain high-flow releases may impact the size and distribution of nonnative fish that have been identified as species that prey on native fish. However, each action has independent methods (dam releases vs. fish monitoring, tracking, and potential removal actions), an independent focus (protection and enhancement of riparian habitat vs. non-native fish research, monitoring and control), and each action has independent utility whether or not the other action proceeds. Moreover, where the two proposed actions are projected to involve overlapping environmental effects (i.e., potential effects on predatory non-native species), the relevant analysis of these common environmental effects is included in both EAs.

Another regulatory basis for NEPA documents to be combined is if the activities in question are "similar actions." Pursuant to 40 C.F.R. § 1508.25(a)(3), similar actions "have similarities that provide a basis for evaluating their environmental consequences together, such as common timing or geography." While the two efforts address areas downstream of Glen Canyon Dam (and thus share a common geography, as well as timing), there are unique areas that will be the focus of each NEPA effort. The primary action of the high flow protocol is the timing, rate and duration of releases of water from Glen Canyon Dam. In terms of downstream research and monitoring, the high-flow protocol has a particular focus on sediment transport and geomorphological processes, and will include research and monitoring focused on the number, size and distribution of sandbars throughout Marble and Grand Canyons. In contrast, the non-native fish control efforts are focused on biological processes and expected to focus analysis on particular areas that are important to both native and non-native fish species, the PBR and LCR reaches.

Even where two actions are deemed to be "similar actions" under the regulations, the applicable NEPA regulations go on to provide that, "[a]n agency may wish to analyze these actions in the same impact statement . . . when the best way to assess adequately the combined impacts of similar actions or reasonable alternatives to such actions is to treat them in a single impact statement." Id. This regulatory provision leaves the agency decision makers with sufficient discretion to determine the "best way" to assess impacts of similar actions. Given the differences between the two efforts, and based on the analysis of the differing scientific focus of each experimental effort, Reclamation, based on the best available information that is available at this stage of analysis, has considered this issue and determined that the best way to analyze each action is to continue to analyze the high flow protocol and the non-native fish control strategy through separate and independent NEPA processes, recognizing that resource analyses that are relevant to both EAs have been documented and included in both EAs, where appropriate (e.g., potential high flow impacts on population and distribution of predatory non-native species). Reclamation is also ensuring that both EAs contain up-to-date information on resource status and impacts and has been carefully coordinating the preparation schedules of the two EAs to ensure consistency of content.

Finally, both actions do not constitute "cumulative actions" necessitating review in a single NEPA document as defined by 40 CFR 1508.25 (a)(2). Nonetheless, Reclamation does address the cumulative effects from both actions in the affected environment section of each EA, under the topical discussion for each resource (see Section 3). Thus Reclamation has properly considered the cumulative effects from these two actions and other actions in both NEPA documents. Consistent with these analyses, at this point in the NEPA process Reclamation has not concluded that the actions have "cumulatively significant impacts" which pursuant to 40 C.F.R. § 1508.25(a)(2) would indicate that the actions "should therefore be discussed in the same impact statement."

1.17 *Relationship between this EA and the Long-Term Experimental and Management Plan*

As discussed herein, there are a number of ongoing activities of the GCDAMP that complement the actions and research anticipated under this EA. In addition, the Department is embarking on the first major, comprehensive analysis of the Glen Canyon Dam GCDAMP since 1996 with the initiation of the Glen Canyon Dam Adaptive Management Program Long Term Experimental and Management Plan (LTEMP). The Department has determined that it is appropriate and timely to undertake a new environmental impact statement (EIS) that reviews and analyzes a broad scope of Glen Canyon Dam operations and other related activities. Given that it has been 15 years since completion of the 1996 ROD on the operation of Glen Canyon Dam, the Department will study new information developed through the GCDAMP, including information on climate change, so as to more fully inform future decisions regarding the operation of Glen Canyon Dam and other management and experimental actions. The LTEMP is a component of the Department's efforts to continue to comply with the ongoing requirements and obligations established by the Grand Canyon Protection Act of 1992 (Pub. L. No. 102-575). The Department has determined that the LTEMP EIS will be co-led by the Bureau of Reclamation and the National Park Service. Reclamation and the NPS will co-lead this effort because Reclamation has primary responsibility for operation of Glen Canyon Dam and the NPS has primary responsibility for GCNP and GCNRA. A formal notice of intent to prepare an EIS is anticipated during the summer of 2011, which will be followed by a thorough scoping process.

The purpose of the proposed LTEMP is to utilize current, and develop additional, scientific information to better inform Departmental decisions and to operate the dam in such a manner as to improve and protect important downstream resources while maintaining compliance with relevant laws including the GCPA, the Law of the River, and the Endangered Species Act (ESA). Information developed through this EA and through the monitoring and implementation of the proposed action will be further reviewed and analyzed as part of the LTEMP process. That is, while this EA is designed to analyze and adopt an approach to non-native fish control, the effectiveness of such actions will also be further analyzed, integrated and potentially refined and/or modified as part of the LTEMP NEPA process. Scientific and resource information developed through this EA, and the implementation of the non-native fish control efforts of the proposed action are essential to ensuring that fully informed decisions are made as part of the LTEMP process. Accordingly, Reclamation has determined that it is essential and appropriate to move forward with this EA because it will provide important information related to non-native fish control. This information is important for independent reasons described throughout this EA, and it will also aid in future decisions associated with the LTEMP process. Continuing with the EA to learn more information about Glen Canyon Dam operations is consistent with the principles of adaptive management, which have guided decision making since the 1996 ROD.

1.18 *Issues for Analysis*

NEPA requires that any issues directly or indirectly caused by implementing the proposed action be analyzed. The Council on Environmental Quality (CEQ) NEPA regulations in 40 CFR 1501.7 allow that issues may be excluded from analysis if they are identified as those: (1) Outside the scope of the proposed action; (2) already decided by law, regulation, plan; (3) irrelevant to the decision to be made; or (4) conjectural and not supported by scientific or factual evidence. Relevant issues must be analyzed to determine the effects of potential actions to resources of concern, and thereby select an alternative that best meets the purpose and need.

The relevant issues to the proposed action were identified through the NEPA process, including through the SDM Project with the cooperating agencies and tribes, and these issues were used in this EA as criteria for selection of the proposed action. In the SDM Project, the "issues" described in this section led to a definition of "objectives" of the undertaking, against which various actions were compared for their ability to achieve the objectives (see Appendix A, Section 4.3). This process revealed that the primary issues surrounding non-native fish control in Grand Canyon deal with effects to natural resources, impacts to recreation, and cultural and socioeconomic concerns. These issues were carefully analyzed in the SDM Project and in this EA to help formulate and evaluate alternatives and identify the proposed action.

The proposed action is designed to benefit native and endangered fish, with the acknowledgement that there may be unintended side effects to this beneficial action. These issues capture what those unintended side effects may be, and were further analyzed in the SDM Project and in other sections of this EA.

Issue 1: American Indian Concerns with the Taking of Life

Beginning with tribal consultation on the first experimental non-native fish removal efforts in 2002, several southwestern tribes (the Hopi Tribe, Hualapai Tribe, and the Pueblo of Zuni) objected to the taking of life at the confluence of the Colorado and Little Colorado rivers. To mitigate these concerns, the action agencies (USGS, NPS, and Reclamation) and the concerned tribes agreed that fish removed from the LCR reach during 2003-2006 and 2009 would be put to a beneficial use. The beneficial use consisted of euthanizing removed fish, which were then ground to an emulsion, packaged in 50-gallon barrels on site in the Grand Canyon, and transported to the Hualapai Tribe where they were used as fertilizer for organic vegetable farms on Hualapai tribal lands. Since 2006, the rainbow trout population has undergone an 800 percent increase in the LCR reach (Wright and Kennedy 2011). In response to increasing trout numbers, and as part of the conservation measure to control non-native fish in the 2008 USFWS Biological Opinion, Reclamation, through the GCDAMP, conducted a single non-native fish removal trip in the LCR Reach to better determine levels of trout abundance in the LCR reach and refine the level of removal necessary to meet as yet undefined goals for trout suppression. The Pueblo of Zuni subsequently expressed concern over the taking of life in the Colorado River from this action, and later the other GCDAMP tribes all indicated some level of concern about this aspect of non-native fish control. The Navajo and Hopi tribes also expressed concerns about the geographic location of non-native removal in the LCR reach, which is an important traditional cultural place for these tribes.

The Pueblo of Zuni has expressed concern over both the action of removing and euthanizing fish and the location of where that action takes place. The Zuni have a familial relationship between all aquatic life and the Zuni people, and place traditional and historical importance on the Grand Canyon and the confluence of the Little Colorado River and Colorado River. The Zuni have stated that it is not only the taking of life that concerns the Zuni people, but also the adverse affect this action has on the Zuni values that are ascribed to the Grand Canyon, the Colorado River, and the confluence of the LCR and Colorado Rivers as a National Register-eligible traditional cultural property.

The GCDAMP tribes and other stakeholders have expressed skepticism in the premise that removing rainbow trout and non-native predatory fish actually benefits humpback chub. This is because, as discussed above, although humpback chub status improved during the period of non-native fish removal from 2003-2006, other factors may have been responsible for this improvement. The 2003-2006 removal efforts successfully reduced numbers of rainbow trout in the LCR reach from approximately 6,446 to 617, and during this period humpback chub recruitment continued to increase and the adult humpback population in the LCR increased from approximately 5,000 to 7,650 (Coggins and Walters 2009). However, as discussed previously, rainbow trout were also undergoing a decline system-wide during this period, possibly due to lower flows and warmer water temperatures, conditions which also may have benefitted humpback chub. And while the work of Yard et al. (2011) provides compelling evidence that rainbow trout can consume large numbers of young humpback chub, tribes and many stakeholders feel that a causal link between non-native trout predation on humpback chub and adult abundance of humpback chub has not been established.

These considerations where analyzed in detail through the SDM Project. The SDM Project identified cultural concerns as a fundamental objective (see Appendix A, Section 4.3), and different non-native fish control actions were evaluated, in part, on their performance in minimizing adverse effects to the tribal concerns. The proposed action is further analyzed here in comparison with no action with regard to effects to cultural resources and in light of cultural concerns in Section 3, Affected Environment and Environmental Consequences. A criticism of some tribes has been that the SDM Project did not place sufficient emphasis on learning to address the uncertainties in the need to conduct removal to conserve humpback chub. Measures to address these concerns are incorporated into the proposed action as described in sections 1.10 and 2.3 of this EA.

Issue 2: Efficacy of Alternative Means of Controlling Non-native fish and Effects on Other Aquatic Life

Several methods have been used to control non-native fish in the Colorado River below Glen Canyon Dam, including:

- Removal of trout with boat electrofishing in the LCR reach;
- Low flows to strand eggs and alevins (“non-native fish suppression flows”);
- Removal of brown and rainbow trout from Bright Angel Creek with a fish weir (this action is both a past and ongoing action by the NPS).

The most effective single method of reducing non-native fish numbers has been removal of fish using boat-mounted electrofishing in the LCR reach. This method directly removes non-native fish, predominantly rainbow trout, from the area of greatest impact to humpback chub and was effective at reducing numbers of trout during 2003-2006 (Coggins et al. 2011), and this action also appeared to substantially reduce predation losses of humpback chub (Yard et al.2011). However the method was applied at a time of system-wide trout decline (Coggins et al. 2011) and the numbers of rainbow trout in the LCR reach recovered to former levels by 2009. Although about 20,000 trout were removed from the LCR reach from 2003-2006 (Coggins, 2008a; Coggins and Yard 2010; Yard et al. *in press*), the large 2008 rainbow trout cohort spawned in Lees Ferry, apparently as a result of the 2008 HFE (Korman et al. 2010), is thought to have led to downriver migration of this cohort, and, combined with local recruitment along downriver sections, contributed to a roughly 800 percent increase in rainbow trout densities in the vicinity of the Little Colorado River since 2006 (Makinster et al. 2010, Wright and Kennedy 2011). This recovery made it clear that in order to reduce trout abundance in the LCR reach numbers of trout moving into the area would have to be controlled on a routine basis or reduced at their sources, at or near the Lees Ferry reach for rainbow trout, and in Bright Angel Creek for brown trout.

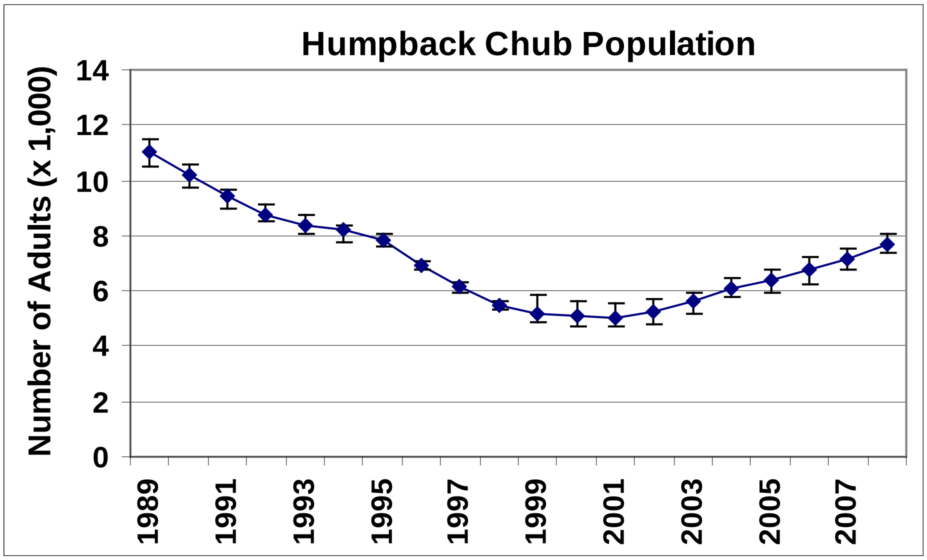
There are a number of other alternative means, including many that have not been tested in this system but have worked in other regulated rivers when applied appropriately. One mechanism that has been tested in the action area and may be effective at controlling non-native fish involves manipulating flows at Glen Canyon Dam to suppress the rainbow trout population at its primary source in Lees Ferry. There is clear evidence that this method can work because unrestrained fluctuating flows of approximately 3,000 to 30,000 cfs from Glen Canyon Dam before the implementation of interim/modified low fluctuating flows in 1991 eliminated almost all natural reproduction of rainbow trout in Lees Ferry, to the point that the fishery was not self-sustaining, and also had adverse affects to native fishes and other resources (leading to the 1995 EIS and 1996 ROD selection of MLFF as an alternative flow operation). To attempt to mimic this effect, fluctuations of from 5,000 to 20,000 cfs were tested from 2003-2005 (“non-native fish suppression flows”). These flows were effective in reducing survival of young trout, but density-dependent factors compensated with higher survival and growth of the remaining fish (Korman et al. 2005), thus the flows were not effective at limiting trout recruitment.

Evaluating the effect of non-native fish control on humpback chub is difficult because losses to fish predation are just one source of humpback chub mortality. Other sources of mortality include starvation, stranding, cold-water shock, parasites and diseases, and downstream transport from the LCR reach to less suitable habitat (Berry and Pimentel 1985; Hoffnagle et al. 2006; Korman et al. 2006; Marsh and Douglas 1997; Robinson et al. 1998; U.S. Fish and Wildlife Service 2002a; Ward and Bonar 2003). It is difficult to isolate the effect of any single mortality source and evaluate its effect on the overall population. Different sources of mortality may have a stronger effect at some times than others, and often the degree of effect from a single source may interact with other sources or environmental factors in complex ways.

Although the population of adult humpback chub (age 4 and >200 mm total length) declined from 1989 to 2001, the adult population of humpback chub has been increasing since 2001 (Figure 3). Because these estimates include fish that are 4 years of age and older, survival of fish that contributed to the population increase after 2001 was affected by factors starting in about 1998 (Coggins and Walters 2009). Although this increase began at the peak of trout density in the Lees Ferry reach, the subsequent increase in the humpback chub population is a pattern opposite that of the declining trout population, and suggests an effect from reduced trout density (Wright and Kennedy 2011). The sudden increase in the trout population in 2008 is attributed, at least in part, to the spring 2008 high flow experiment and the effect of this increase on humpback chub survival and recruitment has not been evaluated. Allowing trout populations to increase poses a risk because the effect of increased trout predation on the adult humpback chub population would not be evident for at least 4 years, the time is takes for humpback chub to reach maturity and be counted as an adult in population estimates (Coggins et al. 2006, Coggins and Walters 2009).

Tribes and members of the public expressed concerns about the effect of elements of potential actions (particularly the use of electrofishing) on invertebrates or other aquatic species. Electrofishing is used widely for sampling fish populations (Snyder 2003), and in some cases there is increased drift of invertebrates resulting from electrofishing, but in most cases there have been no long-lasting or fatal effects reported on macroinvertebrates (Elliott and Bagenal 1972; Fowles 1975; Mesick and Tash 1980); the only case where electrofishing produced mortality of macroinvertebrates (30% mortality of the midge species *Chironomus plumosa*) was in cases where voltages were 15-126 times the maximum levels normally used for sampling fish (Shentyakova et al. 1970). Although there has been no effort to specifically study the effect of electrofishing on macroinvertebrates or other non-target aquatic species, biologists involved in electrofishing in Grand Canyon have not reported any noticeable effect on these species, and it has not been considered by researchers to be an issue of concern.

These issues where analyzed in detail in the SDM Project, which evaluated the performance of different methods of non-native fish control. The proposed action is further analyzed in comparison with no action with regard to effects to the aquatic ecosystem in Section 3, Affected Environment and Environmental Consequences.



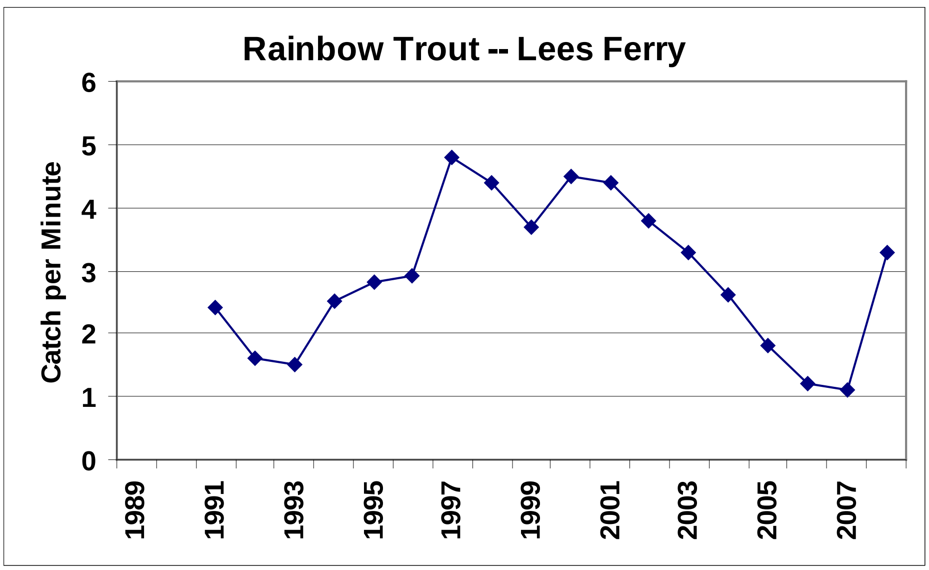


Figure 3. (Top) Annual population estimates of adult humpback chub (age 4+) with an age-structured mark-recapture (ASMR) model, 1989-2008 (Coggins and Walters 2009) (Bottom) Average annual catch rates of rainbow trout in the Lees Ferry reach, 1991-2008 (Makinster et al. 2010)

Issue 3: Diminished Sport Fish Angling Opportunities

Controlling numbers of trout in Grand Canyon has the potential to affect visitors who come to the parks for recreation. Because the actions analyzed here directly affect fish populations, there would be effects to sport fishing, potentially as reduced opportunity for sport fishing in the action area. If non-native fish control were to affect the Lees Ferry trout population, there would also be a potential impact to fishing guides whose livelihoods derive from providing guide services for anglers in the Lees Ferry reach. Reducing the numbers of rainbow trout in the Lees Ferry reach could affect angler catch rates, depending on the number of anglers and the density of trout in areas fished. Adverse impacts to recreational angling and subsistence fishing by local American Indian residents is also an aspect of this issue.

Reducing the numbers of trout in the system could also provide a beneficial effect to the sport fishery in the action area by improving the quality of the fishery. Reducing numbers of rainbow trout in the system, particularly when densities are high, could improve the fishery by providing more space for fish, reducing competition for available food resources, reducing emigration, and possibly increasing growth rate, and size and condition of individual fish. It is possible that reduction of the overall abundance of trout in the Lees Ferry reach would not affect catch rate if current trout density is high and competition is high for a limited food supply. The existing data appear to indicate that rainbow trout are leaving the Lees Ferry reach and moving downstream, presumably as a density-dependent response to high numbers, which may indicate an over-abundance of trout in Lees Ferry (Korman et al. 2010; Wright and Kennedy 2011).

This issue was identified as an objective in the SDM Project (see Appendix A, Section 4.3), and different actions were evaluated, in part, on their performance in minimizing adverse effects to recreational trout fishing, and thereby utilized to select the proposed action. The proposed action is further analyzed here in comparison with no action with regard to effects to recreation, in Section 3, Affected Environment and Environmental Consequences.

Issue 4: Effects to Wilderness

Pursuant to the 1964 Wilderness Act, Grand Canyon National Park was evaluated for wilderness suitability. After the park was enlarged in 1975, Grand Canyon's Wilderness Recommendation was updated following a study of the new park lands. The most recent update of Grand Canyon's Wilderness Recommendation occurred in 2010. Grand Canyon National Park proposed Wilderness or proposed potential Wilderness covers 94 percent of the park. In accordance with NPS Management Policies, these areas are managed in the same manner as designated wilderness, and the NPS will take no action to diminish wilderness suitability while awaiting the legislative process.

The proposed action would implement up to 10 PBR reach trips to remove non-native fishes and up to 6 LCR reach trips if the LCR humpback chub population drops below 7,000 adults. Motorized electrofishing boats would operate at night, utilizing lights and gas-generators to power electrofishing equipment. Removal trips would have up to 6 passes of electrofishing boats through a reach per trip, and this would take place over multiple nights as described in more detail in the Effects of the Proposed Action section. Recreationists seek the GCNRA and GCNP out, in part, due to the wilderness character of these remote areas. The proposed action would result in disturbance to members of the public utilizing these areas for recreation. These impacts would be further assessed and mitigated through the NPS Minimum Requirement Analysis.

The NPS is mandated under the Organic Act of 1916 "to conserve the scenery and the natural and historic objects and the wild life therein and…leave them unimpaired for future generations" (1916 NPS Organic Act). In accordance with this mandate and the NPS Management Policies (National Park Service 2006a, §4.4.4.2), all exotic (i.e., non-native) species must meet an identified park purpose or be controlled or eradicated. Rainbow trout and brown trout in the vicinity of the Colorado and Little Colorado rivers compete with and prey on humpback chub and threaten the recovery of the species. Hence, control of non-native fish within GCNRA and GCNP is consistent with the mission and mandates of the NPS, as well as compliance by the DOI and its agencies under the provision of the ESA, and adds to the wilderness quality of the park in a manner that is consistent with NPS management policies.

These issues were identified as an objective in the SDM Project (see Appendix A, Section 4.3), and different actions were evaluated, in part, on their performance in minimizing adverse effects to wilderness recreation, and thereby utilized to select the proposed action. The proposed action is further analyzed here in comparison with no action with regard to effects to recreation, in Section 3, Affected Environment and Environmental Consequences.

Issue 5: Diminished Public Services and Losses to Local Economies

Recreation in GCNRA and GCNP provides economic benefits to local economies, particularly in the areas of Vermilion Cliffs and Marble Canyon, Page, and Flagstaff, Arizona, and Kanab and surrounding areas of southern Utah. These economic and social benefits are to both small rural communities and to the region. A number of businesses (lodges, restaurants, guides, outfitters, and others) and individuals derive their income from recreationists who have come to the area to fish, hike, or engage in white water rafting. Economic benefits are associated with factors such as the number of days anglers visit the area, and the number of white water rafting trips that occur in a given year.

A key aspect of economic benefits from visitation to the area is associated with wilderness and park experiences. GCNP provides benefits to both local and regional economies. Non-native fish control could affect the experience of the public who come to the area for wilderness recreation through the additional activities associated with the removals, particularly motorized and night-time operations within proposed wilderness that cause disturbance.

The cost of non-native fish control is also an issue because the GCDAMP and Reclamation have limited annual budgets with which to carry out non-native fish control actions. In the past, non-native fish control efforts have utilized flows from Glen Canyon Dam as well as electrofishing at the confluence of the Colorado and Little Colorado Rivers to limit numbers of non-native fishes, particularly rainbow and brown trout. Past control efforts have been costly and GCDAMP stakeholders are interested in finding effective means of non-native fish control that are economically viable.

A key public service provided by Glen Canyon Dam is electricity generation. The electricity produced at Glen Canyon Dam through hydropower is a renewable and environmentally preferred resource. It is integrated into the electrical production of several large Colorado River Storage Dams and it serves part of the needs of over five million people, in the rural Rocky Mountain and desert Southwest. It also provides a large portion of the electrical needs of American Indian communities in the southwest. It is sold as a long-term firm product, at the cost of production, under terms that allow flexibility so as to schedule electrical power deliveries to maximize the value of the Glen Canyon Dam power resource.

Any alternative considered for non-native fish control must be consistent with maintaining required water storage and delivery per the Colorado River Storage Project (CRSP). The CRSP and the Colorado River are managed and operated under numerous compacts, federal laws, court decisions and decrees, contracts, and regulatory guidelines collectively known as the "Law of the River." This collection of documents apportions the water and regulates the use and management of the Colorado River among the seven basin states and Mexico. Glen Canyon Dam is also operated to be in compliance with the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (2007 Colorado River Interim Guidelines).

These issues were thoroughly evaluated in the SDM Project (see Appendix A, Section 4.3) by assessing alternatives, in part, on their performance in minimizing adverse effects to these resources, and thereby used to select the proposed action. The proposed action is further analyzed here in comparison with no action with regard to effects to recreation, in Section 3, Affected Environment and Environmental Consequences.

Issue 6: Constraints Imposed by Reclamation's Authority and Operational and Legal Requirements

This EA is in large part driven by commitments and responsibilities to maintain compliance with the ESA. The need for non-native fish control arose out of an ESA Section 7 consultation on dam operations, and implementation of non-native fish control through the GCDAMP by physical removal remains as a recommended conservation measure in the operating biological opinions (U.S. Fish and Wildlife Service 2008, 2009, 2010). The 2010 biological opinion on cancellation of non-native fish removal trips in 2010 includes an incidental take statement that further guides implementation of the non-native fish control conservation measure as follows:

> "a. Resume nonnative control at the mouth of the LCR in 2011. Attempt to implement the program in a manner compatible with the interests of Tribes and other interested stakeholders.
>
> AND/OR
>
> b. Work with interested Tribes and other parties, expeditiously, to develop options that would move nonnative removal outside of LCR confluence tribal sacred areas in 2011, with the goal that nonnative removal of trout in sacred areas will be reserved for use only to ensure the upper incidental take level is not exceeded." (U.S. Fish and Wildlife Service 2010b, consultation number 22410-1993-F-167R1).

Alternatives must meet Reclamation's responsibilities with regard to operation and maintenance of the dam, as well as meeting scheduled downstream deliveries of water.

Potential actions were evaluated in this regard in the SDM Project and this contributed to the selection of the proposed action.

Reclamation also has a responsibility to recognize Indian Trust Assets and maintain compliance with section 106 of the National Historic Preservation Act (NHPA), which is part of the need for this EA. The Federal government holds Trust responsibilities that recognize the sovereign status and management authority of Tribes, and assures the Tribes that Federal agencies will not knowingly compromise traditional practice and livelihoods in execution of their duties. Executive Order 13007 adds specificity to this principal in stating that Federal agencies "shall avoid adversely affecting the physical integrity of sacred sites," while Secretarial Order 3206 stipulates that within the context of the ESA the "Departments will carry out their responsibilities under the Act in a manner that harmonizes the Federal trust responsibility to tribes." Further, the NHPA requires Federal agencies to take into account the effects of their actions on historic properties, which, through the National Register of Historic Places, includes special provisions for places of cultural and religious importance.

These issues were identified in the SDM Project (see appendix a, section 4.3), and different alternatives were evaluated, in part, on their performance in minimizing adverse effects to Reclamation's operational and legal responsibilities, and thereby used to select the proposed action. The proposed action is further analyzed here in comparison with no action with regard to effects to cultural resources, in Section 3, Affected Environment and Environmental Consequences.

2.0 Description of Alternatives

This chapter describes and compares alternatives considered for non-native fish control in the Colorado River downstream from Glen Canyon Dam. It includes a description of each alternative considered. This section also presents the alternatives in comparative form, defining the differences between alternatives and providing a basis for choice among options by the responsible official and the public. The information is based upon the environmental, social, and economic effects of implementing each alternative.

Both the no action and proposed action alternatives have common elements with regard to ongoing dam operations for the 10-year period of the proposed action, 2011-2020. Under both alternatives, dam operations would continue in accordance with existing RODs including MLFF, with steady flow releases in September and October through 2012. After 2012, MLFF flows as defined under the 1996 ROD (Bureau of Reclamation 1996) would remain in effect. HFEs may also occur as defined in the High Flow Experiment Protocol Environmental Assessment, if implemented (Bureau of Reclamation 2011). Reclamation and NPS are also beginning a separate NEPA process to develop a Long-Term Experimental and Management Plan Environmental Impact Statement (LTEMP EIS). A number of elements of the GDCAMP, including dam operations, may change when the LTEMP EIS is implemented.

2.1 *No Action Alternative*

The no action alternative is defined as the current operation for Glen Canyon Dam as approved and authorized under the 1996 and 2007 RODs. Under the current operation, water is released from the dam under the MLFF alternative. In recent consultations on the effects of Glen Canyon Dam operations on endangered fishes and critical habitat, Reclamation and the USFWS have agreed to reduce the numbers of non-native fish that compete with and prey on the endangered fish as conservation measures. These agreed upon conservation measures occur in the 2007 and 2008 biological opinions, 2009 supplement, and the 2010 biological opinion on cancelling the 2010 non-native fish control removal trips (U.S. Fish and Wildlife Service 2007, 2008, 2009, 2010). This EA is in large part driven by commitments and responsibilities to maintain compliance with the ESA. The need for non-native fish control arose out of ESA Section 7 consultations on dam operations, and implementation of non-native fish control through the GCDAMP by physical removal remains as a recommended conservation measure in the operating biological opinions (U.S. Fish and Wildlife Service 2008, 2009, 2010). The 2010 biological opinion on cancellation of non-native fish removal trips in 2010 includes an incidental take statement that further guides implementation of the non-native fish control conservation measure as follows:

> “a. Resume nonnative control at the mouth of the LCR in 2011. Attempt to implement the program in a manner compatible with the interests of Tribes and other interested stakeholders.

AND/OR

b. Work with interested Tribes and other parties, expeditiously, to develop options that would move nonnative removal outside of LCR confluence tribal sacred areas in 2011, with the goal that nonnative removal of trout in sacred areas will be reserved for use only to ensure the upper incidental take level is not exceeded." (U.S. Fish and Wildlife Service 2010b, consultation number 22410-1993-F-167R1).

The no action alternative consists of no implementation of any form of non-native fish control other than the NPS project to remove non-native rainbow and brown trout from Bright Angel Creek (RM 88) because this project is ongoing, is a separate project being implemented by another DOI agency (NPS), and has existing NEPA compliance (National Park Service 2006b), as well as separate, and complete government-to-government tribal consultation. The NPS Bright Angel Creek Project would be ongoing and can thus be considered as part of every alternative for the purposes of evaluating cumulative effects. NPS is also removing trout in Shinumo Creek as part of efforts to translocate humpback chub from the LCR to Shinumo Creek and the USFWS also translocates humpback chub periodically from the lowermost mile of the LCR to above Chute Falls in the LCR; both of these actions would also continue under no action, and are covered by existing NEPA and have completed tribal consultation. No further efforts to reduce non-native fishes, rainbow trout, rainbow trout migration, or otherwise directly enhance humpback chub populations are undertaken. The intent of this action is to provide a default for comparison of the effects of the proposed action.

2.2 *Proposed Action*

The proposed action is a 10-year effort to evaluate methods of removal of non-native fish as a means to improve conditions for native fish, in particular the humpback chub along with monitoring efforts to track movement and numbers of non-native fish within the river system. The proposed action is also intended to address the concerns of some tribes regarding the taking of life associated with non-native fish control in a sacred location, the Grand Canyon. This alternative would be implemented with continued MLFF dam operations in accordance with the 1996 and 2007 RODs. The 10-year period of the action is appropriate to coincide with the potential implementation of the HFE Protocol EA, also a 10-year action, because there is evidence, discussed in other sections, that HFEs benefit rainbow trout and would provide any needed mitigation for humpback chub or other native fish associated with the proposed action of implementing the High-Flow Experimental Protocol, a separate but related action being evaluated in a separate EA; the 10-year timeframe is also necessary to ensure a long-term commitment to implementing the conservation measure, and to provide a reasonable experimental timeframe to evaluate non-native fish control through research and monitoring in an adaptive management context.

The proposed action utilizes a strategy of research on the effects of non-native fish predation on humpback chub recruitment and investigation of the sources of rainbow trout in the LCR reach to determine the need for continued nonnative fish removal and the most cost-effective location of removal (i.e. the PBR or LCR reach). The proposed action would evaluate the potential to remove non-native rainbow trout in the PBR reach (RM 1 to RM 8) using boat-mounted electrofishing. Two removal trips would be conducted in the initial years of the proposed action to help evaluate the extent to which rainbow trout emigrate from Lees Ferry and the effectiveness of removal to reduce this emigration. Up to 10 PBR reach removal trips could be conducted in any one year for the ten-year period of 2011-2020, but the number of removal trips would depend on the outcome of research efforts to evaluate the extent to which predation limits humpback chub, and the efficacy of PBR removal at reducing rainbow trout abundance in the LCR reach. The proposed action also includes monitoring of humpback chub status, both numbers of adult and juvenile humpback chub, and potential removal of non-native fish in the LCR reach (RM 56-66). Removal of non-native fish in the LCR reach would only take place if monitoring of the adult humpback chub population using the Age Structured Mark Recapture model (Coggins and Walters 2009) indicates that the number of adults have dropped below 7,000 adult fish. If the adult population of humpback chub drops below 7,000 fish, removal of non-native fish in the LCR reach could occur, but would be limited to a maximum of six LCR reach removal trips annually. The proposed action would also include continuing research through the nearshore ecology study to develop triggers for juvenile humpback chub abundance and survivorship to consider in implementing LCR reach removal. This research would also help determine the overall importance of mainstem habitats to humpback chub recruitment. If this research results in monitoring that is capable of detecting changes in juvenile humpback chub abundance and recruitment, triggers to determine if LCR removal would be implemented would be modified to utilize this trend data.

The trigger of 7,000 adult humpback chub for LCR reach removal is necessary to address the concerns of American Indian tribes over non-native fish removal, better understand the relationship between predation by rainbow trout on humpback chub survivorship, and to meet the requirements of USFWS biological opinions. The last ASMR estimate of adult humpback chub in the Little Colorado River was 7,650 adults (Coggins and Walters 2009). The trigger of 7,000 adult chub is appropriate because it identifies a conservative level of loss of humpback chub from the adult population, and is consistent with the USFWS biological opinions. The current USFWS biological opinion on non-native fish control directs Reclamation, in the incidental take statement, to implement non-native fish control as follows: "Resume nonnative control at the mouth of the LCR in 2011. Attempt to implement the program in a manner compatible with the interests of Tribes and other interested stakeholders… and/or…Work with interested Tribes and other parties, expeditiously, to develop options that would move nonnative removal outside of LCR confluence tribal sacred areas in 2011, with the goal that nonnative removal of trout in sacred areas will be reserved for use only to ensure the upper incidental take level is not exceeded." (U.S. Fish and Wildlife Service 2010b, consultation number 22410-1993-F-167R1). The upper incidental take level in the biological opinion is 6,000 adult humpback chub (U.S. Fish and Wildlife Service 2010b). Reclamation proposes to use 7,000 adult humpback chub as a trigger for LCR reach removal because this number is consistent with the guidance provided in the USFWS incidental take statement that "nonnative removal of trout in sacred areas will be reserved for use only to ensure the upper incidental take level is not exceeded."

Use of the ASMR to track adult humpback chub status in the Little Colorado River as a surrogate for the Grand Canyon population is problematic because it relies on subadult and adult animals and the model is typically evaluated every 2-3 years (Coggins and Walters 2009). Humpback chub take up to 3-4 years to reach late subadult and adult size (150-200 mm total length), a size large to mark with a passive integrated transponder tag and be "counted" by the ASMR. So relying on the ASMR model may create a lag in time relative to effects to juvenile humpback chub, the sizes predominantly lost to non-native fish predation. However the proposed action would be sufficiently protective of humpback chub for two reasons. First, because rainbow trout numbers have been elevated since about 2008 (see Section 1.9), ASMR results should begin to detect the effects of predation losses of young fish in 2008 on the adult population in 2011-2012. Thus the 7,000 adult trigger should work, even given the time lag, if elevated numbers of non-native trout are having an effect on humpback chub recruitment. Nevertheless, adult population size is not an ideal metric to detect predation losses of juvenile humpback chub. Reclamation would also, as described above, conduct research to better estimate abundance of early humpback chub year classes, both in the LCR and mainstem. This research would complement ongoing annual monitoring in the LCR, thus providing an annual assessment of humpback chub status. Also, this research may provide for new triggers for implementing non-native fish control, based on juvenile humpback chub status, that are more directly tied to the effect of non-native fish predation on young humpback chub.

The proposed action may result in thousands of fish being removed from the system per year. Prior efforts from 2003-2006 (four years of removal) resulted in 23,266 non-native fish removed. To address the tribal concerns on the disposition of removed fish, it is anticipated that non-native fish would be removed live and stocked into areas that have an approved stocking plan or euthanized and used for later beneficial use (used for human consumption, or for feeding eagles, other raptors, or other captive wildlife, particularly those animals kept and reared by tribes). Other uses for removed fish may be identified over the 10-year period in consultation with appropriate parties including American Indian tribes.

Removal of rainbow and brown trout from Bright Angel Creek with a fish weir in fall of 2002 and 2006 has been shown to be an effective means of non-native fish control for both rainbow and brown trout (Leibfried et al. 2003, 2006). NPS removed from Bight Angel Creek 525 brown trout from 2006-2007, and 454 rainbow trout and 594 brown trout from 2010-2011 using a combination of a fish weir trap and electrofisihing. The NPS Bright Angel Creek removal project is ongoing and is expected to continue to be effective at reducing brown trout in what is considered to be the primary source of brown trout to the LCR reach. The NPS will also be conducting removal in Shinumo Creek as part of a project to translocate humpback chub from the LCR to that stream. NPS removed 1,220 rainbow trout and one brown trout were removed from Shinumo in 2009, and 929 rainbow trout in 2010. Both of these actions have existing compliance including NEPA and completed tribal consultation. The cumulative effects of these actions are analyzed here, along with related effects of humpback chub translocations.

Methods for non-native fish control would be similar to removal conducted from 2004-2006 and in 2009 (Coggins 2008a; Coggins and Yard 2010). The method of removal in the PBR and LCR reaches would be to use boat-mounted electrofishing as described in Coggins et al. (2011) to remove all non-native fish captured. Motorized electrofishing boats would operate at night, utilizing gas-generators to power lights and electrofishing equipment. For PBR reach removal, each trip is anticipated to take place over up to 12 nights. Researchers would be land-based with no riverside camping, and boats would launch for nightly work late in the day, after all recreational trips have launched and traveled downstream. The work would take place between the Paria River and Badger Rapids only. Boats would return to Lees Ferry at the conclusion of their nightly work. Care would be taken to avoid disturbance to walk-in recreationists and anglers at the Paria River confluence beach, although some disturbance to recreationists would be likely to occur due to the presence or fish tanks located near shore or net pens in the river to hold fish that are removed, and the need for multiple nights of electrofishing required for removal. For LCR reach removal trips, duration would likely be several weeks, with removal teams camped and working in the LCR reach for approximately two weeks.

Removal in the PBR reach is predicted to be of primarily juvenile rainbow trout before they descend downstream to the LCR reach, but all non-native fish captured would be removed. PBR reach removal would be done in fall or winter (during expected emigration periods), or via multiple trips throughout the year if necessary. Boats can travel as far downstream as Badger Creek Rapid (RM 8) and return upstream to Lees Ferry without camping, therefore avoiding the costs associated with downriver travel and minimizing impacts to wilderness experience and values through the entire Grand Canyon.

During the first two years of the proposed action, the action would include one rainbow trout marking trip in the Lees Ferry reach (RM -15 to 0) in the fall of each year. This trip would utilize PIT tags to mark individual rainbow trout to detect their downstream movement. Initially, two PBR reach removal trips would conducted in the fall and winter months to test the efficacy of PBR reach removal in reducing downstream emigration of rainbow trout from Lees Ferry. Depending on the results of the two initial PBR reach removal trips, additional trips could be added. Also, three downstream monitoring trips would be conducted in summer 2012 to detect downstream movement of rainbow trout and conduct nearshore ecology work on juvenile humpback chub to better track trends in juvenile humpback chub abundance. Monitoring would be modified based on results from these trips and other monitoring through adaptive management in future years.

Monitoring is needed to determine whether the action is meeting the purpose and need. Initially, monitoring of mainstem fishes would be conducted by using non-lethal electrofishing twice annually in Marble and Grand canyons, as well as during three downstream monitoring trips in the summer months. Future monitoring may be modified through adaptive management. If successful, removal actions would continue to be evaluated and refined to meet management objectives, including the viability of the Lees Ferry trout fishery and recovery of the Grand Canyon population of humpback chub. If unsuccessful, these actions would need to be reevaluated and refined as necessary to achieve the management objectives, and additional actions may need to be considered. In 2014

Reclamation would undertake a scientific review through a workshop with scientists and managers to assess what has been learned from the first two years of non-native fish control. At that time, if the results indicate that the proposed action is not meeting the purpose and need, Reclamation would consider appropriate modifications to the action.

2.2.1 *Other Flow and Non-Flow Actions*

Reclamation would also, as part of the proposed action, begin a one-year process with stakeholder involvement to develop suppression options to reduce recruitment of non-native fish at, and emigration of those fish from, Lees Ferry. Both flow and non-flow experiments focused on the Lees Ferry reach may be conducted in order to experiment on actions that would reduce the recruitment of trout in Lees Ferry, and likely thereby reduce emigration of trout from Lees Ferry. These actions may also serve to improve conditions of the recreational trout fishery at Lees Ferry. Additional environmental compliance may be necessary for these experiments. Although alternatives utilizing Glen Canyon Dam flows to reduce recruitment and emigration rates of trout in Lees Ferry did not perform well in the SDM Project, there is evidence that flows may be a more economical and effective long-term method of mitigating the effects of trout on humpback chub (Korman et al. 2005, Runge et al. 2011). However, developing flows and other actions that are likely to be effective in reducing rainbow trout may present significant impacts to other resources. And flow options alone also may prove to be ineffective at reducing emigration of trout from the Lees Ferry population. Thus the goal is to use adaptive management to experiment with a variety of options to develop a long-term management strategy that is culturally sensitive and cost effective.

In evaluating flow options for use in non-native fish control, Reclamation would evaluate a number of research elements, including, but not limited to, the following:

- Determining if stranding flows could reduce rainbow trout recruitment by de-watering redds or stranding juvenile trout;
- Evaluating the potential for utilizing changes in down-ramp rates to strand or displace juvenile trout and reduce recruitment;
- Evaluating different types and magnitudes of stranding flows;
- Evaluating the potential to use water quality of dam releases (low oxygen levels) below Glen Canyon Dam to reduce trout survivorship.
- Determining if flow and non-flow actions in Lees Ferry are effective in improving the Lees Ferry trout fishery.

Developing and testing dam releases and other non-flow methods would require involvement of both scientists and stakeholders to adequately analyze effects of these actions. Reclamation would work with these groups to develop a proposal and science plan for implementing and evaluating these flow and non-flow actions with these groups over the next one to two years.

2.3 *Mitigation and Monitoring*

Mitigation measures are prescribed to avoid, reduce, or compensate for potential adverse effects of an action. The following mitigation measures would be implemented if the proposed action is selected.

- An interpretive plan would be developed with NPS to develop public information and educational materials describing project effects.

- Crews working in the park units would be required to meet minimum impact requirements, including evaluations and approval, for all work within proposed wilderness areas.

- Fish removed would either be kept alive and stocked into other waters as sport fish or would be euthanized and frozen for later beneficial use (used for human consumption, or for feeding eagles, other raptors, or other captive wildlife, particularly those animals kept and reared by tribes), or may be used for other purposes that may be identified through continued tribal consultation. Stocking into other waters would require an existing stocking plan for the water.

- Resolution of adverse effects to historic properties (traditional cultural properties) would be completed in accordance with Section 106 of NHPA.

Monitoring would be an important aspect of this action, once implemented. Monitoring should be conducted in a manner that evaluates, as much as possible, the effects of removal in both reaches, and to provide information on key hypotheses surrounding non-native fish removal. Every effort should be made to ascertain the degree of effect attributed to each treatment. This is necessary in order to determine if removal in either or both the reaches are having little or no effect and should be eliminated. Monitoring data for both trout and humpback chub abundance would be used to determine when removal would take place. A science plan was developed to better define monitoring and research associated with the proposed action, and is included in Appendix B.

2.4 *Alternatives Considered and Eliminated from Detailed Study*

In addition to the proposed action, Reclamation also evaluated and eliminated the following alternatives from detailed study.

Humpback Chub Head-start Option

This action proposed adding a supplemental hatchery based stocking program to maintain the desired population level for the humpback chub in lieu of control methods currently in place. Wild-caught humpback chub would be grown in hatcheries and stocked into the system. This option does not address or meet the purpose and need since it does not reduce predation and competition from non-native fish on humpback chub. This action would have to be initiated and implemented under the authority of the USFWS, and would likely take time to implement, potentially delaying needed efforts to address the purpose and need for the action. For these reasons, this option was eliminated from further consideration.

Removal of Trout by Anglers

This action proposed changing fishing regulations and restrictions to allow a greater take of rainbow trout and brown trout by anglers as a way to reduce the trout populations. The primary reason this action was not analyzed here is that it is not within the authority of Reclamation to implement. Fishing regulations in the state of Arizona are the purview of the Arizona Game and Fish Commission and AZGFD, as well as the NPS, which has authorities and responsibilities for fisheries management within GCNP and GCNRA. Although there is much uncertainty about the efficacy of this action to remove non-native fish from the system, more aggressive harvest regulations could have the potential to help remove trout from the system, and should be further considered by AZGFD and NPS. It is Reclamation's understanding that NPS intends to address this issue in fisheries management plans for GCNP and GCNRA.

This action also contains a great deal of uncertainty as to whether the fishing public would keep and kill the fish they catch, or if most anglers would continue to practice catch-and-release angling. Also, the fish that are typically caught by anglers in Lees Ferry are older fish that are not believed to be the primary migrants to downstream areas occupied by native fish, thus angling would have little effect on the age-0 fish that use shallow nearshore habitats and are thought to be the principal downstream emigrants. Another uncertainty is the effect of a density-dependent response to reduced numbers of adult trout, whereby the fewer eggs and young produced would have more space and resources and expected higher survival and growth rates.

Use of Barrier Devices to Kill Fish or Impede Their Movement

A variety of barrier devices are in use or in experimental stages that can kill fish (shock wave) or impede their movement (e.g., electric fences, sound, flashing lights, bubble curtains). These strategies were not selected for detailed analysis in the EA process for several reasons. Many of these methods and techniques are experimental and untested, thus their effectiveness in Grand Canyon is highly uncertain. These actions pose potential public safety risks, especially in a place that receives high levels of recreational boating use such as Grand Canyon. A barrier to prevent downstream movement of rainbow trout from Glen Canyon would need to be constructed in Marble Canyon, likely downstream of the Paria Riffle. A barrier of the scale needed in Marble Canyon could pose a public safety hazard because it could harm boaters that routinely navigate through the area. Placing a barrier to impede downstream movement of trout could also indiscriminately affect and injure non-target native fish, especially native flannelmouth suckers. Also, a barrier of the size needed to reduce or eliminate emigration of trout from Lees Ferry in a large river like the Colorado River would be a large construction effort, which would likely degrade the wilderness values for which GCNRA and GCNP were created. For these reasons, such an action is not likely within the scope of an EA, and was not analyzed further in this NEPA process.

Stocking of Triploid Trout

The AZGFD uses triploid trout of various species to stock waters in Arizona for sport fishing. Triploid trout are produced in hatcheries to have three sets of chromosomes (as opposed to the normal two). Triploid trout are similar to normal trout in every respect except that they are sterile and grow faster and larger. Triploid trout therefore present less of a risk in terms of negative impacts of a non-native fish to an ecosystem than normal trout because they do not reproduce. They are also favored by many anglers because they grow quickly and to a larger size than normal trout.

This action was included in several alternatives of the SDM Project. Stocking of triploid trout at Lees Ferry was proposed to be implemented to offset reductions in the trout population from removal or other actions. Triploid trout would not reproduce and thus not add additional spawning trout to the Lees Ferry population, and the addition of stocked triploid trout would help to meet the objectives of the angling community in Lees Ferry by both improving catch rate and mean size of fish caught because triploid trout grow faster and larger than non-triploid trout. However, Reclamation has no authority to stock fish or manage fish populations. Stocking fish in Lees Ferry is an action that falls under the authority and responsibility of the AZGFD and NPS and must be initiated by those agencies. This action was proposed to mitigate losses in fishing quality in GCNRA. The proposed action does not include removal of trout from the GCNRA and is not anticipated to result in year-class losses or severe reductions in fishing opportunity or quality. For these reasons, this action was not considered further. Notably, fishing guides and recreational anglers consulted in this EA process were in support of this action, thus AZGFD should further investigate implementing a stocking program.

Removal of trout 1.5 miles upstream of the LCR

Although this strategy was proposed during the SDM Project, it was not selected for inclusion in any of the alternatives by the cooperating agencies and tribes. This was likely because: it was deemed less effective at reducing predation losses of humpback chub because a much greater proportion of predation occurs downstream from the LCR than upstream (Yard et al. *in press*); it would not address the issue of competition effects between rainbow trout and humpback chub because a greater proportion of humpback chub occur downstream from the LCR; it did not offset the concerns of some GCDAMP tribes regarding the location of removal (i.e., from a location standpoint, this was not substantially different from a tribal perspective than removal in the LCR reach); and the cost and effort to implement is essentially the same as conducting more effective removal in the LCR reach. It was not further evaluated in the EA for these reasons.

Turbidity Enhancement through Sediment Augmentation at the Paria River

This proposal would build a sediment slurry pipeline from Lake Powell to the Paria River to augment sediment in the system as defined in a Reclamation feasibility report (Randle et al. 2006). It was proposed as part of several alternatives in the SDM Project because it was thought that the turbidity caused by sediment augmentation would reduce habitat quality for trout in Lees Ferry and downstream throughout Marble and Grand canyons, reducing overall numbers of trout, and reducing predation and competition from trout on humpback chub. Implementing this action would involve large-scale construction, and would be much more expensive to implement than other non-native fish control actions considered ($430 million, plus an additional $17 million per year to operate). Many aspects of the action, such as its ecological impacts, require more detailed analysis than could be developed in time to be evaluated in this EA. Construction would take a number of years, and it could thus not be implemented within the timeframe necessary to meet the need for this action. For these reasons, this action was not analyzed further.

Turbidity Enhancement through Lees Ferry Fine Sediment Slurry

This action would have similar effects as the Sediment Augmentation at the Paria River proposal, and would utilize a pipeline to deliver fine sediment to the Colorado River from Lake Powell as defined in Randle et al. (2006). Costs were also similar, $300 million for construction, and $7.9 million per year to operate (Randle et al. 2006). It was not further analyzed for the same reasons as the Sediment Augmentation at the Paria River proposal.

3.0 Affected Environment and Environmental Consequences

This section describes the potential changes to the environment due to implementation of the alternatives. It presents the scientific and analytical basis for comparison of alternatives. Resource analysis includes a consideration of direct, indirect, and cumulative impacts in accordance with CEQ and Interior regulations. Each impact topic or issue is analyzed for direct, indirect, or cumulative effects from each of the alternatives, and in consideration of related actions, projects, plans, and documents (Section 1.7). Impacts are described in terms of context (site specific, local or regional), duration (short- or long-term), timing (direct or indirect), and type (adverse or beneficial). Issues related to natural resources are described first, followed by socioeconomic and cultural resources. Any cumulative effects that may be present are discussed in their respective resource areas and not in a stand-alone cumulative effects section.

3.1 *General Setting*

The action area or geographic scope of this environmental assessment is a 294-mile reach of the Colorado River corridor from Glen Canyon Dam downstream to the Lake Mead inflow near Pearce Ferry (Figure 1). Glen Canyon Dam impounds the Colorado River about 16 miles upstream from Lees Ferry, Coconino County, Arizona. This action area includes GCNRA in a 16-mile reach from Glen Canyon Dam to the Paria River; and GCNP, a 277-mile reach from the Paria River downstream from Lees Ferry to the Grand Wash Cliffs near Pearce Ferry. In terms of geomorphic features, Glen Canyon encompasses a 16-mile reach from the dam to the Paria River; Marble Canyon is a 61-mile reach from the Paria River to the LCR; and Grand Canyon is a 217-mile reach from the LCR to near Pearce Ferry. The Glen Canyon segment of the action area is also commonly referred to as the Lees Ferry reach. Additional description of the action area and its associated resources can be found in Gloss et al. (2005).

3.2 *Natural Resources*

Natural resources are those physical, chemical, and biological components of the action area that individually and collectively comprise the ecosystem and contribute to the values of GCNP and GCNRA. These typically include water resources, water quality, air quality, sediment, vegetation, terrestrial invertebrates and herptofauna, aquatic food base, fish, birds, and mammals. Based on a review of all natural resources in the action area, only those resources likely to be directly, indirectly, or cumulatively affected by the proposed action are described herein. Of the natural resources, the alternatives considered in this EA would only have effects to fish, so the other resources are not considered further.

3.2.1 *Fish*

Altogether, 20 species of fish occur in Grand Canyon, including 15 non-native (Table 2) and five native species. Five of the eight fish species native to the Colorado River in Grand Canyon have persisted, including humpback chub, flannelmouth sucker, bluehead sucker, and speckled dace (Valdez and Carothers 1998). The razorback sucker is extirpated from Grand Canyon, but is found as a small reproducing population downstream from the canyon, in and below the Colorado River inflow to Lake Mead (Abate et al. 2002, Albrecht and Holden 2006).

Table 2. Non-native fish species presently found in the Colorado River and lower end of tributaries from Glen Canyon Dam to near Pearce Ferry (Ackerman 2008).
0 = absent, R = rare, L = locally common, N = numerous, A = abundant.

Common Name	Scientific Name	Lees Ferry	Marble Canyon	Grand Canyon
Black bullhead	*Ameiurus melas*	0	R	L
Brown trout	*Salmo trutta*	R	R	L
Largemouth bass	*Micropterus salmoides*	0	0	R
Mosquitofish	*Gambusia affinis*	0	0	L
Red shiner	*Cyprinella lutrensis*	0	0	L
Channel catfish	*Ictalurus punctatus*	0	R	N
Common carp	*Cyprinus carpio*	L	N	N
Fathead minnow	*Pimephales promelas*	0	0	L
Green sunfish	*Lepomus cyanellus*	0	0	R
Plains killifish	*Fundulus zebrinus*	0	0	L
Rainbow trout	*Oncorhynchus mykiss*	A	A	L
Redside shiner	*Richardsonius balteatus*	R	R	R
Smallmouth bass	*Micropterus dolomieu*	R	R	R
Striped bass	*Morone saxatilis*	R	R	R
Walleye	*Sander vitreus*	R	R	R

3.2.1.1 Humpback Chub

The humpback chub is currently listed as endangered under the ESA. The humpback chub recovery plan was approved on September 19, 1990 (U.S. Fish and Wildlife Service 1990), and recovery goals were developed in 2002 (U.S. Fish and Wildlife Service 2002a). The recovery goals were set aside as a result of litigation and are in the process of being revised by the USFWS. Designated critical habitat exists in two reaches near the action area (U.S. Fish and Wildlife Service 1994); the lower 8 miles of the LCR and 173 miles of the Colorado River and its 100-year floodplain in Marble and Grand Canyons from Nautiloid Canyon (RM 34) to Granite Park (RM 208). There are six extant populations, five in the upper Colorado River Basin and one in the lower Colorado River Basin. The largest of these populations is the Grand Canyon population, the population that occurs in the action area. The Grand Canyon population consists of nine aggregations, with most individuals in and near the LCR (Valdez and Ryel 1995). Water in the mainstem is too cold due to impacts of dam releases from Lake Powell for spawning and the species spawns primarily in the LCR, although young are also found in the Fence Fault Warm Springs at RM 30 (Valdez and Masslich 1999) and further downstream in Middle Granite Gorge. Juvenile humpback chub occur downstream from Glen Canyon Dam at most aggregations (Figure 2), but it is uncertain if these fish originated from the LCR or from local reproduction.

Young and juvenile humpback chub are found primarily in the LCR and the Colorado River near their confluence, although many are found upstream of the LCR, presumably from spawning near the Fence Fault Warm Springs (Valdez and Masslich 1999; Anderson et al. 2010). Humpback chub reproduction occurs annually in spring in the LCR and the young fish either remain in the LCR or disperse downstream into the Colorado River. Dispersal of these young fish has been documented as nighttime larval drift during May through July (Robinson et al. 1998), as density dependent movement during strong year classes (Gorman 1994), and as movement with summer floods caused by monsoonal rain storms during July through September (Valdez and Ryel 1995). Survival of these young fish in the mainstem is thought to be low because of cold mainstem water temperatures (Clarkson and Childs 2000; Robinson and Childs 2001), but fish that survive and return to the LCR contribute to recruitment in this population. Predation by rainbow trout and brown trout in the LCR confluence area has been identified as an additional source of mortality affecting survival and recruitment of humpback chub (Valdez and Ryel 1995; Marsh and Douglas 1997; Yard et al. 2011).

Population estimates using an age-structured, mark-recapture (ASMR) method show that the population has ranged from about 11,000 adults (4 years old and older and capable of reproduction) in 1989 to 5,000 adults in 2001 (Coggins and Walters 2009). The number of adults decreased from 1989 to 2001, but increased by approximately 50 percent between 2001 and 2008 to an estimated 7,650 adults (Figure 4). Inter-relationships between river flow and humpback chub habitat show a close association of juveniles (less than 4 years old and 200 mm total length) with certain reaches of river having shoreline cover, including large rock talus, debris fans, and vegetation (Converse et al. 1998). Adults also show an affinity for the same river reaches and generally remain in low-velocity pockets within large recirculating eddies (Valdez and Ryel 1995). The principal area occupied by the Grand Canyon population of humpback chub is in and around the LCR, about 77 mi (123 km) downstream from the dam.

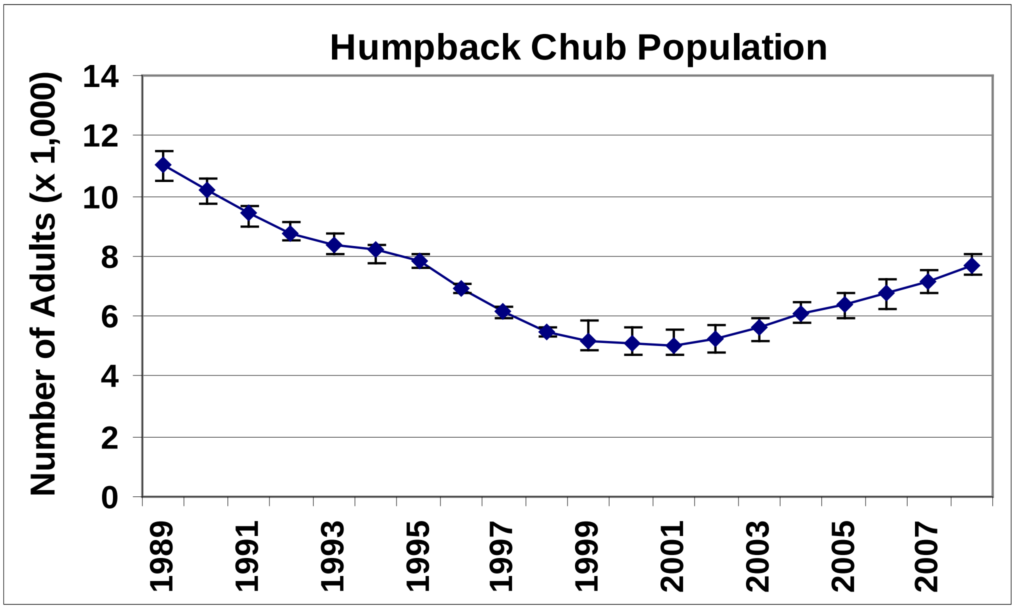


Figure 4. Estimated adult humpback chub abundance (age 4+) from ASMR, incorporating uncertainty in assignment of age. Point estimates are mean values among 1,000 Monte Carlo trials, and error bars represent maximum and minimum 95-percent profile confidence intervals among 1,000 Monte Carlo trials. All runs assume the coefficient of variation of the von Bertalanffy $L\infty$ was CV ($L\infty$) = 0.1 and adult mortality was $M\infty$ = 0.13 (Coggins and Walters 2009).

3.2.1.2 Razorback Sucker

The razorback sucker is currently listed as "endangered" under the ESA (56 FR 54957). Designated critical habitat includes the Colorado River and its 100-year floodplain from the confluence with the Paria River (RM 1) downstream to Hoover Dam, a distance of nearly 500 miles, including Lake Mead to the full pool elevation. A recovery plan was approved on December 23, 1998 (U.S. Fish and Wildlife Service 1998) and recovery goals were approved on August 1, 2002 (U.S. Fish and Wildlife Service 2002b). Primary threats to razorback sucker populations are streamflow regulation and habitat modification and fragmentation (including cold-water dam releases, habitat loss, and blockage of migration corridors); competition with and predation by non-native fish species; and pesticides and pollutants (Bestgen 1990; Minckley 1991).

The razorback sucker has not been reported in Grand Canyon since 1990 and only 10 adults were reported between 1944 and 1995 (Gloss et al. 2005). Carothers and Minckley (1981) reported four adults from the Paria River in 1978-1979. Maddux et al. (1987) reported one female razorback sucker at Upper Bass Camp (RM 107.5) in 1984, and Minckley (1991) reported five adults in the lower LCR from 1989-1990. The razorback sucker is probably extirpated from the Colorado River and its tributaries between Glen Canyon Dam and the Lake Mead inflow, although a small reproducing population occurs in Lake Mead (Albrecht and Holden 2006).

3.2.1.3 Non-Listed Native Fishes

The Colorado River from the Glen Canyon Dam to the Paria River supports small numbers of bluehead sucker, flannelmouth sucker, and speckled dace. Flannelmouth sucker spawn in this reach and in the lower Paria River (McIvor and Thieme 2000; McKinney et al. 1999; Thieme 1998). Bluehead sucker, flannelmouth sucker, humpback chub, and speckled dace occur in moderate numbers in the river between the Paria and Little Colorado rivers (Ackerman 2008; Lauretta and Serrato 2006; Johnstone and Lauretta 2007; Trammell et al. 2002;). Most native fish in the mainstem from the dam to the LCR are large juveniles and adults. Earlier life stages rely extensively on more protected nearshore habitats, primarily backwaters (Lauretta and Serrato 2006; Trammell et al. 2002). The 174 miles from the LCR to Bridge Canyon has six large tributaries and supports a diverse fish fauna of cool- to warm-water species to about Havasu Creek, including the three non-listed native species. Non-listed native fish are also well represented in Bright Angel, Shinumo, Tapeats, Kanab, and Havasu creeks (Johnstone and Lauretta 2007; Leibfried et al. 2006), especially during spawning periods.

The Grand Canyon fish community shifted over the past decade from one dominated by non-native salmonids to one dominated by native species (Ackerman 2008; Johnstone and Lauretta 2007; Lauretta and Serrato 2006; Makinster et al. 2010; Trammell et al. 2002). Catch rates of flannelmouth and bluehead suckers increased four to six-fold from 2000 through 2008, and speckled dace catch rates were steady but generally higher than historical levels (Johnstone and Lauretta 2007; Lauretta and Serrato 2006; Makinster et al. 2010). It is hypothesized that recent shifts from non-native to native fish are due in part to warmer than average water temperatures, although decline of coldwater salmonids has also been implicated (Ackerman 2008; Andersen 2009). Despite the fact that the warmer water temperatures have since dissipated and non-native fish numbers, especially trout, have dramatically increased, the high abundance of native fish has persisted.

3.2.1.4 Trout

Two species of non-native trout are found in Grand Canyon, the rainbow trout and brown trout. The population of rainbow trout in the 15-mile long Lees Ferry tailwater reach has undergone large changes in abundance since standardized monitoring began in 1991. Recruitment and population size appear to be governed largely by dam operations (Arizona Game and Fish Department, 1996; McKinney et al. 1999, 2001; Wright and Kennedy 2011). Rainbow trout are also found fairly consistently in the mainstem Colorado River between the Paria River and the LCR confluence (Makinster et al. 2010). Below that point, small numbers are found associated with tributaries, including Bright Angel Creek, Shinumo Creek, Deer Creek, Tapeats Creek, Kanab Creek, and Havasu Creek. Brown trout are found primarily near and in Bright Angel Creek, where there is a spawning population. Small numbers are found elsewhere in the canyon.

The rainbow trout population in the Lees Ferry reach has been monitored since 1991. From 1993 to 1997, the population increased and remained high until 2001 (Figure 5). McKinney et al (1999) attributed the dramatic increase from 1991 to 1997 to increased minimum flows and reduced daily discharge fluctuations. After 2001, there was a steady decline in the Lees Ferry population until 2007. A similar decline in rainbow trout abundance below the Paria River was observed during that same time period (Makinster et al. 2010). The 2001–2007 decline is attributed to increased water temperatures (associated with low reservoir elevations) and trout metabolic demands coupled with a static or declining food base, periodic oxygen deficiencies and nuisance aquatic invertebrates (New Zealand mudsnails;

Behn et al. 2010). Concurrent with these declines in abundance, however, trout condition (a measure of plumpness or optimal proportionality of weight to fish length) has increased, reflecting a strongly density dependent fish population where growth and condition are inversely related to fish abundance (McKinney et al. 1999, 2001).

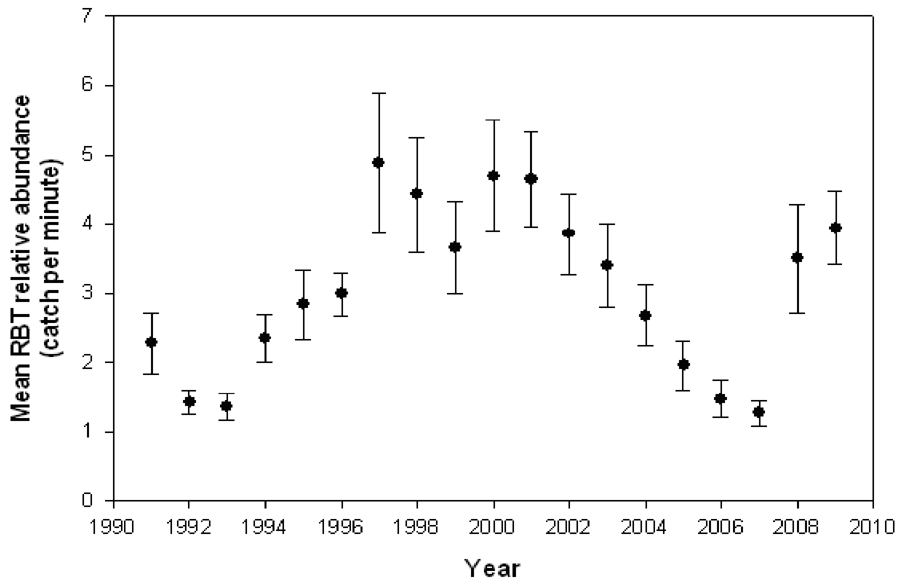


Figure 5. Average annual electrofishing catch rates of rainbow trout in the Lees Ferry reach (Glen Canyon Dam to Lees Ferry) for 1991-2010 (Makinster et al. 2010).

During 2003-2005, “nonnative fish suppression flows” were released from the dam to evaluate these flows in controlling the trout population in the Lees Ferry reach with high and low flows to reduce survival of eggs and young. In addition, a program of mechanical removal was conducted in the vicinity of the LCR during 2003–2006 and 2009 to determine if electrofishing could be used to control trout and minimize competition and predation on humpback chub in that reach. Although the “non-native fish suppression flows” did result in a total redd loss estimate of 23% in 2003 and 33% in 2004, this increased mortality did not lead to reductions in overall recruitment due to increases in survival of rainbow trout at later life stages (Korman et al. 2005; Korman et al. 2011). Removal of non-native fish using boat-mounted electrofishing in the LCR reach was effective for both rainbow trout and brown trout removal. Of 36,500 fish captured from 2003-2006, 23,266 were non-native, including 19,020 rainbow trout and 470 brown trout. Levels of both trout species were effectively suppressed in the LCR reach using this method, especially rainbow trout, which dropped from an initial estimated abundance of 6,466 in January of 2003 to a low of 617 in February 2006 (Coggins et al. 2011). An 800 percent increase in rainbow trout in the LCR reach since 2006 has been attributed to the increased survival and growth of young trout following the March 2008 HFE (Wright and Kennedy 2011). The 2008 HFE likely benefitted rainbow trout by flushing fine sediment from spawning gravels, thus improving survivorship of young trout, and also appears to have resulted in an increase in available food for trout (Korman et al. 2010; Rosi-Marshall et al. 2010).

3.2.1.5 Other Non-Native Fishes

Fifteen non-native fish species are currently found in Grand Canyon (Table 2, Hilwig et al. 2010; Valdez and Carothers 1998). The majority are warm-water species; only two are true cold-water species—rainbow trout and brown trout. The fish population in Glen Canyon (Lees Ferry) is dominated by rainbow trout, with small numbers of brown trout and local abundances of common carp (Ackerman 2008). The fish population in Marble Canyon is dominated by rainbow trout and carp with small numbers of seven other species. In Grand Canyon, dominant warm-water species are channel catfish and carp with local abundances of small minnows and sunfishes.

Recently, a few smallmouth bass (*Micropterus dolomieu*) and striped bass (*Morone saxatilis*) were collected in the vicinity of the LCR (Hilwig et al. 2010), but no population-level establishment has been documented to date. There are also recent records of green sunfish, black bullhead, yellow bullhead (*Ameiurus natalis*), red shiner (*Cyprinella lutrensis*), plains killifish (*Fundulus zebrinus*) and largemouth bass (*Micropterus salmoides*) downstream from the LCR, usually associated with warm springs, tributaries, and backwaters (Johnstone and Lauretta 2007; GCMRC unpublished data). Striped bass are found in relatively low numbers below Lava Falls (Valdez and Leibfried 1999; Ackerman 2008). Common carp are relatively common downstream from Bright Angel Creek, although numbers declined from 2000 through 2006 (Makinster et al. 2010).

Non-native fish collected below Diamond Creek in 2005 (Ackerman et al. 2006) were comprised primarily of red shiner (28 percent), channel catfish (18 percent), common carp (12 percent), and striped bass (9 percent); smallmouth bass, mosquitofish (*Gambusia affinis*), and fathead minnow (*Pimephales promelas*) were also present in low numbers. Bridge Canyon Rapid (RM 235) impedes upstream movement of most fish species, except for the striped bass, walleye, and channel catfish (Valdez 1994; Valdez et al. 1995; Valdez and Leibfried 1999). Above Bridge Canyon Rapid, the red shiner was absent, but below the rapid it comprised 50 percent and 72 percent of all fish captured in tributaries and the mainstream, respectively (Valdez 1994; Valdez et al. 1995). Other common fish species found below Bridge Canyon Rapid include the common carp, fathead minnow, and channel catfish; however, very little fish habitat exists in this reach due to declining elevations of Lake Mead and subsequent downcutting of accumulated deltaic sediments in inflow areas.

3.2.1.6 Effects of HFEs on Fishes

Reclamation is developing an Environmental Assessment concerning high-flow experimental releases from Glen Canyon Dam for the purpose of promoting more natural sediment dispersal throughout the Canyon. A high flow protocol is being developed with the intention to allow for multiple high flow tests over a period of 10 years. The HFE Protocol would have effects to fishes under either no action or the proposed action if implemented. The SDM Project analysis results, along with other recent scientific findings, suggest that there is a close relationship between the decision to conduct high flow experiments and to implement non-native fish control because of the apparent effect that spring HFE flows have on trout recruitment in Lees Ferry. The coupled trout-chub models developed as part of the SDM Project assessment provided some valuable predictions about the effects of HFEs on fishes (see Appendix A, Table 7). Wright and Kennedy (2011) also concluded available evidence indicates that HFEs can substantially impact humpback chub population levels due to the positive effect of HFEs on trout abundance and the negative effect of trout completion and predation on humpback chub and other native fishes. Wright and Kennedy (2011) reported that rainbow trout abundance in the LCR reach increased approximately 800 percent since 2006. They attribute this increase to downriver migration of the large 2008 rainbow trout cohort spawned in the Lees Ferry tailwater reach immediately after the 2008 HFE, together with local recruitment along downriver sections.

Results from the 1996 and 2008 spring HFEs indicate that high flow experiments have the potential to increase numbers of rainbow trout in Lees Ferry and likely influence the abundance of rainbow trout throughout Grand Canyon due to several factors. Korman et al. (2010) found multiple lines of evidence indicating that the March 2008 HFE resulted in large increases in abundance of rainbow trout in Lees Ferry due to improved habitat conditions for young-of-year rainbow trout. Numbers of young-of-year rainbow trout in July of 2008 were four-fold greater than would be expected based on numbers of eggs produced during the 2008 spawn based on stock-recruitment analysis. Survivorship was also greater for fish that hatched after the HFE based on hatch-date analysis, also indicating that habitat conditions were improved after the HFE. Growth rates of young-of-year rainbow trout were also as high as has been recorded in Lees Ferry, despite the fact that abundance was also much greater than previous years, suggesting a greater carrying capacity for young trout in Lees Ferry following the HFE (Korman et al. 2010). Korman et al. (2010) speculate that the 2008 HFE (41,500 cfs for 60 hours) resulted in these effects because the high flow increased interstitial spaces in the gravel bed substrate and food availability or quality, resulting in higher early survival of young-of-year rainbow trout, as well as improved growth of young trout. This improved habitat effect of the 2008 HFE also apparently carried over into 2009; trout abundance in 2009 was more than two fold higher than expected from egg counts (Korman et al. 2010).

Although there is less data from the 1996 and 2004 HFEs, those events appeared to have effects to rainbow trout as well. Trout abundance in Lees Ferry appeared to increase following the 1996 event which was conducted in April (Makinster et al. 2009b). During a three-week period that spanned the November 2004 HFE, abundance of age-0 trout, estimated to be approximately 7 months old at that time, underwent a three-fold decline; a two-fold decline was also observed in November-December 2008 (Korman et al. 2010). The decline observed during the 2004 HFE may have been due to either increased mortality or displacement/disbursal as a result of the higher flow (Korman et al. 2010). However, long-term trout monitoring data indicated that trout started to decline system-wide in 2001-2002 and declined through the period of the 2004 HFE and only began to recover in about 2007 (Makinster 2009b). Also, key monitoring programs to detect ecosystem pathways that affect rainbow trout in Lees Ferry were not in place at the time of the 2004 HFE (Wright and Kennedy 2011). Higher water temperatures and lower dissolved oxygen in fall 2005 also may have increased mortality and reduced 2006 spawning activity (Korman et al. 2010). Thus the overall effect of fall HFEs on rainbow trout abundance is unclear.

The high flow experiment protocol currently under development by Reclamation would provide for the opportunity to conduct multiple high flows over a 10-year period of from 31,500 cfs to 45,000 cfs for 0-96 hours. Proposed time frames are March/April and October/November, periods following the primary sediment-input season are of late

Summer/early fall and winter. A more detailed description of the proposed action can be found in the HFE Protocol EA (Bureau of Reclamation 2011). High flows conducted in the March/April period likely would result in improved conditions for rainbow trout based upon observations from the 1996 and 2008 HFEs. Given the 800 percent increase in rainbow trout that apparently resulted from the 2008 spring HFE (Korman et al. 2010, Wright and Kennedy *in press*), multiple HFEs over a 10-year period would reasonably be predicted to increase rainbow trout abundance system-wide including in the LCR Reach.

3.2.2 *Fish and Fish Habitat under No Action*

Under the no action alternative, no actions to control non-native fish would be taken for the 10-year period. The No Action alternative would implement MLFF for the 10-year period with steady flows in 2011 and 2012. These dam operations have been previously evaluated through prior NEPA compliance, the 1995 EIS and 1996 ROD and the 2008 EA for Glen Canyon Dam operations (Bureau of Reclamation 1996, 1996, 2008). HFEs could also be conducted as an additional dam operation as described in HFE Protocol EA if the protocol is implemented (Bureau of Reclamation 2011). In general, the no action alternative is predicted to result in a potential deterioration of native fish species, including the humpback chub, and habitat for these species, including humpback chub and razorback sucker critical habitat, because non-native fish would be more likely to proliferate and predation losses of young native fish increase, reducing recruitment of these species.

Non-native fish predation has long been identified as a key threat to humpback chub in Grand Canyon (Minckley 1990, Valdez and Ryel 1995, Marsh and Douglas 1996). Wright and Kennedy (2011) found that rainbow trout appear to have a causal link to adult humpback chub population abundance, which is seen in population abundance trends for both species (Figure 3). When rainbow trout populations are large, humpback chub populations generally decline. Wright and Kennedy (2011) ascribe this relationship to a probable combination of increased competition and predation (citing Coggins, 2008; 160 Coggins and Walters, 2009; Coggins and Yard, 2010; Coggins et al., in press; Yard et al., in press). Currently both rainbow trout numbers and humpback chub numbers are high. This suggests that either: 1) the adult humpback chub population has not yet been affected by predation from the trout because it takes four years for juveniles to mature and recruit into the adult population, or 2) other, unknown factors (such as water temperature for flow volume are contributing to oscillations in the trout and humpback chub abundance).

Results from previous non-native fish removal efforts (Yard et al. 2011) of diet content analysis showed that although rainbow trout predation rate on humpback chub was relatively low, the overall loss of young humpback chub to predation by rainbow trout was substantial due to the high density of rainbow trout in the reach. Yard et al. (in press) found that during the 12 removal trips conducted from 2003-2004, 9,326 humpback chub were eaten by trout. Therefore reducing numbers of rainbow trout in the LCR reach (19,020 rainbow trout were removed) effectively reduced predation losses of young humpback chub, a clear beneficial effect to the species, although other factors, such as warmer mainstem water temperatures in Grand Canyon during this period, confounded the overall effect of removal on humpback chub recruitment in the system (Andersen 2009; Coggins et al. 2011; Yard et al. 2011). Also during this period, rainbow trout declined system-wide, indicated both by abundance estimates from the control reach of the non-native control project and from monitoring throughout the system (Coggins et al. 2011; Makinster 2007). No action would not implement any removal efforts, and because numbers of rainbow trout are similar to abundances seen at the begging of the previous removal efforts (i.e. Yard et al. 2011 in 2003), losses of humpback chub due to predation would be similar.

An interesting early finding of the nearshore ecology study is that juvenile chub that occupy eddy complexes and talus slopes of the mainstem approximately 1.5 miles downstream from the LCR mouth have relatively high survivorship rates of 50-60 percent across 3 years of sampling (2008-2010; Dr. B. Pine, Univ. of Florida, pers. comm. 2011). This suggests that high numbers of trout in this reach have apparently had little effect on juvenile survivorship, at least in the small percentage of habitats examined in the nearshore ecology study. Yard et al (*in* press) illustrates that clearly if non-native fish are not removed and controlled, then young humpback chub would continue to be consumed by non-native fish, predominantly trout, and trout would continue to compete with humpback chub for food and space. However, the work of Dr. Pine indicates that there may be more factors at work which ultimately determine juvenile survival, recruitment, and adult humpback chub abundance. Juvenile humpback chub that survive (are not lost to predation or other causes) may have better survival because there are few humpback chub to compete against (known as compensatory survival). This survival may offset losses of young humpback chub to predation. This is an important aspect of non-native fish control to understand, because if predation on young humpback chub is high, but it ultimately has little effect on recruitment, removal of trout would have no effect on humpback chub recovery, and at great expense. One way to test this hypothesis would be to postpone removal long enough to detect an effect on adult humpback chub abundance, approximately four years, the length of time for humpback chub to mature into adults. The no action would provide for this experiment, because no removal would be implemented. However, if humpback chub adult abundance does decline over time due to trout predation, this alternative would provide no means to counteract this effect.

Thus the loss of young humpback chub to predation could have an effect on the population of humpback chub in Grand Canyon by reducing recruitment (Coggins and Yard 2009; Yard et al. *in press*). The effect on the humpback chub population cannot be fully analyzed due to incomplete knowledge of the complexity of survival rates associated with a large number of variables that would translate to adult recruitment, including the uncertainty of numbers and sizes of chub eaten by trout, affects of cold mainstem water temperatures on young humpback chub, various annual densities of juvenile chub depending on year class strength, relationship of predator and prey densities, the causes and levels of other sources of mainstem chub mortality, and the contribution of young humpback chub reared in the mainstem to the adult population.

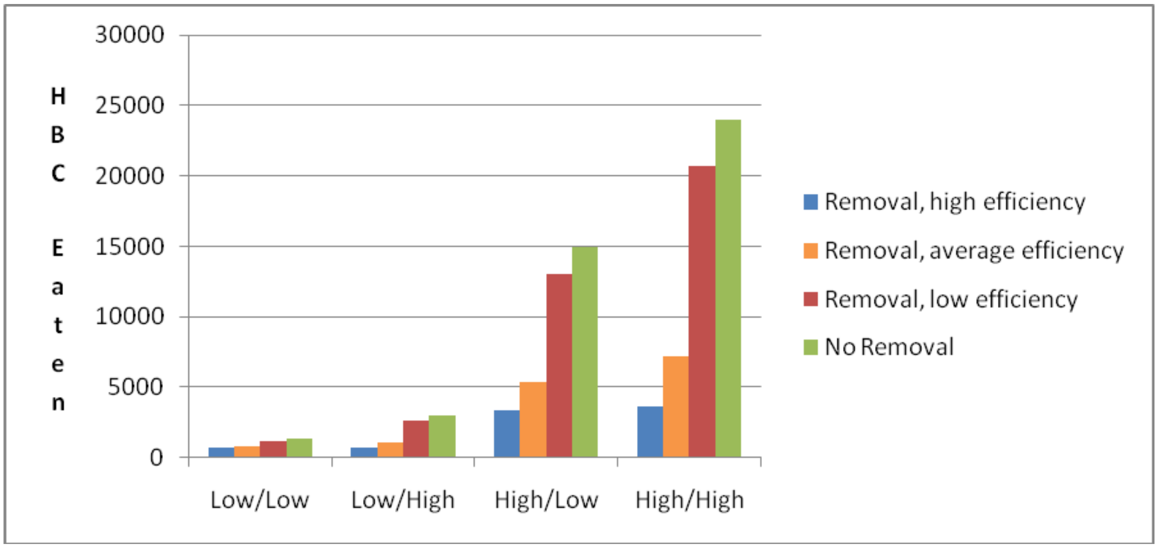


Figure 6. Expected predation of age-0 and subadult humpback chub by trout in the absence of non-native fish removal (green bars) and over a range of removal efficiencies (blue, orange and red bars). X-axis labels refer to assumptions on predator density and piscivory rates. For example, "Low/Low" refers to low levels of predatory density (as a function of trout immigration rates) and low piscivory rates (Yard et al. 2008). The amount of humpback chub that would theoretically be saved through removal efforts is represented by the difference between the green vertical bars and bars of other colors representing the various assumptions on immigration and predation rates (Bureau of Reclamation 2010).

Nevertheless, taking no action would result in losses of young humpback chub due to predation by rainbow trout and other non-native fishes that would not be removed which in turn could result in reductions in humpback chub recruitment and declines in the adult population. Using data from prior removal efforts, we can estimate what effect the no action may have humpback chub recruitment. An analysis of the effects of conducting two removal trips in the LCR reach is provided in Appendix C. Evaluation of population level effects was conducted by converting losses of age-1 humpback chub to losses of adult humpback chub, which is the metric identified in the Recovery Goals (U.S. Fish and Wildlife 2002) and the incidental take statement from the 2009 Supplemental Biological Opinion and the 2010 Reissued Incidental Take Statement (U.S. Fish and Wildlife Service 2009, 2010). We applied published survival rates for humpback chub (Valdez and Ryel 1995; Coggins et al. 2006) to estimate numbers of preyed-upon humpback chub as described above. We then compared these losses to the minimum population size contained in the incidental take statement (6,000 adult humpback chub; U.S. Fish and Wildlife Service 2010b).

Depending on electrofishing efficiency, estimates of not conducting two non-native fish removal electrofishing trips in the LCR reach could increase predation pressure by rainbow trout substantially (Figure 6). An estimated 129-3,292 young humpback chub (age-0 and age-1) would be theoretically lost to predation under the low efficiency scenario, 532-16,851 humpback chub in the average efficiency scenario and 637 to 20,384 humpback chub in the high efficiency scenario. Losses of age-0 and age-1 humpback chub due to predation from not conducting two electrofishing trips would theoretically translate into losses of adult fish (Figure 7). Four to 96 fish would be lost as a result of predation in the low efficiency scenario, 15 to 491 fish in the average efficiency scenario and 19 to 594 humpback chub in the high efficiency scenario. The grand mean of estimated fish lost from predation across all variables (predation and immigration rates as well as electrofishing efficiency) is 169 fish. Note that this estimate is for two LCR reach removal trips. The cost of not conducting additional trips would result in additional losses of young humpback chub, which would translate into fewer adult humpback chub in the adult population.

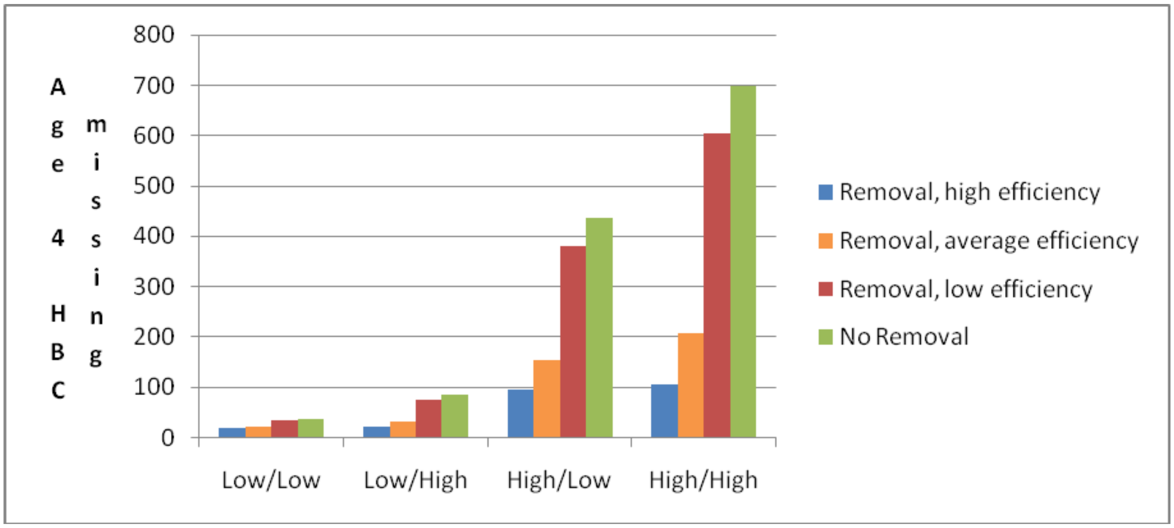


Figure 7. Expected losses of adult humpback chub (age 4+) due to predation by trout in the absence of non-native fish removal (green bars) and over a range of removal efficiencies (blue, orange and red bars, Bureau of Reclamation 2010).

Coggins and Walters (2009) estimated adult (age-4+) humpback chub population size in 2008 to be 7,650 fish. Based on annual mortality rates for humpback chub developed by Coggins et al. (2006) and Valdez and Ryel (1995), and the adult population estimate provided by Coggins and Walters (2009), to arrive at the 2008 population estimate, about 4,511 age-3 humpback chub would have had to be alive in 2007 to produce 2,346 age-4 fish in 2008, because mortality rates would result in a total loss of 2,165 fish (annual mortality of about 48%) between age 3 to 4. Assuming the population size is constant and rates of change remain the same for the next few years, the percentage of total annual mortality due to predation would be average adult fish lost to predation (315) divided by total fish lost to all mortality sources (2,165), or about 15% (a range of 2 – 32%). Thus if recruitment remains sufficient to keep total adult numbers stable or increasing over the next few years, effects of not conducting removal would likely not lead to a large decline in population size. Given the wide range of potential decline due to predation (2 - 32%) there is also some question as to whether a reduction in age-4 humpback chub in the main channel would be detectable under current protocols in the short term. However, over the 10 years of analysis for this EA, losses of humpback chub adults due to not conducting removal could be substantial and exceed incidental take as described in the 2010 revised Incidental Take Statement[6].

[6] On June 29, 2010, the U.S. District Court for the District of Arizona remanded the incidental take statement contained within the 2009 Opinion on Glen Canyon Dam operations back to the USFWS. USFWS reissued the incidental take statement as ordered on September 1, 2010, which essentially stated that take would be exceeded

Losses of humpback chub due to brown trout could be large if their abundance would be comparable to those observed during 2003 and 2004 as described by Yard et al. (2008). Recent electrofishing data through 2009 shows that catch of brown trout in the LCR reach has increased little since a system-wide decline and catch per unit effort is lower than levels observed during 2003-2004 removal efforts (see Makinster et al. 2010, figure 4-C). Recolonization rates of brown trout into the LCR reach are also presumably low, partly because the nearest source population is about 25 miles downstream.

The NPS Bright Angel Creek removal project is ongoing and would continue under the no action alternative. Removal of rainbow and brown trout from Bright Angel Creek with a fish weir in fall of 2002 and 2006 has been shown to be an effective means of non-native fish control for both rainbow and brown trout (Leibfried et al. 2003, 2006). The Bright Angel Creek removal would be expected to continue to be effective at reducing brown trout in what is considered to be the primary source of brown trout to the LCR reach. The NPS will also be conducting removal in Shinumo Creek as part of a project to translocate humpback chub from the LCR to that stream. Both of these actions have been previously addressed through other compliance processes and are incorporated by reference herein. NPS removed from Bight Angel Creek 525 brown trout from 2006-2007, and 454 rainbow trout and 594 brown trout from 2010-2011 using a combination of a fish weir trap and electrofisihing; NPS also removed 1,220 rainbow trout and one brown trout from Shinumo Creek in 2009, and 929 rainbow trout in 2010. The cumulative effects of these actions are analyzed here, along with related effects humpback chub translocations.

Other cumulative actions that could affect fishes include translocations of humpback chub above Chute Falls in the Little Colorado River, to Shinumo and Havasu Creeks, and establishment of humpback chub refuge, all Reclamation conservations measures in ongoing section 7 biological opinions (U.S. Fish and Wildlife Service 2008, 2009). Translocation of humpback chub within the LCR has been occurring since 2003 and translocations from the LCR to Shinumo Creek has been occurred in 2009 and 2010. These actions appear to have benefited the species, as survivorship and growth of fish translocated above Chute Falls have been high (Stone 2009), and fish translocated into Shinumo Creek have exhibited rapid growth, have overwintered in Shinumo Creek, and have been detected moving into the mainstem Shinumo inflow aggregation (B. Healy, NPS, pers. comm. 2010). Additional translocations are planned for these creeks and for Havasu Creek. These projects are expected to continue to benefit the species by improving survivorship and expanding the range of the humpback chub. Reclamation has also assisted USFWS in creating a refuge population at Dexter National Fish Hatchery and Technology Center. This refuge serves as potential brood stock in the event a catastrophic loss of humpback chub in the Grand Canyon population should occur.

Another potential effect of no action is increased competition between adult humpback chub and non-native fishes that would have been removed by the trips, in particular adult rainbow, and brown trout. Valdez and Ryel (1995) found that simulids, chironomids, and *Gammarus*

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if the estimate of the adult humpback chub population dropped below 6,000 fish, using the Age-Structured Mark Recapture Model (Coggins and Walters 2009, U.S. Fish and Wildlife Service 2010).

were the three most prevalent diet items in 158 adult humpback chub stomachs sampled by gastric lavage in the mainstem Colorado River in Grand Canyon. Yard et al. (2011) also found that these same three types of aquatic invertebrates were important components of both rainbow and brown trout diets, often accounting for 40 to 90 percent of the diet by weight over a 1.75 year study from 2003-2004. Thus it appears that there is competition for food resources between trout and humpback chub, although the extent of this not fully understood in relation to overall food availability (i.e., if food resources are unlimited, then there would be no effect from competition). Ongoing food base research should provide insight into the effect of competition with trout in light of food availability.

As discussed above, conducting future HFEs under the proposed HFE Protocol could have adverse effects to humpback chub due to increased numbers of rainbow trout (Korman et al. 2010, Wright and Kennedy 2011). Under the no action alternative, there would be no means of controlling these increasing numbers of rainbow trout. This could further increase losses of young humpback chub to predation by rainbow trout. Although about 20,000 rainbow trout were removed from LCR reach from 2003-2006 (Coggins, 2008a; Coggins and Yard 2010), the large 2008 rainbow trout cohort that resulted from the March 2008 HFE , perhaps combined with local recruitment along downriver sections, contributed to an approximate 800 percent increase in rainbow trout densities in the vicinity of the Little Colorado River since 2006 (figure 3; Makinster and others, 2010; Wright and Kennedy 2010). Under these densities, losses of humpback chub to rainbow trout predation are likely to be similar to those observed by Yard et al. (2011). Yard et al. (2011) found that predation rates by rainbow trout varied from 1.7 to 7.1 prey/rainbow trout/year, and 27.3 percent of fish consumed were humpback chub. Assuming a trout population of 7,000 adult rainbow trout in the LCR reach, annual losses of juvenile humpback chub would be within a range of 2,820-13,568. However, as described in the science plan (Appendix C), although these studies illustrate that losses of humpback chub to rainbow trout predation are occurring, the ultimate effect of rainbow trout predation on the adult humpback chub is not known. Although humpback chub status has continued to improve since the late 1990s, a period that includes mechanical removal of rainbow trout (2003-2006 and 2009), a number of other factors, including warmer mainstem water temperatures during this period, may have contributed to the improvement in the humpback chub's status (Andersen 2009).

Critical habitat for both humpback chub and razorback sucker would likely deteriorate under 10 years of the no action alternative. Critical habitat for these species includes a biological environment primary constituent element (PCE; U.S. Fish and Wildlife Service 1994). The biological environment includes food base, and predation and competition from non-native species. Because the no action alternative would only included limited removal of non-native fishes in Bright Angel Creek and Shinumo Creek, non-native fishes would like proliferate in the mainstem and in the LCR reach. These increases in non-native fish would reduce the quality of the biological environment PCE of critical habitat due to increased predation and competition from non-native fish species, and potential reductions in food base due to competition with non-native fish species.

The no action alternative is expected to have adverse effects to humpback chub and to humpback chub and razorback sucker critical habitat. This is because no non-native fish control would be conducted, with the exception of small-scale removal projects ongoing by the NPS in Bright Angel and Shinumo Creeks. Because no mainstem Colorado River removal efforts would be conducted, non-native fish species, especially trout, would be expected to proliferate to high densities. This effect would likely be magnified if the HFE Protocol is implemented. Increases in non-native fish species would lead to increased predation and competition on endangered humpback chub, resulting increased losses of humpback chub and potentially reduced recruitment, and reductions in adult abundance. The value of critical habitat for humpback chub and razorback sucker would also be reduced.

3.2.3 *Fish and Fish Habitat under the Proposed Action*

Dam operations for the 10-year proposed action would be MLFF with steady flows in 2011 and 2012. These operations were previously evaluated through prior NEPA compliance, the 1995 EIS and ROD and the 2008 EA of Glen Canyon Dam operations (Bureau of Reclamation 1996, 1996, 2008). HFEs may also be conducted as an additional dam operation as described under in HFE Protocol EA (Bureau of Reclamation 2011).

The Proposed Action utilizes boat-mounted electrofishing to remove all non-native fish species in the PBR and LCR reaches of the mainstem Colorado River in Marble and Grand Canyons. Up to 6 LCR reach removal trips and up to 10 PBR reach removal trips could be conducted in any one year. Removal of non-native fish in the LCR reach would only take place if the number of adult humpback chub, as measured using the Age-Structured Mark Recapture Model (ASMR; Coggins and Walters 2009) indicates that adult abundance has dropped below 7,000 adult humpback chub.

The proposed action would also include research to improve understanding of several aspects of the fishery in the action area related to improve understanding the effects of non-native fish predation. Research efforts would be implemented to improve estimates of young humpback chub (juveniles less than 150 mm in total length) to potentially develop a trigger for non-native fish control based on abundance of these young fish. This research would also help determine the overall importance of mainstem habitats to humpback chub recruitment. To better determine the degree to which emigration of rainbow trout from Lees Ferry is the source of rainbow trout in the LCR reach, a marking study (two marking trips) would be initiated in the fall in Lees Ferry. Also, three downstream monitoring trips in the summer would monitor trout occurrence in Marble Canyon to attempt to detected marked fish from Lees Ferry moving downstream. PBR removal would begin testing in the winter months with two removal trips in the first year. The marking and PBR removal trips would enable researchers to begin to answer science questions associated with the numbers of trout emigrating from Lees Ferry, and in evaluating the effectiveness of PBR removal at limiting trout emigration to downstream areas. LCR Removal would be reserved for implementation only if adverse effects are detected, if adult humpback chub decline below 7,000 fish. Removal and research actions in out years would be implemented through adaptive management based on monitoring and research results.

The number of trout in the inflow reach following removal appears dependent on numbers of trout immigrating into the reach, plus any trout reproduction within the inflow reach, which is thought to be low (Coggins 2008a). Hilwig et al. (2010) used immigration rates observed by Coggins (2008a) to estimate potential numbers of trout in the inflow reach, relative to hypothetical scenarios of 1, 2, or 3 removal trips conducted per year, and given a target abundance of 600-1,200 rainbow trout in the LCR reach. At the lowest immigration rate of 50 fish per month, two removal trips per year appears sufficient to keep trout numbers below 1,200 rainbow trout in the reach. However, at higher immigration rates of 300 fish per month, even 3 trips per year appears insufficient to achieve the 600-1,200 fish target for much of the year (Hilwig et al. 2010).

As with no action, we analyzed the effect of the proposed action by assessing the effect of doing two non-native fish removal trips in the LCR reach, should LCR removal be necessary because the humpback chub trigger in the LCR reach had been exceeded. Additional LCR reach trips would have a stronger effect, and the effect of PBR trips is unknown because removal there has not been attempted. Conducting even two LCR removal trips could reduce predation pressure by rainbow trout substantially. If the removal has low efficiency, total humpback chub predation would be reduced by 10-14% depending on immigration rates and individual trout predation rates. Assuming average electrofishing efficiency, total humpback chub predation would be reduced by 41-70%, and 49-85% under high efficiency conditions depending on immigration rates and individual trout predation rates. Similarly, 129-3,292 humpback chub would be theoretically saved from predation under the low efficiency scenario, 532-16,851 humpback chub in the average efficiency scenario and 637 to 20,384 humpback chub in the high efficiency scenario.

Two LCR reach removal trips have been estimated to prevent losses of age-0 and age-1 humpback chub due to reduced predation year classes, and would theoretically translate into more adult fish (Figure 7). Four to 96 fish would survive due to reduced predation in the low efficiency scenario, 15 to 491 fish in the average efficiency scenario, and 19 to 594 humpback chub in the high efficiency scenario. The grand mean of estimated fish saved from predation across all variables (predation and immigration rates as well as electrofishing efficiency) is 169 fish. Note that this estimate is for two LCR reach removal trips. Additional removal trips would likely not result in a linear increase in adult humpback chub saved, but would result in substantial additional increases in fish saved. However, as discussed in the no action section, questions remain concerning the degree of effect of predation on humpback chub. The proposed action would only implement removal in the LCR reach if humpback chub numbers drop below 7,000 adult humpback chub. By taking this approach, the proposed action would provide the opportunity to better understand the effects of predation on humpback chub, and would only implement removal in the culturally-sensitive LCR reach if necessary.

Two electrofishing removal trips in the PBR reach would have unknown effects on trout predation and competition effects to humpback chub downstream in the LCR reach. However, in results of the SDM Project analysis, adding PBR reach removal to LCR reach removal improved performance of an alternative on maintaining the adult humpback chub population. The predictive population models used to evaluate the consequences of policy alternatives on humpback chub and rainbow trout objectives in the SDM Project analysis involved a set of 3 coupled models. The elements of this coupled model included: (1)

Emigration from Lees Ferry into Marble Canyon, (2) dynamics of rainbow trout during movement from Lees Ferry to LCR, and (3) the interaction between rainbow trout and humpback chub in the LCR (Fig. 4). Rates of rainbow trout emigration from Lees Ferry into Marble Canyon were based on analysis of Lees Ferry recruitment in year *t* and monthly emigration in year *t*+1. The proposed action was the best performing alternative in the SDM Project analysis because these models indicated emigration from Lees Ferry can be at least partially controlled by removal in the PBR reach.

This alternative would not affect other aquatic resources other than the collateral effects of electrofishing on native fish species and macroinvertebrates. The effects of electrofishing on Colorado River endangered fishes including humpback chub were reviewed by Snyder et al. (2003). Electrofishing can result in harmful effects on fish. Spinal injuries and associated hemorrhages have been documented in fish examined internally. These injuries are thought to result from convulsions of the body musculature, likely caused by sudden changes in voltage. Fewer spinal injuries have been reported with the use of direct current and low-frequency pulsed direct current, as opposed to alternating current. However, Snyder et al. (2003) found that endangered cyprinids of the Colorado River Basin, including humpback chub, are generally much less susceptible to these effects than other fishes. Mortality, when it has been documented, is usually due asphyxiation, a result of excessive exposure to electrodes or poor handling of captured specimens. Effects of electrofishing on reproduction are contradictory, but electrofishing over spawning grounds can harm embryos. Snyder et al. (2003) concluded from the review that:

> “The survival and physical condition of endangered and other native cypriniforms (including razorback sucker) that had been electrofished in recapture and radiotag investigations… suggest that electrofishing injuries or mortality are probably not a serious problem. Even so, the sensitivity of the matter warrants a heightened awareness of the potential for electrofishing injuries, a continuing effort to minimize any harmful impacts by every practical means, and a readiness to adjust, alter, or abandon electrofishing techniques if and when potentially serious problems are encountered… Electrofishing is a valuable tool for fishery management and research, but when resultant injuries to fish are a problem and cannot be adequately reduced, we must abandon or severely limit its use and seek less harmful alternatives. This is our ethical responsibility to the fish, the populace we serve, and ourselves.”

For the proposed action, ESA section 10(a)(1)(A) recovery permits from the USFWS would be required to conduct removal activities. These recovery permits would address the take associated with collateral effects of electrofishing and handling to humpback chub from the proposed action.

The NPS ongoing actions of removal of non-native fish, predominantly trout, from Bright Angel and Shinumo creeks would be expected to continue under the proposed action. Removal of rainbow and brown trout from Bright Angel Creek with a fish weir in fall of 2002 and 2006 has been shown to be an effective means of non-native fish control for both rainbow and brown trout (Leibfried et al. 2003, 2006). The NPS Bright Angel Creek removal project is ongoing and is expected to continue to be effective at reducing brown trout in what is considered to be the primary source of brown trout to the LCR reach. Removal of trout from Bright Angel Creek would augment removal actions of the proposed action and potentially reduce numbers of predators in the LCR reach to the benefit of humpback chub and other native fish. Bright Angel Creek also appears to be the primary spawning ground for brown trout in the system, so this project could substantially reduce predation by brown trout.

Other cumulative actions that could affect fishes include translocations of humpback chub above Chute Falls in the Little Colorado River, to Shinumo and Havasu Creeks, and establishment of humpback chub refuge, all Reclamation conservations measures in ongoing section 7 biological opinions (U.S. Fish and Wildlife Service 2008, 2009). Translocation of humpback chub within the LCR has been occurring since 2003 and translocations from the LCR to Shinumo Creek has been occurred in 2009 and 2010. These actions appear to have benefited the species, as survivorship and growth of fish translocated above Chute Falls have been high (Stone 2009), and fish translocated into Shinumo Creek have exhibited rapid growth, have overwintered in Shinumo Creek, and have been detected moving into the mainstem Shinumo inflow aggregation (B. Healy, NPS, pers. comm. 2010). Additional translocations are planned for these creeks and for Havasu Creek. These projects are expected to continue to benefit the species by improving survivorship and expanding the range of the humpback chub. Reclamation has also assisted USFWS in creating a refuge population at Dexter National Fish Hatchery and Technology Center. This refuge serves as potential brood stock in the event a catastrophic loss of humpback chub in the Grand Canyon population should occur.

Rainbow trout abundance in Lees Ferry could be affected by the proposed action. Although the trout in Lees Ferry would not be directly affected, there would still be effects that population if fish removed in the PBR reach, and perhaps the LCR reach, reduce overall abundance in the system. Reducing the numbers of trout in the system could result in both positive and negative effects to the Lees Ferry sport fishery which are discussed in Section 3.4.2.1.

In addition to the actions described above, Reclamation would also continue to investigate other alternatives under the proposed action. As part of the adaptive management process, Reclamation plans to evaluate development of other non-native fish suppression options, with stakeholder involvement, that reduce recruitment of non-native fish at, and emigration of those fish from, Lees Ferry. Both flow and non-flow experiments focused on the Lees Ferry reach may be conducted to test their ability to reduce the recruitment of trout in Lees Ferry, and lower trout emigration from Lees Ferry. These actions could benefit humpback chub by reducing numbers of rainbow trout in the system, and could also improve conditions of the recreational trout fishery at Lees Ferry. Additional environmental compliance may be necessary for these experiments.

Critical habitat for both humpback chub and razorback sucker would likely improve under 10 years of the proposed action alternative. Critical habitat for these species includes a biological environment PCE (U.S. Fish and Wildlife Service 1994). The biological environment includes food base, and predation and competition from non-native species.

Because the proposed action alternative would implement potentially both PBR and LCR reach removal, and would include the NPS ongoing actions of removal of non-native fishes in Bright Angel Creek and Shinumo Creek, non-native fish abundance would likely decrease in the mainstem and in the LCR reach. These decreases in non-native fish would increase the quality of the biological environment PCE of critical habitat due to reduced predation and competition from non-native fish species, and potential increases in food base available to native fish.

The proposed action alternative is expected to have beneficial effects to humpback chub and to humpback chub and razorback sucker critical habitat. This is because non-native fish control would be conducted potentially in both the PBR and LCR reaches, augmenting ongoing removal projects by the NPS in Bright Angel and Shinumo Creeks. Abundance of non-native fish species, especially trout, would be expected to decline. The potential adverse effect of HFEs resulting in increases in rainbow trout would potentially be mitigated by removal efforts. Decreases in non-native fish species would lead to decreased predation and competition on endangered humpback chub, resulting in increases in young humpback chub and potentially increased recruitment, and increases in adult abundance. The value of critical habitat for humpback chub and razorback sucker would also be improved. Reclamation has reviewed the best available science, and, using our technical expertise to interpret the science, our conclusion is that the proposed action represents the best option to implement the non-native fish control conservation measure in a way that satisfies our legal commitments and responsibilities under the ESA, is protective of the humpback chub, and is least damaging to cultural and other resources.

3.3 *Cultural Resources*

Cultural resources include historic properties which the National Historic Preservation Act (NHPA) defines (16 USC 1470w) as districts, sites, buildings, structures, and objects that are eligible for listing on the National Register of Historic Places.

Cultural resources also include Indian sacred sites as defined by Executive Order 13007. Under Executive Order 13007, an Indian sacred site is defined as a specific, discrete, narrowly delineated location on Federal land that is identified by an appropriately authoritative representative of an Indian religion as sacred by virtue of its established religious significance to, or ceremonial use by, an Indian religion.

3.3.1 *Sacred Sites under No Action*

The Hopi Tribe, Kaibab Band of Paiute Indians, Navajo Nation, and the Pueblo of Zuni are concerned with the taking of life in the Grand Canyon and particularly in the vicinity of the confluence of the Colorado and Little Colorado rivers.

Under no action, both Reclamation and the NPS, as the executive branch agencies with statutory or administrative responsibility for the management of the Indian sacred sites, have continuing obligations under EO 13007 to ensure that, where practicable and appropriate, reasonable notice is provided of any proposed actions that might restrict future access to the site or adversely affect its physical integrity. Under no action, no non-native fish would be removed or killed, thus there would be no effect to sacred sites.

3.3.2 *Sacred Sites under the Proposed Action*

The Hopi Tribe, Kaibab Band of Paiute Indians, Navajo Nation, and the Pueblo of Zuni consider the proposal an adverse effect on an Indian sacred sites due to the taking of life associated with the proposed action. These tribes are being consulted with on a government-to-government basis regarding how these adverse effects might be minimized or mitigated.

3.3.3 *Historic Properties under No Action*

Section 106 of the NHPA requires Federal agencies to consider the effects of their actions on historic properties and to seek comments from an independent reviewing agency, the Advisory Council on Historic Preservation (Council). Under section 106, review is also required by the Arizona State Historic Preservation Officer and the Hualapai and Navajo Nation Tribal Historic Preservation Officers (see 36 CFR 800).

With the 1992 amendments to the NHPA, Congress added section 101(d)(6)(A) specifying that properties of traditional religious and cultural importance to an Indian tribe may be determined to be eligible for inclusion on the National Register of Historic Places. These are termed traditional cultural properties (TCPs). Congress also added section 101(d)(6)(B), directing Federal agencies, in carrying out their responsibilities under section 106 of the NHPA, to consult with any Indian tribe that attaches religious and cultural importance to historic properties.

Under no action, no effects are anticipated to occur to historic properties, although the Navajo Nation has indicated that they believe conservation of the humpback chub, including non-native fish control, is essential, and thus no action could affect a TCP of this tribe of which humpback chub are a part.

3.3.4 *Historic Properties under the Proposed Action*

The area of potential effect of the proposed action is the Colorado River, and that portion of the adjacent shoreline that might be affected by related research and monitoring. Reclamation and the NPS agree with the tribes that the Colorado River and floodplain are considered eligible historic properties (TCPs) under the NHPA and the eligibility determinations have been submitted to the Arizona State Historic Preservation Officer (SHPO).

While consultation with the SHPO has not been completed, application of the criteria of effect and the NPS's policies in National Register Bulletin 15 would result in a finding of adverse effect for the proposal, given the concerns of the tribes. The Governor of the Pueblo of Zuni sent Reclamation a Zuni Tribal Council Resolution, No. M70-2010-C086, that states that the Zuni Tribe's position is that the Grand Canyon and Colorado River are Zuni traditional cultural properties eligible to the National Register of Historic Places. The Hopi tribe has also submitted documentation to the Bureau of Reclamation identifying the Grand Canyon, including the project area, as a Traditional Cultural Property.

Mitigating measures are being discussed to offset the direct, indirect, and cumulative impacts of the proposed action with the tribes per 36 CFR 800.6. Reclamation is committed to completing the process of resolving adverse effects with the tribes and other interested parties prior to implementation of the proposed action.

3.4 *Socioeconomic Resources*

Social and economic conditions were examined to determine whether the proposed action would affect them. The indicators reviewed include Indian trust assets, recreation, and environmental justice (E.O. 13175).

3.4.1 *Recreation under No Action*

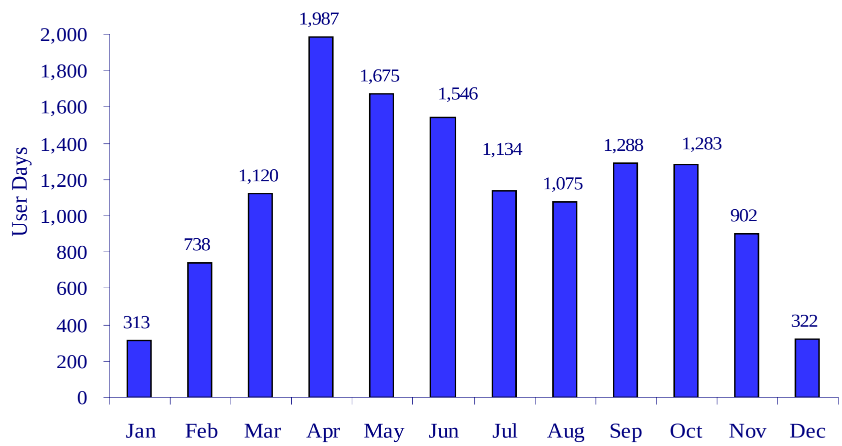
Recreational resources of concern include trout fishing and recreational boating from Glen Canyon Dam to Lees Ferry, whitewater boating through Grand Canyon, and the Hualapai Tribe's boating enterprise at the western end of Grand Canyon and into Lake Mead.

3.4.1.1 Fishing under No Action

The approximately 15-mile reach between Glen Canyon Dam and Lees Ferry is heavily used by visitors.[7] Most of the whitewater boating trips through the Grand Canyon launch from Lees Ferry. Many hiking, fishing, day-use boating, and some camping trips also take place in this reach of the Colorado River.

The Arizona Game and Fish Department and NPS manage the tailwater (the Colorado River from below the Glen Canyon Dam to Lees Ferry) for sport fishing. There is a popular non-native rainbow trout fishery in the Lees Ferry reach and for some distance downstream. Most fishing occurs from boats or is facilitated by boat access, including guide services, but some anglers wade in the area around Lees Ferry and fish downstream into the PBR reach. As described in Loomis et al. (2005), the quality of the fishery had fallen and angler use had declined dramatically in recent years, from more than 20,000 anglers in 2000 to less than 6,000 in 2003. Fishing use increased to approximately 13,000 user days in 2006 (Henson 2007) and fell to approximately 9,800 user days in 2009 (G. Anderson, NPS, pers. comm. 2010). Heaviest fishing use occurs in April and May (Figure 8).

[7] This reach of the Colorado River is known as the Lees Ferry reach and is also known as the Glen Canyon reach.



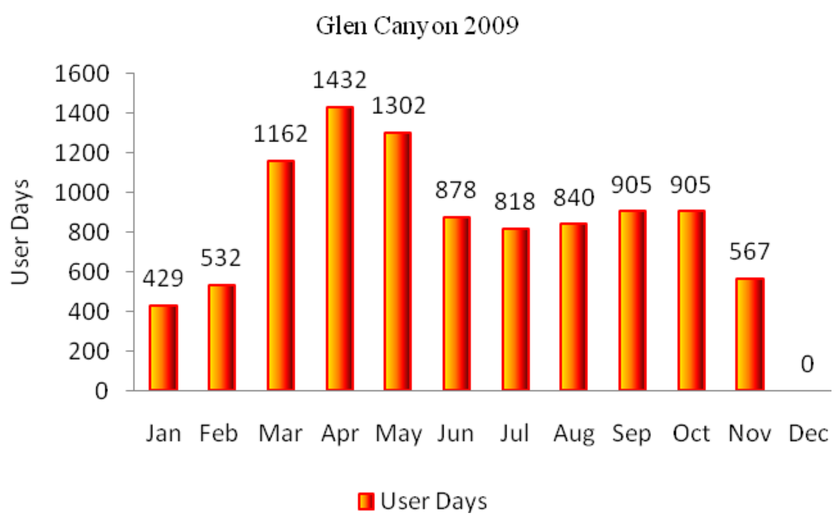


Figure 8. Fishing user days by month in the Lees Ferry reach for 2006 (top) and 2009 (bottom).

Under the no action alternative, there would be no effect on the fishery. No control actions would be implemented.

3.4.1.2 Recreational Boating under No Action

For river management purposes, the Colorado River is divided into two reaches. The upper reach runs from Lees Ferry (river mile (RM) 0) to Diamond Creek (RM 226) and is known as the Marble/Grand Canyon reach or upper river. The lower reach or lower river, starts at Diamond Creek (RM 226) on the Hualapai Reservation and goes to Lake Mead (RM 277).

The 15-mile reach between Glen Canyon Dam and Lees Ferry is heavily used by day-use boaters who take one-half day scenic boat trips offered by a NPS concessionaire. Day-use boating in Glen Canyon is a trip in a motorized or oar powered boat in a reach of the Colorado River that is without any noticeable rapids or rough water. The trip leaves from the town of Page, AZ and begins with a ride down the two-mile long Glen Canyon access tunnel.

These scenic trips are on calm water without rapids and launch at the base of Glen Canyon Dam and are a motorized float through the 15-mile reach to Lees Ferry.

There were about 50,411 user days of day-use boating during 2009 and 53,340 user days of day-use boating in 2010 (J. Balsom, NPS, pers. comm. 2011). The majority of the day-use boating visitation takes place during the summer months and June is typically the peak use month. There is little or no day use boating in the winter months.

Under the no action alternative, there would be no effect on day-use rafting. No control actions would be implemented.

Whitewater boating (kayaking, boating, canoeing, etc.) in the upper reach below Lees Ferry is internationally renowned. In 2006, the NPS completed a new *Colorado River Management Plan* (CRMP) for whitewater boating through Grand Canyon National Park (National Park Service 2006c). This management plan governs use in both the reach from Lees Ferry to Diamond Creek and the reach from Diamond Creek down to Lake Mead. Under this plan, total whitewater boating use was increased and the distribution of that use during the year was altered. Annual use in the Marble/Grand Canyon reach is expected to be no more than 115,500 commercial user-days and approximately 113,500 private user-days (National Park Service 2006c). Highest-use months for commercial operations extend from May through September, but are relatively consistent throughout the year for noncommercial boating (Figure 9). The CRMP allows up to 1,100 total yearly launches (598 commercial trips and 504 noncommercial trips). Up to 24,567 river runners could be accommodated annually if all trips were taken and all were filled to capacity.

Under the no action alternative, there would be no effect on the number of visitors participating in whitewater rafting. No control actions would be implemented.

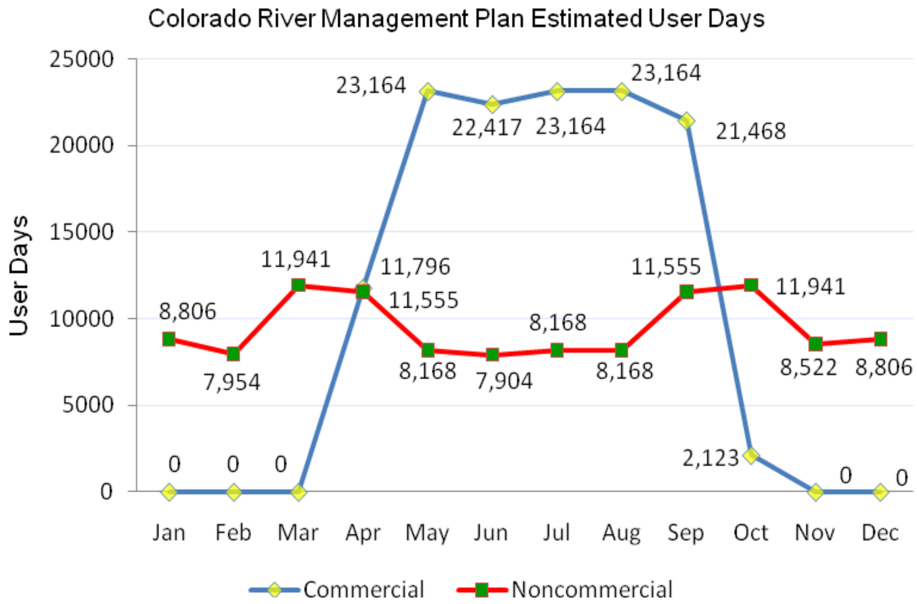


Figure 9. Recreational boating in the Grand Canyon, annual use by month (National Park Service 2006c).

3.4.1.3 Net Economic Use Value of Recreation under No Action

Recreation and the tourism industry are important economic sectors on the Hualapai Indian Reservation. Hualapai River Runners (HRR), the commercial rafting operation run by the Hualapai Tribe, provides guided day use and overnight use trips as well as the separate concession run day-use boat operation directly depend upon the Colorado River for their existence. Other recreation and hospitality operations (restaurant, hotel, skywalk, etc.) also have connections to the Grand Canyon if not the river itself. The various recreational-related enterprises generate a large proportion of the total revenue earned by the Hualapai Tribe. This revenue supports the tribal economy and creates jobs for its members. Much investment in infrastructure has been made to induce increased tourism on the reservation, e.g. the skywalk.

Visitors to Lees Ferry and the Grand Canyon spend large sums of money in the region purchasing gas, food and drink, lodging, guide services, and outdoor equipment while visiting the region. These expenditures impact the regional economy through direct effects, indirect effects, and induced effects. Direct effects represent a change in final demand for the affected industries caused by the change in spending. Indirect effects are the changes in inter-industry purchases as industries respond to the new demands of the directly affected industries. Induced effects are the changes in spending from households as their income increases or decreases due to the changes in production.

The regional economic activity that results from nonresident anglers, recreational boaters, and day boaters who visit Glen and Grand Canyons was estimated in a previous study at approximately $25.7 million in 1995 dollars (Bureau of Reclamation 1995). Douglas and Harpman (1995) estimated that Glen Canyon and Grand Canyon recreational use in the region comprised of Coconino and Mojave Counties supports approximately 585 jobs. A more recent study by Hjerpe and Kim (2003) estimated that recreational use in Coconino County (alone) supports approximately 394 jobs.

The region as defined in this analysis is Mohave and Coconino Counties in Arizona which corresponds with past economic studies of the impacts of changes in Glen Canyon Dam operations. Flagstaff, in southeast Coconino County, is the largest city in this nearly 32,000 square mile mostly rural region. In 2007 the area supported over 138,000 jobs and produced more than $15 billion worth of goods and services (Table 3). Labor earned more than $4.8 billion in total compensation.

Table 3. Mohave and Coconino Counties, Arizona – Baseline Socioeconomic Data (in 1,000's; Minnesota IMPLAN Group, Inc. 2008).

Industry Category	Employ ment	Output	Employee Compensati on	Proprietor Income	Other Property Type Income	Indirect Business Taxes
Agriculture	753	$90,035	$12,054	$3,149	$9,072	$2,684
Mining	257	$67,968	$11,338	$3,173	$23,070	$3,811
Construction	11,621	$1,541,069	$376,239	$126,497	$91,944	$9,856
Manufacturing	7,695	$2,491,463	$435,518	$13,374	$261,766	$12,462
TIPU	4,321	$684,106	$177,976	$32,383	$108,207	$27,217
Trade	22,485	$1,670,373	$604,674	$106,965	$175,621	$250,340
Service	65,943	$6,714,451	$1,838,582	$369,220	$1,326,742	$318,646
Government	25,193	$1,777,551	$1,346,715	$0	$200,779	$0
Total	138,268	$15,037,014	$4,803,097	$654,761	$2,197,201	$625,018

Economic impacts on the Navajo were not estimated in previous evaluations of changes of operations at Glen Canyon Dam on recreation and recreation economics because it was thought that there was no connection between the river flows and recreation and the Navajo Nation and fiscal or economic benefits. However, representatives of the Navajo indicated they believe there is a connection.

Navajo tradespeople who make their living selling jewelry and souvenirs to the traveling public along routes 89 and 89A have seen their business decline in recent years. The relatively high income clientele of the fishing guides were especially important (R. Lovett 2010, Marble Canyon Outfitters, pers. comm. 2010; W. Gunn, Lees Ferry Anglers Guides and Fly Shop, pers. comm. 2010). The reduction in the fishing guide business has been felt by the Navajo tradespeople and crafts workers. The Navajo vendors selling jewelry and souvenirs along highways 89 and 89A have had their sales and income greatly reduced in recent years. The recent recession added to the decline in visitation to Lees Ferry to further reduce the traffic along routes 89A and 89 reducing the potential customer base for Navajo made products sold by Navajo vendors at the roadside stands resulting in increased economic hardship. Any loss of income or jobs affects not only the individual but usually other workers (the makers of the products sold) and the worker's extended family.

In the last ten years there have been as many as 99 individual vending stands where handmade Navajo jewelry and souvenirs were sold at the 33 pullouts along highways 89 and 89A (M. Christie, Antelope Valley Trade Association, pers. comm. 2010). Now this number has been reduced to 80 stands. Four of these stands are affiliated with the Antelope Trails Vending Organization (ATVO).[8] The other stands are individually owned. Each pullout may have from one to 10 selling stands with one to two people or perhaps a whole family participating in the business. Jewelry vending and production is a primary employment sector of the economy in this part of the Nation for the Navajo people providing 400 to 700 jobs (Table 4). Jobs held by the Navajo people are especially important due to the long-term high rate of unemployment on the Nation and due to the fact that wage earners usually are supporting extended families.[9]

Table 4. Navajo Roadside Vending and Employment (Employment numbers are estimates, M. Christie, Antelope Valley Trade Association, pers. comm. 2010).

Highway	Location	# of Pullouts with Vending Businesses	# of Employed People Vending**	# of Employed People Producing Products
Route 89	Page to Bitter Springs	3	4 + family members helping	–
Route 89A	Marble Canyon to Bitter Springs	6	12	12 to 20
Route 89A	Marble Canyon to Jacob Lake	3	12 to 20	200 + family members
Route 89	Bitter Springs to Gray Mountain	21	65 to 140	130 to 280
		33	93 to 176	342 to 500

Members of the Bodaway/Gap Chapter of the Dine′ Nation have indicated that non-native fish control may affect their way of life (the Navajo use the beaches for sacred ceremonies and they fish for recreation and for food) and adversely affect their sales of items to the visiting tourists.

There are many other factors affecting the amount of traffic and numbers of potential souvenir buyers on the roads. Right now unemployment and economic uncertainty are huge factors in people's decisions to travel or vacation in northern Arizona and whether or not to purchase items from Navajo roadside stands. However, even though non-native fish control may or may not negatively affect the rainbow trout fishery at Lees Ferry the perception by the Navajo is that many actions taken at Glen Canyon Dam in Lees Ferry and Grand Canyon can negatively impact their souvenir sales.

[8]ATVO has 170 individual members. The members rotate among the four sites so each has a chance to sell their merchandise. Each business may sell at a different site on different days of the month. Not all members sell every day.

[9]The Nation is an area that has chronic high unemployment and high poverty rates. In 1999 per capita income was $7,578, only 35 percent of the national average of $21,587. While the national poverty rate for individuals in 1999 was 12.4 percent; the Nation's poverty rate was 41.9 percent.

Under the no action alternative, there would be no effect on the net economic value of recreational use. No control actions would be implemented.

3.4.1.4 Nonuse Economic Value under No Action

Social scientists have long acknowledged the possibility that humans could be affected by changes in the status of the natural environment even if they never visit or otherwise use these resources. These individuals may be classified as non-users, and economic expressions of their preferences regarding the status of the natural environment are termed “nonuse” or “passive use” value. A straightforward and readily available overview of this topic is provided by King and Mazzotta (2007).

Aquatic and riparian resources along the Colorado River are directly affected by the operations of Glen Canyon Dam. Although visitation to Glen Canyon National Recreation Area and the Grand Canyon National Park is quite extensive, only a very small proportion of these visitors physically use these riverine resources. Nonetheless, visitors to the Grand Canyon and members of the general public hold strong preferences about the status of these resources.

In the late 1980’s, the National Academy of Science Committee to Review the Glen Canyon Environmental Studies recommended that a study be commissioned to estimate nonuse value for Grand Canyon resources (National Academy of Sciences 1987). As related in Harpman et al. (1995), the Bureau of Reclamation retained an independent consulting company to complete an analysis of total economic value for the Glen Canyon EIS. Welsh et al (1995) undertook a comprehensive study of nonuse value for Glen and Grand Canyon resources. Their research encompassed both individuals residing within the area where electricity from the dam is sold and all citizens of the United States. The survey instrument was painstakingly designed following a series of focus groups, a peer review, and an extensive pilot-test. Survey response rates were exceptional; 83% and 74% for the power marketing area and national samples respectively. In many respects, these response rates demonstrated the saliency of these resources to stakeholders and members of the public.

As shown in Table 5, Welsh et al, (1995) estimated the average nonuse value (that is, when asked what they were willing to pay to implement certain actions, the response, for three flow regimes) for U.S. households was $18.74 (indexed to 2008 dollars) for the moderately low fluctuating flow alternative. When expanded by the pertinent population, this yields an aggregate estimate of $3,159.21 million per year (in 2008 dollars) for the national sample.

Table 5. Estimates of Nonuse Value for Three Flow Scenarios Relative to Historical Operations (Welsh et al. 1995).

	National Sample	National Sample
Flow Scenario	Value Per Household (2008 $)	Aggregate Value (millions of 2008 $)
Moderate fluctuating flow	$18.74	$3,159.21
Low fluctuating flow	27.84	4,660.88
Seasonally Adjusted Steady flow	$28.39	$4,756.22

The findings of this study clearly illustrate the significance of Grand Canyon resources and the value placed upon them by members of the public. Although the results of the nonuse value study were unavailable for inclusion in the *Operation of Glen Canyon Dam EIS*, they were cited and summarized as Attachment 3 in the Record of Decision (U.S. Department of the Interior 1996).

The Hopi Tribe believes that its cultural values for the Grand Canyon should be considered within the Western analysis framework as non-use values. Management actions that occur there can have effects at Hopi that do not depend on whether Hopi people enter (use) the Grand Canyon or not. The no action alternative would have no effect to Hopi non-use values.

The effect of no action may have an effect on nonuse values considering that the ecosystem would not benefit from the removal on non-native fish species and humpback chub adult abundance could decline. This could result in a decline in nonuse value.

3.4.2 *Recreation under Proposed Action*

3.4.2.1 Fishing under Proposed Action

The Colorado River from below the dam to Lees Ferry is an important recreational rainbow trout fishery, attracting anglers from the state and beyond. Most angling occurs from boats in the Lees Ferry reach, i.e., the 15 miles of river below the dam. Navajo Nation tribal members also periodically fish for trout in the Lees Ferry area. The NPS does not allow any commercialization of fishing below Lees Ferry. The Arizona Game and Fish Department sets bag limits for trout below Lees Ferry through Grand Canyon. Current fishing regulations allow for the harvest of six rainbow trout and unlimited harvest of all other sportfish from the Paria riffle to Navajo Bridge. Below Navajo Bridge (to Separation Canyon) there is no limit on angler harvest of sportfish species.

With regard to sport fishing in the Lees Ferry reach, the SDM Project analyzed the effect of this and the other alternatives on both catch rate and the percent of fish captured over 20 inches in total length. This alternative had no effect on either of these variables. Removal in the LCR reach is far enough away that it would have no effect on trout numbers or size classes in Lees Ferry. Although removal in the PBR reach is much closer, trout removed are predicted to be of young fish that are emigrating out of the Lees Ferry reach downstream. Removing these fish is not expected to have any effect on the adult population of trout in Lees Ferry. However, if this assumption is false, and PBR-reach removal does have an effect on the overall population of adult trout in Lees Ferry, the net result could conceivably be a reduction in catch rates and an increase in the size of adult fish caught. This effect was seen in the SDM Project analysis for alternatives that contain actions which more directly affected the overall Lees Ferry population (as opposed to fish that are emigrating) such as flow manipulations designed to strand young trout. Such a result would be considered beneficial to Lees Ferry trout fishery because it could result in a healthier, more sustainable population with a balanced age-structure with larger trout of better condition.

For PBR reach removal, each trip is anticipated to take place over up to 12 nights. Researchers would be land-based with no riverside camping, and boats would launch for nightly work late in the day, only after all recreational trips have launched and traveled downstream. The work would take place between the Paria River and Badger Rapids only. Boats would return to Lees Ferry at the conclusion of their nightly work. Care would be taken to avoid disturbance to walk-in recreationists and anglers at the Paria River confluence beach. For LCR reach removal trips, duration would likely be several weeks, with removal teams camped and working in the LCR reach for approximately two weeks.

Although the proposed action is not expected to result in any adverse or beneficial effect on the quality of sport fishing in Lees Ferry, because there may be up to 10 removal trips in the PBR reach each year, and these trips would operate out of Lees Ferry, there could be some effect in the form of disturbance to anglers and fishing guides in Lees Ferry. However, removal crews would be working the 7-mile PBR reach downstream from Lees Ferry. Lees Ferry anglers and fishing guides utilize the Glen Canyon section of Lees Ferry, that is the 15 miles of the river from Lees Ferry upstream to Glen Canyon Dam. Fisherman also utilize the section of the river downstream of Lees Ferry to about Jackass Canyon for shore fishing, as well as other hike in sites downstream, such as Soap Creek, Salt Creek, Houserock, and South Canyon. Removal in the PBR reach is likely to cause some level of disturbance to the angling community that shore fishes in this area, and a reduction in fish numbers may also affect catch rates for these anglers. The primary aspect of disturbance would be in the form noise and visual intrusion from boats launching from Lees Ferry either to perform short duration PBR removal trips, or to engage longer-term LCR removal trips, and from electrofishing operations in the Lees Ferry Reach (i.e. noise from boat motors and generators, and lights).

3.4.2.2 Recreational Boating under Proposed Action

For PBR reach removal, each trip is anticipated to take place over up to 12 nights. Researchers would be land-based with no riverside camping, and boats would launch for nightly work late in the day, after recreational trips have launched and traveled downstream. The work would take place between the Paria River and Badger Rapids only. Boats would return to Lees Ferry at the conclusion of their nightly work. Care would be taken to avoid disturbance to walk-in recreationists and anglers at the Paria River confluence beach. For LCR reach removal trips, duration would likely be several weeks, with removal teams camped and working in the LCR reach for approximately two weeks

An important part of the recreational experience enjoyed by visitors to Grand Canyon National Park is the opportunity to be in a wilderness setting with minimal contact with other people and few sights and sounds associated with human activities. Non-native fish removal activities have the potential to disturb the wilderness experience for others, particularly those rafting the river, or hiking and camping near the river. These impacts include the noise and lights associated with removal actions, especially when they occur at night, the competition for camping sites along the river, and the simple presence of more people on the river.

The SDM Project analysis utilized an NPS metric for the purpose of evaluating non-native fish control methods. Penalized user-days per year in the GCNP wilderness during administrative trips were used to assess this affect, an NPS metric. Penalized user-days per year is calculated by using the staff size (number of people on a river trip administering science, in this case, non-native removal) multiplied by the number of days in the wilderness (this is the basic measure); this is adjusted by a penalty factor multiplier for activities that result in greater disturbance. Penalty factors include: boat (motor) user-days during motor season, penalty factor of 1 as a multiplier; boat (motor) user-days during non-motor season, 2; helicopter trips, 2; nighttime management activities, 3. Thus, for example, a 14-day removal trip with a staff of 8, conducted by boat during the non-motor season, with management activities primarily at night would have a score of 672 penalized user-days (14 days x 8 users x 2 [non-motor multiplier] x 3 [night multiplier]). If helicopter removal of live fish was required, with, say, 2 trips daily for 8 of the 14 days, an additional 32 penalized user-days (2 trips/day x 8 days x 2 [helicopter penalty multiplier]) would be added. The number of boats is not included in the calculation; presumably the number of users is tied to the number of boats. The proposed action scored poorly in this category, with 6,824 penalized-user days. This is understandable because of the amount of effort using motorized boats to remove non-native fish in two different areas of the parks.

Noise from outboard motors and gas generators would occur and the presence of researchers would add more people to the PBR reach and the LCR reach when removal activities are occurring. This alternative would result in direct, short-term, effects on wilderness character due to noise and visual intrusion. Despite the fact the SDM Project found that there would be disturbance effects to recreation from the proposed action in terms of increased disturbance, and that this effect would be substantial, these effects were minimal in terms of economic effects; in other words, the disturbance effects from the proposed action are not expected to affect the actual number of visitors to GCNP for wilderness or recreational rafter experiences. Also, despite the fact that these actions would result in disturbance to members of the public utilizing these areas for recreation, the area of disturbance in the removal reaches is comparatively small relative to that available to recreation within the parks.

The effects would be different for the PBR reach than for the LCR reach. The PBR reach includes 4 miles of wilderness (50% of reach) while the LCR includes 100% wilderness. In addition, very little hiking and riverside camping occurs in the first 8 miles, and overnight camping is not permitted in the first 4 miles (to Navajo Bridge). The effects would be of moderate intensity for visitors camping in the LCR reach, and of minor intensity for visitors rafting in the PBR reach. The effects are not negligible. Effects would be on wilderness character and experience and include intrusion to site, sound, and smell (gasoline), especially when these activities occur during the non-motorized boating season.

3.4.2.3 Net Economic Use Value of Recreation under Proposed Action

Angling in Glen Canyon National Recreation Area (Lees Ferry) provides economic benefits to local economies, particularly in the areas of Vermilion Cliffs, Page, and Flagstaff, Arizona, and Kanab and surrounding areas of southern Utah. These economic and social benefits are to both small rural communities and to the region. A number of businesses (lodges, restaurants, guides, outfitters, and others) and individuals derive their income from anglers who have come to Marble Canyon for the fishing experience. Economic benefits are associated with factors such as the number of days anglers visit the area, and the number of white water rafting trips that occur in a given year.

A key aspect of economic benefits from visitation to the area is associated with wilderness and park experiences. Grand Canyon National Park provides benefits to both local and regional economies, and, with regard to non-native fish control, businesses that could be affected such as those associated with wilderness recreation that originates at Lees Ferry, such as recreational rafting. Non-native fish control would affect the experience of wilderness recreation, but in the SDM Project, the affect of disturbance from removal activities of the proposed action was not anticipated to affect the economic value derived from recreational rafting.

The proposed action would result in impacts to local economies resulting from effects, or perceived effects by the public, resulting from the disturbance to visitors to GCNRA or GCNP to fish, hike, boat, or otherwise recreate in these parks. In the SDM Project, although substantial disturbance effects to white water boaters were recognized, this was estimated to have no effect on the contribution of white water rafting to local and regional economies.

The effect of the proposed action on the contribution of fishing in the Lees Ferry area is less clear. The proposed action is not anticipated to have an effect on the fishery itself, but would, as described in previous sections, result in disturbance effects to local anglers. This could result in less fishing activity in Lees Ferry, although this seems unlikely, given that there is some distance between the PBR reach and areas commonly fished in Lees Ferry. However, if fishing user days are affected, this could negatively affect local businesses that benefit from fishing in Lees Ferry, the fishing guides, local area businesses, and the Navajo Nation vendors. The local fishing guides informed Recreation that they believe their business has been affected directly by Reclamation's actions in the past (predominantly flow manipulations associated with HFEs). Data provided by the guides do indicate that their business has diminished in recent years (Figure 9). Conversely, removing fish in the PBR reach, if it reduces abundances in the Lees Ferry reach, could improve the quality of the Lees Ferry fishery by creating a fishery with fewer but larger, healthier fish. This could positively affect local businesses if the improvement in the fishery results in more anglers visiting the area.

Local businesses in the Marble Canyon area may also benefit from increased business resulting from researchers and technicians working in the PBR reach to remove non-native fish, as these individuals would likely use lodging in the area, eat meals at local restaurants, and purchase fuel and equipment in local stores.

Figure 9. Numbers of anglers served by one fishing guide business.

3.4.2.4 Nonuse Economic Value under Proposed Action

There are different possible outcomes in terms of nonuse on values from the proposed action that are difficult to predict. If the public at large values the improvement in the native ecosystem that the non-native fish control would likely bring about, then nonuse values could benefit. This seems plausible, given that the natural beauty and native wilderness are values for which GCNP and GLNRA were established, and NPS management policies support removing non-native fish from the GCNP.

The Hopi Tribe believes that its cultural values for the Grand Canyon should be considered within the Western analysis framework as non-use values. Management actions that occur there can have effects at Hopi that do not depend on whether Hopi people enter (use) the Grand Canyon or not. The proposed action would have effects to Hopi non-use values as described in section 3.3.

3.5 *Indian Trust Assets*

Indian trust assets are legal interests in property held in trust by the US government for Indian tribes or individuals. Examples of such resources are lands, minerals, or water rights. The action area is bounded on the east by the Navajo Indian Reservation and on the south in part by the Hualapai Indian Reservation and the Havasupai Indian Reservation. Reservation land is a trust asset.

3.5.1 *Indian Trust Assets under No Action*

Reclamation has ongoing consultation with these tribes regarding potential effects of the proposed action on their trust assets. The no action alternative would have no effect on Indian trust assets.

3.5.2 *Indian Trust Assets under the Proposed Action*

The proposed action, with its focus on the Colorado River itself and on lands managed by the NPS would not impact Indian lands, minerals, or water rights. There is a possibility that the related science plan and future monitoring efforts would require access to Navajo Nation lands, particularly those in the LCR. All necessary consultations, permits and permissions would be obtained from the BIA and Navajo Nation prior to undertaking any work on Navajo lands. Removing non-native sport fish could affect the Indian trust asset of sport fish in the areas of the action area with tribal waters by potentially reducing sport fish populations in these systems, such as the Little Colorado River on Navajo Nation lands.

3.6 *Wild and Scenic Rivers*

Wild and scenic rivers were not noted as an evaluation need during development of this EA, but is considered here as an issue per 16 USC 1271 and 40 CFR 1508.27(b)(3). The Wild and Scenic Rivers Act of 1969 calls for preservation and protection of free-flowing rivers. Pursuant to §5(d) of the Wild and Scenic Rivers Act, the NPS maintains a nationwide inventory of river segments that potentially qualify as wild, scenic, or recreational rivers. Within the action area, overlapping study segments have been proposed: (1) from the Paria Riffle (RM 1) to 237-Mile Rapid in Grand Canyon, and (2) from Glen Canyon Dam (RM -15) to Lake Mead. Grand Canyon National Park (National Park Service 1995, 2005b:18) acknowledges that the Colorado River meets the criteria for designation under the Wild and Scenic Rivers Act as part of the nationwide system; however, formal study and designation have not been completed.

3.7 *Wilderness*

Pursuant to the 1964 Wilderness Act, Grand Canyon National Park was evaluated for wilderness suitability. After the park was enlarged in 1975, Grand Canyon's Wilderness Recommendation was updated following a study of the new park lands. The most recent update of Grand Canyon's Wilderness Recommendation occurred in 2010. Grand Canyon National Park proposed Wilderness or proposed potential Wilderness covers 94 percent of the park. In accordance with NPS Management Policies, these areas are managed in the same manner as designated wilderness, and the NPS will take no action to diminish wilderness suitability while awaiting the legislative process.

The issue of effects to wilderness was evaluated in the SDM Project. The analysis for wilderness experience in this EA is contained in section 3.12.2 above. In addition to a wilderness experience as defined by the Wilderness Act as "outstanding opportunities for solitude or a primitive and unconfined type of experience," the Act also defines wilderness character as "untrammeled," undeveloped land retaining its "undeveloped land retaining primeval character in influence without permanent improvements or human habitation.

The No Action will continue to have a long-term adverse impact to wilderness character by allowing non-native populations to increase and as endangered populations decline.

The Proposed Action would have varying effects on other qualities and characteristics of wilderness depending upon implementation in the PBR or LCR. These would be of similar intensity described in 3.12.2 for wilderness character, but overall the proposed action would have long-term beneficial effects to wilderness by implementing actions to improve conditions for native species.

3.8 *Environmental Justice Implications under No Action*

Environmental justice refers to those issues resulting from a proposed action that disproportionately affects minority or low-income populations. To implement Executive Order 12898, *Environmental Justice in Minority Populations and Low Income Populations*, the Council on Environmental Quality (1997) instructs agencies to determine whether minority or low-income populations or Indian tribes might be affected by a proposed action, and if so, whether there might be disproportionate high and adverse human health or environmental effects on them. There would be no Environmental Justice impacts from the no action alternative.

3.9 *Environmental Justice Implications under the Proposed Action*

Coconino County Arizona has a disproportionate number of low income populations per the 2000 U.S. Census data. Reviewing each of the resources affected by the proposed action, there would be no human health effects. There would be environmental effects but these would not be disproportional high and adverse with one exception. American Indian tribes consider the proposed action to have a substantial effect on their sacred sites and traditional cultural properties. Also, the local Navajo community, especially those living in the Bodeway-Gap Chapter, uses trout as a subsistence resource. Removal of trout could result in a reduction in catch rates in portions of the action area. Alternatively, removal of trout may also improve the overall fishery by improving population dynamics of the population, and increasing the number of larger healthier trout. Regardless, these impacts would occur to all anglers equally, thus not resulting in a high and disproportionate adverse effect to minority populations. We do not anticipate any other Environmental Justice impacts from the proposed action.

4.0 Consultation and Coordination

The 1995 EIS and 1996 Record of Decision called for an adaptive management approach to the management of the dam and powerplant. Since then, monitoring and research has substantially increased knowledge of the effects of dam operations on resources downstream in GCNP and GCNRA, including knowledge of effects to native and non-native fishes in the Colorado River downstream from the dam. Pursuant to the Grand Canyon Protection Act, the Colorado River Storage Project Act, and the other federal laws and regulations, this new EA should add to this knowledge and understanding.

4.1 *Consultation*

Tribal consultations on a government-to-government basis are ongoing and will be completed before a decision notice is completed for the proposed action.

4.2 *Public Scoping Activities*

Based on the previous experiments and before beginning preparation of this EA, a wide variety of people were contacted to get their ideas and concerns about the status of endangered fish in the Colorado River and possible treatments to reduce numbers of non-native fish, as well as the anticipated effects of these treatments. The Grand Canyon Monitoring and Research Center convened and conducted a Non-native Fish Workshop on March 30-31, 2010, to: (1) Describe non-native fish management in Grand Canyon, (2) identify critical issues and develop approaches to these issues, describe American Indian perspectives on management of native and non-native fish species, and (3) describe agency roles for non-native control in conservation and recovery of native fish in Grand Canyon. An integrated modeling workshop held April 14-15, 2010 and on October 12-15, 2010 helped to clarify the role of trout predation on the humpback chub and preliminarily identified possible strategies and treatments for managing trout populations in Grand Canyon. Reclamation also held two meetings with flyfishing guides regarding the proposal on March 20, August 20, and December 20, 2010. Reclamation and the USGS also conducted a Structured Decision Making Project with two workshops, October 18-20 and November 8-10, 2010.

The draft EA was published on January 18, 2011 for a 30-day public review and comment period. In response to requests from the interested public, the comment period was extended to March 18, 2011. Thirty-five comment letters or emails were received and were fully considered in making revisions to the draft EA. This revised draft EA is being circulated again for a two-week public review and comment in July 2011 in order to provide the interested public the opportunity to review revisions to the previously published draft EA.

4.3 *Agency Cooperation*

Table 6. List of persons, agencies, and organizations consulted for purposes of this EA.

Name	Purpose & Authorities for Consultation or Coordination	Findings & Conclusions
Arizona Game & Fish	Consult with AZGFD as agency with expertise on fish and game species.	Data and analyses with respect to trout, fish, etc.
Arizona State Historic Preservation Officer	Consult for undertaking, as required by NHPA (16 USC 470)	Pending, but assume eligibility and adverse effect under NHPA
Bodeway-Gap Chapter of the Navajo Nation	Minority community for environmental justice and economic effects	
Bureau of Indian Affairs	Consult with BIA over Indian trust assets and other American Indian tribal concerns	Adverse effect under EO 13007
Coconino County	Air quality data and concerns with economics and environmental justice	
Hualapai Indian Tribe	Consult regarding land and resource effects, consult with THPO over NHPA	Pending
Kaibab Band of Paiute Indians	Consultation as required by the American Indian Religious Freedom Act of 1978 (42 USC 1531) and NHPA (16 USC 1531) and EO 13007	Pending
Marble Canyon and Lees Ferry Community	Recreational and economic effects	
National Park Service	Land managing agency for GLCA and GRNP	
Navajo Nation	Consult regarding land and resource effects, consult with THPO over NHPA. Project might require permits to access land.	Pending
Paiute Indian Tribe of Utah	Consultation as required by the American Indian Religious Freedom Act of 1978 (42 USC 1531) and NHPA (16 USC 1531) and EO 13007	Pending
Pueblo of Zuni	Consultation as required by the American Indian Religious Freedom Act of 1978 (42 USC 1531) and NHPA (16 USC 1531) and EO 13007	Pending
U.S. Geological Survey	Information regarding resources. Figure 1 provided.	
U.S. Fish and Wildlife Service	Consult with USFWS as an agency with expertise on fish and wildlife resources, including endangered species, under the ESA	Data and analysis with respect to aquatic ecosystem and ESA compliance.
Western Area Power Administration	Information regarding hydropower and environmental justice	

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6.0 APPENDICES

Appendix A: Non-native Fish Management below the Glen Canyon Dam Report from a Structured Decision Making Project

Non-Native Fish Control below Glen Canyon Dam—Report from a Structured Decision-Making Project

Open-File Report 2011–1012

U.S. Department of the Interior
U.S. Geological Survey

Non-Native Fish Control below Glen Canyon Dam—Report from a Structured Decision-Making Project

By Michael C. Runge[1], Ellen Bean[1], David R. Smith[2], and Sonja Kokos[3]

Open-File Report 2011–1012

U.S. Department of the Interior
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Conversion Factors and Abbreviations

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).
Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).
Altitude, as used in this report, refers to distance above the vertical datum.

Abbreviations Used

AMWG	Adaptive Management Working Group
AZGF	Arizona Game and Fish Department
BIA	Bureau of Indian Affairs, Department of the Interior
BNT	Brown trout (*Salmo trutta*)
CRSP	Colorado River Storage Project
DOI	U.S. Department of the Interior
EA	Environmental Assessment
ESA	Endangered Species Act of 1973
EVPI	Expected value of perfect information
GCDAMP	Glen Canyon Dam Adaptive Management Program
GCMRC	Grand Canyon Monitoring & Research Center, U.S. Geological Survey
GCNP	Grand Canyon National Park, National Park Service
GCNRA	Glen Canyon National Recreation Area, National Park Service
GCPA	Grand Canyon Protection Act of 1992
HBC	Humpback chub (*Gila cypha*)
HFE	High-flow experiment
LCR	Little Colorado River
MLFF	Modified Low Fluctuating Flow
NEPA	National Environmental Protection Act
NHPA	National Historic Preservation Act of 1966
NPS	National Park Service, Department of the Interior
PBR	Paria to Badger reach, Colorado River
RBT	Rainbow trout (*Onchorhynchus mykiss*)
Reclamation	Bureau of Reclamation, Department of the Interior
RM	River mile (location along the Colorado River, relative to Lees Ferry)
ROD	1996 Record of Decision
SDM	Structured decision making
Service	U.S. Fish and Wildlife Service, Department of the Interior
USGS	U.S. Geological Survey, Department of the Interior
WAPA	Western Area Power Administration, Department of Energy

Non-Native Fish Control below Glen Canyon Dam—Report from a Structured Decision-Making Project

By Michael C. Runge[4], Ellen Bean[4], David R. Smith[5], and Sonja Kokos[6]

1. Abstract

This report describes the results of a structured decision-making project by the U.S. Geological Survey to provide substantive input to the Bureau of Reclamation (Reclamation) for use in the preparation of an Environmental Assessment concerning control of non-native fish below Glen Canyon Dam. A forum was created to allow the diverse cooperating agencies and Tribes to discuss, expand, and articulate their respective values; to develop and evaluate a broad set of potential control alternatives using the best available science; and to define individual preferences of each group on how to manage the inherent trade-offs in this non-native fish control problem.

This project consisted of two face-to-face workshops, held in Mesa, Arizona, October 18–20 and November 8–10, 2010. At the first workshop, a diverse set of objectives was discussed, which represented the range of concerns of those agencies and Tribes present. A set of non-native fish control alternatives ("hybrid portfolios") was also developed. Over the 2-week period between the two workshops, four assessment teams worked to evaluate the control alternatives against the array of objectives. At the second workshop, the results of the assessment teams were presented. Multi-criteria decision analysis methods were used to examine the trade-offs inherent in the problem, and allowed the participating agencies and Tribes to express their individual judgments about how those trade-offs should best be managed in Reclamation's selection of a preferred alternative.

A broad array of objectives was identified and defined, and an effort was made to understand how these objectives are likely to be achieved by a variety of strategies. In general, the objectives reflected desired future conditions over 30 years. A rich set of alternative approaches was developed, and the complex structure of those alternatives was documented. Multi-criteria decision analysis methods allowed the evaluation of those alternatives against the array of objectives, with the values of individual agencies and tribes deliberately preserved.

Trout removal strategies aimed at the Paria to Badger Rapid reach (PBR), with a variety of permutations in deference to cultural values, and with backup removal at the Little Colorado River reach (LCR) if necessary, were identified as top-ranking portfolios for all agencies and Tribes. These PBR/LCR removal portfolios outperformed LCR-only removal portfolios, for cultural reasons and for effectiveness—the probability of keeping the humpback chub population above a desired threshold was estimated to be higher under the PBR/LCR portfolios than the LCR-only portfolios. The PBR/LCR removal portfolios also outperformed portfolios based on flow manipulations, primarily because of the

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effect of sport fishery and wilderness recreation objectives, as well as cultural objectives. The preference for the PBR/LCR removal portfolios was quite robust to variation in the objective weights and to uncertainty about the underlying dynamics, at least over the ranges of uncertainty investigated.

Examination of the effect of uncertainty on the recommended outcomes allowed us to complete a "value of information" analysis. The results of this analysis led to an adaptive strategy that includes three possible long-term management actions (no action; LCR removal; or PBR removal) and seeks to reduce uncertainty about the following two issues: the degree to which rainbow trout limit chub populations, and the effectiveness of PBR removal to reduce trout emigration downstream into Marble and eastern Grand Canyons, where the largest population of humpback chub exist. In the face of uncertainty about the effectiveness of PBR removal, a case might be made for including flow manipulations in an adaptive strategy, but formal analysis of this case was not conducted.

The full set of conclusions described above is not definitive, however. This analysis described in this report is a simplified depiction of the true decision; it is only meant to aid decision-makers by helping them see the structure of the problem, not to make the decision for them. This analysis can best be used as a starting point for the deliberative consultations that will lead to the final decision. In particular, this structured decision-making process will be useful to the Department of the Interior (DOI) as it undertakes an analysis of removal strategies under the National Environmental Policy Act.

2. Introduction

The Glen Canyon Dam is located on the Colorado River in Arizona, USA, upstream of Grand Canyon National Park (fig. 1), and is managed by the Bureau of Reclamation (Reclamation). The Glen Canyon Dam Adaptive Management Program (GCDAMP) was established in 1997 to provide input to Reclamation and the DOI on the effects to the downstream ecosystem resulting from operation of the dam. The GCDAMP project area stretches along the Colorado River from the forebay of Glen Canyon Dam to the westernmost boundary of Grand Canyon National Park (this area is henceforth referred to as "the Canyon"). Locations along the river are indexed by river miles (RM), with a reference point at Lees Ferry (RM 0). The dam itself is at RM −15.5 (15.5 mi upstream of Lees Ferry). Other important locations that are referenced in this report include the following: Paria River (RM 1.0), Badger River (RM 8.0), Little Colorado River (RM 61.4), and Bright Angel Creek (RM 87.8). The reach from Lees Ferry to the Little Colorado River is known as Marble Canyon; Grand Canyon proper begins at the Little Colorado River.

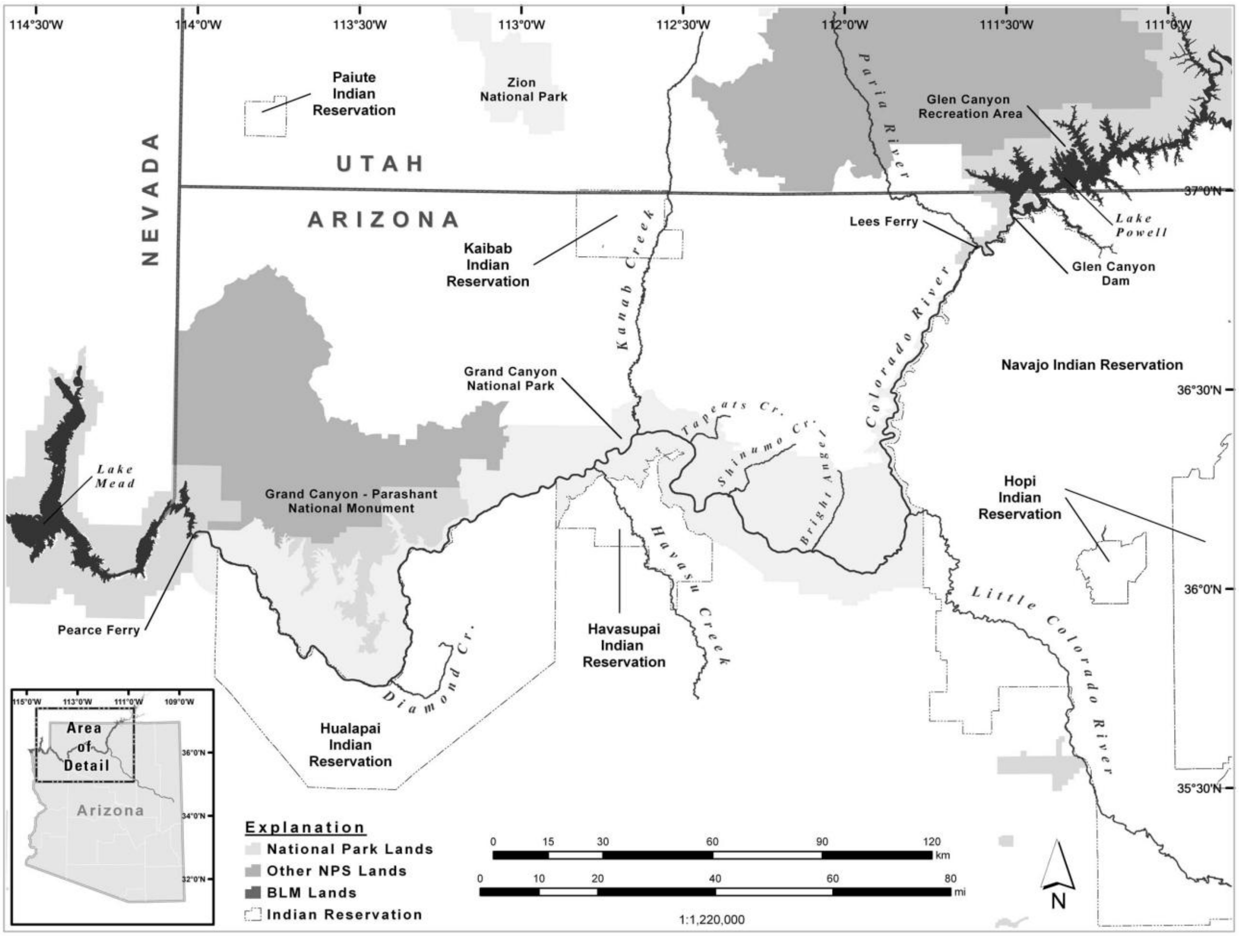

Figure 1. Location map of the Colorado River ecosystem below Glen Canyon Dam, depicting the Glen Canyon Dam Adaptive Management Program project area. The analysis described in this report focuses primarily on the Colorado River from Glen Canyon Dam to Bright Angel Creek. Map credit: Thomas Gushue, U.S. Geological Survey.

In the 2008 Biological Opinion on Reclamation's proposed experimental dam operations for Glen Canyon Dam, the U.S. Fish and Wildlife Service (Service) found that the actions may affect humpback chub (*Gila cypha*), an endangered fish, and Kanab ambersnail (*Oxyloma haydeni kanabensis*), an endangered land snail. As part of this Biological Opinion, the Service included non-native fish control as a conservation measure, to address the threat to humpback chub posed by rainbow trout (*Onchorhynchus mykiss*) and brown trout (*Salmo trutta*). Mechanical removal of trout at the confluence of the Colorado River and Little Colorado River (LCR) was experimentally implemented in 2003–06, and was shown to be effective at controlling trout populations (Coggins, 2008; Coggins and Yard, 2010; Coggins and Yard, in press). An increase in humpback chub adult abundance was observed over the same period of time, but the causal connection is in dispute. In accordance with the 2008 Biological Opinion, one additional mechanical removal trip in the LCR treatment reach occurred in spring 2009.

Several Native American Tribes raised serious concerns about the lethal removal of thousands of fish from the treatment reach, an area sacred to the Tribes and fundamental to their religious beliefs and ceremonies. In response to this concern, Reclamation decided to forego planned mechanical removal in 2010 and initiated a National Environmental Protection Act (NEPA) process that would use an Environmental Assessment (EA) to evaluate alternative methods for non-native fish control.

There are a number of cooperating agencies and Tribes interested in this EA process. Reclamation is responsible for operation of Glen Canyon Dam and is the decision-making agency for this non-native fish control EA. The Service is responsible for administering the Endangered Species Act (ESA), including recovery of the humpback chub; and the Fish and Wildlife Coordination Act for conservation of fish and wildlife resources. The National Park Service (NPS) administers both the Grand Canyon National Park (GCNP) and the Glen Canyon National Recreation Area (GCNRA), and is responsible for trust resources and public recreation in those areas. The Bureau of Indian Affairs (BIA) has a trust responsibility to the Tribes. The Western Area Power Administration (WAPA) is responsible for marketing and delivery of power generated by the dam. The Arizona Game and Fish Department (AZGF) regulates sport fishing statewide, including rainbow trout in the Lees Ferry tailwaters reach and rainbow and brown trout throughout the Canyon. For the Pueblo of Zuni, the LCR, and its confluence with the Colorado River, are sacred places and tied to their accounts of creation. The non-beneficial destruction of life is of grave concern to them. For the Hopi Tribe, the entire Grand Canyon and especially the LCR are deeply sacred areas. Further, they agreed, when they emerged into this world, to be caretakers of the Canyon. Lands of the Navajo Nation and the Hualapai Tribe border the Colorado River, with the reservations of the two Kaibab Bands of Paiute Indians nearby. All of these Tribes have an interest in the management of resources. The U.S. Geological Survey (USGS) Grand Canyon Monitoring and Research Center (GCMRC) is responsible for scientific investigations that provide information to the GCDAMP about the status of key resources of the river below the dam, as well as ecosystem modeling that serves to help guide monitoring and experimental design decisions.

The problems related to non-native fish control are multi-faceted and complex. One problem is the many competing objectives within and among agencies and Tribes. Other problems are that all the management options have not been clearly defined and the ecological science about the effects of potential management alternatives on the natural resources is uncertain. Also there is uncertainty about the effects of potential management alternatives on cultural resources.

The Assistant Secretary of the Interior for Water and Science, in a letter to the Adaptive Management Working Group dated September 17, 2010, asked that Reclamation undertake a Structured Decision Making (SDM) process to evaluate options for non-native fish control, as an additional means by which the cooperating agencies and Tribes could submit their input to Reclamation as it prepares its EA (appendix 1).

2.1. Purpose

The purpose of this report is to describe a structured approach developed by the U.S. Geological Surevey (USGS), to develop and provide substantive input to Reclamation for use in preparation of an EA concerning management of non-native fish below Glen Canyon Dam. The structured approach provided a forum for the diverse cooperating agencies and Tribes to discuss, expand, and express their respective values; to develop and evaluate a broad set of potential non-native fish control alternatives using the best available science; and to indicate how they would individually prefer to manage the inherent trade-offs in this resource management problem.

This structured approach has two important facets: it promotes value-focused thinking, that is, an emphasis on the values that underlie a decision; and it uses problem decomposition to disentangle the complicated scientific and policy elements of a decision. The intended methods for this structured approach include multi-criteria decision analysis (Hammond and others, 1999), an approach for understanding how decision alternatives affect the achievement of an array of multiple objectives.

Two workshops were held in Mesa, Arizona prior to release of the draft EA for public comment. At the first workshop, objectives were defined and alternative fish control strategies (called "portfolios" throughout this report) created. Between the first and second workshops, four assessment teams evaluated the portfolios against the individual objectives. At the second workshop, representatives from the agencies and tribes weighted objectives, and a preliminary analysis of the decision was completed. This preliminary analysis led to insights about objectives, alternatives, and consequences; as a result, a number of modifications to the analysis were requested. A consolidated list of alternatives was carried forward in the final analysis.

2.2. Legal and Regulatory Context

Reclamation proposes to control non-native fish in the Colorado River downstream of Glen Canyon Dam to ensure that its operations do not jeopardize the continued existence of endangered native species. Since passage of the ESA and its implementing regulations (50 CFR 402), Reclamation has consulted with the Service to ensure that its operation of Glen Canyon Dam does not jeopardize the continued existence of the endangered endemic Colorado River fishes—humpback chub and razorback sucker (*Xyrauchen texanus*)—or destroy or adversely modify their designated critical habitat. Colorado pikeminnow (*Ptychocheilus lucius*) and bonytail chub (*Gila elegans*) are no longer found in this reach of the Colorado River and are not included in this assessment. One of six populations of humpback chub occurs in the GCDAMP project area (fig. 1) and the razorback sucker occurs immediately downstream of the project area.

Critical habitat for these fishes was designated by the Service in 1994 (50 CFR 17) and includes areas in Marble and Grand Canyons. For humpback chub, critical habitat extends for 175 mi of the Colorado River from Nautiloid Canyon (RM 34) to Granite Park (RM 209) and the lower 8 mi of the LCR. Critical habitat for razorback sucker extends for 234 mi of the Colorado River from the Paria River confluence (RM 1) to the Lake Mead inflow at maximum pool (RM 235). These reaches of designated critical habitat lie within the boundaries of GCNRA and GCNP and are managed by NPS.

Reclamation and the Service have agreed that controlling the numbers of non-native fish would serve as a conservation measure for Reclamation's dam operations. Non-native fish control was identified as a conservation measure in the February 27, 2008, Final Biological Opinion on the Operation of Glen Canyon Dam (U.S. Fish and Wildlife Service, 2008, consultation number 22410-1993-F-167R1), and the October 29, 2009, Supplement to the 2008 Final Biological Opinion for the Operation of Glen Canyon Dam (U.S. Fish and Wildlife Service, 2009, consultation number 22410-1993-F-167R1). Control of non-native fish species in Marble and Grand Canyons is also part of the conservation measures identified in the 2007 Biological Opinion for the Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operation for Lake Powell and Lake Mead (U.S. Fish and Wildlife Service, 2007, consultation number 22410-2006-F-0224). A fourth biological opinion on the cancellation of nonnative mechanical removal trips in 2010 was issued on November 9, 2010 (U.S. Fish and Wildlife Service, 2010, consultation number 22410-1993-F-167R2), and required as a term and condition that Reclamation

> "Resume nonnative control at the mouth of the LCR in 2011. Attempt to implement the program in a manner compatible with the interests of Tribes and other interested stakeholders.
>
> "AND/OR
>
> "Work with interested Tribes and other parties, expeditiously, to develop options that would move nonnative removal outside of LCR confluence tribal sacred areas in 2011, with the goal that nonnative removal of trout in sacred areas will be reserved for use only to ensure the upper incidental take level is not exceeded."

Once Reclamation accepted these conservation measures, implementation of non-native fish control became a part of proposed action, although there is discretion in exactly where, when, and how non-native fish control is conducted.

Reclamation is serving as the lead Federal agency in this action because it has operational authority over Glen Canyon Dam and it has agreed to the terms of the biological opinions issued by the Service. Reclamation's implementation of additional non-native control measures during 2011–12 (and potentially additional periods) will be analyzed through the ongoing NEPA process and subsequent further ESA consultation. However, Reclamation's legal authority does not include direct management of Colorado River fishes. Agencies with such authority include AZGF, the state resource agency responsible for managing sport fish; NPS, the Federal land management agency responsible for the multitude of resources within GCNRA and GCNP; and the Service, under the ESA. In the biological opinions to Reclamation, these control actions need to be coordinated with other agencies, such as the Service, AZGF, and NPS, because of their responsibilities for managing aquatic and fishery resources in the Glen, Marble, and Grand Canyons.

Laws that govern Reclamation's actions and convey some of the values of the people of the United States as they pertain to ecological and cultural resources are numerous. The following paragraphs include a partial list of those laws.

> The ESA of 1973, as amended (16 USC 1531 *et seq.*), requires that all U.S. Federal agencies shall seek to conserve threatened and endangered species, and utilize their authorities in furtherance of the purposes of the ESA. Action agencies must implement Section 7 consultations with the Service to ensure that "…any action authorized, funded, or carried out by such an agency…is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of habitat of such species."
>
> The National Historic Preservation Act of 1966, as amended (NHPA, 16 USC 470 *et seq.*), requires Federal agencies to take into account the effects of their undertakings on historic properties. Historic properties are those that are included in, or eligible for inclusion in, the National Register of Historic Places. The NHPA makes specific provisions for inclusion of places of religious and cultural significance to Native American Tribes on the National Register.
>
> The Grand Canyon Protection Act of 1992 (GCPA, Pub. L. 102–575, title XVIII) requires the Secretary of Interior to operate Glen Canyon Dam "…in accordance with the additional criteria and operating plans specified in section 1804 and exercise other authorities under existing law in such a manner as to protect, mitigate adverse impacts to, and improve the values for which GCNP and GCNRA were established, including, but not limited to natural and cultural resources and visitor use."

As part of its ongoing implementation of the GCDAMP, which serves to implement obligations established by the GCPA, in late 2010 Reclamation was in the process of developing an EA for a high-flow experimental release protocol (separate from the non-native fish control EA), the purpose of which is to improve the natural resources of the Canyon through sandbar-building flows.

2.3. Ecological Context

Two goals of the Glen Canyon Dam Adaptive Management Working Group (AMWG) are to conserve endangered aquatic species, and to preserve native communities and ecological processes within the Colorado River. Ensuring the persistence of humpback chub is a core component of this mission, and requires a dual purpose research program to better understand humpback chub ecology and threats to the species persistence.

The presence of non-native fish is an acknowledged primary threat to native fish, and two introduced predatory species, rainbow trout and brown trout, are of particular concern. These species also may have indirect negative effects on humpback chub persistence by competing for resources and habitat. Dietary research (Yard and others, in press; Coggins and Yard, 2010) demonstrates that non-native trout prey upon humpback chub, with brown trout displaying higher rates of predation than rainbow trout. However, the potential benefit of reduced predation by rainbow trout is attenuated given the abundance of that species below the dam in Grand Canyon National Park (Makinster and others, 2010). Whereas preliminary evidence indicates that predation is an important limiting factor, the full extent to which trout limit humpback chub population growth and affect age-structure is unknown.

Beginning in January 2003, and continuing through August 2006, in response to a recommendation by the AMWG, Reclamation initiated an experimental research program to examine the potential effect on humpback chub recovery of reducing the population size of non-native fish. The site of the removal, the confluence of the LCR with the main stem of the Colorado River (fig. 1), is an important spawning and rearing area for humpback chub and other native species. All captured non-native fish were removed from the system. Results of the removal experiment are detailed in Coggins (2008), Coggins and Yard (2010), and Coggins and others (in press), but two key findings are relevant to the decision analysis, particularly to the impact of uncertainty on the decision process. Trout removals may have been effective in altering community level dynamics and in causing a simultaneous increase in native abundance along with juvenile survival and recruitment. The results are inconclusive, however, owing to a concurrent natural increase in river-wide temperatures resulting from drought in the Upper Colorado River Basin and decreased storage in Lake Powell that benefitted native fish ecology, and a system-wide decrease in rainbow trout abundance, possibly linked to changes in the aquatic food base. Another important factor that confounded the removal experiment is the high degree to which naturally occurring turbidity varies in the main channel in response to infrequent, but large tributary flooding from the Paria River (RM 1).

Whereas the results of the removal trials may have demonstrated a clear, direct link between trout abundance and humpback chub population persistence, further experimentation would be needed to tease apart other system level dynamics that could have contributed to adult humpback chub population increases observed since 2000 (Coggins and Walters, 2009). The predictive models used to assess consequences of the proposed portfolios incorporate this uncertainty. Other key areas of uncertainty considered relate to the effects of artificial floods released from the dam (high flow experiments intended to rebuild and maintain sandbars) on rainbow trout spawning; recruitment and adult population growth (Korman and others, 2010; Korman and others, in press; Makinster and others, 2010); and the efficacy of manipulating flow regimes to reduce trout survival and downstream emigration into Marble and Grand Canyons.

2.4. Cultural Context

The motivation for broadening the scope of the discussion of non-native fish control is to address concerns expressed by members of the AMWG, specifically its Tribal partners. Through formal and informal consultation, some Tribes have indicated that current practices that result in the massive taking of life present an unnecessary emotional, psychological, and spiritual burden on their communities.

As described by the Governor of Zuni,

> “the Grand Canyon figures as an extremely important place in the history, religion and culture of the Zuni people. The Grand Canyon is a vital component of the Zuni cultural landscape that contributes to the definition of who we are as a people.”

This sentiment has also been expressed by other participating Tribes, and highlights the profound relationship with, and deep respect for, the landscape that includes the Colorado River and its tributaries. Because of this relationship, some Tribes possess a strong sense of stewardship for the life found within the Canyon, including both native and non-native fish species. Large-scale lethal removal, especially in the face of perceived uncertainty regarding the effects of non-native fish on native fish, is a violation of this stewardship ethic.

Further, the location of the prescribed removal is primarily at the confluence of the LCR with the mainstem of the Colorado River, a place of great power and life-sustaining properties for many Tribal partners. Actions taken here, especially if coupled with lethal or otherwise disrespectful methods, can result in a disruption of the balance and interconnectedness within the universe.

3. Decision Framework

Reclamation’s Upper Colorado River Regional office is the sole decision-maker for this EA. Several agencies and Tribes are formal Cooperating Agencies for this EA (BIA, Service, NPS, WAPA, AZGD, GCMRC, Pueblo of Zuni, and Hualapai Tribe), and several additional Tribes have a strong vested interest (Hopi Tribe, Southern Paiute Consortium, and Navajo Nation). The decision analysis developed at these SDM workshops, and described in this report, is meant to allow the Cooperating Agencies and Tribes to provide substantive input to Reclamation as it considers its decision about a preferred alternative for non-native fish control below Glen Canyon Dam. This future action is being considered particularly in order to reduce the threat posed by non-native fish to humpback chub. The methods ultimately employed need to be within the jurisdiction of Reclamation.

Reclamation desires to release a draft EA to the public in January 2011, with consultation under section 7 of the ESA and a decision notice to be completed by March 1, 2011. The time frame of the actions proposed in the EA will be on the order of 5 years, but there is some recognition that the strategy employed may have longevity beyond that time. DOI is also in the process of conducting government-to-government tribal consultation on this action.

The decision in the EA is a one-time decision and a single preferred alternative needs to be identified and implemented for the period of time specified. But there is strong recognition that the preferred alternative may have state-dependent features in which certain components of the strategy may only be implemented if and when certain conditions are met. Further, the preferred alternative may also be adaptive, in that a range of strategies may need to be experimentally tested, to reduce uncertainty about the most effective strategies.

Thus, the decision problem can be characterized as one of multiple-objective trade-offs in the face of uncertainty, where the management actions are multi-faceted and possibly state-dependent, and where there may also be opportunities to reduce uncertainty early and improve management later through adaptive implementation.

4. Objectives

Defining values that affect a decision is an important first step in decision analysis. A commonly understood and comprehensive vision about the underlying values to guide future steps was an important first step for this project. This includes defining a set of standards that could be used to measure progress for each objective.

The first SDM workshop provided a structured framework for listening to all voices and incorporating each stakeholder's values into the decision process. Taken together, the objectives represent a range of values and perspectives that apply to the control of non-native fish in the lower Colorado River. For Federal and State agencies, these values arise from their respective missions, enabling legislation, regulatory responsibilities, and constituent concerns. For the Tribes, the values arise more directly from their cultural and spiritual traditions. The combined set of values provides, in part, the necessary guidance for making an informed and defensible choice of a preferred alternative for non-native fish control and underscores the aspects of the decision that matter.

Four main categories of decision-making objectives were identified (Keeney, 2007). *Fundamental objectives* are sometimes described as the "bottom line," or core concern, and can be identified when the question of "why is this important" concludes with "simply because" or "it just is". *Means objectives* are often methodological and describe an intermediary step in reaching a fundamental objective, in other words they address the "how." Means objectives are not important in and of themselves, but only insofar as they help achieve the fundamental objectives. *Process objectives* describe the ground rules for the decision process itself. For example, within the context of this workshop, we established open and consultative communication as an objective that would be adhered to throughout. Similarly, any proposed objectives or actions would need to comply with the large regulatory framework under which all the cooperating agencies and Tribes operate. *Strategic objectives* are objectives that are fundamental to a broader set of decisions than the one in question; they cannot be solely attained by the decision at hand, but there can be a contribution to them. Often strategic objectives are tied to linked decisions and broader mandates of the decision makers.

The focus of this section of the report is on the fundamental objectives, as these make explicit the key concerns of the lead and cooperating agencies as well as the Tribal groups. Although certain stakeholder groups (for example, sport fisheries and recreational user groups) were not formally represented within the official cooperating partners, their concerns were included by soliciting information from knowledgeable agency partners (especially, AZGF and NPS). Plenary and small group formats were implemented to discuss and craft the set of objectives. Through a deliberative process, the group worked to distinguish between the various types of objectives, as well as to eliminate redundant objectives and to consolidate similarly defined objectives.

Four broad classes of fundamental objectives were identified after much discussion. These classes summarize (1) the cultural and spiritual dimensions of the non-native fish control issue, (2) ecological aspects including both species and ecosystem level components, (3) recreational interests and uses, and (4) operational and economic components of the issue (fig. 2). A fifth class of objectives was identified between the two workshops; these are strategic objectives that concern the authority, jurisdiction, and legal responsibilities of Reclamation. In the analysis, these objectives will not be traded-off against other objectives, rather, they will serve to screen for admissible non-native fish control alternatives.

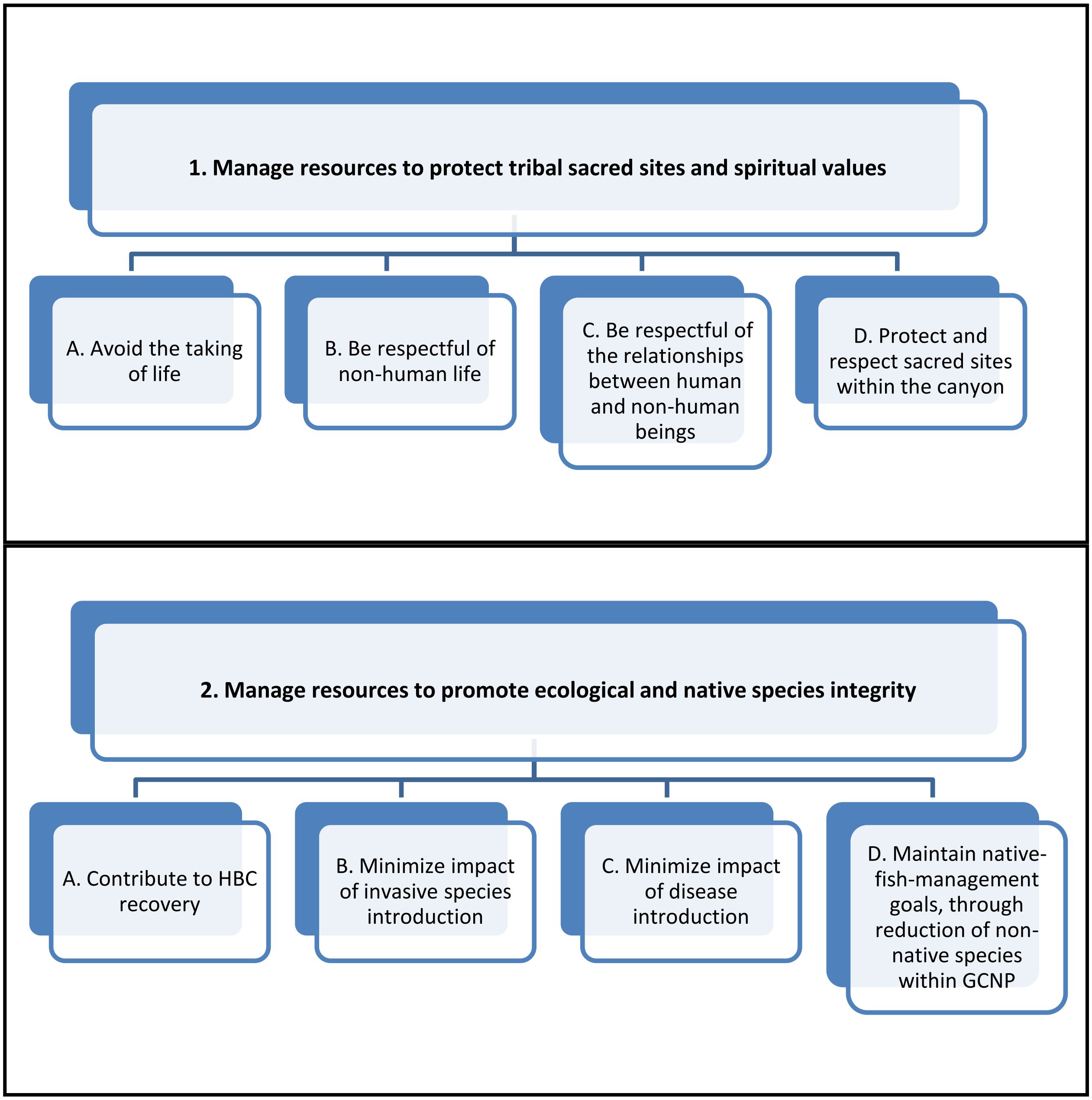

Figure 2. Hierarchy of fundamental objectives for non-native fish control below Glen Canyon Dam. HBC, humpback chub; GCNP, Grand Canyon National Park; GCNRA, Glen Canyon National Recreation Area; Reclamation, Bureau of Reclamation; HFE, high-flow experiment; NHPA, National Historic Preservation Act.

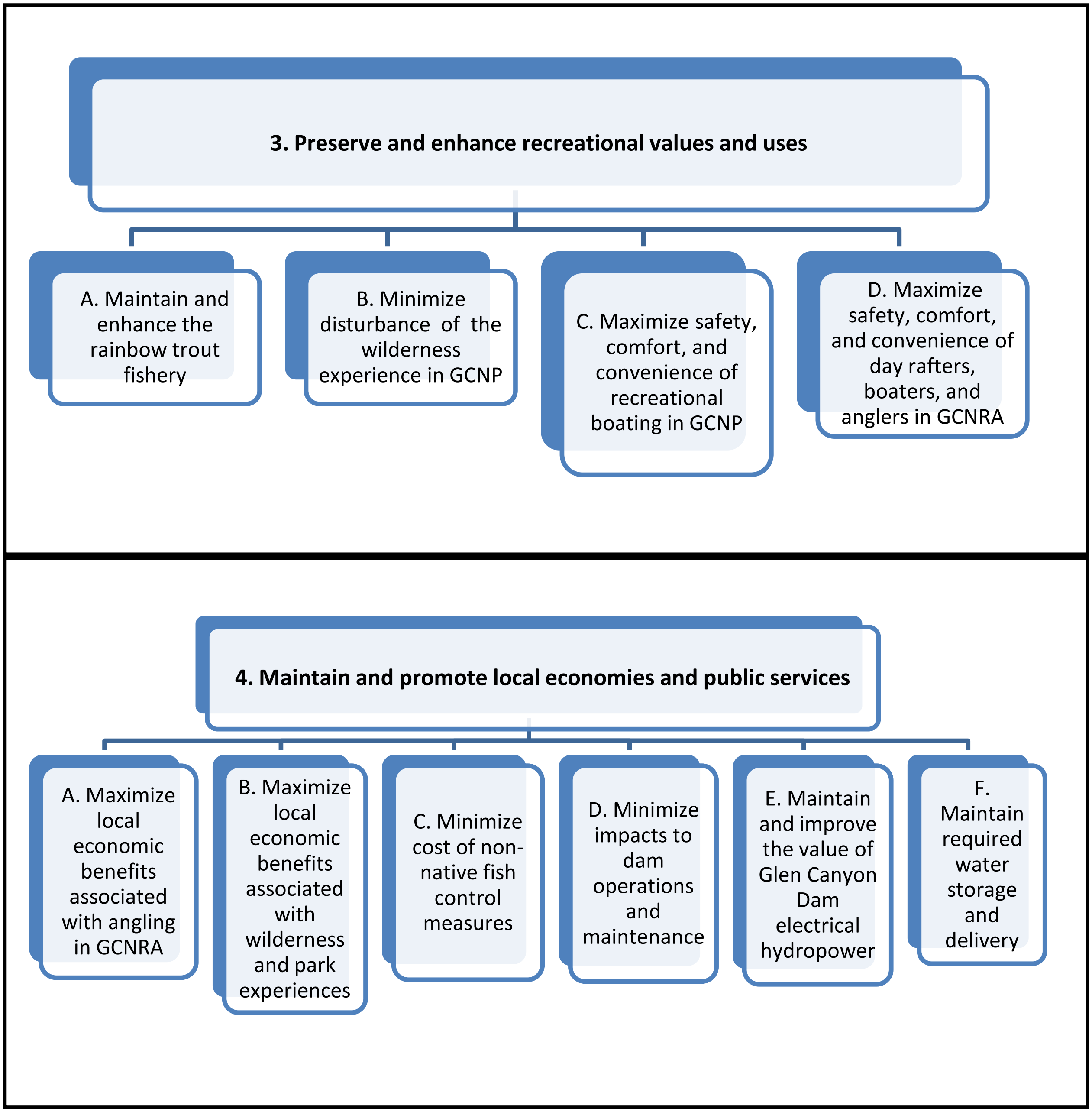

Figure 2. Hierarchy of fundamental objectives for non-native fish control below Glen Canyon Dam.—Continued

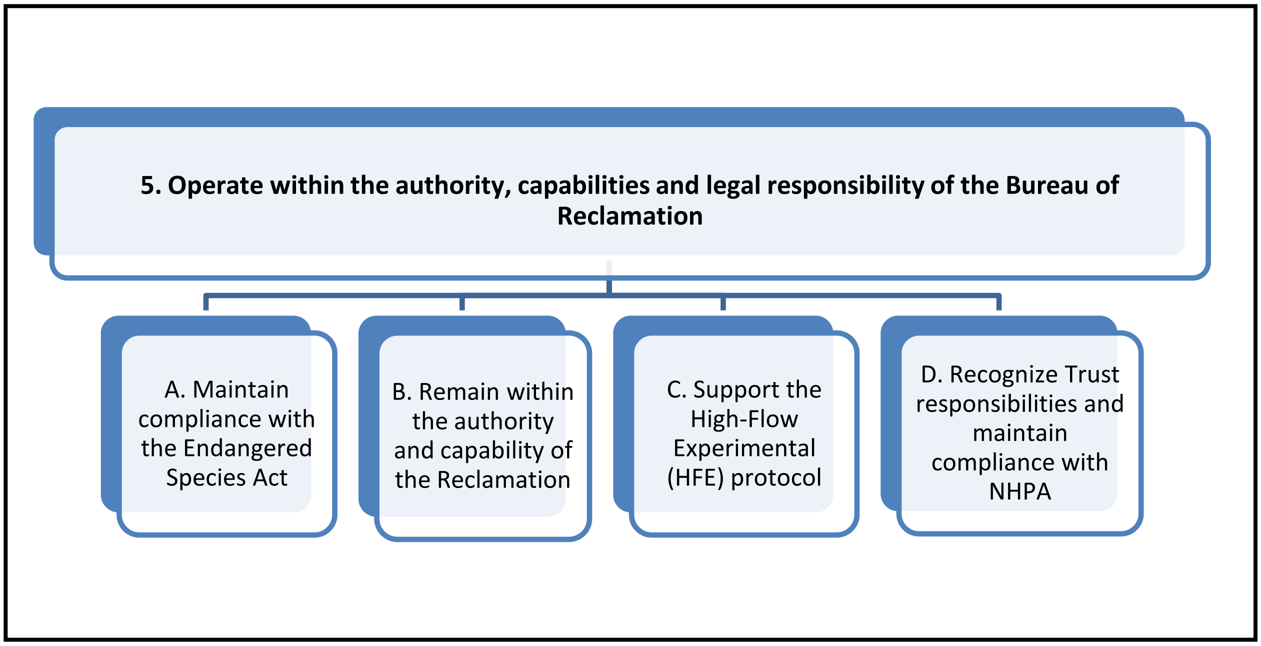

Figure 2. Hierarchy of fundamental objectives for non-native fish control below Glen Canyon Dam.—Continued

With particular reference to the Tribal cooperating partners, each Tribe has a distinct voice and perspective, and the proposed objectives and attributes may not fully reflect either the nuances within, or diversity among, the Tribes. The full spectrum of concerns within a Tribe may not have been addressed with these objectives, and will require further consultation with community members and elected leaders. As of late 2010, DOI is in the process of conducting government-to-government tribal consultation on this action, but this is not yet complete. The Hualapai Tribe had limited involvement in this process owing to other engagements, and representatives from both the Southern Paiute Consortium and Navajo Nation were unable to attend for the full duration of both workshops. This process and this report, therefore, do not represent definitive statements of the objectives of the Tribes, merely an attempt to identify the main features that are important.

4.1. Fundamental Objectives Hierarchy

The draft set of fundamental objectives is shown in the hierarchy below (and also in fig. 2). Detailed descriptions of each of the objectives are found in Section 4.3. Note that the order of presentation of the fundamental objectives is not meant to imply an order of preference.

1. Manage resources to protect tribal sacred sites and spiritual values
    - A. Avoid the taking of life
    - B. Be respectful of non-human life
    - C. Be respectful of the relationships between human and non-human beings
    - D. Protect and respect sacred sites within the Canyon

2. Manage resources to promote ecological and native species integrity
    A. Contribute to humpback chub recovery
    B. Minimize impact of invasive species introduction (including risk of introduction, impact of spread, and opportunities for mitigation and treatment)
    C. Minimize impact of disease introduction (including risk of introduction, impact of spread, and opportunities for mitigation and treatment)
    D. Maintain native-fish-management goals, through reduction of non-native species within Grand Canyon National Park

3. Preserve and enhance recreational values and uses
    A. Maintain and enhance the rainbow trout fishery within the Lees Ferry tailwaters reach (RM –16 to RM 0) to provide a memorable experience for anglers
    B. Minimize disturbance of the wilderness experience as a result of non-native fish management in the wilderness-managed area of GCNP
    C. Maximize safety, comfort, and convenience of recreational boating in the wilderness-managed area of GCNP, as affected by flow regimes from Glen Canyon Dam
    D. Maximize safety, comfort, and convenience of day-rafters, boaters, and anglers in the GCNRA, as affect by flow regimes from Glen Canyon Dam

4. Maintain and promote local economies and public services
    A. Maximize local economic benefits associated with angling in GCNRA (Lees Ferry tailwaters reach)
    B. Maximize local economic benefits associated with wilderness and park experiences
    C. Minimize cost of non-native fish control measures
    D. Minimize impacts to dam operations and maintenance
    E. Maintain and improve the value of Glen Canyon Dam electrical hydropower
    F. Maintain required water storage and delivery to downstream users

5. Operate within the authority, capabilities, and legal responsibility of the Bureau of Reclamation
    A. Maintain compliance with the Endangered Species Act
    B. Remain within the authority and capability of Reclamation
    C. Support the High-Flow Experimental (HFE) protocol
    D. Recognize Trust responsibilities and maintain compliance with section 106 of the NHPA

4.2. Measurable Attributes

Measurable attributes are scales on which fundamental objectives can be evaluated. These are sometimes also called performance measures. Measurable attributes evaluate how well a particular alternative is likely to achieve the aspirations expressed by each objective. The measurable attributes are shown in table 1, and described more fully in Section 4.3.

Table 1. Measurable attributes for the fundamental objectives.

[HBC, humpback chub; LCR, Little Colorado River; GCNP, Grand Canyon National Park; RBT, rainbow trout; GCNRA, Glen Canyon National Recreation Area; ESA, Endangered Species Act of 1973; NHPA, National Historic Preservation Act of 1966; $/yr, dollars per year]

Fundamental objective	Measurable attribute
1. Manage resources to protect tribal sacred sites and spiritual values	
A. Avoid the taking life	1A. Yes/No, life taken
B. Be respectful of non-human life	1B. Relative respectfulness of use, scale 1–10
C. Be respectful of the relationships between human and non-human beings	1C. Yes/No, culturally appropriate
D. Protect and respect sacred sites within the Canyon	1D. Yes/No, interferes with sanctity of the canyon
2. Manage resources to promote ecological and native species integrity	
A. Contribute to humpback chub recovery	2A. Probability of HBC adult abundance at LCR greater than 6,000 over the next 30 years
B. Minimize impact of invasive species introduction (including risk of introduction, impact of spread, and opportunities for mitigation and treatment)	2B1. Likelihood of introduction to Glen or Grand Canyon: none, low, medium, high 2B2. Likelihood of introduction from Glen or Grand Canyon: none, low, medium, high
C. Minimize impact of disease introduction (including risk of introduction, impact of spread, and opportunities for mitigation and treatment)	2C1. Likelihood of introduction to Glen or Grand Canyon: none, low, medium, high 2C2. Likelihood of introduction from Glen or Grand Canyon: none, low, medium, high
D. Maintain native-fish-management goals, through reduction of non-native species within GCNP	2D1. RBT abundance within GCNP 2D2. Frequency of HBC adult abundance greater than 10,000 over the next 30 years
3. Preserve and enhance recreational values and uses	
A. Maintain and enhance the rainbow trout fishery within the Lees Ferry tailwaters reach to provide a memorable experience for anglers	3A1. Catch rate (fish/hr) 3A2. Fraction of trout greater than 20 in.
B. Minimize disturbance of the wilderness experience as a result of non-native fish management in the wilderness-managed area of GCNP	3B. Penalized user-days
C. Maximize safety, comfort, and convenience of recreational boating in the wilderness-managed area of GCNP, as affected by flow regimes from Glen Canyon Dam	3C. Days/year that flow is within specifications
D. Maximize safety, comfort, and convenience of day-rafters, boaters, and anglers in the GCNRA, as affected by flow regimes from Glen Canyon Dam	3D. Days/year that flow is within specifications

Fundamental objective	Measurable attribute
4. Maintain and promote local economies and public services	
A. Maximize local economic benefits associated with angling in GCNRA (Lees Ferry tailwaters reach)	4A. Annual economic value ($)
B. Maximize local economic benefits associated with wilderness and park experiences	4B. Annual economic value ($)
C. Minimize cost of non-native fish control measures	4C. Total cost of action ($)
D. Minimize impacts to dam operations and maintenance	4D. Yes/No, compatibility with schedule
E. Maintain and improve the value of Glen Canyon Dam electrical hydropower	4E. Relative economic value ($/yr)
F. Maintain required water storage and delivery to downstream users	4F. Yes/No, compatibility with specified responsibilities
5. Operate within the authority, capabilities, and legal responsibility of the Bureau of Reclamation	
A. Maintain compliance with the ESA	5A. Relative efficacy of method, scale 0–2
B. Remain within the authority and capability of Reclamation	5B. Yes/No, with commentary
C. Support the High-Flow Experimental Protocol	5C. Yes/No, provide robust non-native fish options in the face of flow effects
D. Recognize Trust responsibilities and maintain compliance with section 106 of the NHPA	5D. Three-point constructed scale

4.3. Narratives for Objectives and Attributes

Where not otherwise noted, the objectives were developed to reflect long-term desired conditions, where “long-term” was interpreted as being 30 years or more.

Objective 1A. *Avoid the taking of life.* This reflects, in part, the belief in the sanctity of life and the role that aquatic life plays in traditional belief systems and creation stories of the participating Tribal nations. The taking of life is non-trivial and the relative acceptability of its occurrence is entirely dependent upon the respect paid in its taking and its purposeful use. Within the context of the decision problem at hand, the legitimacy and acceptability of the taking of non-native fish life depends upon the benefits to the humpback chub population, and the final use of the trout lethally removed from the ecosystem.

> Measurable attribute 1A: Utility scale (0-1), where a score of 0 indicates that life is taken under the hybrid portfolio, and a score of 1 indicates that it is not.

Objective 1B. *Be respectful of non-human life*. This reflects a stewardship ethic, and states that the taking of life should be purposeful and only done with good intent, and that in its taking, other life should be sustained.

> Measureable attribute 1B: The 10-point constructed scale considers the relative degree of respectfulness for the proposed end uses, with a score of 0 indicating a strong lack of respect and a score of 10 indicating a strong respect for the lives of the fish taken. The value may differ among the Tribes and other stakeholders.

Objective 1C. *Be respectful of the relationships between human and non-human beings.* This objective reflects a world view recognizing that human and non-human lives are inter-connected and that no living being is superior to another. Any action taken that affects one life form may have ripple effects that radiate out and affect other life forms. Because of this, human interactions with the world must minimize the disturbance and potential cause of harm, by being respectful of these relationships. Otherwise, these interactions may lead to the loss of balance between living beings. This philosophy serves as a foundation for traditional practices by the Tribes.

> Measurable attribute 1C: Utility scale (0-1), where a score of 0 indicates that the method of capture is not culturally appropriate, and a score of 1 indicates that it is culturally appropriate. Intermediate values reflect the degree of appropriateness.

Objective 1D. *Protect and respect sacred sites within the Canyon*. This objective reflects the importance of the Canyon in the traditional cultures, beliefs, and practices of the Tribes. Disturbance to the Canyon, and to sites of historical and spiritual significance specifically, leads to the degradation of the sanctity of the Canyon. This degradation in turn leads to the further alienation of Tribal communities from the Canyon, and interferes with their ability to fulfill their role in maintaining ecological, cultural, and social harmony within the world.

> Measurable attribute 1D: Utility scale (0-1), where a score of 0 indicates the hybrid portfolio negatively affects the sanctity of the Canyon and a score of 1 indicates the portfolio protects and respects the sanctity of the Canyon. Intermediate values reflect the degree of protection of the sanctity of the Canyon.

Objective 2A. *Contribute to humpback chub recovery.* According to the Biological Opinion for the Operation of Glen Canyon Dam (February 27, 2008), Reclamation is a primary contributor to the development of the GCDAMP Comprehensive Plan for the management and conservation of humpback chub in Grand Canyon, and continues to work with GCDAMP cooperators to develop a comprehensive approach to management of humpback chub. Dam-controlled flow has the potential to affect humpback chub directly or indirectly through effects on predator or competitor species abundances. Non-native rainbow and brown trout, among other non-native fishes, are potential predators and competitors of humpback chub and Reclamation has proposed measures to achieve conservation benefits for humpback chub. The Service has used adult humpback chub abundance in recent biological opinions on Glen Canyon Dam operations to gauge the efficacy of these measures against the adverse effects of dam operations.

> Measurable attribute 2A: Probability of the adult humpback chub population remaining above 6,000 over the next 30 years. Adult humpback chub in the LCR remaining above a threshold (6,000) abundance over 30-years has been proposed as an attribute that links to population viability and humpback chub population status. This attribute was predicted using a Population Viability Analysis (PVA) model, and abundance has been estimated and monitored using an age-structured mark recapture model (Coggins, 2007; Coggins and Walters, 2009).

Objective 2B. *Minimize impact of invasive species introduction (including risk of introduction, impact of spread, and opportunities for mitigation and treatment).* Introduction of invasive species can have far reaching impacts on native species, impacts which are difficult or impossible to reverse. Opportunities for mitigation or treatment depend on early detection of introductions, and preventing introduction could be the most efficient approach to invasive species management. Several species are of primary concern at present. The New Zealand mudsnail (*Potamopyrgus antipodarum*) currently inhabits the Colorado River primarily in Glen Canyon (Cross and others, 2010). Prevalence is high and distribution is throughout Glen and Grand Canyons. Trout consume mudsnails but they may pass through their digestive system unaffected. Movement of live trout from Glen or Grand Canyons to other receiving waters would be a likely vector for introduction to unaffected waters. There is some evidence that *Didymosphena geminata* (didymo or rock snot) occurs in Glen and perhaps Grand Canyon. Prevalence is low or suspect. Transport of water (with live trout) to other watersheds could be a vector for introduction of didymo to unaffected waters or watersheds. Invasive species could be introduced to Glen or Grand Canyon through stocking of trout at Lees Ferry.

> Measurable attribute 2B1: Likelihood of introduction of invasive species to Glen or Grand Canyon. This attribute is a 4-point constructed scale to measure the risk of impact. The attribute has two components: (1) prevalence of invasive species and (2) frequency of vector events. Each component ranges numerically from 3 (high prevalence or frequency) to 0 (no prevalence or frequency). The component scores are assessed and multiplied, and then the product is converted to the 4-point scale of none, low, medium, or high.
>
> Measurable attribute 2B2: Likelihood of translocating invasive species from Glen or Grand Canyon to an outside location. This attribute is a 4-point constructed scale to measure the risk of impact. The attribute has two components: (1) prevalence of invasive species and (2) frequency of vector events. Each component ranges numerically from 3 (high prevalence or frequency) to 0 (no prevalence or frequency). The component scores are assessed and multiplied, and then the product is converted to the 4-point scale of none, low, medium, or high.

Objective 2C. *Minimize impact of disease introduction (including risk of introduction, impact of spread, and opportunities for mitigation and treatment).* Introduction of disease to fish populations can reduce productivity or lead to extirpation. Treatment options can be costly, impractical, or unavailable. Preventing introduction of disease agents and controlling their spread is a basic management principle among natural resource agencies. Several diseases are of concern in Glen and Grand Canyons. Disease agents could be introduced to Glen or Grand Canyon through stocking of trout at Lees Ferry. The trout in Glen and Grand Canyon are considered exposed to Whirling Disease, a virulent salmonid disease detected in one lot of fish tested from Glen Canyon in 2003. Rainbow trout in Glen Canyon have not, however, displayed symptoms of the disease. Prevalence is considered low. Transport of live trout, or trout carcasses, to other receiving locations could result in introductions to unaffected waters and watersheds. The trout in Glen and presumably Grand Canyon carry an intestinal nematode that, under conditions of stress, can proliferate and affect the condition of individuals and populations. Transport of live trout, or trout carcasses, to other receiving locations could be a vector for introductions to unaffected waters and watersheds. Native fishes in Grand Canyon carry an intestinal parasite (Asian tapeworm), which is readily spread to other fishes. Asian tapeworm is relatively broadly distributed across Arizona. Transport of the parasite via this vector can be controlled through treatment, although the treatment is complicated and carries some risk to the fish.

Measurable attribute 2C1: Likelihood of introducing disease to Glen or Grand Canyon. This attribute is a 4-point constructed scale to measure the risk of impact. The attribute has two components: prevalence of disease and frequency of vector events. Each component ranges numerically from 3 (high prevalence or frequency) to 0 (no prevalence or frequency). The component scores are assessed and multiplied, and then the product is converted to the 4-point scale of none, low, medium, or high.

Measurable attribute 2C2: Likelihood of transporting disease from Glen or Grand Canyon to an outside location. This attribute is a 4-point constructed scale to measure the risk of impact. The attribute has two components: prevalence of disease and frequency of vector events. Each component ranges numerically from 3 (high prevalence or frequency) to 0 (no prevalence or frequency). The component scores are assessed and multiplied, and then the product is converted to the 4-point scale of none, low, medium, or high.

Objective 2D. *Maintain native-fish-management goals, through reduction of non-native species within GCNP.* According to NPS Management Policies (National Park Service, 2006), the NPS will maintain, as parts of the natural ecosystems of parks, all plants and animals native to park ecosystems. The NPS will act to preserve and restore the natural abundances, diversities, dynamics, distributions, habitats, and behaviors of native plant and animal populations and the communities and ecosystems in which they occur. Furthermore, the NPS will remove, when possible, or otherwise contain, individuals or populations of introduced or non-native species that have already become established in parks. High priority will be given to managing exotic species that have, or potentially could have, a substantial impact on park resources, and that can reasonably be expected to be successfully controlled. The NPS will survey for, protect, and strive to recover all species native to national park system units that are listed under the ESA.

Measurable attribute 2D1: Rainbow and brown trout abundance within GCNP. These attributes measure the level of non-native fish that could substantially impact the endangered humpback chub and other native fish. Abundance can be estimated through monitoring programs. Predicted abundance of rainbow trout in the LCR can be used as a proxy in decision analyses.

Measurable attribute 2D2: Frequency at which the adult humpback chub population in the LCR confluence reach remains above threshold abundance (10,000). Different from Measurable Attribute 2A, this attribute measures how often the annual population crosses this higher threshold (10,000), and has been proposed to measure how well proposed actions maintain NPS management goals for the endangered humpback chub.

Objective 3A. *Maintain and enhance the rainbow trout fishery within the Lees Ferry tailwaters reach (RM –16 to RM 0) to provide a memorable experience for anglers.* At one time, when the tailwaters provided a better food base, the Lees Ferry fishery was a national trophy rainbow trout fishery. Currently (2010), the fishery provides a unique angling experience in a desert tailwater environment; and this fishery could be enhanced to once again provide a high-quality, destination fishing experience that is respected nationally and attracts both national and international visitors. Two important aspects of the trout stock that would affect this experience are abundance and size-distribution. A larger population size results in a higher catch rate. When the size-distribution contains a high fraction of "preferred" fish (greater than 20 in.), anglers have more opportunity to catch large fish.

Measurable attribute 3A1: Catch rate (fish/hour), as measured by creel surveys. In 2009, the catch rate was 0.85 fish/hour (fish/hr), less than three-quarters of what it was in the late 1990s. The desire is to see this returned to the levels of the late 1990s (1.2 fish/hr). The catch rate predicted as part of this attribute should be the expected catch rate in the longer term (approximately 10 years) after the stock has adjusted to the new management conditions.

Measureable attribute 3A2: Fraction of the trout stock that is of at least “preferred” size (greater than 20 in.), as measured by electrofishing surveys. Currently, the stock is dominated by fish in the 6–8 in. range, with less than 0.5 percent greater than 20 in. The desire is to see this fraction increased to several percent, providing a non-negligible opportunity for anglers to catch a large fish. As with attribute 3A1, the predicted attribute should be the expected size-distribution in the long term after the stock has adjusted to the new management conditions.

Objective 3B. *Minimize disturbance of the wilderness experience as a result of non-native fish management in the wilderness-managed area of GCNP.* An important part of the recreational experience enjoyed by visitors to GCNP is the opportunity to be in a wilderness setting with minimal contact with other people and few sights and sounds associated with human activities. Non-native fish control activities, whether on foot, by boat, or by helicopter, and any infrastructure associated with them, however temporary, have the potential to undermine the wilderness experience for others (particularly people rafting the river or backpacking at river camping areas) and may be inconsistent with NPS wilderness policy. Effects of fish-control activities include the noise and lights associated with removal actions (especially when at night), the competition for camping sites along the river, and the simple presence of more people on the river.

Measurable attribute 3B: Penalized user-days per year in the GCNP wilderness during administrative trips for the purpose of non-native fish management. The staff size times the number of days in the wilderness is the basic measure; this is multiplied by a penalty factor for activities that result in greater disturbance. Penalty factor for boat (motor) user-days during motor season is 1; boat (motor) user-days during non-motor season, 2; helicopter trips, 2; and nighttime management activities, 3. Thus, for example, a 14-day removal trip with a staff of eight, conducted by boat during the non-motor season, with management activities primary at night would have a score of 672 penalized user-days (14 days × 8 users × 2 [non-motor] × 3 [night]). If helicopter removal of live fish was required, with 2 trips daily for 8 of the 14 days, an additional 32 penalized user-days (2 trips/day × 8 days × 2 [helicopter penalty]) would be added. The number of boats is not included in the calculation; presumably the number of users is tied to the number of boats.

Objective 3C. *Maximize safety, comfort, and convenience of recreational boating in the wilderness-managed area of GCNP, as affected by flow regimes from Glen Canyon Dam.* Several aspects of the flow regime from the dam can affect the experience of boaters in the Canyon. Low flows (under 8,000 cubic feet per second [ft^3/s]) can make a number of sections of the river dangerous or even possibly unnavigable. High flows (greater than 31,000 ft^3/s) can create uncomfortable or dangerous whitewater boating conditions in some places. Flows that fluctuate widely, particularly over a short period of time, can create unpredictable conditions for boating, and inconvenient conditions for camping. Current operating rules under the 1996 Record of Decision (ROD; U.S. Department of the Interior, 1996) specify maximum daily flow fluctuation ranges of 5,000, 6,000, or 8,000 ft^3/s (depending on the monthly release volumes). Daytime fluctuating flow operations are limited to between 8,000 and 25,000 ft^3/s under these daily operating rules, with hourly ramping rates restricted to 4,000 ft^3/s per hour as flows increase and no greater than 1,500 ft^3/s per hour as flows are ramped down following daily peaks. Daily lows can go to 5,000 ft^3/s, but only between the hours of 07:00 pm and 07:00 am,

> Measurable attribute 3C: Number of days per year during which the flow from the dam operates inside of the following conditions that promote safety, comfort, and convenience for rafting in the wilderness area of GCNP—flows greater than 8,000 ft^3/s, flows less than 31,000 ft^3/s, daily fluctuations less than 5,000 ft^3/s.

Objective 3D. *Maximize safety, comfort, and convenience of day-rafters, boaters, and anglers in the GCNRA, as affected by flow regimes from Glen Canyon Dam.* Several aspects of the flow regime from the dam can affect the experience of anglers, boaters, and rafters in the GCNRA. Extremely low flows (under 3,000 ft^3/s) can make a number of sections of the Lees Ferry tailwaters reach unnavigable, particularly past 3-mile Bar (RM –3). High flows (greater than 30,000 ft^3/s) can create uncomfortable or dangerous conditions in some places. Flows that fluctuate widely, particularly high upramping rates, can create unpredictable conditions for boaters and anglers.

> Measurable attribute 3D: Number of days per year during which the flow from the dam operates inside of the following conditions that promote safety, comfort, and convenience for angling and boating in GCNRA—flows greater than 3,000 ft^3/s, and flows less than 30,000 ft^3/s. Specific maximum upramp rates are not included because none of the alternative strategies had upramp rates outside of the 1996 ROD conditions. If faster upramp rates than the 1996 ROD conditions were considered, these rates might need to be included in this attribute.

Objective 4A. *Maximize local economic benefits associated with angling in GCNRA (Lees Ferry tailwaters reach).* The rainbow trout fishery provides economic and social benefit to a small rural community and to the region. A number of businesses (lodges, restaurants, guides, outfitters, and others) and individuals derive their income from anglers who come to Marble Canyon for the fishing experience. Whereas this economic benefit is associated with the number of angler-days, some factors (like the increase in day trips from larger cities) do not result in as much local economic benefit.

> Measurable attribute 4A: Annual economic value, in dollars, of the Lees Ferry tailwaters reach fishery to the local community. The predicted attribute should be the expected economic value in the long-term (approximately 10 years), after adjustments to the fishery and local economy owing to changes associated with new management conditions. We assume that the annual economic value is proportional to angler-days, with a multiplier of $210 per angler-day, on the basis of studies from Arizona State University (Silberman, 2003).

Objective 4B. *Maximize local economic benefits associated with wilderness and park experiences.* GCNP provides benefits to both local and regional economies. With regard to non-native fish management, the businesses that could be affected are those associated with wilderness recreation that originates at Lees Ferry, namely, white-water rafting. While the potential management actions being considered for non-native fish management could affect the experience of wilderness recreation, the demand for such opportunities is so high, and the supply so low, that it is unlikely that any of the potential actions will have a differential effect on this objective. Thus, while this objective is important, it does not help to distinguish any of the non-native fish control alternatives being considered.

Measurable attribute 4B: Annual economic value, in dollars, of the wilderness industry to the local economy. The predicted attribute should be the expected economic value in the long-term (approximately 10 years), after adjustments to the local economy because of changes associated with new management conditions. No effort was made to estimate this economic value, because it likely will not differ across the alternatives being considered.

Objective 4C. *Minimize cost of non-native fish control measures.* The GCDAMP and Reclamation have limited annual budgets. In the past, non-native control efforts have utilized flows from Glen Canyon Dam as well as electrofishing at the confluence of the Colorado and Little Colorado Rivers to limit numbers of non-native fishes, particularly rainbow and brown trout. Non-native fish control utilizing electrofishing to remove fish, predominantly the two trout species, has cost on average $150,000 per mechanical removal river trip, which includes logistics and research analysis. The costs of other strategies for removing non-native fish or reducing their survival and recruitment, as well as possible mitigation measures to offset tribal concerns, such as translocating live fish further downstream within GCNP or to other waters, need to be determined. This cost analysis does not take into consideration the costs to other resources, such as recreation, hydropower, or other monitoring and research needs of the GCDAMP, only the logistics and research associated with conducting non-native fish control activities.

Measurable attribute 4C: Cost in US Dollars, incorporating both fixed and variable costs over the next 5 years.

Objective 4D. *Minimize impacts to dam operations and maintenance.* Glen Canyon Dam has eight generating units, penstocks, and associated infrastructure. At any given time these units may be down for maintenance. Typically only one unit will be down, but at times up to three may be down. The dam also has requirements for regulation and spinning reserve that effectively reduce the release capacity by approximately 2,500–3,500 ft^3/s so that regulation and spinning reserves can be maintained. The maintenance schedule can be modified to meet certain release requirements or objectives, to some degree. This objective attempts to assess the degree to which different non-native fish control strategies may interfere with operation and maintenance of Glen Canyon Dam.

Measurable attribute 4D: Binary response (yes/no): operation is compatible with the maintenance schedule.

Objective 4E. *Maintain and improve the value of Glen Canyon Dam electrical hydropower.* Electricity is an integral part of every aspect of residential, commercial, and industrial life. The electricity produced at the dam is a renewable and environmentally preferred resource. The Glen Canyon Dam is integrated into the electrical production of several large Colorado River Storage Dams and it serves part of the needs of over 5 million people, in the rural Rocky Mountain and desert Southwest. The Dam provides a significant portion of the electrical needs of more than 50 Native American areas. Electricity is sold as a long-term firm product, at the cost of production, under terms that allow flexibility so as to schedule electrical power deliveries to maximize the value of the Glen Canyon Dam power resource.

Measurable attribute 4E: Annual economic value in dollars per year ($/yr) of power produced at Glen Canyon Dam, relative to current conditions.

Objective 4F. *Maintain required water storage and delivery to downstream users.* Glen Canyon Dam is operated by Reclamation and is the key water storage unit of the Colorado River Storage Project (CRSP). The CRSP and the Colorado River are managed and operated under numerous compacts, federal laws, court decisions and decrees, contracts, and regulatory guidelines collectively known as the "Law of the River." This collection of documents apportions the water and regulates the use and management of the Colorado River among the seven basin states and Mexico. Glen Canyon Dam is also operated to be in compliance with Treaty and Compact Delivery requirements under the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Interim Guidelines), as well as the GCPA. This objective attempts to assess the degree to which different non-native fish control strategies may interfere with water storage and delivery operations of Glen Canyon Dam.

> Measurable attribute 4F: Binary response (yes/no): Operation is compatible with Reclamation's responsibilities for water storage and delivery.

Objective 5A. *Maintain compliance with the ESA.* The need for non-native fish control resulted from an ESA section 7 consultation on dam operations, and mechanical removal remains one of the recommended conservation measures in the operating biological opinion. Reclamation, as a Federal agency, has a responsibility to comply with Federal law, including the ESA. To a large degree, compliance with the ESA is reflected in the status of humpback chub (Objective 2A). However, one major aspect of ESA compliance is satisfaction of conservation measures. The current conservation measure calls for mechanical removal of trout at the mouth of the LCR. To evaluate whether an alternative would be equivalent to the mechanical removal conservation measure, one mode of analysis is to compare the effectiveness of various non-native control techniques with the effectiveness of mechanical removal as stated in the conservation measure.

> Measurable attribute 5A: 3-point constructed scale: action does not perform as well as original conservation measure (score: 0 points); action performs as well as original conservation measure (1 point); action outperforms original conservation measure (2 points); the performance of the action is unknown (n/a). This will be evaluated by Reclamation, and should be understood as Reclamation's perception of the likelihood of compliance, given past opinions and current information. This scale is not, of course, binding to the Service in subsequent biological opinions under section 7 of the ESA.

Objective 5B. *Remain within the authority and capability of Reclamation.* Reclamation has limited authority and limited capability in terms of the types of actions it can initiate, fund, or execute. Admissible alternatives will need to be within these bounds, and also within the scope of the Non-native Fish Control EA.

> Measurable attribute 5B: Binary scale (yes/no), with notes. If the alternative is within the authority and capability of Reclamation, and within the scope of the EA, it should be scored "yes." If not, it should be scored "no", with additional commentary on which agencies, Tribes, or other stakeholders have, perhaps joint, authority for the alternative.

Objective 5C. *Support the High-Flow Experimental Protocol.* In a separate ongoing EA process, Reclamation is considering alternatives for ongoing high-flow experimental releases from Glen Canyon Dam for the purposes of sandbar building in the Canyon. High-flow experimental releases have been one mechanism that DOI has historically used to comply with the GCPA. High flow releases are also believed to increase rainbow trout populations, perhaps depending on the time of year, and thus, may increase the threat to humpback chub through competition and predation. Non-native fish control alternatives that are not effective at robustly controlling trout and preventing jeopardy to humpback chub may undermine ongoing dam operations and could inhibit future dam operations such as high flow experiments that may increase the non-native fish population in the Canyon. This is largely related to whether the alternative will be compliant with the ESA (Objective 5A), but there may be other nuances to it.

> Measurable attribute 5C: Binary scale (yes/no): Does the alternative provide robust options for controlling rainbow trout, in the event that high-flow releases increase rainbow trout populations and the trout populations in turn negatively affect humpback chub?

Objective 5D. *Recognize Trust responsibilities and maintain compliance with section 106 of the NHPA.* The Federal government holds trust responsibilities that recognize the sovereign status and management authority of Tribes, and that assure the Tribes that Federal agencies will not knowingly compromise traditional practice and livelihoods in execution of their duties. Executive Order 13007 adds specificity to this principal in stating that Federal agencies "shall avoid adversely affecting the physical integrity of sacred sites," whereas Secretarial Order 3206 stipulates that within the context of the ESA the "Departments will carry out their responsibilities under the Act in a manner that harmonizes the Federal trust responsibility to tribes." Further, the NHPA requires Federal agencies to take into account the effects of their actions on historic properties, which, through the National Register includes special provisions for places of cultural and religious significance. To some degree, the cultural values outlined by Objectives 1A–1D reflect existing policy but those objectives do not clearly specify, nor fully encapsulate, the unique and complex relationship between the Tribes and the Canyon, a relationship that is recognized legally by the U.S. Claims Court and programmatically in the Strategic Plan adopted by the GCDAMP. The inclusion of this objective ensures that proposed alternatives support Federal responsibilities.

> Measurable attribute 5D: 3-point constructed scale: action does not perform as well as original conservation measure (score: 0 point); action performs as well as original conservation measure (1 point); action outperforms original conservation measure (2 points); the performance of the action is unknown (n/a). This will be evaluated by Tribal representatives, and should be understood as the Tribal perception of the likelihood of meeting those responsibilities, given past opinions and current information. This scale is not, of course, binding to Reclamation.

5. Alternatives

The non-native fish control alternatives under consideration are complex, multi-faceted approaches, which perhaps will involve adaptive components. To understand the structure of these alternatives, we built them up from the simplest components and identified several layers of complexity. At the simplest level, the alternatives consist of *action elements*, specific and detailed aspects of on-the-ground actions. Action elements that are related can be combined into *single strategies*, which focus on a particular method for addressing some aspect of the problem. The single strategies themselves can be combined into *hybrid portfolios*. These hybrid portfolios are meant to be the alternatives for long-term management of the resources, and are the focus of the evaluation (see section 6). In the short-term, however, because the hybrid portfolios are based on untested assumptions, consideration of *adaptive strategies* that include multiple hybrid portfolios may be warranted. Development and evaluation of potential adaptive strategies follows the initial evaluation of the hybrid portfolios.

5.1. Action Elements

Action elements in this problem fall into broad categories of (1) removal of non-native fish, (2) suppression of non-native fish, and (3) enhancement of humpback chub populations. Because each action element contains several options, the elements in this problem are complex (fig. 3). For example, options for removal of non-native fish include which species and age class to remove, magnitude of the removal, removal method, location and timing of the removal, and disposition of removed fish (fig. 3A). Also, there are several options for suppressing non-native fish or enhancing humpback chub populations that involve flow alterations, sediment augmentation (Randle and others, 2007), and other non-removal approaches (fig. 3B).

What species and age classes are removed?

a) RBT adults
b) RBT juveniles
c) BNT
d) Warm water NNF

What is the magnitude of the removal (i.e., percent removed relative to baseline abundance)?

a) 0
b) 20
c) 40
d) 60
e) 80
f) 100

What is the disposition of removed fish?

a) Euthanize and use for
   a. Fertilizer
   b. Return to river
   c. Food for domestic animal or wildlife
   d. Food for human consumption
b) Live removal followed by
   a. Stocking in tribal ponds
   b. Transport and release downstream of RM 76

What triggers removal?

a) RBT, BNT, HBC, or native fish abundance
b) Post HFE
c) Flow or sediment load

Where is the removal located?

a) Mouth of LCR
b) PBR
c) Bright Angel and other tributaries
d) Lees Ferry to LCR
e) Below LCR

When does removal occur?

a) Non-motor season (Sept 15 – Apr 1)
b) Motor season
c) Most vulnerable time (time of highest capture efficiency)

What is the capture method?

a) Electrofishing
b) Gillnet or trammel net
c) Other netting or trapping (hoop net, trap, weir, wheel, ladder)
d) Angling (hook and line)
e) Other angling e.g., spearfishing or dip net
f) Chemical

Who conducts the removal?

a) Agency
b) Native Americans
c) Public via regulations, reward/bounty, outreach

Figure 3. Action elements for alternative control strategies for (A) removal of non-native fish, and (B) suppression of non-native fish or other non-removal actions designed to enhance humpback chub populations in the Colorado River below Glen Canyon Dam.

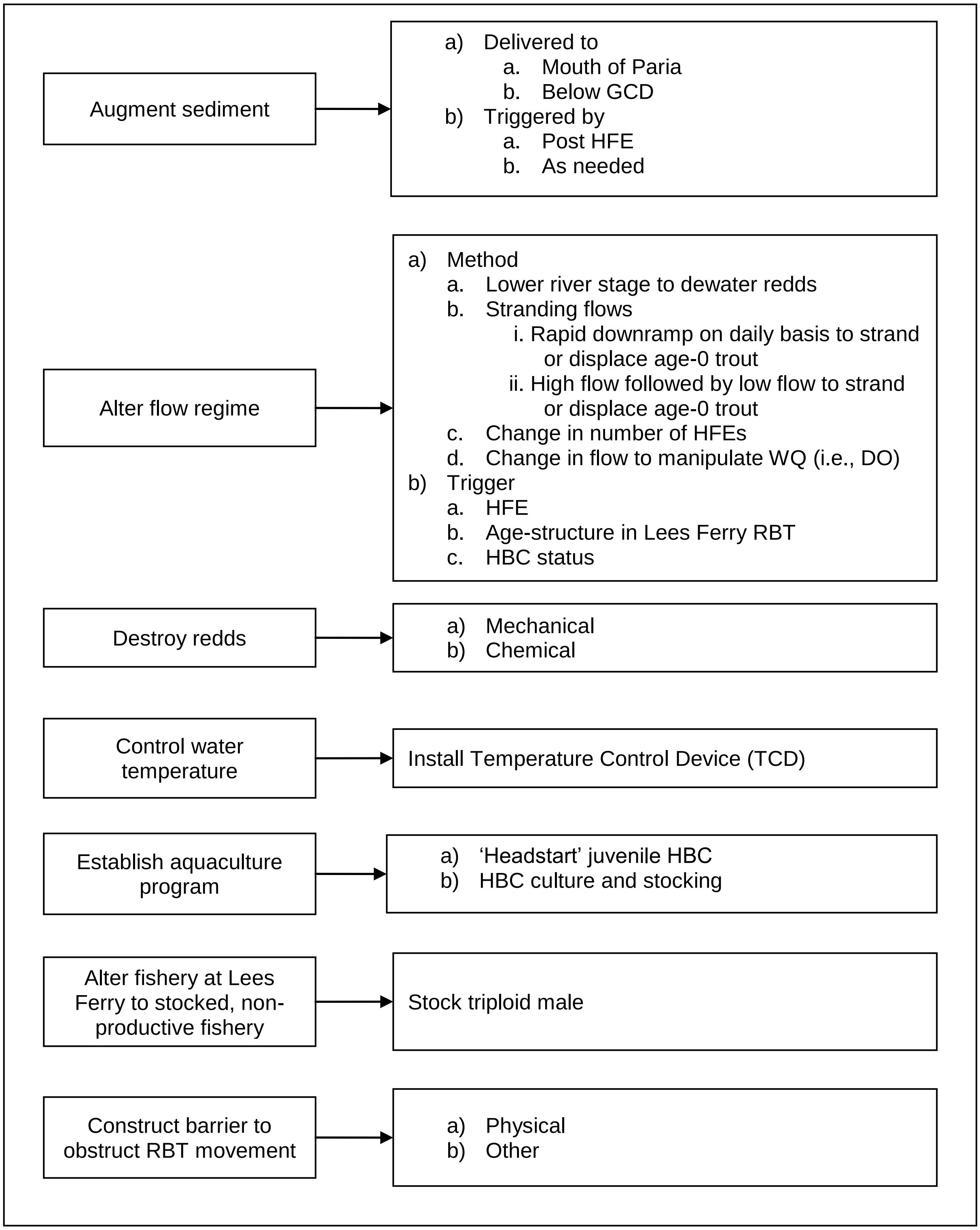

Figure 3. Action elements for alternative control strategies for (A) removal of non-native fish, and (B) suppression of non-native fish or other non-removal actions designed to enhance humpback chub populations in the Colorado River below Glen Canyon Dam.—Continued

5.2. Single Strategies

Action elements can be combined to form single strategies (table 2). These single strategies are meant to be precise descriptions of certain activities that might be undertaken, although it's not envisioned that any of these would be undertaken alone. Rather, the single strategies are building blocks for the hybrid portfolios. The single strategies range from no action with regard to rainbow trout (strategy 1) to the historical mechanical removal method (strategy 2) to stranding flows (strategies 9 and 11), sediment augmentation (strategies 13 and 14), and humpback chub headstarting (strategy 18). At this time, it is not yet clear which of these single strategies are within the jurisdiction of Reclamation and the scope of the non-native fish control EA, but this wide range is being explored to encourage a creative search for solutions.

Table 2. Single strategies for removal or suppression of non-native fish, or enhancement of humpback chub populations in the Colorado River below Glen Canyon Dam.

[RBT, rainbow trout; BNT, brown trout, LCR, Little Colorado River; PBR, Paria-to-Badger reach; HFE, High-flow experiment; ROD, Record of Decision; HBC, humpback chub]

1. No action with regard to RBT (action may or may not be taken with regard to BNT)
2. Lethal removal of RBT @ LCR, fertilizer use, 2–6 trips per year during the motor season as needed, 4–6 depletion passes per trip
3. Removal of adult RBT @ LCR, beneficial use (live or lethal), trout trigger (greater than 1,200 trout at LCR), up to 6 trips per year (Jan–Mar, Jul–Sep), 6 depletion passes per trip
    a. Electrofishing, euthanasia, freeze or smoke, human consumption
    b. Electrofishing, euthanasia, freeze, domestic or endangered animal consumption
    c. Gill netting, euthanasia, freeze or smoke, human consumption
    d. Gill netting, euthanasia, freeze, domestic or endangered animal consumption
    e. Electrofishing, live removal, stock tribal fish ponds
    f. Electrofishing, live removal, transport downstream (RM 76)
    g. Gill netting, live removal, stock tribal fish ponds
    h. Gill netting, live removal, transport downstream (RM 76)
    i. And other possible options and combinations
4. Removal of RBT adults 1.5 mi upstream from LCR confluence, beneficial use (live or lethal), RBT & HBC triggers (options the same as in #3 above)
5. RBT removal @ PBR, beneficial use (live or lethal), untriggered, 10 months/year, 6 depletion passes per month
    a. Juveniles, electrofishing, HFE trigger, euthanasia, domestic or endangered animal consumption
    b. Juveniles, gill netting, HFE trigger, euthanasia, domestic or endangered animal consumption
    c. Juveniles, fish traps, HFE trigger, euthanasia, domestic or endangered animal consumption
    d. Adults, electrofishing, euthanasia, freeze, smoke, or fresh, human consumption
    e. Adults, electrofishing, euthanasia, freeze, domestic or endangered animal consumption
    f. Adults, gill netting, euthanasia, freeze or smoke or fresh, human consumption
    g. Adults, gill netting, euthanasia, freeze, domestic or endangered animal consumption
    h. Adults, electrofishing, live removal, stock tribal fish ponds
    i. Adults, gill netting, live removal, stock tribal fish ponds
    j. And other possible options and combinations
6. BNT removal from Bright Angel Creek (fish weir)
7. BNT removal expanded to multiple tributaries
8. BNT removal as standard operating procedure coinciding with monitoring activities

9. Stranding flows to reduce reproduction and recruitment (de-water redds). Similar to trout suppression flows of 2003–2005, but modified to be more effective (lower daily flow at 2,500 ft^3/s). Period: Feb 1–Apr 30. Flow: Up to 20,000 ft^3/s (17,500 ft^3/s if maintenance limitations constrain operations) maximum daily flow for 13 days (min. daily flow doesn't matter). On day 14, drop flow to 2,500 to 5,000 ft^3/s between 8 am–1 pm, then resume normal ROD operations. Repeat.
10. Increase daily downramp to strand or displace age-0 trout. Period: May 1–Aug 1. Flow: ROD operations but unrestricted downramp rates.
11. Stranding flows (high flow followed by low flow) to strand or displace age-0 trout. Period: May 1–Aug 1. Flow: High (20,000 ft^3/s) for 2–4 days, followed by rapid decline to 2,500–5,000 ft^3/s held for ½ to one day. Repeat (2 cycles/month = 6 cycles total).
12. Mechanical or chemical disruption of redds
13. Fine-sediment augmentation @ Paria River confluence
14. Lees Ferry fine sediment slurry (mitigates for HFE enhanced production response, RBT trigger – abundance or RBT juvenile survival)
15. Construction of some barrier to downstream movement of trout
16. Alter fishery to a stocked, non-productive fishery (triploid males)
17. Expand harvest of trout (reward program, tribal guides, other methods)
18. Headstarting (remove young HBC from the wild, grow in hatchery until large enough to avoid predation, then reintroduce in the wild)

5.3. Hybrid Portfolios

Single strategies can be combined to form hybrid portfolios, which represent alternatives for long-term management of the resources (table 3). The portfolios were built up from combinations of single strategies to emphasize certain objectives or actions. For example, a portfolio emphasizing cultural sensitivity during removal actions (hybrid portfolio C) was created by finding beneficial uses (live or lethal) for removed fish, using humane methods of capture and handling, and establishing triggers so the removal is minimized and restricted to when and where it is thought to be necessary for humpback chub recovery.

Table 3. Hybrid portfolios, composed of multiple single strategies (table 2), for removal or suppression of non-native fish, or enhancement of humpback chub populations.

[The key uncertainties and their relationships to the hybrid portfolios are more fully described in figure 4; RBT, rainbow trout; BNT, brown trout; LCR, Little Colorado River; HBC, humpback chub; PBR, Paria-to-Badger reach]

A. No action (single strategies: 1, 6) Assumptions: RBT do not limit chub recovery, but BNT do.
B. Status quo (single strategies: 2, 6): 4.2 LCR trips per year Assumptions: RBT and BNT limit chub recovery, RBT near LCR are self-sustaining or no other methods work to reduce RBT density at LCR, other objectives collectively outweigh tribal cultural concerns.
C_1. Culturally sensitive removal at LCR (single strategies: 3a, 6): 4.2 LCR trips per year Assumptions: RBT and BNT limit chub recovery, RBT near LCR are self-sustaining or no other methods work to reduce RBT density at LCR, tribal concerns can be met through beneficial use.
C_2. Culturally sensitive removal at LCR (single strategies: 3b, 6): 4.2 LCR trips per year Assumptions: see C_1.
C_3. Culturally sensitive removal at LCR (single strategies: 3a,b,e; 6): 4.2 LCR trips per year, 20 percent of trout removed alive (by helicopter), 20 percent smoked for human consumption, 60 percent frozen for animal consumption. Assumptions: see C_1.
C_4. Culturally sensitive removal at LCR (single strategies: 3e, 6): 4.2 LCR trips per year, all trout removed alive by equipping boats with livewells and floating downstream, for stocking in tribal ponds. Assumptions: see C_1.
C_5. Culturally sensitive removal at LCR (single strategies: 3e, 6): 4.2 LCR trips per year, all trout removed alive by helicopter, for use in tribal fish ponds. Assumptions: see C_1.
D_1. Removal curtain (single strategies: 3b, 5e, 6): #5 is the long-term strategy to reduce emigration, but #3 is needed in short-term to reduce extant RBT population. Expect 1.6 LCR trips per year on average. All trout frozen and used for animal consumption. Assumptions: RBT and BNT limit HBC recovery, Lees Ferry is the source of RBT, removal @ PBR effectively stops emigration.
D_2. Removal curtain (single strategies: 3b, 5h, 6): #5 is the long-term strategy to reduce emigration, but #3 is needed in short-term to reduce extant RBT population. Expect 1.6 LCR trips per year on average. Trout removed at LCR are frozen and used for animal consumption; at PBR, trout removed alive and used to stock tribal fish ponds. Assumptions: see D_1.
D_3. Removal curtain (single strategies: 3e, 5h, 6): #5 is the long-term strategy to reduce emigration, but #3 is needed in short-term to reduce extant RBT population. Expect 1.6 LCR trips per year on average. All trout removed alive (use of helicopters at LCR) and used to stock tribal fish ponds. Assumptions: see D_1.
E. Sediment curtain (single strategies: 3b, 5e, 6, 13): #13 is long-term strategy to emigration; #5 is the short-term strategy to emigration while infrastructure is being built; #3 is needed in short-term to reduce extant RBT population Assumptions: RBT and BNT limit HBC recovery, Lees Ferry is the source of RBT, removal @ PBR or sediment curtain will work to reduce emigration; in the long-term, sediment curtain is cheaper than ongoing removal.
F. Stranding flow (single strategies: 6, 11) Assumptions: RBT and BNT limit chub recovery, Lees Ferry is the source of RBT and extant RBT population at LCR will disappear after migration is curtailed, stranding flows alone are sufficient to eliminate emigration F'. Stranding flow with stocking of triploid males (single strategies: 6, 11, 16) Assumptions: RBT and BNT limit HBC recovery, Lees Ferry is the source of RBT and extant RBT population at LCR will disappear after migration is curtailed, stranding flows and stocking of triploid males are needed to eliminate emigration. This strategy could also arise if stranding flows alone are sufficient to reduce BRT production and emigration, but have a negative impact on fishery, which can be compensated

	for by stocking triploid males.
G.	Stranding flow with augmentation (single strategies: 5e, 6, 11): #11 is the long-term strategy to reduce production and emigration from Lees Ferry; #5 is used in the short-term to reduce emigration a bit quicker Assumptions: RBT limit HBC recovery; Lees Ferry is the source of RBT, stranding flows in combination with PBR will work to eliminate emigration, extant RBT population at LCR will disappear after migration is curtailed. G'. Stranding flow with augmentation and stocking of triploid males (single strategies: 5e, 6, 11, 16): #11 is the long-term strategy to reduce production and emigration from Lees Ferry; #5 is used in the short-term to reduce emigration a bit quicker Assumptions: RBT limit HBC recovery; Lees Ferry is the source of RBT, stranding flows in combination with PBR will work to eliminate emigration, extant RBT population at LCR will disappear after migration is curtailed, stranding flows have negative impact on fishery, which can be compensated for by stocking triploid males.
H.	Stranding flow with assurances (single strategies: 3b, 6, 11): #11 is the long-term strategy to reduce production and emigration from Lees Ferry; #3 is used in the short-term to reduce extant RBT population Assumptions: RBT limit HBC recovery, Lees Ferry is an important source of RBT, stranding is effective at eliminating emigration from Lees Ferry, but removal at LCR is needed to deal with extant RBT population and/or downstream self-sustaining RBT. H'. Stranding flow with assurances and stocking of triploid males (single strategies: 3b, 6, 11): #11 is the long-term strategy to reduce production and emigration from Lees Ferry; #3 is used in the short-term to reduce extant RBT population Assumptions: RBT limit HBC recovery, Lees Ferry is an important source of RBT, stranding is effective at eliminating emigration from Lees Ferry, but removal at LCR is needed to deal with extant RBT population and/or downstream self-sustaining RBT, stranding flows have negative impact on fishery, which can be compensated for by stocking triploid males.
I.	Dewater redds with assurances (single strategies: 5e, 6, 9) Assumptions: RBT limit HBC recovery, Lees Ferry is the source of RBT, dewatering works to some extent, but PBR removal is needed to remove the compensatory effect.
J_1.	Kitchen Sink I (single strategies: 3b, 5e, 6, 7, 8, 9, 10, 11): intended to reduce or eliminate the need for mechanical removal, by reducing trout recruitment and emigration through flow manipulation. Expect 1.3 LCR trips per year. All trout removed (LCR, PBR) frozen and used for animal consumption. Assumptions: RBT limit HBC recovery, Lees Ferry a primary source of RBT in LCR, little spawning by RBT south of Lees Ferry, BNT threaten chub recovery, HFE promote trout production, mechanical removal at LCR alone ineffective at maintain low trout abundance, flow manipulations can reduce recruitment and emigration of trout. J_1'. Kitchen Sink I with stocking of triploid males (single strategies: 3b, 5e, 6, 7, 8, 9, 10, 11, 16). Assumptions: see J_1. In addition, flow manipulations have a negative impact on trout fishery, which can be compensated by stocking triploid males.
J_2.	Kitchen Sink II (single strategies: 3e, 5h, 6, 7, 8, 9, 10, 11): intended to reduce or eliminate the need for mechanical removal, by reducing trout recruitment and emigration through flow manipulation. Expect 1.3 LCR trips per year. All trout removed alive and used to stock tribal fish ponds. Assumptions: see J_1. J_2'. Kitchen Sink II with stocking of triploid males (single strategies: 3e, 5h, 6, 7, 8, 9, 10, 11, 16). Assumptions: see J_1'.
K.	Zuni-Hopi-NPS strategy (single strategies: 5h, 6, 9, 17): Redd dewatering flows and expanded trout harvest at Lees Ferry to reduce trout emigration, with live removal at PBR to further reduce downstream emigration. No activity at LCR. Assumptions: (1) RBT not significantly limiting recruitment on HBC; HBC have survived in the system along with RBT for many decades. (temperature more a limiting factor than predation by RBT). High degree of uncertainty about relationship between RBT predation and recruitment; until resolved, not worth the other (spiritual) costs. (2) HBC range has decreased throughout the system (3) Life is sacred; unnecessary taking of life should not occur (4) RBT is a non-native in the system (Hopi perspective, not

	Zuni) (5) Human activity should be limited in the Grand Canyon (6) This is human caused situation – people caused the problem, now taking the easy way out but fish pay the penalty; human activities now having a negative cumulative effect on the whole system,
L.	Strategy K plus headstarting and barrier (single strategies: 5h, 6, 9, 15, 17, 18) Assumptions: (1) RBT not significantly limiting recruitment on HBC; HBC have survived in the system along with RBT for many decades. Temperature is a more limiting factor than predation by RBT. High degree of uncertainty about relationship between RBT predation and recruitment; until resolved, not worth the other (spiritual) costs.(2) HBC range has decreased throughout the system (3) Life is sacred; unnecessary taking of life should not occur (4) RBT is a non-native in the system (Hopi perspective, not Zuni) (5) Human activity should be limited in the Grand Canyon (6) This is human caused situation – people caused the problem, now taking the easy way out but fish pay the penalty; human activities now having a negative cumulative effect on the whole system, (7) additional actions (headstarting barrier) required.
M.	Selective-sacrifice and strand portfolio: (single strategies: 5j, 9 with trigger, (6): Portfolio is similar to stranding flow with assurances (H), but de-watering redds employed rather than flows to strand juveniles. Conduct stranding flows seasonally, approximately April–May. Assumptions: RBT limit HBC recovery, Lees Ferry is an important source of RBT, Lees Ferry is the source of RBT, stranding flows in combination with PBR will work to eliminate emigration, extant RBT population at LCR will disappear after migration is curtailed.
N.	BNT expanded removal (single strategies: 1, 3b, 6, 7, 8) Assumptions: BNT is large source of mortality on HBC, removal of BNT effective at maintaining high juv HBC survival, removal during monitoring trips will be effective at reducing BNT abundance, encounter rate consistent with on-site consumption.
O.	Expanded sediment curtain (single strategies: 3b, 5e, 6, 13, 14): sediment augmentation also introduced at Lees Ferry (#14), #13 is long-term solution to emigration; #5 is the short-term solution to emigration while infrastructure is being built; #3 is used to reduce extant RBT population Assumptions: RBT limit HBC recovery, Lees Ferry is the source of RBT, removal @ PBR stops emigration; sediment curtain will work to reduce emigration; in the long-term, sediment curtain is cheaper than ongoing removal.

Underlying each hybrid portfolio is a set of assumptions about how biological systems will respond to proposed actions. The consequences of the actions in terms of the objectives could differ depending on whether the assumptions hold or not. A diagram of critical assumptions relevant to this problem is shown in figure 4.

Workshop participants created 27 different hybrid portfolios representing a range of approaches, and an array of underlying assumptions (table 3). The portfolios can be grouped according to the basic underlying assumptions they rest on (fig. 4). Detailed narratives for the hybrid portfolios are found in appendix 2.

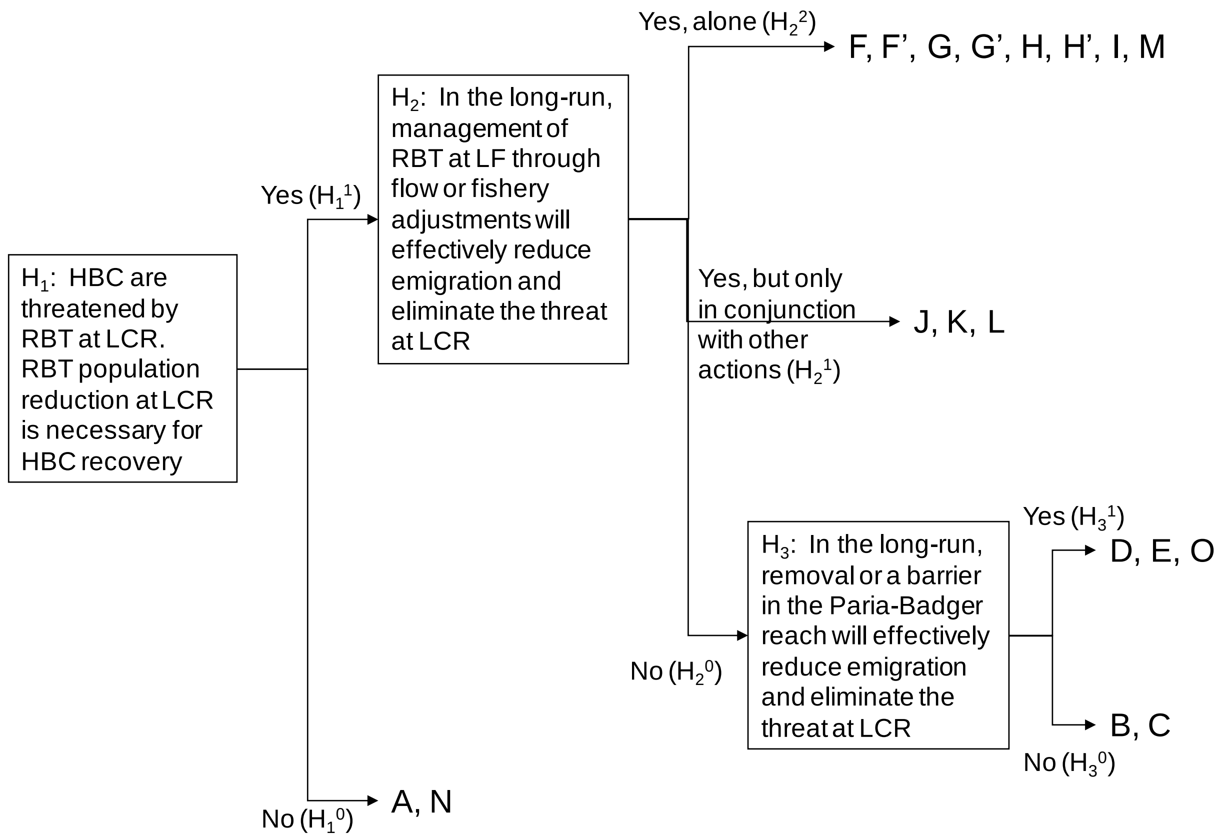

Figure 4. Flowchart showing key uncertainties in predicting the response of rainbow trout and humpback chub populations to management actions. The ends of the flowchart point to the hybrid portfolios (table 3) that are predicated on the series of hypotheses that lead to them. This flowchart is not, however, meant to be a decision tree, as the particular portfolios need not be favored even if the hypotheses on which they were created are true, owing to competing objectives.

5.4. Adaptive Strategies

If it were known which set of assumptions was valid, it would be easy to identify which hybrid portfolios were reliable candidates to carry forward in a decision analysis. In reality, there is uncertainty surrounding the underlying biological assumptions. Many of the stakeholders believe that the preferred approach will need to be adaptive, that is, it will need to entertain several hybrid portfolios as candidates, in a strategy that seeks to reduce uncertainty about the underlying mechanisms, and so identify the appropriate way forward to long-term management. An *adaptive strategy* may include experimental elements initially, but an important feature of an adaptive strategy is an understanding of which hybrid portfolio would eventually be adopted on a long-term basis once the relevant uncertainty has been acceptably resolved.

For example, one potential adaptive strategy was advanced by a group of scientists from GCMRC and elsewhere that met at any ecosystem modeling workshop in October 2010. This adaptive strategy can be characterized as including hybrid strategies {A, C, D}. This would be designed to test the assumptions about whether rainbow trout were limiting the LCR humpback chub population, and the effectiveness of removal in the PBR to stop emigration from Lees Ferry. If, after the next 1 to 2 years, rainbow trout in the LCR reach were found not to limit humpback chub, then hybrid Portfolio A would possibly be the best overall long-term management solution with respect to non-native fish control in the Canyon. If rainbow trout were found to limit humpback chub and removal in the PBR effectively stopped emigration, then hybrid Portfolio D would possibly be the best overall long-term solution. If rainbow trout were found to limit humpback chub and removal in the PBR was not effective, then hybrid Portfolio C would possibly be the best overall long-term management solution for non-native fish control.

Our view is that adaptive strategies should arise out of analysis of the hybrid portfolios and consideration of how key uncertainties affect the choice of a management option. Thus, development of adaptive strategies is discussed in section 7.4 after evaluation of the individual hybrid portfolios and a consideration of the expected value of information.

6. Consequences of the Hybrid Strategies

In a multi-criteria decision analysis, the evaluation stage consists of an examination of each of the alternatives against each of the objectives (as expressed by the measurable attributes). These *consequences* link the actions to the objectives and provide the basis for a trade-off analysis.

6.1. Methods

Four teams of experts were assembled to evaluate the consequences of the hybrid portfolios, a Cultural Objectives team, an Ecological Objectives team, a Recreational Objectives team, and a Public Service Objectives team. These teams reviewed the objectives, developed appropriate scales on which to measure achievement of those objectives (measurable attributes), and scored each hybrid portfolio against each of the measurable attributes. In some cases, the “scoring” was done through development of a quantitative model for predicting the outcomes associated with each alternative; in other cases, expert elicitation was employed to develop the scoring.

6.2. Evaluation of Cultural Objectives

The consequences for the cultural objectives (measurable attributes 1A–1D) are shown in table 4. Representatives from three Tribes (Hopi Tribe, Pueblo of Zuni, and Navajo Nation) attended the second workshop and participated in the assessment of consequences to cultural objectives. Given that each Tribe is a sovereign entity with a distinct perspective, their scores were treated separately in the analysis. All five tribes had been invited to participate in the discussions between workshops, but only the three above, plus the Hualapai representative, were able to provide feedback in the development of objectives and measurable attributes.

Table 4. Consequence matrix for cultural objectives.

[Scores are shown for three different Tribal perspectives (Zuni/Hopi/Navajo). Hybrid portfolios shaded in light green were included in the final analysis. Note that the measurable attributes changed between the initial and final analyses, and only the portfolios included in the final analysis were scored on the new scale. LCR, Little Colorado River; NPS, National Park Service; BNT, brown trout]

Hybrid portfolio		1A: Avoid taking life	1B: Respect life	1C: Culturally appropriate	1D: Protect sanctity
		0–1	0–10	0–1	0–1
		Maximize	**Maximize**	**Maximize**	**Maximize**
A	No action	0 / 1 / 0	7 / 10 / 1	1 / 1 / 0	1 / 1 / 0
B	Status quo	ns[7]	0 / 9 / 1	ns	ns
C_1	LCR removal (3a)	ns	7 / 9 / 5	ns	ns
C_2	LCR removal (3b)	0 / 0 / 0	5 / 9 / 5	0 / 0.4 / 0	0 / 0.3 / 0
C_3	LCR removal (3abe)	0 / 0 / 0	5 / 9 / 5	0 / 0.4 / 0	0 / 0.2 / 0
C_4	LCR removal (3e, boat)	0 / 1 / 0	9 / 10 / 10	1 / 0.5 / 0	0 / 0.4 / 1
C_5	LCR removal (3e, helicopter)	0 / 1 / 0	9 / 10 / 10	1 / 0.5 / 0	0 / 0.1 / 1
D_1	Removal curtain (3b, 5e)	0 / 0 / 0	5 / 9 / 10	0 / 0.3 / 0	0 / 0.4 / 1
D_2	Removal curtain (3b, 5h)	0 / 0 / 0	5 / 9 / 5	0 / 0.3 / 0	0 / 0.4 / 1
D_3	Removal curtain (3e, 5h)	0 / 1 / 0	9 / 10 / 10	1 / 0.4 / 0	0 / 0.3 / 1
E	Sediment curtain	ns	5 / 10 / 10	ns	ns
F	Stranding flow	ns	5 / 3 / 10	ns	ns
F’	Stranding flow with triploid	ns	0 / 3 / 10	ns	ns
G	Stranding flow with augmentation	ns	2 / 3 / 10	ns	ns
G’	Stranding flow with augmentation and triploid	ns	2 / 3 / 10	ns	ns
H	Stranding flow with assurances	ns	0 / 9 / 10	ns	ns
H’	Stranding flow with assurances and triploid	ns	2 / 9 / 10	ns	ns
I	De-water redds	ns	3 / 3 / 10	ns	ns
J_1	Kitchen sink (3b, 5e)	0 / 0 / 0	0 / 0 / 5	0 / 0.2 / 1	0 / 0.2 / 1
J_1’	Kitchen sink (3b, 5e) with triploid	0 / 0 / 0	0 / 0 / 5	0 / 0.1 / 1	0 / 0.5 / 1

[7] Not scored in the final analysis.

Hybrid portfolio		1A: Avoid taking life	1B: Respect life	1C: Culturally appropriate	1D: Protect sanctity
		0–1	0–10	0–1	0–1
		Maximize	**Maximize**	**Maximize**	**Maximize**
J_2	Kitchen sink II (3e, 5h)	0 / 0 / 0	0 / 0 / 5	0 / 0.2 / 1	0 / 0.4 / 1
J_2’	Kitchen sink II (3e, 5h) with triploid	0 / 0 / 0	0 / 0 / 5	0 / 0.2 / 1	0 / 0.4 / 1
K	Zuni-Hopi-NPS	0 / 0 / 0	7 / 10 / 10	1 / 0.3 / 1	0 / 0.9 / 1
L	K + head-starting and barrier	ns	7 / 10 / 10	ns	ns
M	Selective-Sacrifice & Strand	ns	4 / 3 / 10	ns	ns
N	Expanded BNT	ns	7 / 9 / 10	ns	ns
O	Expanded sediment curtain	ns	3 / 3 / 10	ns	ns

The development of attributes for each of the cultural objectives proved somewhat difficult as there was reluctance to ascribe value or scalar levels to spirituality. This is entirely understandable. Perhaps a more efficient process would have been to develop other objectives that were less “fundamental” from a spiritual perspective and more akin to means objectives. For example, preserving the sanctity of the Canyon may have been easier to convey by describing this as “minimizing the footprint” of the proposed actions, which then could have led to the development of a scale measuring disturbance. The location of the action within the Canyon was considered, but this measure was less effective at supporting the fundamental objective because the entire Canyon is considered sacred. See section 8.2 for further comments on the process of scoring cultural objectives.

Between the initial analysis (conducted at the second workshop) and the final analysis, the set of alternatives being considered changed, and the interpretation of these four measurable attributes changed as well. The initial set of alternatives was never evaluated with the final interpretation of the attributes, so some scores are not shown in table 3. The interpretations that follow are for the final analysis only.

For attribute 1A, the Zuni and Navajo representatives simply evaluated whether life was being taken at all; since all of the alternatives involve some taking of life (note the no action alternative, A, includes brown and rainbow trout removal at Bright Angel Creek), all of them scored 0. The Hopi representative viewed the scale differently, and gave a score of 1 to those alternatives that took a minimum of life.

For attribute 1B, the tribal representatives interpreted the degree to which the beneficial use of any trout removed reflected a respect for life. Live removal options tended to score higher on this attribute, but there was a significant difference in how the three tribes scored this attribute.

For attribute 1C, the Zuni and Navajo representatives used a binary scale, evaluating whether the alternative was culturally appropriate or not. The Hopi representative used a continuous utility scale between 0 and 1 and applied fractional values for alternatives that would have intermediate value.

For attribute 1D, the Zuni and Navajo representatives used a binary scale, evaluating whether the alternative preserved the sanctity of the Canyon or not. The Hopi representative used a continuous utility scale between 0 and 1 and applied fractional values for alternatives that would have intermediate value.

6.3. Evaluation of Ecological Objectives

The consequences for the ecological objectives (measurable attributes 2A–2D) are shown in table 5. Three of these measurable attributes (2A, 2D1, and 2D2) were developed using predictive population models; the other four (2B1, 2B2, 2C1, and 2C2) were developed using a constructed scale.

Table 5. Consequence matrix for ecological objectives.

[HBC, humpback chub; NNF, non-native fish; yr, year; RBT, rainbow trout; LCR, Little Colorado River; NPS, National Park Service; BNT, brown trout]

Hybrid portfolio		2A: HBC recovery	2B1: Invasive species import	2B2: Invasive species export	2C1: Disease import	2C2: Disease export	2D1: NNF abund.	2D2: Native fish goals
		Pr(*N* greater than 6,000 for 30 yr)	Risk	Risk	Risk	Risk	RBT at LCR	Freq (HBC greater than 10,000)
		Maximize	**Minimize**	**Minimize**	**Minimize**	**Minimize**	**Minimize**	**Maximize**
A	No action	0.232	None	None	None	None	6,486	0.19
B	Status quo	0.346	Low	Low	Low	Low	4,673	0.25
C_1	LCR removal (3a)	0.341	Low	Low	Low	Low	4,673	0.26
C_2	LCR removal (3b)	0.341	Low	Low	Low	Low	4,673	0.26
C_3	LCR removal (3abe)	0.341	Low	High	Low	Med.	4,673	0.26
C_4	LCR removal (3e, boat)	0.341	Low	High	Low	Med.	4,673	0.26
C_5	LCR removal (3e, helicopter)	0.341	Low	High	Low	Med.	4,673	0.26
D_1	Removal curtain (3b, 5e)	0.532	Low	Low	Low	Low	827	0.39
D_2	Removal curtain (3b, 5h)	0.532	Low	High	Low	Med.	827	0.39
D_3	Removal curtain (3e, 5h)	0.532	Low	High	Low	Med.	827	0.39
E	Sediment curtain	0.557	Low	Low	Low	Low	333	0.43
F	Stranding flow	0.228	None	None	None	None	5,302	0.17

Hybrid portfolio		2A: HBC recovery	2B1: Invasive species import	2B2: Invasive species export	2C1: Disease import	2C2: Disease export	2D1: NNF abund.	2D2: Native fish goals
		Pr(N greater than 6,000 for 30 yr)	Risk	Risk	Risk	Risk	RBT at LCR	Freq (HBC greater than 10,000)
		Maximize	**Minimize**	**Minimize**	**Minimize**	**Minimize**	**Minimize**	**Maximize**
F’	Stranding flow with triploid	0.224	Med.	None	Low	Low	6,039	0.17
G	Stranding flow with augmentation	0.278	Low	Low	Low	Low	1,516	0.21
G’	Stranding flow with augmentation and triploid	0.279	Med.	Low	Med.	Low	1,662	0.21
H	Stranding flow with assurances	0.355	Low	Low	Low	Low	3,388	0.25
H’	Stranding flow with assurances and triploid	0.341	Med.	Low	Med.	Low	3,836	0.25
I	De-water redds	0.276	Low	Low	Low	Low	1,791	0.20
J_1	Kitchen sink (3b, 5e)	0.555	Low	Low	Low	Low	677	0.41
J_1’	Kitchen sink (3b, 5e) with triploid	0.536	Med.	Low	Med.	Low	697	0.41
J_2	Kitchen sink II (3e, 5h)	0.555	Low	High	Low	Med.	677	0.41
J_2’	Kitchen sink II (3e, 5h) with triploid	0.536	Med.	High	Med.	Med.	697	0.41
K	Zuni-Hopi-NPS	0.291	Low	High	Low	Med.	1,410	0.22
L	K + head-starting and barrier	--[8]	Med.	Low	Low	Low	--	--
M	Selective-Strand & Sacrifice	0.276	Low	Low	Low	Low	1,791	0.20
N	Expanded BNT	--	Low	Low	Low	Low	--	--

[8] Not enough detail was provided about Portfolios L and N to predict the trout and chub population responses.

Hybrid portfolio		2A: HBC recovery	2B1: Invasive species import	2B2: Invasive species export	2C1: Disease import	2C2: Disease export	2D1: NNF abund.	2D2: Native fish goals
		Pr(*N* greater than 6,000 for 30 yr)	Risk	Risk	Risk	Risk	RBT at LCR	Freq (HBC greater than 10,000)
		Maximize	**Minimize**	**Minimize**	**Minimize**	**Minimize**	**Minimize**	**Maximize**
O	Expanded sediment curtain	0.557	None	None	None	None	333	0.43

The predictive population models used to evaluate the consequences of policy alternatives on humpback chub and rainbow trout objectives (cf Section 4.3) involved a set of 3 coupled models (Lew Coggins, Service, and Josh Korman, Ecometric Research, Inc., oral commun., 2010). The elements of this coupled model included (1) emigration from the Lees Ferry tailwaters reach into Marble Canyon, (2) dynamics of rainbow trout during movement from Lees Ferry to LCR, and (3) the interaction between rainbow trout and humpback chub in the LCR confluence reach (fig. 5). This conceptual model provided the basic structure for development of a predictive model, which took as input the alternative hybrid portfolios, and produced as output the desired measurable attributes. Uncertainties were incorporated as stochastic parameters or as competing models with corresponding model weights (cf Section 6.6). The predictive model was implemented in an Excel spreadsheet and Monte Carlo-based estimates of expected responses were generated using a PopTools add-in. The results were projected over a 30-year time horizon, and means were calculated from 500 replicates of the stochastic model.

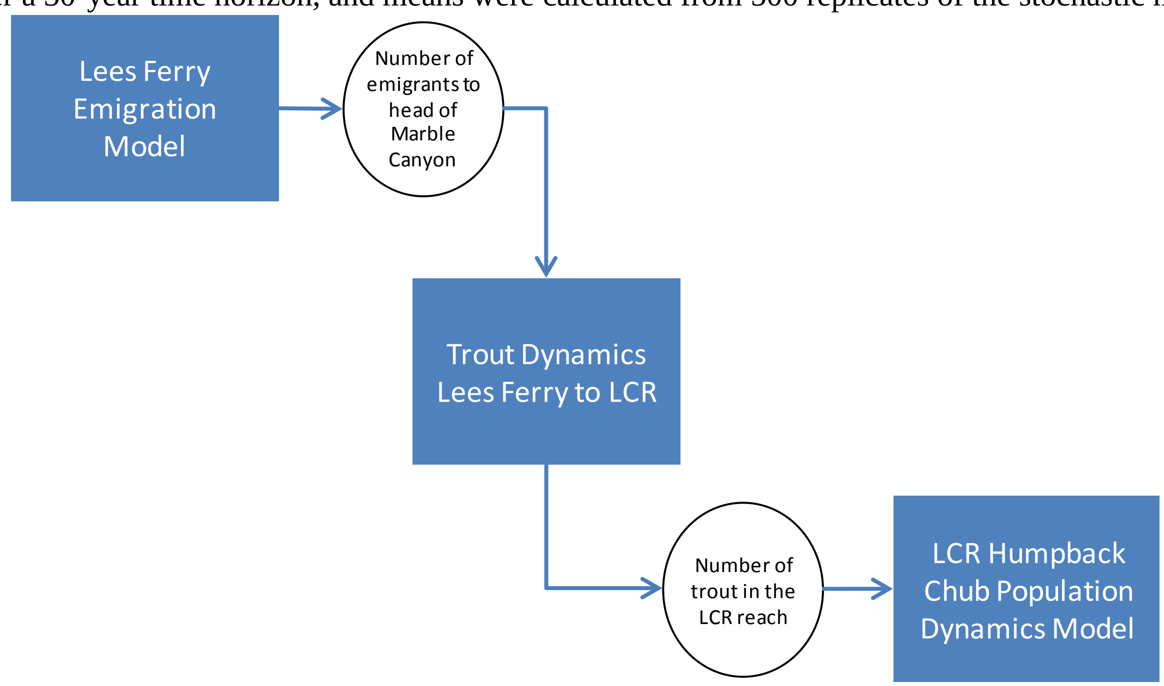

Figure 5. Conceptual model of fish community dynamics in the Colorado River below Glen Canyon Dam (Lew Coggins, Service, written commun., 2010). This provided the basis for a predictive model (Lew Coggins, Service, and Josh Korman, Ecometric Research, Inc., written commun., 2010) to support the decision analysis.

Rates of rainbow trout emigration from Lees Ferry into Marble Canyon were based on analysis of Lees Ferry recruitment in year t and monthly emigration in year $t + 1$. Base recruitment rates were modeled as a function of flow policy, and affect emigration rates. The Modified Low Fluctuating Flow (MLFF) record-of-decision operating strategy (U.S. Department of the Interior, 1996) provided the baseline recruitment and emigration rates. Alternative flow strategies (that is, de-watering redds and fry displacement or stranding flows) reduce recruitment and suppress emigration; however, high-flow experiments (HFEs) have been shown to increase recruitment and enhance emigration (table 6) as recently reported by Korman and others (2010). In the model, release of triploid males at Lees Ferry (in the stocking alternatives) increased baseline recruitment from 50 to 70 and 200 to 220 (×1,000) under the "Without HFE" and "With HFE" scenarios, respectively.

Table 6. Predictions of Lees Ferry rainbow trout recruitment and emigration to Marble Canyon as affected by flow policies, and incorporated into the model to predict consequences of alternatives on ecological objectives.

[Predictions are based on analyses that fit a monthly stock assessment model to monitoring data from the Lees Ferry tailwaters reach and Marble Canyon (Josh Korman, Ecometric Research, Inc., oral commun., 2010); ROD, 1996 Record of Decision]

Flow policy	Recruitment reduction	Monthly emigration (x1,000)	
		Without high flow experiment	With high flow experiment
Modified Low Fluctuating Flow (1996 ROD)	0.00	1.95	7.20
Dewatering redds	0.10	1.78	6.50
Rapid downramping	0.30	1.43	5.10
Stranding flows	0.40	1.25	4.40
All suppression flows combined	0.62	0.86	2.85

Movement of rainbow trout through reaches within Marble Canyon was modeled on a monthly time step. Each reach was defined to have a ‘carrying capacity’ so that excess abundance ‘spilled over’ into the adjacent downstream reach. In addition, stochastic movement was modeled to be independent of reach-specific abundance. Baseline monthly survival rate was 0.97. Reach-specific abundance was affected by alternatives that included removal, whether from the Paria River to Badger Creek reach (PBR, RM 0 to 8), or from the reach near the LCR (Kwagunt Canyon to Lava Canyon reach, RM 56 to 66). The magnitude of removal was a function of capture probability, number of passes per trip, and number of months when removal occurred. Capture probability was 0.15 based on prior removal experiments. Optionally, removal was triggered by a critical abundance of rainbow trout within the respective reach. Fine-sediment augmentation implemented to increase turbidity in Marble Canyon lowered the monthly survival rate to 0.85.

An age-structured model was used to predict the dynamics of humpback chub in the LCR and adjacent mainstem habitats. Movement of juveniles from the LCR to the mainstem was on a half-year time step over the 4 years prior to maturity. The interaction between humpback chub and rainbow trout was modeled to occur in the mainstem habitats. Survival of juvenile humpback chub was modeled as a logistic function of rainbow-trout abundance within the Kwagunt Canyon to Lava Canyon reach. The logistic function was tuned to generate on average 10,000 adult humpback chub in the absence of an rainbow-trout effect (RBT hypothesis false) and 2,500 adult humpback chub for a maximum rainbow-trout effect (RBT hypothesis true). The logistic function could be turned off to model humpback chub dynamics as independent of rainbow-trout abundance. The predicted response of humpback chub to each alternative hybrid portfolio is shown in table 7, as a function of all combinations of the three underlying hypotheses (see section 6.6 for discussion of the three hypotheses).

Table 7. Predicted humpback chub response as a function of the combinations of three hypotheses.

[The response variable shown is the probability of the humpback chub population at the Lower Colorado River reach remaining above 6,000 adults for a 30-year period. The hypotheses concern (1) the effect of high-flow experimental releases (HFE) on trout recruitment and emigration, (2) the effect of rainbow trout on humpback chub (RBT), and (3) the effectiveness of specific flow regime to reduce trout recruitment and emigration (Flow). The weight on the eight combinations is found from the expert-elicited weight on the individual hypotheses. Pink shading shows the worst performing alternative under a particular combination of hypotheses, light green shows the best.]

HFE	No	No	No	No	Yes	Yes	Yes	Yes	
RBT	No	No	Yes	Yes	No	No	Yes	Yes	
Flow	No	Yes	No	Yes	No	Yes	No	Yes	
Weight	0.050	0.124	0.094	0.233	0.050	0.124	0.094	0.233	Average
Alternative									
A	0.660	0.660	0.010	0.010	0.660	0.660	0.000	0.000	0.232
C_2	0.660	0.660	0.344	0.344	0.660	0.660	0.000	0.000	0.341
C_3	0.660	0.660	0.344	0.344	0.660	0.660	0.000	0.000	0.341
C_4	0.660	0.660	0.344	0.344	0.660	0.660	0.000	0.000	0.341
C_5	0.660	0.660	0.344	0.344	0.660	0.660	0.000	0.000	0.341
D_1	0.660	0.660	0.509	0.509	0.660	0.660	0.418	0.418	0.532
D_2	0.660	0.660	0.509	0.509	0.660	0.660	0.418	0.418	0.532
D_3	0.660	0.660	0.509	0.509	0.660	0.660	0.418	0.418	0.532
J_1	0.660	0.660	0.509	0.525	0.660	0.660	0.418	0.502	0.555
J_1’	0.660	0.660	0.479	0.499	0.660	0.660	0.391	0.468	0.536
J_2	0.660	0.660	0.509	0.525	0.660	0.660	0.418	0.502	0.555
J_2’	0.660	0.660	0.479	0.499	0.660	0.660	0.391	0.468	0.536
K	0.660	0.660	0.100	0.110	0.660	0.660	0.048	0.098	0.291

The consequences of the alternatives to the risks and impacts of disease and invasive species (attributes 2B1, 2B2, 2C1, and 2C2) were derived from expert elicitation (Larry Riley and Bill Stewart, Arizona Game and Fish Department, written commun., 2010). For attribute 2B1 (the risk of invasive species import), the factors that increase the risk of import of an invasive species include the transportation of live fish to Glen or Grand Canyon from an outside location. Much of the risk can be controlled through use of preventative measures, but there is some inherent risk. For attribute 2B2 (the risk of invasive species export), the factors that increase the risk of export of resident unwanted species (such as New Zealand mudsnail and didymo) include the removal of live fish from Glen or Grand Canyon and transportation to other locations. The probability of mudsnail transport is high and their prevalence is high. Some degree of control can be exerted through control of destination. Any portfolio that includes the removal of live trout would score high based on these assumptions.

For attribute 2C1 (the risk of disease import), the factors that increase the risk of import of a disease agent include the transportation of live fish to Glen or Grand Canyon from an outside location. Much of the risk can be controlled through use of preventative measures, but there is some inherent risk. For attribute 2C2 (the risk of disease export), the factors that increase the risk of export of wildlife disease agents/parasites (Whirling Disease, Asian tapeworm, trout nematode) include the transportation of live (and sometimes dead) fish from Glen or Grand Canyon to other locations. Although there is uncertainty about the prevalence of Whirling Disease, it is assumed to be uncommon. Other parasites are fairly common.

6.4. Evaluation of Recreational Objectives

The consequences for the recreational objectives (measurable attributes 3A–3D) are shown in table 8.

Table 8. Consequence matrix for recreational objectives.

[LF, Lees Ferry; GCNRA, Glen Canyon National Recreation Area; hr, hour; yr, year; LCR, Little Colorado River; NPS, National Park Service; BNT, brown trout]

Hybrid portfolio		3A1: LF catch rate	3A2: LF size distri-bution	3B: Wilderness disturbance	3C: Wilderness boating experience	3D: GCNRA boating experience
		Fish/hr	Percent greater than 20 in.	Penalized user-days/yr	Days/yr within specifications	Days/yr within specifications
		Maximize	**Maximize**	**Minimize**	**Maximize**	**Maximize**
A	No action	0.76	0.05	0	365	365
B	Status quo	0.76	0.05	4,991	365	365
C_1	LCR removal (3a)	0.76	0.05	5,003	365	365
C_2	LCR removal (3b)	0.76	0.05	5,003	365	365
C_3	LCR removal (3abe)	0.76	0.05	5,037	365	365
C_4	LCR removal (3e, boat)	0.76	0.05	5,003	365	365
C_5	LCR removal (3e, helicopter)	0.76	0.05	5,154	365	365
D_1	Removal curtain (3b, 5e)	0.76	0.05	6,824	365	365
D_2	Removal curtain (3b, 5h)	0.76	0.05	6,824	365	365
D_3	Removal curtain (3e, 5h)	0.76	0.05	6,867	365	365
E	Sediment curtain	0.76	0.05	3,442	365	365
F	Stranding flow	0.46	2.5	0	359	359
F’	Stranding flow with triploid	0.76	1.0	0	359	359
G	Stranding flow with augmentation	0.46	2.5	2,700	359	359
G’	Stranding flow with augmentation and triploid	0.76	1.0	2,700	364	359

Hybrid portfolio		3A1: LF catch rate	3A2: LF size distri-bution	3B: Wilderness disturbance	3C: Wilderness boating experience	3D: GCNRA boating experience
		Fish/hr	Percent greater than 20 in.	Penalized user-days/yr	Days/yr within specifications	Days/yr within specifications
		Maximize	**Maximize**	**Minimize**	**Maximize**	**Maximize**
H	Stranding flow with assurances	0.46	2.5	4,596	364	359
H’	Stranding flow with assurances and triploid	0.76	1.0	5,051	364	359
I	De-water redds	0.68	0.5	2,700	364	362
J_1	Kitchen sink (3b, 5e)	0.29	2.5	6,753	359	354
J_1’	Kitchen sink (3b, 5e) with triploid	0.76	1.0	6,777	359	354
J_2	Kitchen sink II (3e, 5h)	0.29	2.5	6,793	359	354
J_2’	Kitchen sink II (3e, 5h) with triploid	0.76	1.0	6,818	359	354
K	Zuni-Hopi-NPS	0.46	1.0	5,400	364	354
L	K + head-starting and barrier	0.46	1.0	5,400	364	354
M	Selective-Strand & Sacrifice	0.46	2.5	5,400	364	354
N	Expanded BNT	0.76	0.05	--	365	365
O	Expanded sediment curtain	0.11	1.0	3,442	365	365

The results for attributes 3A1 (catch rate) and 3A2 (size distribution) were based on mean rates over the past 10 years (catch rate 0.76 fish/hr from creel surveys, 0.05 percent trout greater than 20” from electrofishing surveys, Bill Stewart, Arizona Game and Fish Department, written commun., 2010). It was assumed that these rates would remain the same for all portfolios that focused only on activities downstream of Lees Ferry (Portfolios A, B, C, D, E, N). For the various flow regimes in which stocking was not included (Portfolios F, G, H, M), it was assumed the trout recruitment at Lees Ferry would decline by 40 percent (Josh Korman, Ecometric Research, Inc., oral commun., 2010), and catch rates would decline similarly (to 0.46/hr), but the frequency of large fish would increase (to 2.5 percent) because of reduced intraspecific competition. For the portfolios that included stocking (F’, G’, H’, J_1’, J_2’), it was assumed the fish stocking would be at a level to return the catch rates to baseline (0.76/hr), even with reduced recruitment, but that the stocking would increase intraspecific competition so the frequency of large fish would drop to 1 percent. For the remaining portfolios (I, J_1, J_2, K, L, and O), the catch rate was assumed to decline to the same degree that the flow or sediment regimes reduced the age-0 recruitment, and the frequency of large fish would generally increase with decreases in catch rate, as a result of reduced intraspecific competition.

The consequences for attribute 3B (wilderness disturbance) were developed using the penalized user-days scale described in section 4.3. The number of LCR removal trips per year (where applicable) was predicted by the rainbow trout model used for attribute 2A (because trout removal is only triggered when the rainbow trout population exceeds 1,200 in the LCR removal reach). LCR removal trips were assumed to be 19 days long, with a staff of 14 taking half of the trips during the non-motor season and half during the motor season, and with all removal work done at night. For live removal from the LCR, it was assumed that a helicopter could move two drums per trip, each with 50 trout in it, and that approximately 1,800 trout would be removed per LCR trip. The number of PBR removal trips per year (where applicable) was assumed to be fixed at 10 per year, of 15 days in duration, and using a staff of eight. In the PBR, live removal can occur much more easily without helicopter support.

The consequences for attributes 3C (wilderness boating experience) and 3D (recreation area boating experience) were developed by estimating the number of days per year that conditions would remain within the parameters specified by the measurable attributes (see section 4.3). For attribute 3D, the following assumptions were made. First, many of the portfolios do not employ flow changes, so the expected number of days per year within the boating specifications is 365 (this assumes that current flow conditions allow for 365 boatable days per year). For the stranding flow portfolios (F, G, H), 6 days per year were anticipated to have flows greater than 3,000 ft^3/s for ½ day during daylight hours. For the de-watering redd portfolios (I, K, L, M), flows are restricted to less than 3,000 ft^3/s for ½ day on 3 days per year (once per month, February–April) during daylight hours. For the kitchen sink portfolios (J_1, J_2), three de-watering events and six stranding events per year are assumed, each of ½ day duration with flows less than 3,000 ft^3/s. In all cases, if the low flows are 5,000 ft^3/s rather than 3,000 ft^3/s, the boating conditions would not be affected, and the days per year within the specifications would remain at 365. With regard to the Lees Ferry sediment curtain (Portfolio O), it is difficult to know the effect on boating in the area. Certainly water clarity might change, which may modify some aspects of recreational experience. Turbid water conditions would not make navigational hazards, but they would make them harder to see for boaters.

6.5. Evaluation of Public Service Objectives

The consequences for the public service objectives (measurable attributes 4A–4F) are shown in table 9.

Table 9. Consequence matrix for economic and public service objectives.

[NNF, non-native fish; M$, million dollars; yr, year; LCR, Little Colorado River; NPS, National Park Service; BNT, brown trout]

Hybrid portfolio		4A: Economic value of fishery	4B: Economic value of wilder-ness	4C: Cost of NNF manage-ment[9]	4D: Impacts to Dam operation	4E: Power production	4F: Impacts to water delivery
		M$/yr	M$/yr	M$ over 5-yr	Yes/No	M$/yr (relative)	Yes/No
		Maximize	**Maximize**	**Minimize**	**Minimize**	**Maximize**	**Minimize**
A	No action	$7.67	nc[10]	$0.00	No	0	No
B	Status quo	$7.67	nc	$3.13	No	0	No
C_1	LCR removal (3a)	$7.67	nc	$3.17	No	0	No
C_2	LCR removal (3b)	$7.67	nc	$3.17	No	0	No
C_3	LCR removal (3abe)	$7.67	nc	$3.53	No	0	No
C_4	LCR removal (3e, boat)	$7.67	nc	$3.38	No	0	No
C_5	LCR removal (3e, helicopter)	$7.67	nc	$4.65	No	0	No
D_1	Removal curtain (3b, 5e)	$7.67	nc	$3.47	No	0	No
D_2	Removal curtain (3b, 5h)	$7.67	nc	$3.98	No	0	No
D_3	Removal curtain (3e, 5h)	$7.67	nc	$4.36	No	0	No
E	Sediment curtain	$7.67	nc	$436.78	No	0	No
F	Stranding flow	$4.60	nc	$0.00	No	−0.25	Yes
F’	Stranding flow with triploid	$7.67	nc	$0.18	No	−0.25	Yes
G	Stranding flow with augmentation	$4.60	nc	$1.29	No	−0.25	Yes
G’	Stranding flow with augmentation and triploid	$7.67	nc	$1.46	No	−0.25	Yes
H	Stranding flow with assurances	$7.67	nc	$2.92	No	−0.25	Yes
H’	Stranding flow with assurances	$7.67	nc	$3.38	No	−0.25	Yes

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9 This is the cost to Reclamation and the GCDAMP and does not include costs to other agencies or entities.

10 Not calculated. The value to the local economy of wilderness experiences is not expected to be affected by the alternative portfolios, so this assessment was not completed in full.

Hybrid portfolio		4A: Economic value of fishery	4B: Economic value of wilder-ness	4C: Cost of NNF manage-ment[9]	4D: Impacts to Dam operation	4E: Power production	4F: Impacts to water delivery
		M$/yr	M$/yr	M$ over 5-yr	Yes/No	M$/yr (relative)	Yes/No
		Maximize	**Maximize**	**Minimize**	**Minimize**	**Maximize**	**Minimize**
	and triploid						
I	De-water redds	$6.90	nc	$1.29	No	1.0	Yes
J_1	Kitchen sink (3b, 5e)	$2.93	nc	$3.43	No	2.00	Yes
J_1'	Kitchen sink (3b, 5e) with triploid	$7.67	nc	$3.62	No	2.00	Yes
J_2	Kitchen sink II (3e, 5h)	$2.93	nc	$4.08	No	2.00	Yes
J_2'	Kitchen sink II (3e, 5h) with triploid	$7.67	nc	$4.32	No	2.00	Yes
K	Zuni-Hopi-NPS	$4.60	nc	$3.03	No	1.00	Yes
L	K + head-starting and barrier	$4.60	nc	nc[11]	No	1.00	Yes
M	Selective-Strand & Sacrifice	$4.60	nc	$2.99	No	1.0	Yes
N	Expanded BNT	$7.67	nc	nc	No	0	No
O	Expanded sediment curtain	$1.07	nc	$594.78	No	0	No

The results for measurable attribute 4A (economic value of the Lees Ferry fishery) were based on the mean angler days per year (1967–97, McKinney and Persons, 1999; and 2001, Silberman, 2003) and the average expenditures per angler-day ($210/day, Silberman, 2003) for a base rate of $7.67 million per year. It was then assumed that angler-days are proportional to the catch rate (McKinney and Persons, 1999), and the economic values were adjusted in proportion to the catch rates (attribute 3A1).

As noted above, the economic value of wilderness recreation (attribute 4B) was not expected to differ across alternative portfolios. The demand for the wilderness experience exceeds availability (with limited permits for boat trips issued each year), so any changes to the wilderness experience brought about by the alternatives considered here were assumed to have a negligible effect on the recreational use and its local economic benefits.

The results for measurable attribute 4C (cost of non-native fish management) were developed by building up the costs associated with the components of the hybrid portfolios. The following assumptions about costs formed the basis of this calculation. The number of LCR removal trips per year (where applicable) was predicted by the rainbow trout model used for attribute 2A (because trout removal is only triggered when the rainbow trout population exceeds 1,200 in the LCR removal reach). For live removal from the LCR, it was assumed that a helicopter could move two drums per trip, each

[11] Not enough detail was specified for Portfolios L and N to calculate the costs of implementation.

containing 50 trout, and that approximately 1,800 trout would be removed per LCR trip. The number of PBR removal trips per year (where applicable) was assumed to be fixed at 10 per year. Each LCR river trip was assumed to cost $150,000, each PBR trip $50,000. Helicopter use was assumed to cost $3,500 per trip in and out of the canyon (approximately 1 hour). The costs for various beneficial uses were as follows: use of a smoker, $1,500 per trip; use of a freezer, $5,000 per year plus $500 per trip; use of a livewell, $2,000 per trip; cost to transport and place live fish in tribal stocking ponds, $5 per fish. The cost of stocking triploid male trout in Lees Ferry was estimated at $35,000 per year. Previous studies have estimated the cost of construction and operation of fine-sediment slurry pipelines: a pipeline to Paria River has an estimated construction cost of $380 million and an annual operational cost of $11 million; a fine-sediment slurry pipeline to just below Glen Canyon Dam has an estimated construction cost of $140 million and an annual operational cost of $3.6 million (Randle and others, 2007).

The results for measurable attribute 4D (impacts on dam operation) were evaluated by Reclamation staff. The assessment was made that none of the proposed alternatives would have a negative effect on dam operation.

The results for measurable attribute 4E (effect on power production) were developed by staff from the WAPA, and represent the change in the economic value of power production at Glen Canyon Dam relative to current conditions. A number of the alternatives that allow for high ramping rates provide the opportunity for an increase in power generation, while those that impose fixed flows for long periods reduce the power generation potential.

The results for measurable attribute 4F (impacts to water delivery) were developed by staff from the Reclamation and reflect expert judgment about whether the alternatives will require Reclamation to reallocate monthly obligations for water delivery. All of the alternatives that involve changes to flows have the potential to alter water delivery to some extent.

The consequences for the strategic objectives (measurable attributes 5A–5D) are shown in table 10. These were developed by Reclamation staff and show a tentative judgment about the degree to which the alternative portfolios are likely to meet these obligations.

Table 10. Consequence matrix for strategic objectives.

[ESA, Endangered Species Act of 1973; HFE, high-flow experiment; LCR, Little Colorado River; NPS, National Park Service; BNT, brown trout]

Hybrid portfolio		5A: Maintain compliance with ESA	5B: Remain within Reclamation authority	5C: Support the HFE protocol	5D: Recognize Trust responsibilities
		0/1/2	Yes/No	Yes/No	0/1/2
		Max	**Max**	**Max**	**Max**
A	No action	0	Yes	No	ns[12]
B	Status quo	2	Yes	Yes	ns
C_1	LCR removal (3a)	2	Yes	Yes	ns
C_2	LCR removal (3b)	2	Yes	Yes	ns
C_3	LCR removal (3abe)	2	Yes	Yes	ns
C_4	LCR removal (3e, boat)	2	Yes	Yes	ns
C_5	LCR removal (3e, helicopter)	2	Yes	Yes	ns
D_1	Removal curtain (3b, 5e)	2	Yes	Yes	ns
D_2	Removal curtain (3b, 5h)	2	Yes	Yes	ns
D_3	Removal curtain (3e, 5h)	2	Yes	Yes	ns
E	Sediment curtain	2	No	Yes	ns
F	Stranding flow	0	Yes	No	ns
F’	Stranding flow with triploid	0	No	No	ns
G	Stranding flow with augmentation	1	Yes	No	ns
G’	Stranding flow with augmentation and triploid	1	No	No	ns
H	Stranding flow with assurances	2	Yes	Yes	ns
H’	Stranding flow with assurances and triploid	2	No	Yes	ns
I	De-water redds	1	Yes	No	ns

[12] Not scored. At the time of analysis, scores had not been developed for this attribute.

Hybrid portfolio		5A: Maintain compliance with ESA	5B: Remain within Reclamation authority	5C: Support the HFE protocol	5D: Recognize Trust responsibilities
		0/1/2	Yes/No	Yes/No	0/1/2
		Max	**Max**	**Max**	**Max**
J_1	Kitchen sink (3b, 5e)	1	No	No	ns
J_1’	Kitchen sink (3b, 5e) with triploid	1	No	No	ns
J_2	Kitchen sink II (3e, 5h)	1	No	No	ns
J_2’	Kitchen sink II (3e, 5h) with triploid	1	No	No	ns
K	Zuni-Hopi-NPS	1	No	No	ns
L	K + head-starting and barrier	1	No	No	ns
M	Selective-Strand & Sacrifice	1	Yes	No	ns
N	Expanded BNT	1	Yes	No	ns
O	Expanded sediment curtain	2	No	Yes	ns

6.6. Estimation of the Likelihood of the Assumptions

Several key uncertainties could affect optimal non-native fish control (fig. 4). Uncertainty around three hypotheses was deliberately defined, quantified, and incorporated into the decision analysis. The hypotheses are described below, as are the methods used to gauge the uncertainty about these hypotheses.

Hypothesis 1 (HFE hypothesis): high-flow experimental releases from Glen Canyon Dam will increase and sustain rainbow trout production in the Lees Ferry tailwaters reach at the levels seen in 2008 and 2009. When spring high-flow experiments were conducted in the past, there is evidence that trout productivity increased substantially, perhaps as a result of cleansing of the Glen Canyon river bed and other effects. In the March 2008 HFE, there is strong evidence that the effect was caused by the HFE, but the evidence is not as compelling for the March 1996 HFE (Korman and others, 2010). Whether these effects would be sustained over a long period of HFEs is not known. Uncertainty was characterized by specifying two competing models: in the null model (or if HFEs are not used), production in (and hence emigration from) Lees Ferry will continue at the base levels seen in the past decade (2000-10). In the alternative model, HFEs, released annually on average, will result in increased and sustained production and emigration of rainbow trout at levels consistent with the observations after recent spring high-flows (Korman, 2009).

Hypothesis 2 (RBT hypothesis): rainbow trout limit recovery of humpback chub through predation on juvenile chub, resource competition, and displacement. As noted earlier, there is empirical evidence that rainbow trout prey on juvenile chub (Yard and others, in press), and there is circumstantial evidence that trout removal efforts have benefited the humpback chub population at the LCR confluence (Coggins and others, in press). However, the strength of evidence for trout limitation of humpback chub is questioned by a number of the stakeholders in this process, as well as aquatic scientists conducting monitoring and research in collaboration with the GCMRC staff. Again, two competing models were used to characterize uncertainty. In the null model, juvenile humpback chub survival is not affected by the abundance of trout at the LCR; in the alternative model, juvenile humpback chub survival is a steep negative logistic function of trout abundance near the LCR confluence.

Hypothesis 3 (flow hypothesis): flow regimes (for example, de-watering redds, stranding juveniles) are effective in reducing rainbow trout production and emigration downstream from Lees Ferry into Marble and Grand Canyons. A number of alternative portfolios were proposed that were designed to reduce the trout pressure at LCR by reducing production at, and emigration from, the Lees Ferry trout population, but these methods are untested. Again, two competing models were used to characterize uncertainty. In the null model, flow regimes had no effect on Lees Ferry tailwaters reach rainbow trout production and emigration rates. In the alternative model, monthly survival and emigration rates were reduced by flow-suppression strategies.

To quantify the uncertainties around these three key uncertainties, a panel of experts was asked to assess the evidence and place weight on the two competing models for each hypothesis. This expert elicitation process used a modified Delphi method (Kuhnert and others, 2010), and involved the elicitation of four points of information (Speirs-Bridge and others, 2010): the lower limit on the range of the elicited uncertainty, the upper limit on the range of the elicited uncertainty, the most likely (or best) value for the elicited uncertainty, and the confidence that the range includes the true uncertainty. The panel consisted of scientists with specific expertise in rainbow trout and humpback chub dynamics in the Colorado River, from USGS (Michael D. Yard, Theodore S. Melis, John F. Hamill), Ecometric Research, Inc. (Joshua Korman), the Service (Lewis G. Coggins, Jr.,) Reclamation (Glen W. Knowles), AZGF (Andrew S. Makinster), and WAPA (Shane Capron).

The ranges of uncertainty specified by the experts were standardized to 80-percent confidence interval, by assuming that their ranges followed a normal distribution, and the best values and 80-percent confidence bounds were averaged across experts (table 11). The average support for the HFE hypothesis was 0.50 (0.194–0.715), mostly reflecting that there has only been one documented, but unreplicated, spring-timed HFE followed by significantly increased rainbow trout production (Korman and others, 2010, in press). The average support for the RBT hypothesis was 0.653 (0.463–0.780), mostly reflecting a relatively large data set on rainbow trout predation (Yard and others, in press) and recent, but as yet unpublished data indicating that food production is limited in the main channel and that rainbow trout and humpback chub are known to compete for the same few taxa in the LCR confluence reach (T. Kennedy, Grand Canyon Monitoring and Research Center, oral commun., 2010). The average support for the flow hypothesis was 0.713 (0.553–0.822), mostly reflecting 2 years of experimental results reported by Korman (2009) when winter fluctuating flows were increased in 2003–04 to test a variant of the flow hypothesis relative to rainbow trout spawning, survival and recruitment (Korman and others, in press).

Table 11. Expert elicitation of the weight of evidence in favor of three underlying hypotheses.

[The four-point elicitation method was used, and the ranges were adjusted to an 80-percent confidence interval, assuming a normal distribution. The capital letters refer to individual experts.]

	Four-point elicitation				Adjusted 80-percent confidence interval	
Expert	**Low**	**High**	**Best**	**Confidence**	**Low**	**High**
HFE Hypothesis						
A	0.4	0.6	0.5	50	0.310	0.690
B	0.25	0.6	0.5	80	0.250	0.600
C	0.3	0.8	0.65	60	0.117	0.878
D	0.2	0.6	0.35	70	0.165	0.659
H	0.2	0.7	0.5	70	0.129	0.747
Average			**0.5**		**0.194**	**0.715**
Rainbow Trout Hypothesis						
A	0.3	0.5	0.4	50	0.210	0.590
B	0.55	0.85	0.7	80	0.550	0.850
C	0.3	0.7	0.6	80	0.300	0.700
D	0.3	0.9	0.66	95	0.425	0.817
E	0.6	0.95	0.8	90	0.644	0.917
F	0.4	0.8	0.66	80	0.400	0.800
G	0.7	0.8	0.75	90	0.711	0.789
Average			**0.653**		**0.463**	**0.780**
Flow Hypothesis						
A	0.7	0.8	0.75	90	0.711	0.789
B	0.6	0.8	0.7	80	0.600	0.800
C	0.4	0.8	0.7	80	0.400	0.800
D	0.5	0.9	0.7	80	0.500	0.900
Average			**0.7125**		**0.553**	**0.822**

Elicitation included discussion to identify important factors likely to affect the expert's opinion regarding the source and level of uncertainty. Regarding the effect of rainbow trout on humpback chub, experts discussed the evidence for mechanisms (such as predation and competition) and concurrent trends in monitoring data. Regarding flow regimes, experts stressed importance of the level of low flows on rainbow trout production, and that their opinions were based on an assumed low flow of 2,500 ft^3/s, relative to the 5,000 ft^3/s low flows that were actually experimentally evaluated in winters of 2003–04. Also, the experts emphasized that the design of the flow regimes should take advantage of observed fish behavior and interaction with bank morphology, namely low angle compared to high angle shoreline habitats.

The elicitation on HFEs focused on the ecological effect of relatively more frequent HFEs in the context of a future long-term sandbar conservation flow experiment on rainbow trout production and subsequent emigration and ignored the uncertainty regarding whether or not an HFE policy would be implemented. Thus, the experts were asked to express their uncertainty regarding ecological effects given that HFEs would be implemented on a frequent basis, such as annually or near annually. The discussion assumed a sediment-based policy, which would call for a 1/3 spring and 2/3 fall implementation schedule, estimated on the basis of historical annual Paria River sand production data.

The experts acknowledged greater evidence for effects on rainbow trout from spring HFE compared to fall HFE. However, the consensus was that a fall HFE event could also increase trout production.

Note that uncertainty concerning whether rainbow trout removal at PBR would be effective in reducing emigration and trout abundance at LCR was not formally analyzed. The predictive models for rainbow trout and humpback chub abundance assumed that PBR removal activities would be effective in removing a large number of rainbow trout in the PBR, and therefore, emigration downstream would be reduced considerably.

7. Decision Analysis

Multi-criteria decision analysis methods were used to evaluate the consequences of the proposed hybrid portfolios. At the second workshop, 20 hybrid portfolios were included in the analysis, objective weights were elicited from the agency and Tribal representatives, and the results were discussed (these results are not included in this report). A number of portfolios (B, C1, F, F', G, G', H, H', I, M) were eliminated from further consideration because their performance was robustly poor. Several others (L, N) were eliminated because the details of them were not well developed and they could not be evaluated. Finally, two high-ranking portfolios (E, O) were eliminated from further consideration because of their exorbitant cost and because they were clearly outside the scope of this EA. An additional seven hybrid portfolios were created (mostly permutations of C, D, and J), and a total of 13 portfolios were carried forward for final analysis.

7.1. Swing Weighting

Weights on 20 objectives (1A through 4F, less 4B and 4D) were elicited from the agencies and Tribes who had been present at the second workshop through a process called swing weighting (von Winterfeldt and Edwards, 1986). Weights were assigned on the basis of the absolute importance of the objective in question as well as the range of values over which the attribute varied across alternatives. Because of the large number of objectives, the swing weighting was conducted in a hierarchical manner, with attributes clustered into eight major categories according to relatedness of the objectives and correlation in the attributes.

In addition to weights on the objectives, the representatives were asked to assign weights to the three cultural tables, and to the three hypotheses. It's important to note that these tasks are all quite distinct. In the objective weighting, the representatives were asked to express how their agency or Tribe values the objectives relative to one another. In the weighting of the cultural tables, the representatives were asked how well they felt the three tables represented the cultural values that were at stake in this question. In weighting the hypotheses, the representatives were evaluating the scientific evidence in favor of the system dynamics they captured.

The results of these elicitations are shown in table 12. Most of the representatives gave equal weight to the three cultural tables, presumably to reflect the sovereignty of these Nations. Most of the representatives deferred to the expert panel (table 11) for the weights on the hypotheses, although several representatives chose either the high or the low end of the confidence bounds expressed by the experts.

Table 12. Objective weights.

[The weights derived from swing weighting for each of the measurable attributes are shown, for each agency and tribe in attendance at the second workshop. In addition, the weights across the three different cultural tables are shown for each agency, as well as the beliefs in the three hypotheses that characterized the key uncertainties. AZGF, Arizona Game and Fish Department; BoR, Bureau of Reclamation; FWS, Fish and Wildlife Service; NPS, National Park Service; WAPA, Western Area Power Administration; RBT, rainbow trout; HFE, high-flow experiment]

Objective	AZGF	BoR	FWS	Hopi	Navajo	NPS	WAPA	Zuni	Average
1A	0.029	0.067	0.036	0.105	0.039	0.046	0.047	0.093	0.058
1B	0.042	0.061	0.036	0.100	0.039	0.046	0.052	0.070	0.056
1C	0.038	0.020	0.035	0.084	0.043	0.048	0.058	0.075	0.050
1D	0.025	0.013	0.036	0.063	0.039	0.046	0.038	0.075	0.042
2A	0.125	0.147	0.098	0.211	0.099	0.110	0.186	0.134	0.139
2B1	0.037	0.018	0.027	0.014	0.038	0.028	0.023	0.039	0.028
2B2	0.061	0.036	0.032	0.023	0.023	0.020	0.020	0.039	0.032
2C1	0.025	0.015	0.026	0.012	0.031	0.025	0.021	0.039	0.024
2C2	0.055	0.007	0.029	0.022	0.015	0.020	0.014	0.039	0.025
2D1	0.089	0.105	0.171	0.004	0.161	0.116	0.026	0.078	0.094
2D2	0.075	0.044	0.093	0.105	0.079	0.122	0.074	0.100	0.087
3A1	0.091	0.032	0.040	0.009	0.016	0.033	0.047	0.008	0.034
3A2	0.054	0.020	0.042	0.088	0.019	0.049	0.055	0.008	0.042
3B	0.007	0.077	0.039	0.084	0.033	0.096	0.049	0.009	0.049
3C	0.015	0.046	0.037	0.004	0.056	0.067	0.029	0.007	0.033
3D	0.005	0.004	0.033	0.002	0.032	0.001	0.019	0.008	0.013
4A	0.073	0.040	0.038	0.007	0.022	0.033	0.047	0.008	0.033
4C	0.111	0.114	0.095	0.035	0.071	0.070	0.078	0.016	0.074
4E	0.013	0.078	0.038	0.005	0.075	0.004	0.065	0.104	0.048
4F	0.032	0.055	0.019	0.026	0.068	0.019	0.052	0.052	0.040
Weights on Cultural Tables:									
Zuni	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Hopi	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0
Navajo	1.0	1.0	1.0	1.0	1.0	0.0	1.0	0.0	1.0
Hypothesis Weights:									
RBT	0.653	0.653	0.653	0.463	0.653	0.500	0.780	0.653	0.653
Flow	0.600	0.713	0.713	0.713	0.713	0.500	0.822	0.713	0.713
HFE	0.400	0.500	0.500	0.250	0.500	0.500	0.715	0.500	0.500

There were some substantial differences in the assignment of weights on the objectives among representatives (table 12). A principal components analysis of the objective weights showed that 68.7 percent of the variation could be explained by the first two principal components (fig. 6). The first principal component was positively correlated with the weight on the cultural objectives (1A–1D) and the humpback chub objective (2A) and negatively correlated with the non-native fish objective (2D1). The second principal component was positively correlated with the sport fishery objectives (3A1, 3A2, 4A) and cost objective (4C) and negatively correlated with the power generation objective (4E). The plots of the scores for these components for each agency and Tribe help to show the diversity of views expressed through this process (fig. 6).

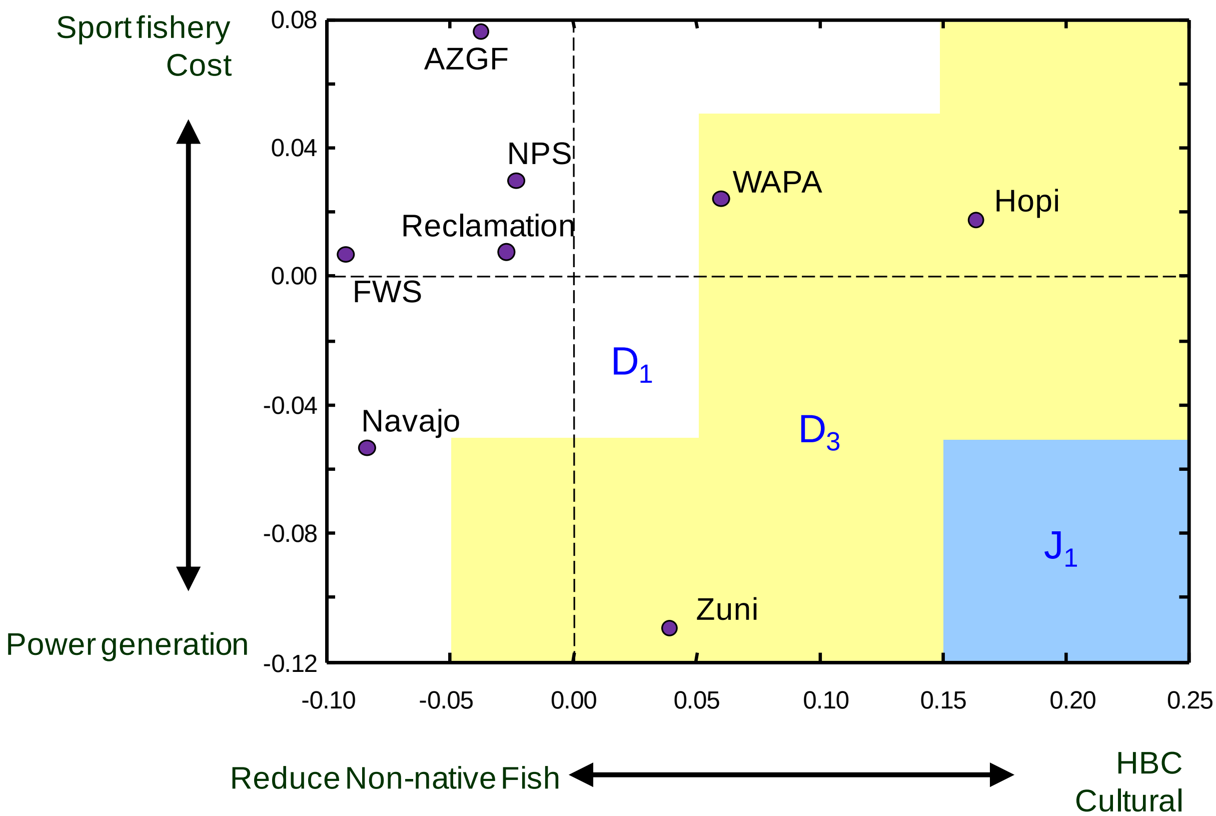

Figure 6. Graph showing principal-components analysis of the objective weights. The first principal component (which explains 47.4 percent of the variation in objective weights across the eight agencies and tribes) is driven positively by the weights on humpback chub recovery (2A) and the cultural objectives (1A–1D), and negatively by the weight on reducing non-native fish abundance in the Canyon (2D). The second principal component (which explains an additional 21.3 percent of the variation) is driven positively by the weights on the sport fishery (3A1, 3A1, 4A) and cost (4C) objectives, and negatively by the weight on the power generation objective (4E). The shaded regions of the graph show the hybrid portfolios (D_1, D_3, and J_1) favored under each combination of 1st and 2nd principal component (with the remaining principal components at their average values). The objectives are defined in table 1 and the hybrid portfolios are defined in table 3. AZGF, Arizona Game and Fish Department; NPS, National Park Service; WAPA, Western Area Power Administration; FWS, U.S. Fish and Wildlife Service; Reclamation, Bureau of Reclamation; HBC, humpback chub.

7.2. Analysis of Hybrid Portfolios in the Face of Uncertainty

The objective weights, cultural table weights, and hypothesis weights unique to each agency or Tribal representative were used as input to a multi-criteria decision analysis to produce individual rankings of the alternatives (table 13). All agencies and Tribes identified either D_1 or D_3 as their preferred alternative, and those two alternatives were found in the top three for every agency or Tribe. The only other alternatives to place in any representative's top two were A and J_1. Alternatives C_3 and K showed uniformly poor performance across objective weightings. When the objective weights were averaged across representatives, equal weights were given to the cultural tables, and the expert-derived hypothesis weights were used, the best-performing alternative was D_1.

Table 13. Composite scores from the multi-criteria decision analysis for each hybrid portfolio, using the objective and hypothesis weights of the individual agencies and Tribes.

[The pink shading shows the lowest ranking alternative for each Federal/State agency or Tribe, and the green shading shows the highest ranking. The top five alternatives are also shown. Yellow and light yellow shading are used to draw attention to hybrid portfolios D_1 and D_3, respectively. AZGF, Arizona Game and Fish Department; BoR, Bureau of Reclamation; FWS, Fish and Wildlife Service; NPS, National Park Service; WAPA, Western Area Power Administration]

Hybrid portfolio	AZGF	BoR	FWS	Hopi	Navajo	NPS	WAPA	Zuni	Average
A	0.598	0.527	0.497	0.563	0.498	0.647	0.432	0.462	0.501
C_2	0.505	0.418	0.418	0.450	0.428	0.474	0.308	0.314	0.402
C_3	0.427	0.380	0.373	0.419	0.397	0.443	0.280	0.267	0.361
C_4	0.478	0.440	0.428	0.545	0.458	0.512	0.353	0.370	0.437
C_5	0.444	0.404	0.397	0.527	0.433	0.483	0.326	0.366	0.411
D_1	0.672	0.589	0.649	0.571	0.648	0.629	0.557	0.504	0.606
D_2	0.584	0.538	0.596	0.525	0.610	0.598	0.519	0.457	0.554
D_3	0.610	0.578	0.623	0.618	0.645	0.651	0.565	0.558	0.603
J_1	0.522	0.496	0.567	0.586	0.553	0.503	0.501	0.519	0.539
J_1'	0.610	0.525	0.583	0.528	0.537	0.508	0.523	0.481	0.545
J_2	0.439	0.452	0.519	0.559	0.522	0.474	0.472	0.471	0.497
J_2'	0.524	0.479	0.532	0.497	0.503	0.473	0.491	0.433	0.500
K	0.365	0.387	0.426	0.459	0.436	0.472	0.293	0.346	0.390
Rank									
1	D_1	D_1	D_1	D_3	D_1	D_3	D_3	D_3	D_1
2	J_1'	D_3	D_3	J_1	D_3	A	D_1	J_1	D_3
3	D_3	D_2	D_2	D_1	D_2	D_1	J_1'	D_1	D_2
4	A	A	J_1'	A	J_1	D_2	D_2	J_1'	J_1'
5	D_2	J_1'	J_1	J_2	J_1'	C_4	J_1	J_2	J_1

To explore the sensitivity of the best-performing alternative to the weights on the objectives, the best-performing alternative was calculated over a grid of values from the first two principal components (fig. 6); the patterns help to explain the difference in preference among representatives. Alternative D_1 is favored at the average objective weights, and continued to be favored as more weight is given to sport fishery objectives, cost objective, or the desire to reduce non-native fish in the ecosystem. As more weight is given to cultural objectives or humpback chub objectives, D_3 is favored. At strong weightings of cultural objectives and power generation, J_1 rises to the top. It's worth noting that figure 6 only shows the effect of the first two principal components. The NPS weighting for the first two components indicates that D_1 is their best-performing alternative, but in fact it is D_3 because of weight given to the native fish and recreational objectives (which appear in the third principal component). The result, however, is that the ranking of alternatives D_1 and D_3 is fairly robust to variation in the objective weights.

7.3. Value of Information

The results presented in the previous section reflect the ranking of the alternatives in the face of uncertainty. Throughout the development of this analysis, there was substantial discussion among the participants about the importance of uncertainty, with the implication that the resolution of uncertainty might lead to different preferred non-native fish control strategies. Value of information methods from the field of decision analysis (Runge and others, in press) provide a way of assessing the importance of uncertainty in a decision context. These methods are different from typical sensitivity analyses—they do not just determine whether there is substantial uncertainty in the system dynamics, but whether that uncertainty would change the decision.

Uncertainty was compared across the three hypotheses the expert panel had evaluated, by constructing eight scenarios that included all permutations of those hypotheses, then conducting a value of information analysis (table 14) using the average weights on the objectives. It was assumed that the hypotheses were independent, so that the probability of each combination could be calculated from the appropriate product of beliefs in each of the component hypotheses.

Table 14. Expected value of perfect information for discerning among the underlying hypotheses.

[The composite score from the multi-criteria decision analysis, using the average objective weights, is shown for each of eight combinations of the three underlying hypotheses (the HFE, RBT, and Flow hypotheses). The green shading shows the preferred alternative under each combination of hypotheses. In the face of uncertainty, the average response weighted across hypotheses indicates that D_1 is the best action to take, with composite score of 0.606. If uncertainty can be fully resolved before choosing an action, the expected performance increases to 0.643 (light green shading). Thus the expected value of perfect information is 0.038 (6.2 percent increase over the expected response in the face of uncertainty). HFE, high-flow experiment; RBT, rainbow trout]

	Eight combinations of the underlying hypotheses								Average
HFE	No	No	No	No	Yes	Yes	Yes	Yes	
RBT	No	No	Yes	Yes	No	No	Yes	Yes	
Flow	No	Yes	No	Yes	No	Yes	No	Yes	
Weight	0.050	0.124	0.094	0.233	0.050	0.124	0.094	0.233	
Alternative									
A	0.875	0.875	0.391	0.391	0.766	0.766	0.271	0.271	0.501
C_2	0.700	0.700	0.451	0.451	0.590	0.590	0.095	0.095	0.402
C_3	0.659	0.659	0.410	0.410	0.549	0.549	0.053	0.053	0.361
C_4	0.735	0.735	0.486	0.486	0.624	0.624	0.129	0.129	0.437
C_5	0.709	0.709	0.460	0.460	0.598	0.598	0.103	0.103	0.411
D_1	0.716	0.716	0.589	0.589	0.708	0.708	0.509	0.509	0.606
D_2	0.665	0.665	0.538	0.538	0.657	0.657	0.458	0.458	0.555
D_3	0.713	0.713	0.587	0.587	0.705	0.705	0.506	0.506	0.603
J_1	0.630	0.631	0.504	0.513	0.622	0.629	0.423	0.491	0.539
J_1’	0.646	0.646	0.506	0.517	0.638	0.644	0.426	0.492	0.546
J_2	0.589	0.589	0.462	0.472	0.581	0.587	0.382	0.450	0.497
J_2’	0.601	0.601	0.461	0.472	0.593	0.599	0.381	0.447	0.501
K	0.674	0.674	0.250	0.258	0.665	0.667	0.205	0.237	0.390
Best	0.875	0.875	0.589	0.589	0.766	0.766	0.509	0.509	0.643

The best performing alternative in the face of uncertainty, that is, averaged over the eight scenarios, is D_1 (as noted in section 7.2), but if uncertainty could be fully removed before committing to an action, there are scenarios that point to Portfolio A as the best-performing alternative. If the uncertainty can be removed before an action is taken, the expected performance increases from 0.608 to 0.645, thus, the expected value of perfect information (EVPI) across these hypotheses is 0.038 (or a 6.2-percent increase in performance). But note that all of this value of information comes from resolving uncertainty about the RBT hypothesis, and none from resolving uncertainty about the HFE or Flow hypotheses. The partial value of perfect information is 6.2 percent for the RBT hypothesis, and 0 percent for the HFE and Flow hypotheses. This is not to say there isn't uncertainty about the HFE and Flow hypotheses—the experts agreed that there was—just that it does not affect the top-ranked alternative.

The uncertainty in the other hypotheses does have some subtle effects, however, on the second- to fifth-ranking portfolios (fig. 7). In particular, even if rainbow trout do not threaten chub, an HFE effect increases the ranking of upstream removal portfolios (like D_1, and D_3) to reduce the number of non-native fish in the river ecosystem.

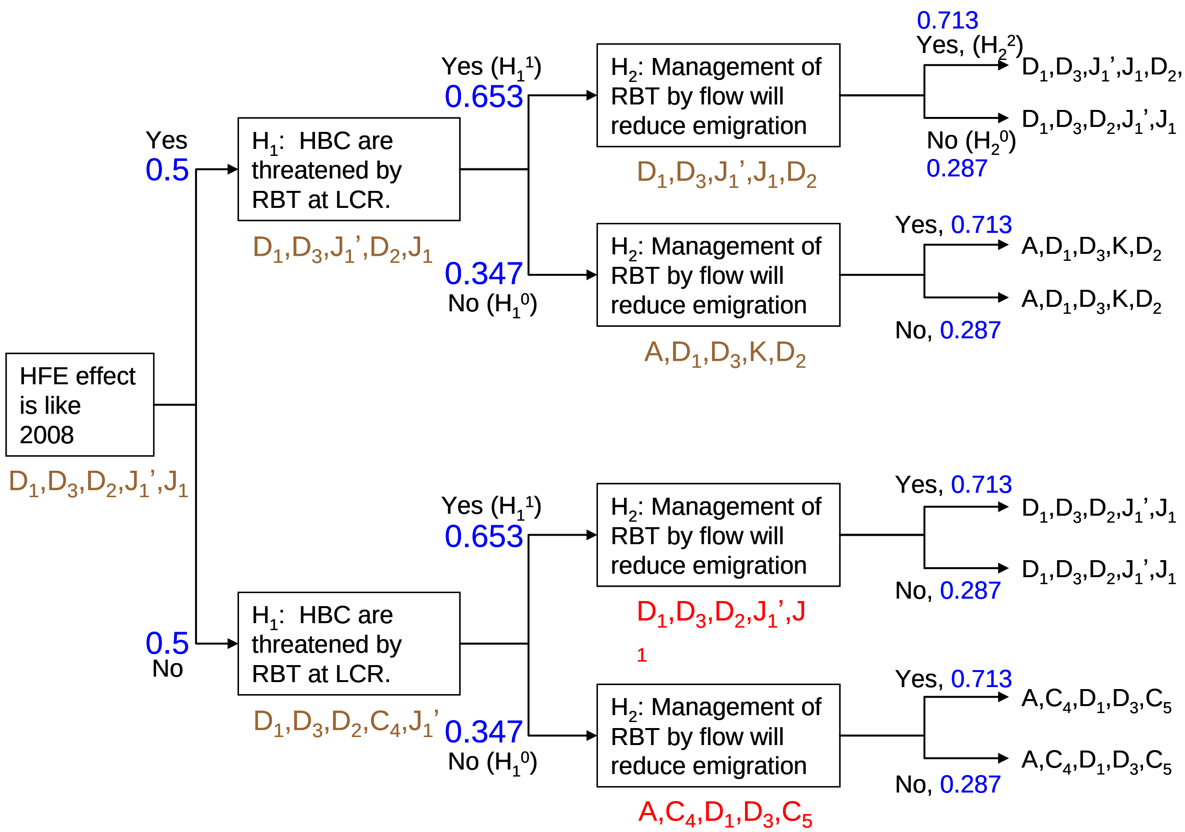

Figure 7. Flowchart showing the preferred alternatives as a function of the underlying hypotheses. The final nodes at the right of the tree show the top-ranked alternatives (in decreasing order) if the uncertainty can be fully resolved on all three hypotheses. For example, if all three hypotheses are true, then the preferred alternative is D_1 followed by D_3. The next node back shows the top-ranked alternatives averaged over the flow hypothesis (using the mean expert weight). The first node on the left shows the top-ranked alternatives in the face of uncertainty about all three hypotheses (using the mean expert weights). The weights on each hypothesis, based on expert judgment (table 11), are shown in blue at each node. The hybrid portfolios (A, C_4, D_1, and others) are defined in table 3.

The analysis shows that Portfolio A is favored whenever the RBT hypothesis is false, and Portfolio D_1 is favored whenever the RBT hypothesis is true. If the RBT hypothesis is false, humpback chub are not threatened by rainbow trout, and there is no need to undertake removals. The other objectives push the strategy toward no action. If the RBT hypothesis is true, the humpback chub objective (on which all representatives placed substantial weight) has the most influence, and trout removal in the PBR of Upper Marble Canyon is favored. The preferred portfolio switches from A to D_1 as a function of the weight on the RBT hypothesis (fig. 8). If the weight on the RBT hypothesis is less than 0.33, the best performing portfolio is A, otherwise it is D_1 (with D_3 an extremely close second). The expert panel believed the evidence provided 0.653 weight on the RBT hypothesis, with an 80-percent confidence interval that did not include 0.33, indicating that the choice of Portfolio D_1 over A is robust to the level of uncertainty about the RBT hypothesis.

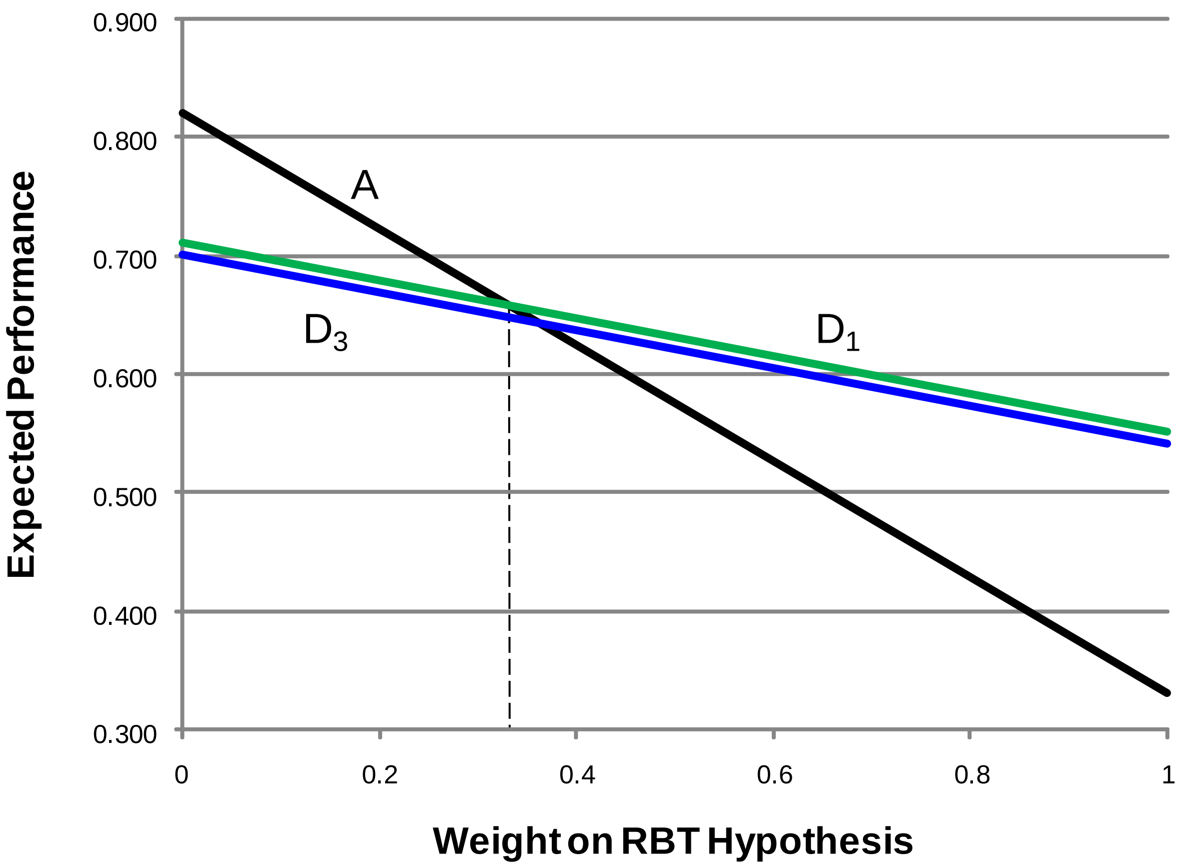

Figure 8. Graph showing expected performance of three hybrid portfolios as a function of the weight on the rainbow trout (RBT) hypothesis. If the weight on the RBT hypothesis is less than 0.33, alternative A (no action) is preferred; otherwise D_1 (removal curtain) is preferred. Note that with the average objective weights, alternative D_3 slightly underperforms D_1 across all weights on the RBT hypothesis.

7.4. Adaptive Strategies

Adaptive strategies are designed to resolve uncertainty passively over time by allowing monitoring to provide feedback about the underlying hypotheses, and actively by undertaking probing actions designed to accelerate learning. But adaptive strategies are only valuable if they target uncertainty for which there is a high value of information, that is, uncertainty that leads to different preferred actions. The results of the EVPI analysis indicate there is some value in resolving the RBT hypothesis, but not much (only 6.2 percent expected increase in performance) because the evidence already favors D_1 strongly. Further, the results indicate that the other hypotheses are not worth testing, at least for the decision regarding non-native fish control. By this argument, an effective adaptive strategy might be characterized as {A, D}, a strategy that uses either Portfolios A or D in the long-run, and seeks to resolve uncertainty about the RBT hypothesis in the short-run. There is little in this analysis to indicate that a more complicated adaptive strategy is needed, at least with regard to the non-native fish control decision.

The removal curtain portfolios (the variants of D) already have an implicit adaptive component because they include removal at both LCR and PBR. That is, D is already an adaptive strategy that combines C (a pure LCR removal portfolio) with a pure PBR removal portfolio. The LCR removal component provides assurance that if the PBR removal is impractical or ineffective, there is a back-up plan for removing trout in the Canyon downstream where humpback chub exist. Thus, an adaptive strategy that combines {A, C, D} addresses both the uncertainty about the effect of rainbow trout on humpback chub, as well as uncertainty about the effectiveness of PBR removal (which was not specifically evaluated in this analysis).

Other adaptive strategies have been proposed in 2010, both formally and informally, by a number of groups. The “kitchen sink” proposal, as originally described by Richard Valdez and others (written commun., 2010), was an experimental strategy that combined a large number of potential management actions and sought to first implement them all, then remove them piecemeal to find a cost-effective strategy. The “adaptive control” proposal, by Mike Senn and others (AZGF, written commun., 2010), is a more refined adaptive strategy that might be characterized as {C, D, J}, and focuses on resolving uncertainty in two ways: (1) whether PBR removal can be successful in reducing downstream emigration, and (2) whether various flow regimes can be effective in reducing rainbow trout production and emigration from the Lees Ferry reach. The analysis in this report, however, does not naturally lead to inclusion of flow regimes in an adaptive strategy because flow regimes are not superior to PBR removal under any of the scenarios investigated. It is worth asking if something was left out of the analysis that would favor flow regimes. First, uncertainty about the effectiveness of PBR removal was not specifically investigated. If PBR removal is not effective, flow regimes may become more advantageous. Second, the cost and effort of PBR removal is thought to be quite high, whereas flow regimes themselves have minimal cost and might possibly increase power revenue. It is possible costs in this analysis were not weighed properly. Third, cultural values may favor flow regimes over PBR removal in ways that the analysis in this report did not fully capture. Several Tribal representatives have indicated that non-native fish control that more closely mimics natural processes (like flow manipulations) would be preferable and more in line with cultural values than more aggressive human-mediated control (like removal). Because the kitchen sink portfolios (J_1, and others) included LCR and PBR removal, they did not have high scores on cultural attributes. A pure flow portfolio (for example, like J_1 but without the removal actions) might have scored much higher on cultural objectives than the kitchen sink portfolios, and might be favored as the preferred portfolio if the weight on the RBT and flow hypotheses were strong. Thus, our alternatives and scoring may need to be restructured to examine the value of a long-term strategy that relies primarily on flow manipulations.

8. Summary and Discussion

The purpose of this report is to describe the methods used to provide a structured forum in which cooperating agencies and Tribes could provide substantive input to Reclamation regarding methods and necessity of controlling non-native fish in the Colorado River ecosystem below Glen Canyon Dam. The intent of the forum was not to reach a consensus recommendation, nor provide a single preferred alternative to Reclamation, but rather to understand the values that were important to the stakeholders and relevant to controlling non-native fish populations.

A broad array of decision-making objectives was identified and defined, and an effort was made to understand how these objectives are likely to be achieved by a variety of strategies. A set of alternative approaches was developed, and the complex structure of those alternatives was illustrated. Multi-criteria decision-analysis methods allowed the evaluation of those alternatives against the array of objectives, while preserving the values of individual agencies and Tribes.

Trout removal strategies aimed at the PBR, with a variety of permutations in deference to Tribal cultural values, were identified as top-ranking options for all agencies and Tribes. These PBR removal approaches outperformed LCR removal approaches, both for cultural and effectiveness reasons—the probability of keeping the humpback chub population above 6,000 was estimated to be higher under the PBR portfolios than under the LCR-only portfolios (tables 5, 7). The PBR removal portfolios also outperformed portfolios based on flow manipulations, primarily because of the effect of sport fishery, wilderness recreation, and cultural objectives. The preference for the PBR removal portfolios (particularly D_1 and D_3) was dominant despite variation in the objective weights and uncertainty about the underlying dynamics, at least over the ranges investigated in this round of structured decision making on the topic of non-native fish control.

A value of information analysis pointed to an adaptive strategy that contemplates three possible long-term management actions (no action, A; LCR removal, C; or PBR removal, D) and seeks to reduce uncertainty about the following two issues: the degree to which rainbow trout limit humpback chub populations, and the effectiveness of PBR removal to reduce trout emigration downstream in the Marble and Grand Canyons. By bringing in considerations not captured in this analysis, a case might be made for including flow manipulations in an adaptive strategy, but we emphasize that the analysis herein does not lead to that conclusion.

The decision analysis described in this report is meant to aid Reclamation by helping them see the central structure of the non-native fish control decision, but is not meant to make the decision for them. This analysis can best be used as a structure and starting point for the deliberative consultations that will lead to the final decision as the EA process proceeds to completion.

8.1. Disagreement about the Science

Differing opinions on key uncertainties, such as the hypothesis about the effect of rainbow trout on humpback chub, were acting as partial impediments to decision making. Prior to the SDM workshops, participants voiced a wide range of beliefs ranging from near dismissal of any effect of rainbow trout on humpback chub to near certainty of that effect. During the second workshop, scientists presented current evidence and expressed their judgments regarding the strength of evidence for the key uncertainties. At the end of the second workshop, each agency and Tribe was given the opportunity to express their belief about the weight of evidence for these key hypotheses. In general, the range of opinions narrowed. Also, the differences in opinions on key uncertainties did not determine the preferred portfolios, and thus should not impede decision making.

As part of this process, an age-structured population model was built by subject matter experts to aid in decision making. The model, while rapidly developed, reflects current scientific understanding about ecological relationships and the population dynamics of humpback chub in the Colorado and Little Colorado Rivers. This predictive population model allowed (1) assumptions to be fully identified and tested, (2) sensitivity of the decision to sources of uncertainties to be evaluated, and (3) current status of knowledge to be communicated to facilitate a common understanding of the scientific basis for management. Further, the model is a valuable starting point, which can be updated and revised as information improves and learning continues to occur in the GCDAMP.

8.2. Cultural Values and the Viewpoint of the Tribes

The assessment of the consequences of alternative non-native fish control strategies on cultural objectives was limited in scope and not necessarily representative of the appropriate persons or decision making bodies within the Tribes. As such, the scores shown in table 4 are not fully representative of the actual preferences and values, but were included as place holders for the Tribal perspectives. If further input is required from the Tribes, additional consultation could occur at the government-to-government level and could, at a minimum, include discussion of the topics listed toward the end of this section, as well as the potential consequences of the proposed actions on the objectives. The Tribal representatives suggested that succinct summaries of each of the following would be valuable when consulting with the Tribes: (1) the main scientific evidence in support of removing trout, (2) the potential “footprint” of each of the proposed actions, and (3) the beneficial effects of the proposed actions on the humpback chub population. The description of the footprint would include location, duration, and frequency of the activity; the targeted species, including numbers of individuals affected; numbers of staff involved, and equipment being considered; proposed use of any fish removed; and cost.

It was challenging to elicit and define cultural and spiritual values. The decision analysis process required participants to deconstruct the elements of the decision and to evaluate individual objectives against the hybrid portfolios. In other words, objectives were taken in isolation and consequences evaluated; tradeoffs among the whole suite of objectives were considered in the final analysis, but this step was not readily apparent from the initial scoring of the consequence matrix. In the language of decision analysis, the assumption of preferential independence did not hold for cultural objectives. Thus, this approach was unsatisfactory for some of the Tribal representatives, because the relative appropriateness of any particular portfolio depended on the context of the action being applied. For example, the taking of life may be appropriate provided it serves a greater purpose, namely to sustain other life. Yet considered in isolation that objective scored poorly in the consequence matrix as the relative context was not clearly defined. Because of the difficulty this framework posed for defining and scoring cultural objectives, the importance of cultural objectives to the selection of top portfolios might not be appropriately captured in this analysis.

As noted in the previous paragraph, several questions were highlighted by the Tribal representatives. These include:

1. What is the evidence for stating that rainbow trout are negatively affecting humpback chub persistence and recruitment? To what degree is the science certain about this hypothesis?
2. If rainbow trout are having a negative effect, what are the long-term solutions for reducing emigration and threats from predation and competition? Repeated removal activities are likely infeasible over the long term, and will not sufficiently address cultural concerns.
3. Can the problem be thought of more holistically? For example, rather than focus on a certain number of rainbow trout, would it be useful to think about the ratio between trout and humpback chub and how that ratio may temper interactions?
4. What about the other non-native species in the system? That is, why is the issue focused only on the trout?

Finally, throughout this project, there was considerable discussion about the process by which Reclamation was making its decision. Of particular concern was the extent to which Tribal values were going to be incorporated in the decision making, and the need for direct government-to-government consultation. While it was not the purpose of this project to negotiate the timing and substance of such consultation, it is understood that the tribes are still interested in direct conversation with Reclamation and DOI on this issue. This report may provide a structure that could help to organize those ongoing consultations.

8.3. High-Flow Experimental Dam Releases (HFE)

In a parallel NEPA process, Reclamation is developing an EA regarding a protocol for repeated HFE releases from Glen Canyon Dam for the purpose of determining whether or not there is sufficient remaining renewable sand supply from tributaries below the dam to rebuild and maintain sandbar habitats throughout the Canyon (Wright and others, 2008; Rubin and others, 2002). As the consequence analysis in this report indicates, there is a close relation between the HFE decision and the non-native fish control decision, because of the apparent effect that HFEs have on increasing rainbow trout recruitment in the Lees Ferry tailwaters reach. The coupled trout-chub models developed as part of this report provide some valuable predictions about the effects of HFEs (table 7). If rainbow trout are indeed limiting humpback chub, then repeated ongoing high-flows may reduce the likelihood of keeping humpback chub population levels in the desired range. Aggressive rainbow trout removal at PBR, coupled with back-up removal at LCR (i.e., Portfolio D_1 or D_3), and perhaps with trout-suppression flows (i.e., Portfolio J), provides the best opportunity for mitigating the potentially harmful effects of more frequent HFEs on the LCR chub population. Such an investigation was not the primary purpose of the analysis in this report, but the models described in this report (Lew Coggins, Service, and Josh Korman, Ecometric Research, Inc., written commun., 2010) may be valuable in the future for evaluating the effect of HFEs.

8.4. Linked Decisions

In this decision analysis, the question of non-native fish control was treated as an isolated decision, but as the preceding section discusses, non-native fish control is linked to decisions about high-flow experiments, and likely to other decisions as well. When linked decisions are analyzed separately, the independent results may work against each other or at least may not be optimal. On the other hand, the combined problem may be fairly difficult to solve, especially if the time-frame, jurisdiction, and stakeholder interests differ for the linked pieces. One way around this problem is to include objectives that acknowledge the linkage between the two decision contexts. Two objectives and one hypothesis in this decision analysis acknowledge the link between the HFE and the non-native fish EAs: Objective 5C (support HFE EA) seeks a non-native fish control solution that does not undermine the HFE protocol; Objective 4C (minimize cost) recognizes that there are limited funds for operations and research; and the uncertainty around the HFE hypothesis builds in the rainbow trout response that might result from an HFE protocol.

The cost objective (Objective 4C) actually serves to indirectly link this decision to many other decisions. There is a limited amount of money available for operations, control, and research. By seeking to minimize the cost of non-native fish control, funds are available for other activities. But without defining the specific competing demands for funding, the participants in this process may have undervalued the cost objective.

The solution to the challenges brought about by linked decisions is to view the results in this report as an initial analysis, without consideration of linkages. These results of this report can be examined by Reclamation, DOI, and the GCDAMP, to consider the relation between the non-native fish control decision and other decisions (the HFE protocol among them).

8.5. Learning as a Means Objective

Throughout this SDM process, there was a strong interest on the part of many participants to advance solutions that focused heavily on learning. For example, adaptive strategies were recommended early on before uncertainty was defined, and learning was proposed as a fundamental objective. The decision analysts who facilitated the SDM process actively resisted this direction because Reclamation's decision was a management decision, not an academic decision. The role of learning in a management decision-making process is to reduce uncertainty that impedes decisions. Not all uncertainty impedes decisions, therefore, not all adaptive strategies are warranted. To identify adaptive strategies, the decision in the face of uncertainty must first be analyzed, then the value of information in improving expected performance must be evaluated. The value of information points toward useful adaptive, learning-centered strategies. In other words, learning is a means objective, not a fundamental objective.

The GCDAMP is centered on a mission of adaptive management, and so it is understandable that learning figures heavily in its planning. As outsiders to the GCDAMP, the authors of this report are not familiar with the history or objectives of the program, and do not know whether learning is appropriately a fundamental or means objective. If it is the latter, however, then decision analysis must precede experimental design. It is the decision context and the role of uncertainty that provide the justification for learning.

9. Acknowledgments

The authors thank Ann Gold and Glen Knowles from Reclamation for their generous help in explaining the framework for the non-native fish control decision. Gratitude is also given to the staff at the USGS Grand Canyon Monitoring and Research Center, especially Ted Melis, Matthew Andersen, John Hamill, and Kyrie Fry, who provided all the logistical arrangements for the SDM workshops. This project could not have been completed without the extraordinary contributions of the expert panels who worked between the two workshops to predict the consequences of the hybrid portfolios. Lew Coggins (Service) and Josh Korman (Ecometric Research, Inc.) deserve special recognition for developing the humpback chub and rainbow trout models, a challenging task that was completed in just 2 weeks. Other experts who made important contributions included: Jan Balsom (NPS); Helen Fairley, Ted Melis, and Mike Yard (GCMRC); Loretta Jackson-Kelly (Hualapai Tribe); Glen Knowles (Reclamation); Clayton Palmer (WAPA); Larry Riley and Bill Stewart (AZGF); and Mike Yeatts (Hopi Tribe). Glen Knowles, Ted Melis, Sam Spiller, Pam Sponholtz, and Drew Tyre provided careful reviews of, and editorial suggestions for, this report. Finally, for their open minds, generosity of spirit, and thoughtful contributions, the authors are grateful to the participants in the SDM workshops: Matthew Andersen, Helen Fairley, John Hamill, Ted Melis, and Mike Yard (GCMRC); Jan Balsom, Martha Hahn, Norm Henderson, and Palma Wilson (NPS); David Bennion, Shane Capron, LaVerne Kyriss, and Clayton Palmer (WAPA); Debra Bills, Lew Coggins, Sam Spiller, and Pam Sponholtz (Service); Charley Bulletts (Southern Paiute Consortium); Gary Cantley (BIA); Marianne Crawford, Ann Gold, Glen Knowles, Heather Patno, and David Trueman (Reclamation); Kurt Dongoske (Pueblo of Zuni); John Halliday, Rod Smith, and Justin Tade (DOI); John Jordan (Federation of Fly Fishers); Josh Korman (Ecometric Research, Inc.); Andy Makinster, Larry Riley, Mike Senn, and Bill Stewart (AZGF); James Morel (Navajo Nation); and Mike Yeatts (Hopi Tribe). Although this report attempts to reflect their expertise and values, this report does not express the official position of the participants or the agencies and Tribes they represent.

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Appendix 1 Letter from Anne Castle to Adaptive Management Working Group and Technical Working Group Members and Alternates, September 17, 2010

TO: AMWG AND TWG MEMBERS AND ALTERNATES

FROM: ANNE CASTLE, SECRETARY'S DESIGNEE, ASSISTANT SECRETARY FOR WATER AND SCIENCE

DATE: SEPTEMBER 17, 2010

SUBJECT: ENVIRONMENTAL ASSESSMENT OF METHODS OF NON-NATIVE FISH CONTROL

The Bureau of Reclamation (Reclamation) has been engaged for several months in an Environmental Assessment (EA) of various methods of controlling non-native fish in the Grand Canyon. Because nonnative fish, particularly rainbow and brown trout, are known to prey on the endangered humpback chub, the U.S. Fish and Wildlife Service (FWS) 2008 Biological Opinion included a conservation measure that addressed non-native fish control. That conservation measure provided that Reclamation would continue non-native control efforts through the Adaptive Management Program (AMP) and anticipated the mechanical removal of non-native trout at the confluence of the Colorado River mainstem and the Little Colorado River (LCR), as well as other control methods. Grave concern has been expressed by several of the Native American tribes that are represented on the Adaptive Management Work Group (AMWG), particularly the Pueblo of Zuni, about this taking of life within a place that is sacred to the tribes and fundamental in several creation stories.

In direct response to these concerns, Reclamation determined to forego the planned mechanical removal trips during 2010 and to take time to evaluate alternative methods of non-native fish control in upcoming years. Reclamation re-initiated consultation with FWS on the planned delay and FWS agreed to review the one-year hiatus in the use of mechanical removal. In early 2010, Reclamation initiated an EA process to evaluate non-native fish control alternatives. The Pueblo of Zuni, the Hualapai tribe, U.S. Geological Survey (USGS), Bureau of Indian Affairs, FWS, National Park Service, Arizona Game and Fish Department, and Western Area Power Administration are cooperating agencies to Reclamation in the EA process. Thus far, several meetings and conference calls have occurred with the cooperating agencies and interested members of the public. The cooperating agencies continue to participate on weekly conference calls. Formal, government-to-government consultation with the interested and affected Native American tribes and pueblos is ongoing. These ongoing efforts as part of the AMP were discussed with AMWG members and other stakeholders at last month's AMWG meeting in Phoenix.

This is an issue that requires extremely careful evaluation. As a federal agency, Reclamation is required to ensure that its actions do not jeopardize the continued existence of endangered species, in this case, the humpback chub in particular. Trout have been identified as a known predator of young humpback chub, particularly in the area of the confluence of the Colorado River and the LCR, and mechanical removal of trout at that location through the AMP has been specified as a conservation measure in the FWS's 2008 Biological Opinion. At the same time, various tribes have objected to the taking of life through the mechanical removal process and particularly at the confluence. Reclamation is also obligated to conduct government-to-government consultation with the tribes and pueblos on matters of concern, a process that does not pre-determine the outcome of any such discussions but requires that meaningful and timely tribal input is secured. Such consultation ensures that our officials have the input and recommendations of the tribes and pueblos, and that such input is fully considered by Departmental officials. We remain committed to meaningful government-to-government consultation in this process.

Our goal in the EA process is to promote: (a) the best possible engagement of all interested parties, including the AMWG members and other stakeholders; (b) appropriate and adequate opportunity by all parties to express their views, and; (c) meaningful participation by all parties in the process of proposing and evaluating alternative non-native fish control measures that will serve to implement the non-native control conservation measure and assist in the conservation of the endangered native fish. To that end, I have requested that Reclamation utilize a Structured Decision Making (SDM) process to evaluate options for non-native fish control. In the SDM process, the discussions of alternatives will be guided by an experienced facilitator who is knowledgeable about the constraints imposed by law on Reclamation for protection of the humpback chub, but also cognizant of the gravity of the concerns expressed about the mechanical removal method. Dr. Michael C. Runge, Research Ecologist from the USGS Patuxent Wildlife Research Center, an expert in the use of SDM, will facilitate two 2½-day workshops in Phoenix in October or November, through which the cooperating agencies will work to develop, evaluate, and assess alternatives for consideration in the EA.

This type of process has not been widely used in environmental assessment processes, but the disparate interests involved here and the need to work within applicable legal constraints have led me to conclude that SDM may serve our purposes well and we should give it a try. While we are eager to utilize and assess the effectiveness of SDM in this effort, I want to emphasize that this process will entail "structured" decision-making, but not "delegated" decision-making. The federal agencies involved here cannot delegate or abdicate their statutory responsibilities and do not intend to do so. Nevertheless, we believe that through the involvement and participation by all stakeholders, operating within the framework of our legal obligations, we can reach a more-informed, effective, and implementable set of final agency decisions. Whatever the outcome of the alternatives evaluated and the preferred alternative selected, I am hopeful that the SDM process will ensure that all voices have been fully heard and that appropriate accommodations are made when feasible.

As described, the use of the SDM method involves concentrated and dedicated time and effort by multiple parties. In order to schedule the two recommended workshops and ensure strong participation by interested stakeholders, the schedule we initially set out for completion of this EA must be extended. We now expect that Reclamation will complete the EA by December 8, 2010, and the FWS will render a new Biological Opinion on the preferred alternative no later than April 23, 2011. I realize that this delay is not ideal, but I am convinced that it is advisable in order to fully engage the wide-ranging interests at stake. This revised schedule will not undermine Reclamation's ability to conduct any necessary nonnative fish control during appropriate periods in 2011.

Appendix 2 Detailed Description of the Hybrid Portfolios

Abbreviations Used

AZGF	Arizona Game and Fish Department
BNT	Brown trout (*Salmo trutta*)
GCMRC	Grand Canyon Monitoring & Research Center, U.S. Geological Survey
HBC	Humpback chub (*Gila cypha*)
HFE	High-flow experiment
LCR	Little Colorado River
NPS	National Park Service, Department of the Interior
PBR	Paria to Badger reach, Colorado River
RBT	Rainbow trout (*Onchorhynchus mykiss*)
Reclamation	Bureau of Reclamation, Department of the Interior
RM	River mile (location along the Colorado River, relative to Lees Ferry)
ROD	1996 Record of Decision

Hybrid Portfolio A: *No Action Alternative (Single strategies: 1, 6).* Doing nothing is an action that has consequences. In this 'no action' portfolio, RBT are not removed in the mainstem, ROD flow regimes are maintained, and the ongoing trout reduction program at Bright Angel Creek (which targets BNT but removes RBT as well) continues as initiated by NPS. No efforts to reduce RBT migration or directly enhance HBC populations are undertaken. The intent of this portfolio is to provide a default for comparison to other portfolios, which would be justified if RBT do not limit HBC recovery. Trout removal at Bright Angel Creek is conducted by NPS or their contractors. The underlying hypotheses are that the HBC population at LCR is not limited by RBT abundance, although BNT do limit HBC.

Hybrid Portfolio B: *Status Quo (Single strategies: 2, 6).* This portfolio represents the removal of RBT at LCR that had been conducted during the experimental period (2003–06) and one additional time in spring 2009. These actions involve multiple trips per year and multiple depletion passes per trip. The magnitude, and therefore effort and cost, of the removal depends on abundance in LCR relative to the abundance target, which is 600 to 1,200 RBT in the LCR confluence reach based on 10–20 percent of 2003 RBT abundance. Removal of RBT is followed by euthanasia and use for fertilizer. Removal of BNT is by weir and electrofishing during October and January, and BNT are prepared for human consumption. Actions aimed at RBT in the main channel of the Colorado River are conducted by Reclamation, or AZGF (as contractor to GCMRC) and those actions aimed at BNT are conducted by NPS or their contractors. The underlying hypotheses are that RBT and BNT limit HBC and that movement of RBT from Lees Ferry to LCR cannot be effectively reduced or eliminated, particularly when RBT production is increased by repeated HFEs.

Hybrid Portfolios C_1, C_2, C_3, C_4, and C_5: *Culturally sensitive removal at LCR (Single strategies: 3, 6).* These portfolios involve removal of RBT in the LCR reach, but include options for the method of capture and beneficial use that could meet tribal concerns. Trout (and possibly HBC) population size at the LCR is used as a trigger for removal. The method of capture is electrofishing. Options for beneficial use include euthanasia and preservation for human consumption (C_1), euthanasia and freezing for animal consumption (C_2), or live removal and transport for release outside of the Colorado River system (C_3, C_4, and C_5; these three differ in the amount and the method of live removal, see table 3). Actions aimed at RBT in the main channel of the Colorado River are conducted by Reclamation or AZGF (as contractor to GCMRC) and those actions aimed at BNT are conducted by NPS or their contractors. The underlying hypotheses are that RBT and BNT limit HBC and that movement of RBT from Lees Ferry to LCR cannot be effectively reduced, particularly when RBT production is increased by repeated HFEs.

Hybrid Portfolios D_1, D_2, and D_3: *Removal curtain (Single strategies: 3, 5, and 6).* These portfolios combines a short-term strategy of removing RBT at the LCR to reduce the existing threat with a long-term strategy of removing RBT in the PBR to reduce or eliminate movement from Lees Ferry to LCR (that is, the creation of a “curtain” that blocks downstream movement by removing RBT in the PBR). The removal at LCR is triggered in the same way as Portfolio C, but is expected to be needed only about a third as often. The magnitude of removal at PBR is based on either a fixed effort applied annually or an undefined trigger. The three versions of D differ in the method of removal and the beneficial use: D_1 includes lethal removal at both LCR and PBR; D_2 includes lethal removal at LCR, but live removal at PBR; and D_3 includes live removal at both LCR (via helicopter) and PBR. BNT removal is conducted in Bright Angel Creek as described in Portfolio A. Actions aimed at RBT in the main channel of the Colorado River are conducted by Reclamation, or AZGF (as contractor to GCMRC) and those actions aimed at BNT are conducted by NPS or their contractors. The underlying hypotheses are that RBT and BNT limit HBC, which can be alleviated by reducing or eliminating movement from the Lees Ferry tailwaters reach (for RBT). Also, movement of RBT from Lees Ferry to LCR can be effectively reduced or eliminated through removal, but not through flow or sediment augmentation.

Hybrid Portfolio E: *Sediment curtain (Single strategies: 3b, 5e, 6, 13).* This portfolio combines a short-term strategy of removing RBT at LCR and PBR to reduce the extant threat with a long-term strategy of sediment augmentation to reduce or eliminate movement from Lees Ferry to LCR. The magnitude of short-term removal is similar to Portfolio B, but the magnitude of removal at PBR is based on either a fixed effort applied annually or an undefined trigger. Options for method of capture and beneficial use are similar to Portfolio C_2. BNT removal is conducted as described in Portfolio A. Sediment is augmented at Paria through construction of a sediment pipeline from above Glen Canyon Dam. Actions aimed at RBT in the main channel of the Colorado River are conducted by Reclamation, or AZGF (as contractor to GCMRC) and those actions aimed at BNT are conducted by NPS or their contractors. The underlying hypotheses are that RBT and BNT limit HBC, which can be alleviated by reducing or eliminating movement from Lees Ferry (for RBT). Also, movement of RBT from Lees Ferry to LCR can be effectively reduced or eliminated through sediment augmentation in the long term (see Randle and others 2007).

Hybrid Portfolio F: *Stranding flow (Single strategies: 6, 11).* This portfolio varies flow to strand 0-age trout and reduce juvenile survival and recruitment of RBT in the Lees Ferry tailwaters reach. The intent is to reduce or eliminate movement of RBT from Lees Ferry to the LCR reach. High steady flows (20,000 cubic feet per second [ft^3/s]; 17,500 ft^3/s if maintenance limitations constrain operations) are maintained for 2 to 4 days followed by rapid decline to 2,500–5,000 ft^3/s for 12 hours to 1 day. These flows are implemented during May 1–August 1, and repeated twice a month (for six cycles total). BNT removal is conducted in Bright Angel Creek as described in Portfolio A. Flow is managed by Reclamation. The underlying hypotheses are that HBC are limited by RBT and that the threat can be reduced or eliminated effectively by stranding flows.

Hybrid Portfolio F': *Stranding flow with stocking of triploid male trout (Single strategies: 6, 11, 16).* This portfolio is identical to Portfolio F, with the addition of trout stocking at Lees Ferry to offset reductions in the trout population. AZGF manages stocking operations. The underlying hypotheses are the HBC are limited by RBT and that the threat can be reduced by stranding flows; addition of stocked trout is needed to meet the objectives of the recreational angling community.

Hybrid Portfolio G: *Stranding flow with augmentation (Single strategies: 5e, 6, 11).* This portfolio uses short-term removal from the PBR and variation in flow to strand 0-age trout to reduce juvenile survival and recruitment of RBT. The intent is to reduce or eliminate movement of RBT from Lees Ferry to LCR reach initially through removal at PBR, but in the long run through flow variation. High steady flows (20,000 ft^3/s; 17,500 ft^3/s if maintenance limitations constrain operations) are maintained for 2 to 4 days followed by rapid decline to 2,500–5,000 ft^3/s for 12 hours to 1 day. These flows are implemented during May 1–August 1, and repeated twice a month (for six cycles total). The magnitude of removal at PBR is based on either a fixed effort applied annually or an undefined trigger. Options for method of capture and beneficial use are similar to Portfolio C_2. BNT removal is conducted in Bright Angel Creek as described in Portfolio A. Flow is managed by Reclamation. Removal is conducted by Reclamation or AZGF (as contractor to GCMRC) and NPS or their contractors. The underlying hypotheses are that HBC are limited by RBT and that the threat can be reduced by stranding flows, but initially removal at PBR is needed to reduce or eliminate the threat in the short term.

Hybrid Portfolio G': *Stranding flow with augmentation and stocking of triploid male trout (Single strategies: 5e, 6, 11, 16).* This portfolio is similar to Portfolio G, but with the addition of trout stocking for the same reasons as in Porfolio F'.

Hybrid Portfolio H: *Stranding flow with assurances (Single strategies: 3b, 6, 11).* This portfolio uses short-term removal at LCR reach and variation in flow to strand 0-age trout to reduce juvenile survival and recruitment of RBT. The intent is to reduce or eliminate movement of RBT from Lees Ferry to LCR, with the removal of RBT from LCR as needed, especially in the short term. The magnitude of short-term removal is similar to Portfolio B. Options for method of capture and beneficial use are similar to Portfolio C_2. High steady flows (20,000 ft^3/s; 17,500 ft^3/s if maintenance limitations constrain operations) are maintained for 2 to 4 days followed by rapid decline to 2,500–5,000 ft^3/s for 12 hours to 1 day. These flows are implemented during May 1–August 1, and repeated twice a month (for six cycles total). BNT removal is conducted in Bright Angel Creek as described in Portfolio A. Flow is managed by Reclamation. Removal is conducted by Reclamation or AZGF (as contractor to GCMRC) and NPS or their contractors. The underlying hypotheses are the HBC are limited by RBT and that the threat can be reduced by stranding flows, but removal at LCR is needed to eliminate the threat, at least initially.

Hybrid Portfolio H': *Stranding flow with assurances with stocking of triploid male trout (Single strategies: 3b, 6, 11, 16).* This portfolio is similar to Portfolio H, but with the addition of trout stocking for the same reasons as in Porfolio F'.

Hybrid Portfolio I: *Dewater redds with assurances (Single strategies: 5e, 6, 9).* This portfolio uses removal from the PBR and variation in flow to dewater redds and reduce juvenile survival and recruitment of RBT. The intent is to reduce or eliminate movement of RBT from Lees Ferry to LCR, initially through removal at PBR, but in the long-run through dewatering redds. Up to 20,000 ft^3/s maximum daily flow for 13 days (minimum daily flow doesn't matter). On day 14, drop flow to 2,500–

5,000 ft^3/s between 8 am–1 pm, then resume normal ROD operations. These flows are implemented during February 1–April 30. The magnitude of removal at PBR is based on either a fixed effort applied annually or an undefined trigger. Options for method of capture and beneficial use are similar to Portfolio C_2. BNT removal is conducted in Bright Angel Creek as described in Portfolio A. Flow is managed by Reclamation. The underlying hypotheses are that HBC are limited by RBT and that the threat can be reduced by flows to dewater redds, but removal at PBR is needed to remove the compensatory effect (enhanced survival of young fish that emerge from eggs that are not killed through dewatering) and reduce or eliminate the threat to HBC.

Hybrid Portfolios J_1 and J_2: *Kitchen Sink I and II (Single strategies: 3, 5, 6, 7, 8, 9, 10, 11).* These portfolios combine a wide variety of flow and non-flow actions simultaneously. The intent is to do everything conceivable to reduce trout production in the Lees Ferry tailwaters reach, reduce emigration to the LCR reach, reduce predation of HBC, and improve recruitment of HBC. Removal magnitude and methods are similar to Portfolio D. The two versions of the portfolio differ in the removal method, with J_1 using lethal methods (3b, 5e) and J_2 using live removal methods (3e, 5h). Flow methods are similar to Portfolios E, F, G, and H. BNT removal is conducted in Bright Angel Creek as described in Portfolio A. Flow is managed by Reclamation. Removal is conducted by Reclamation or AZGF (as contractor to GCMRC) and NPS or their contractors. The underlying hypotheses are that HBC are threatened by RBT at the LCR to some degree, movement of RBT to LCR can be managed partially through flow and fishery regulations to reduce or eliminate threat at LCR.

> Hybrid Portfolios J1’ and J2’: *Kitchen Sink I and II with stocking of triploid male trout (Single strategies: 3, 5, 6, 7, 8, 9, 10, 11, 16).* These strategies are similar to J1 and J2, but with the addition of stocking of triploid trout, for the same reasons and by the same methods as described in Portfolio F’. AZGF would manage stocking operations.

Hybrid Portfolio K: *Zuni-Hopi-NPS strategy (Single strategies: 5h, 6, 9, 17).* This portfolio combines live removal of RBT in PBR, BNT removal at Bright Angel, stranding (redd dewatering) flows, and expanded harvest of trout at Lees Ferry. The intent of the portfolio is to limit downstream emigration, enhance HBC population at LCR and avoid unnecessary taking of life. The magnitude of removal at PBR is based on a fixed effort applied annually; removal method is live removal with beneficial use. Stranding flows focus on dewatering redds. BNT removal is conducted in Bright Angel Creek as described in Portfolio A. Harvest in the Lees Ferry tailwaters reach is expanded to reduce population size. Flow is managed by Reclamation. Removal is conducted by Reclamation or AZGF (as contractor to GCMRC) and NPS or their contractors. AZGF manages the fishery at Lees Ferry. The underlying hypotheses are that HBC are threatened by RBT at the LCR to some degree, movement of RBT to the LCR can be managed partially through flow and fishery regulations to reduce or eliminate threat at the LCR

Hybrid Portfolio L: *Strategy K plus headstarting and barrier (Single strategies: 5h, 6, 9, 15, 17, 18).* This portfolio combines live removal of RBT in PBR, BNT removal at Bright Angel, stranding (redd dewatering flows), expanded harvest of trout at Lees Ferry, a headstarting program for HBC, and barriers to downstream emigration. The intent of the portfolio is to limit downstream emigration, enhance HBC population at the LCR and avoid unnecessary taking of life. The magnitude of removal at PBR is based on a fixed effort applied annually; removal method is live removal with beneficial use. Redd dewatering flows are employed. BNT removal is conducted in Bright Angel Creek as described in Portfolio A. Harvest at Lees Ferry is expanded to reduce population size. The methods for headstarting HBC are undetermined. The barrier could be fine-sediment augmentation, similar to Portfolio E, or electrical, sound, or floating net, but not a constructed barrier. Flow is managed by Reclamation. Removal is conducted by Reclamation or AZGF (as contractor to GCMRC) and NPS or their contractors. AZGF manages the fishery at Lees Ferry. The lead on HBC culture is undetermined. The lead on barrier development is undetermined. The underlying hypotheses are that (1) HBC are threatened by RBT at LCR to some degree and (2) movement of RBT to LCR can be managed partially through flow and fishery regulations, but that additional measures (barrier and headstarting) will be needed to reduce or eliminate threat at LCR.

Hybrid Portfolio M: *Selective-sacrifice and strand portfolio (Single strategies: 5j, 6, 9 with trigger).* This portfolio combines removal of RBT in PBR based on an abundance trigger at Lees Ferry, beneficial use of removed fish, BNT removal in Bright Angel, and stranding flows to dewater redds. The intent of the portfolio is to limit downstream emigration, enhance HBC population at LCR, minimize need for removal, and incorporate beneficial use of removed fish. The magnitude of removal at PBR is based on either a fixed effort applied annually or an undefined trigger. Options for method of capture and beneficial use are similar to Portfolio C. BNT removal is conducted in Bright Angel Creek as described in Portfolio A. Flows are similar to Portfolio I. Flow is managed by Reclamation. Removal is conducted by Reclamation or AZGF (as contractor to GCMRC) and NPS or their contractors. The underlying hypotheses are that HBC are threatened by RBT at LCR to some degree, movement of RBT to LCR can be managed partially through flow, but some removal will be necessary in the PBR to reduce or eliminate the threat at LCR.

Hybrid Portfolio N: *BNT expanded removal (Single strategies: 1, 3b, 6, 7, 8).* This portfolio combines no action on RBT with an expanded effort to remove BNT from multiple tributaries in addition to Bright Angel Creek and to incorporate BNT removal as a standard operating procedure in fish monitoring activities. The intent of the portfolio is to enhance the HBC population at the LCR by eliminating BNT from the system to the degree possible. BNT removal is conducted in Bright Angel Creek as described in Portfolio A. BNT are also removed in multiple tributaries and during monitoring activities using weir and electrofishing. Removal is conducted by Reclamation or AZGF (as contractor to GCMRC) and NPS or their contractors. The underlying hypotheses are that HBC are threatened by BNT at LCR and extirpation of BNT from the system is needed to reduce or eliminate the threat at LCR.

Hybrid Portfolio O: *Expanded sediment curtain (Single strategies: 3b, 5e, 6, 13, 14).* This portfolio combines short-term removal of RBT at LCR to reduce the extant threat with long-term management to reduce movement of RBT to LCR using fine-sediment augmentation (via pipeline from upstream sources in Lake Powell; see Randle and others 2007). The intent of the portfolio is to enhance HBC at LCR by reducing RBT by short-term removal followed by long term fine-sediment augmentation. The portfolio is similar to Portfolio E, but sediment is augmented at an upstream point in the Lees Ferry tailwaters reach (presumably, to attenuate dramatic increases in primary production following HFEs) as well as at the Paria River confluence. The magnitude of removal is similar to Portfolio B, but magnitude of removal at PBR is based on either a fixed effort applied annually or an undefined trigger. Options for method of capture and beneficial use are similar to Portfolio C_2. BNT removal is conducted in Bright Angel Creek as described in Portfolio A. Actions are conducted by Reclamation or AZGF (as contractor to GCMRC) and NPS or their contractors. The underlying hypotheses are that HBC are threatened by RBT at LCR, flow or fishery management at Lees Ferry is not effective, and fine-sediment augmentation at Lees Ferry and Paria will be effective methods to reduce or eliminate the threat at LCR.

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Runge and others— Non-Native Fish Control below Glen Canyon Dam—Report from a Structured Decision-Making Project —Open-File Report 2011-1012

Appendix B: Science Plan

Preliminary Research and Monitoring Plan in Support of the Draft Environmental Assessment Non-Native Fish Control Downstream from Glen Canyon Dam

February 7, 2011

Southwest Biological Science Center
Grand Canyon Monitoring and Research Center
US Geological Survey
Flagstaff, Arizona

Preface

This preliminary research and monitoring plan outlines a general framework for evaluating key research questions described in the January 28, 2011 Draft Environmental Assessment Non-Native Fish Control Downstream from Glen Canyon Dam. The plan will be refined and subjected to additional peer review once management agencies provide additional guidance on the scope of nonnative fish control efforts and the importance of resolving uncertainties surrounding the efficacy of nonnative fish removal to benefit the endangered humpback chub (*Gila cypha*). Prior to implementing this plan, GCMRC recommends convening a workshop of scientist and managers to evaluate appropriate study designs and approaches, and determine how data will be analyzed/modeled to address the different science questions and project objectives.

Introduction

This science plan is developed in support of the **Draft Environmental Assessment Non-Native Fish Control Downstream from Glen Canyon Dam** dated January 28, 2011 (hereafter referred to as the EA). The purpose of the proposed action is to minimize the negative impacts of competition and predation on an endangered fish, the humpback chub in Grand Canyon (see Appendix A). Along with describing the purpose and need for the proposed action, the U.S. Bureau of Reclamation (Reclamation) identified three research questions in their EA:

1. Can a decrease in the abundance of rainbow trout and other cold- and warm- water non-natives in Marble and eastern Grand canyon's be linked to a higher recruitment rate of juvenile humpback chub in the adult population?

2. Can removal efforts focused in the Paria River to Badger Rapid (PBR) reach (e.g., interception fishery) be effective in reducing downstream movement of rainbow trout (*Oncorhynchus mykiss*) such that trout levels in the Little Colorado River (LCR) reach remain low? Will recolonization from tributaries, from downstream and upstream of the removal reach, or local production require that removal be an ongoing management action in the LCR reach?

3. Can non-native fish control offset any increases in rainbow trout from multiple High Flow Experiments (HFE)?

To answer these questions, Reclamation identifies that nonnative removal at the LCR and within the PBR Reach will be used (figure 1). Instead of prescribing a specific number of trips, the EA identifies a range of trip numbers and that an adaptive management approach would be used to decide how much removal is needed at either location.

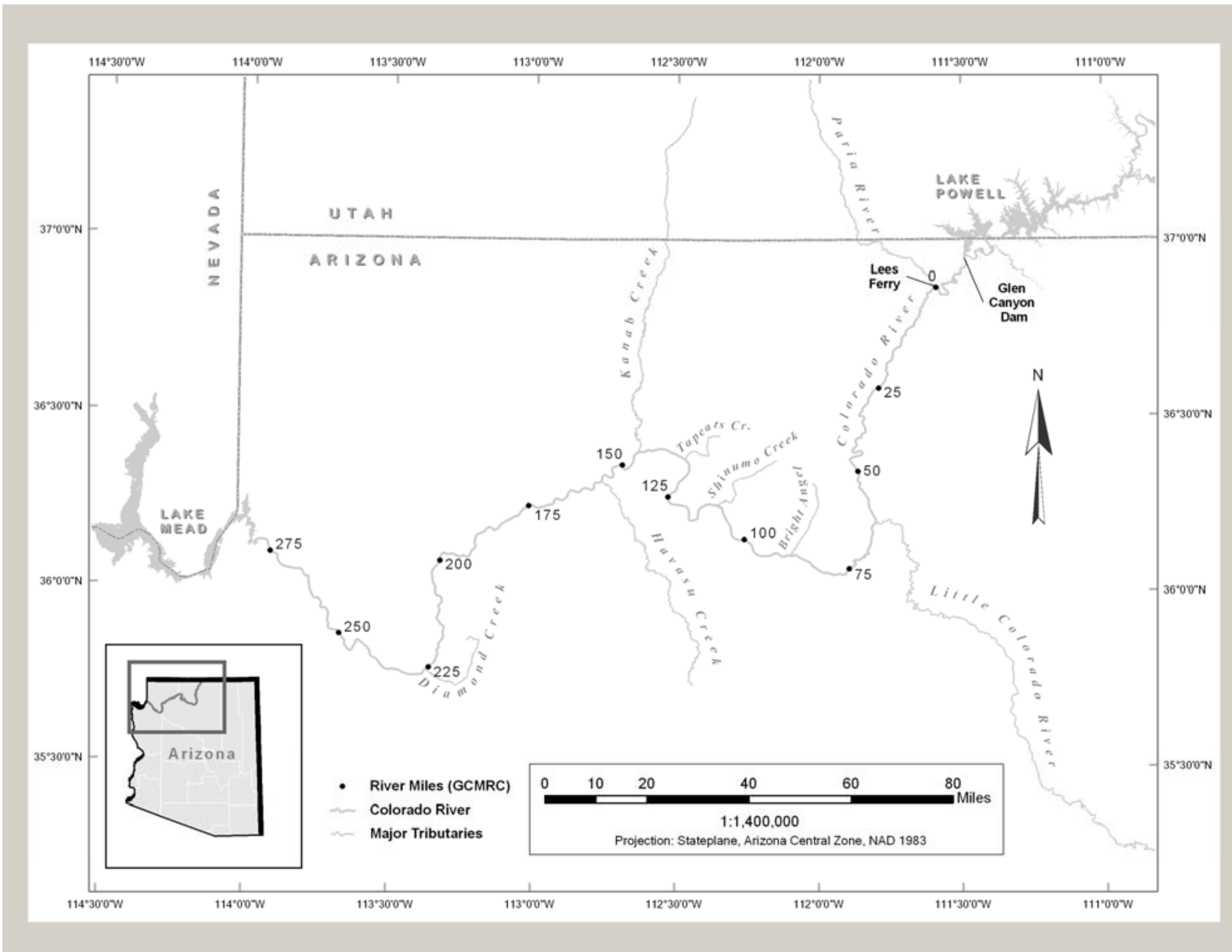

Figure 1. Map of the extent of the study area with river miles identified in 25 mile segments starting at Lees Ferry. The Little Colorado River (LCR) is identified and its confluence is at river mile 61. The Paria to Badger Rapid (PBR) Reach extends from river mile 1 to 8

There are four fundamental premises at the heart of the nonnative fish control actions described in the EA. The premises are listed in order of precedence:

1) Survival and recruitment of juvenile humpback chub rearing in the Colorado River mainstem are significant factors limiting the adult humpback chub population in the LCR/Colorado River,

2) Competition and/or predation between humpback chub and nonnative fishes, especially rainbow trout is significantly limiting survival and recruitment of juvenile humpback chub in the Colorado River mainstem,
3) The origin of rainbow trout near the confluence of the LCR is from Lees Ferry, and
4) Trout numbers near the LCR confluence can be controlled by fish removal activities implemented upstream in the PBR reach.

If all of these premises are correct, then these proposed nonnative fish control actions will probably benefit humpback chub populations. However, if the foremost premise is found to be incorrect, then it negates the relevance of the remaining premises and the utility of the proposed management actions. For example, if the Colorado River mainstem rearing environment is not contributing significantly to juvenile humpback chub growth, survival and recruitment, then the observed changes in adult humpback chub abundance that have occurred since around 1990 are attributable to factors occurring in the LCR, independent of the mainstem. If this was the case, it is unlikely that any management activity directed at trout removal would have significant positive benefits to humpback chub. On the other hand, if a relatively high proportion of humpback chub that move/disperse into the mainstem ultimately recruit into the adult population, then rainbow trout predation and competition may be limiting humpback chub recruitment in the Colorado River mainstem. Current research and monitoring results (Coggins and others, in press, Yard and others, in press; Korman and others, in review) has identified uncertainty in all of the above premises.

Many physical and biological variables vary annually and can confound direct assessment of the effect that rainbow trout in the mainstem Colorado River have on the humpback chub population. High annual variation in timing and magnitude of flood events within the LCR can impact spawning success and survival of larval humpback chub (Gorman and Stone 1999). Density dependent effects, such as a strong cohort of juvenile humpback chub within the Little Colorado River, may also impact the survival of subsequent humpback chub cohorts. In addition, changes in mainstem water temperatures impact humpback chub growth rates (Coggins and Pine 2010) and subsequent swimming ability of native fishes (Ward et al. 2002), which in turn can alter predation rates (Ward and Bonar 2003). High turbidity in the mainstem Colorado River is also known to alter predation rates (Yard et al. *in press*) and altered mainstem flow regimes may also impact juvenile chub survival.

To determine the effect of an experimental management action on humpback chub populations, the management action needs to be applied for a duration that approaches or exceeds the generation time of humpback chub—four to six years. Alternatively, inferences regarding the impact of a management action on humpback chub populations can be made using data on how a management action affects juvenile humpback chub growth or survival. Regardless of which approach is taken to reducing uncertainty (that is, designing management actions that are long enough in duration to elicit a population response, or designing shorter duration management experiments and monitoring vital rates for juvenile humpback chub), variation in environmental factors (for example, water temperature) can complicate interpretation of results. Water temperature is a strong lever that affects native fish growth and predation/ competition interactions (Coggins, 2008a). Water temperature in the mainstem of the Colorado River near the confluence with the LCR is primarily affected by initial release temperatures from Glen Canyon Dam (Wright and others, 2008). Higher than average release temperatures from 2003-2006 while nonnative fish control at the LCR confluence was occurring confounded interpretation of humpback chub response to mechanical removal of rainbow trout (Coggins, 2008a). Therefore, as a contingency for this science plan for nonnative removal, if Glen Canyon release temperatures exceed the 2004-2005 average, then it is recommended that fish removal activities be discontinued. This would allow scientists to disentangle the effects of water temperature versus rainbow trout on humpback chub recruitment. Comparisons could then be made between humpback chub vital rates during elevated temperatures that had both high and low trout abundance.

Objectives

A stated purpose of the proposed action in the EA (Appendix A) is to evaluate, in an adaptive management framework, the effectiveness of conducting nonnative fish control actions in conserving the endangered humpback chub and other native fishes. This science plan describes objective-based studies that can be implemented to improve management decisions concerning the effects of nonnative fish on juvenile humpback chub survival in the mainstem. We identify three objectives that need to be addressed to support management decision making:

1) Understand the role of the Little Colorado River and the mainstem Colorado River in juvenile humpback chub survival rates and recruitment to the adult humpback chub population. (In support of EA research question 1)
2) Determine the linkage between nonnative fish abundances and humpback chub juvenile abundance and survival rates in the mainstem near the LCR confluence. (In support of EA research question 1)
3) Determine the natal origins of rainbow trout found in Marble Canyon/LCR confluence area and assess the efficacy of rainbow trout removal in the PBR reach. (In support of EA research question 2)

Results from objectives 1 and 2 inform EA research question 3.

Structured Decision Making (SDM) and Science Planning

Structured decision making is an approach that can be used to facilitate management decisions involving multiple competing objectives. A structured decision-making (SDM) approach (Runge and others, 2011) was used by Reclamation to identify and evaluate alternative non-native fish control actions for use in the EA (U.S. Department of Interior, 2011). The project consisted of two workshops with representatives of EA cooperating agencies and tribes. The workshop focused on developing and evaluating a wide range of non-native fish control alternatives, considering both effectiveness and other factors, such as stakeholder values and costs. Trout removal at the PBR, with backup removal at the LCR if necessary, ranked highest among the “value weighted” control alternatives considered. Ranking was based on a variety of factors, including five fundamental objectives:

1. Manage resources to protect tribal sacred sites and spiritual values,
2. Manage resources to promote ecological and native species integrity,
3. Preserve and enhance recreational values and uses,
4. Maintain and promote local economies and public services and,
5. Operate within the authority, capabilities, and legal responsibility of the Bureau of Reclamation.

Two key uncertainties emerged from the SDM project: 1) the degree to which rainbow trout limit humpback chub populations, and 2) the effectiveness of PBR removal to reduce trout out-emigration from the Lees Ferry reach to Marble and Grand Canyons (fig. 1). The SDM analysis identified two approaches that might be pursued by resource managers: 1) a direct action strategy for nonnative fish control that assumes that native and nonnative fish interactions in mainstem and near the LCR confluence limits humpback chub recovery, and 2) an adaptive strategy that delays removal to verify the assumption in approach 1.

The outcome of the SDM project suggested that the GCDAMP was not driven by learning as a fundamental of objective. The authors of the SDM project concluded that approach 1 was a logical step accepted by managers. The conclusion by managers to move toward approach 1 may have been a based on several studies (Coggins and Yard, 2010; Yard and others, in press) which indicate the rainbow trout prey upon and compete with HBC. In light of ESA mandates to management agencies to take reasonable actions to avoid jeopardy to and promote recovery of HBC, approach 1 emerged as the preferred approach by workshop participants. The draft EA emphasizes taking appropriate management action to conserve HBC by controlling rainbow trout while addressing some of the key uncertainties related to the impacts that rainbow trout have upon humpback chub recovery.

Objective 1-- Understand the role of the Little Colorado River and the mainstem Colorado River in juvenile humpback chub survival rates and recruitment to the adult humpback chub population.

Although juvenile humpback chub are found in the LCR confluence area and downstream of the confluence, it is not known to what degree those fish contribute to the reproducing population in the LCR. If juvenile humpback chub rearing in the mainstem recruit to the adult population in low numbers relative to juvenile humpback chub rearing in the LCR, then determining the best approach for managing nonnative fish abundance in the mainstem is somewhat irrelevant. Thus, understanding the relative contribution of the LCR rearing environment versus the mainstem rearing environment in sustaining humpback chub populations would help managers to determine whether nonnative fish removal in the confluence area is even necessary.

To resolve this key uncertainty, we recommend a new hybrid research project be implemented that incorporates elements of the nearshore ecology (NSE) project, aquatic food base monitoring and ongoing humpback chub monitoring in the LCR and mainstem Colorado River. The overall goals of the project would be to assess the carrying capacity of the LCR to support humpback chub, and determine the relative importance of mainstem versus LCR rearing to sustaining humpback chub populations. This information would also provide guidance regarding how many humpback chub can be taken from the LCR for translocations to other tributaries, and how translocations upstream of Chute Falls affect carrying capacity within the Little Colorado River.

Objective 2--Determine the linkage between nonnative fish abundances and humpback chub juvenile abundance and survival rates in the mainstem near the LCR confluence.

Three options are proposed to approach nonnative removal at the LCR confluence and address objective 2. All three options would include the following study components:

- Annual assessments of juvenile humpback chub survival rates and abundance in the mainstem using methods developed in the NSE study (new study)
- Enhanced mainstem fish monitoring to assess the relative abundance of rainbow trout and other nonnative fishes in Marble Canyon (expansion of existing study)
- LCR and mainstem humpback chub monitoring to estimate the abundance of adult humpback chub using ASMR (existing study)

The options weigh the risk of harm to humpback chub cohorts in the mainstem with the benefits of resolving the uncertainties about the effect of high rainbow trout densities on humpback chub recruitment. Options 1 and 2 accelerates learning about the uncertainties related to the impacts of rainbow trout on humpback chub and could save time and money, in the long run. On the other hand, if managers are unwilling to accept the risk of losing a portion of juvenile cohorts of humpback chub that occupy the mainstem, then option 3 provides for immediate removal at the LCR. Under Option 3, uncertainties regarding the impact of rainbow trout on humpback chub populations could only be resolved over a longer period of time, if at all.. Management agencies will have to identify the option that will be implemented at the LCR confluence

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Option 1–Postpone removal to accelerate learning about Objective 1

Approach— Juvenile humpback chub survival rates and abundance in the mainstem would be assess annually using methods developed in the NSE study. Nonnative fish removal at LCR would be postponed until juvenile HBC mainstem survival estimates drop 25% below 2009-2010 baseline. ASMR would continue to be updated every three years; nonnative removal could also be implemented depending on ASMR adult abundance estimates. This approach is consistent with recommendations from the October 2010 ecosystem modeling workshop (Carl Walters, written communication, 2010).

Strengths of Option 1:

- Accelerate learning regarding Objective 1
- Risk is reduced because adult humpback chub population estimates are relatively high (7,600—Coggins and Walters, 2009)
- Reduces cultural concerns about removal at the LCR confluence.
- Provides more time to evaluate effectiveness of other control methods (for example, PBR removal or Flow Suppression)
- Low cost in near term

Weakness of Option 1:

- May adversely affect survival and abundance of juvenile humpback chub in the mainstem

Option 2 – Postpone removal for one year to accelerate learning about Objective 1

Approach—Same as Option 1 except nonnative removal would be implemented in 2012 during high rainbow trout abundance, regardless of juvenile humpback chub survival rate and abundance.

Strengths of Option 2:

- Limits potential threat to juvenile humpback chub rearing in the mainstem relative to option 1
- Reduces cultural concerns about removal at the LCR confluence for one year.
- Provides more time to evaluate effectiveness of other control methods (for example, PBR removal or Flow Suppression)

Weakness of Option 2:

- Limits learning regarding Objective 1
- May adversely affect mainstem juvenile humpback chub survival and abundance
- Increased cost relative to Option 1

Option 3 – Control nonnative fish at the LCR for six year.

Approach—Sustained annual removal at LCR for six years. Continue estimating juvenile HBC mainstem survival and abundance. Continue updating ASMR every three years. Reassess need for removal based on new knowledge regarding objectives 1 and 2.

Strength of Option 3 –

- Minimizes the potential risk to humpback chub from rainbow trout predation and competition.

- Allows for learning, but at a slower pace than for Options 1 and 2.

Weakness

- Most expensive option
- Reduces variability in trout abundance at LCR, which limits our ability to work towards Objective 1
- Variability in trout abundance will be dependent on PBR or Flow Suppression activities.
- Cultural concerns remain
- Electrofishing/handling stress on humpback chub possible

Objective 3— Determine the natal origins of rainbow trout found in Marble Canyon/LCR confluence area and assess the efficacy of rainbow trout removal in the PBR reach

Rainbow trout abundances are greatest in the Lees Ferry reach and generally decline downstream, reaching their lowest abundances in western Grand Canyon (Makinster and others, 2010). Sources of rainbow trout in the mainstem below Lees Ferry could include downstream migration of trout from Lees Ferry, trout that spawn in tributaries such as Nankoweep, Bright Angle or Tapeats Creek, or local reproduction in the mainstem. The relative contribution of each of these potential sources to the mainstem population is uncertain enough as to warrant further study. Of particular interest to managers is whether changes in the Lees Ferry trout population affect downstream rainbow trout abundances. Though there is not conclusive evidence linking high rainbow trout abundances in the Lees Ferry with high mainstem trout abundance, the patterns of increase between these areas are similar, with generally a one year lag between pronounced spikes in Lees Ferry rainbow trout abundance and a comparable increase in rainbow trout abundance downstream (Makinster and others, 2010; Makinster and others, in press).

To clearly understand the number and size classes of rainbow trout that might move downstream, a program of tagging, mark/recapture and depletion will be initiated that focuses efforts from Lees Ferry to Badger Rapid. Ongoing downstream monitoring for nonnative fish in the mainstem will sample the Marble Canyon/LCR reaches and contribute catch data to inform objectives laid out in this plan.

1. Lees Ferry Age-0 Trout Marking Project

The Lees Ferry (juvenile fish) Age-0 trout marking (LFTM) project would determine what fraction of rainbow trout in the Marble Canyon/LCR area were spawned and reared in the Lees Ferry reach. Analysis of size-frequency data for rainbow trout captured in Marble Canyon indicate an absence of small-sized fish, which suggests these populations are supported by individuals that migrated from Lees Ferry. Alternatively, it is possible that scattered local reproduction in Marble Canyon, combined with relatively high growth and survival of juveniles rainbow trout in Marbel Canyon, may also contribute sufficient numbers of trout to support observed adult densities (Korman, pers comm.). Resolving these competing hypotheses is important to determining the viability of removing rainbow trout from the PBR reach as a way to manage the trout population near the LCR. The LFTM project would determine the natal origin of downstream rainbow trout, and if emigration is due to Lees Ferry fishery trout production, then:

1. Determine what factors (density dependent versus flows) or interaction of factors are responsible for emigration
2. Determine the fraction of fish that are not intercepted by the PBR fish control effort.

Annually 10-15% of the age-0 year class over a 4-year period would be marked. Marking would occur every year in the fall (October) following seasonal growth and high summer mortality, but before young fish are expected to show high downstream dispersal rates. Young fish will be marked (i.e., individually based tags such as coded wire tags or passive integrated transponders) and released at site of capture. Based on ongoing monitoring and research projects, as described earlier, modeled proportions of marked fish (observed versus expected) will be used to address the above study objectives identified above

2. The Paria to Badger Reach Sampling and Removal Project (modified from existing Work Plan)

The PBR project is intended to:

1. Estimate age stratified downstream movement of rainbow trout from the Lees Ferry reach to Badger Rapid.
2. Estimate age stratified capture probability of rainbow trout in the Lees Ferry and PBR study reaches.
3. Estimate age stratified abundance of rainbow trout in the Lees Ferry and PBR study reaches.
4. Estimate proportions of marked juveniles for comparison to proportions established upstream through the marking program.
5. Assess the effectiveness of removal in the PBR reach

If rainbow trout move downstream and out of the Lees Ferry reach, this project will provide information about the age- and size-class structure of fish that move downstream, and whether there is any “dilution” in the upstream mark rate indicative of local recruitment in the Paria-Badger reach. Understanding population dynamics and the movement characteristics is an important first step in being able to assess the potential for successful control of rainbow trout immediately below Lees Ferry. If fish from Lees Ferry are found to be a primary source for rainbow trout downstream, then removing fish in this reach of river may be less intrusive and more culturally acceptable than control efforts conducted at the LCR confluence. Information from this project will incorporate ongoing monitoring data for rainbow trout upstream from Lees

Ferry to assess any potential correlation between rainbow trout density in the Lees Ferry reach and potential emigration out of the reach. This project is proposed as an experimental research project to be conducted from FY 2011 through FY 2014 to increase knowledge of rainbow trout movement patterns. Fish would be removed and disposed of in a manner that is consistent with the EA.

Sampling Below Badger Rapid for Marked Rainbow Trout.

A combination of different monitoring programs (PBR Project, Monitoring Mainstem Fishes, and LCR Nonnative Fish Control) will be used to determine Lees Ferry trout emigration. In addition, a set of three sampling trips will be conducted in the fall (July-September) that intensively sample for marked fish throughout Marble Canyon (8-56 RM). This recapture effort will be done in combination with another project conducted at the LCR for determining monthly juvenile chub (Age-0 to Age-4) abundance, and survival and growth rates. A stratified sampling design would be used, which longitudinally subdivides Marble Canyon into seven reaches. Reach boundaries would be based on un-navigable rapids or reach lengths (approximately 10 to 13 km/reach). Within each reach, shoreline (excluding cliff-habitat equivalent to 18.6% of all available shoreline types) would be further subdivided into 500 m sites, and would be randomly selected and assigned to one of the three scheduled trips. Marble Canyon could be effectively sampled using two electrofishing boats, sampling 7 sites per boat per night. Sampling effort would be evenly distributed between trips and would sample over 25% of available shoreline per trip. We estimate that cumulative coverage would be over 85% of the total shoreline available.

Linkages to Existing Monitoring and Research Projects

As part of the Glen Canyon Adaptive Management Program there are five existing long-term monitoring projects (USGS, 2010) that will also provide additional data to evaluate the efficacy of nonnative fish removal efforts and natal origin objectives. These long-term monitoring projects include:

1. Monitoring Lees Ferry Fishes (BIO 4.M2.10) – Ongoing status of the Lees Ferry trout fishery (Adult and juvenile fish),
2. Monitoring Mainstem Fishes (BIO 2.M4.10 – Ongoing downstream monitoring of nonnative fish distribution and relative abundance in the mainstem (includes Diamond down),
3. Stock Assessment of Native Fish in Grand Canyon (BIO 2.R7.10) – age-structured mark recapture recruitment modeling update for adult humpback chub (Age- 4^{+}),
4. Little Colorado River Humpback Chub Monitoring (BIO 2.R1.10) – annual point estimates for HBC population in the lower 13.57 km,
5. Mainstem HBC aggregation trips. – distribution and relative abundance of HBC in the mainstem.

Research and reporting efforts that are part of the monitoring and research programs associated with the mainstem and its tributaries will also help inform the adaptive decision-making process.

1. Annual Nonnative fish Workshop-a scientists/manager workshop to review current data/finding and adapt the program as needed, GCMRC biannual work plan project BIO 2.R17.11-12
2. Evaluate Lees Ferry Recreation Experience Quality—to assess how will multiple high flows and other flow experiments conducted over the next 10 years affect recreational experience quality in the Colorado River corridor in Glen Canyon (REC 9.R4.11,12)
3. Brown trout removal at Bright Angel Creek conducted by the National Park Service.
4. Continued ecosystem modeling. (PLAN 12.P1.11,12)

Annual Reporting

Annual reporting is scheduled to occur in early December as part of the GCMRC's Annual Fish Cooperators Meeting. A written summary will also be provided that includes the annual resource assessment and criteria for supporting the decision making process to be used the coming year. The primary information provided will include: 1) humpback chub abundance, 2) humpback chub survival rates, 3) LCR trout abundance estimates and total fish catch and removal numbers (depending on which removal option is selected), 4) PBR trout abundance estimates and total fish catch and removal, and 5) Lees Ferry age-0 trout marking numbers and recaptures (Lees Ferry, PBR and Marble Canyon/LCR).

General budget

Under development

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Appendix A

Purpose and need statement and description of the Proposed Action as identified in the January 28, 2011.Draft Environmental Assessment Non-Native Fish Control Downstream from Glen Canyon Dam (The entire EA is available at http://www.usbr.gov/uc/envdocs/ea/gc/nnfc/index.html)

1.2 *Purpose of and Need for Action*

The federal action analyzed in this Environmental Assessment is the control of non-native fish in the Colorado River downstream from Glen Canyon Dam within GCNRA and GCNP, Coconino County, Arizona. The purpose of the action is to reduce the negative impacts of competition and predation by rainbow trout and brown trout on the endangered humpback chub (*Gila cypha*) and its critical habitat in the Grand Canyon. The need for this action is to fulfill the conservation measures and terms and conditions of several U.S. Fish and Wildlife Service (USFWS) biological opinions, to contribute to the recovery of humpback chub by helping to maintain high juvenile survival and recruitment rates resulting in an increasing adult population, and to address concerns expressed by American Indian Tribes over the killing of trout in the Grand Canyon, a location of cultural, religious, and historical importance to a number to tribes. This action is being conducted through the Glen Canyon Dam Adaptive Management Program. Accordingly, an additional purpose of this action is to evaluate, in an adaptive management framework, the effectiveness of conducting these non-native fish control actions in conserving the endangered humpback chub and other native fishes.

Reclamation proposes that this action start in 2011 and extend to 2020. Starting the action in 2011 addresses the importance and need for implementing non-native fish control activities as soon as possible in order to address the ongoing threat to the humpback chub, as well as a number of cultural and socioeconomic concerns and issues, further described in the Issues section of this EA.

2.3 *Proposed Action*

The proposed action alternative was the top performing alternative in the SDM Project. This alternative combines a strategy of removing rainbow trout in the LCR reach (RM 56 to 66) to reduce the extant threat of large numbers of rainbow trout in that reach, with removal of trout in the PBR reach (RM 1 to RM 8) to test a strategy of removing rainbow trout immediately downstream of Lees Ferry to reduce emigration of rainbow trout from Lees Ferry to the LCR reach. Up to 6 LCR reach removal trips and up to 10 PBR reach removal trips would be conducted in any one year for the ten-year period of 2011-2020. The 10-year period of the action is appropriate to coincide with the HFE Protocol EA, also a 10-year action, because there is evidence, discussed in other sections, that HFEs benefit rainbow trout, and is also necessary to ensure a long-term commitment to implementing the conservation measure, and provide a reasonable experimental timeframe to evaluate non-native fish control through research and monitoring in an adaptive management context. In the short term (one to several years), the focus would be to reduce trout at the LCR reach. If trout abundance at the LCR reach can be kept low through PBR reach-removal (which assumes both that PBR removal is effective at limiting emigration of rainbow trout from Glen Canyon, and Lees Ferry is the primary source of rainbow trout in the LCR reach), effort can be shifted to the PBR reach to alleviate concerns of the tribes about removal in the LCR reach. Tribes are also concerned about the taking of life on a large scale with no beneficial use of the fish. The proposed action may result in thousands of fish being removed from the system per year. Prior efforts from 2003-2006 resulted in 23,266 non-native fish removed. To address the tribal concerns on the disposition of removed fish, it is anticipated that they would be frozen and stored for later beneficial use (used for human consumption, or for feeding eagles, other raptors, or other captive wildlife, particularly those animals kept and reared by tribes), or may be used for other purposes that may be identified through continued tribal consultation.

Removal of rainbow and brown trout from Bright Angel Creek with a fish weir in fall of 2002 and 2006 has been shown to be effective (Leibfried et al. 2003, 2006). The NPS Bright Angel Creek removal project would be ongoing and be expected to effectively reduce what is considered to be the primary source of brown trout to the LCR reach. The NPS will also be conducting removal in Shinumo Creek as part of a project to translocate humpback chub from the LCR to that stream.

Non-native fish control actions would be similar to removal conducted in 2004-2006 and 2009 (Coggins 2008a; Coggins and Yard 2010). The method of removal in the PBR and LCR reaches would be to use boat-mounted electrofishing as described in Coggins (2008a) and Coggins and Yard (2010) to remove all non-native fish captured. Using similar methods as described in Coggins (2008a), removal trips would utilize from 1 to 6 passes of electrofishing boats through the removal reaches per trip. Removal of non-native fish would attempt to minimize abundance of rainbow trout in the LCR Reach. The number of removal trips conducted in each removal reach in a given year is variable and would depend on numbers of trout in the LCR reach as well as abundance and other population parameters of humpback chub, and would be determined in coordination with the USFWS and other appropriate agencies through adaptive management for the 10-year proposed action. If removal in the PBR reach proves effective at limiting trout abundance in the LCR reach, LCR removal may not be necessary.

Removal in the PBR reach is predicted to be of primarily juvenile rainbow trout before they descend downstream to the LCR reach, but all non-native fish captured would be removed. This would be done in fall or early spring (during expected emigration periods), or via multiple trips throughout the year if necessary. Fish removed as far downstream as Badger Creek Rapid (RM 8) would enable boats to return upstream to Lees Ferry the same day and avoid the costs associated with downriver travel and impacts to wilderness experience and values through the entire Grand Canyon. Seasonal timing of movement by young trout from the Lees Ferry reach and how long moving fish reside in the Paria-Badger reach is unknown. If their residence time in this reach is short, only a small fraction of downstream migrants might be removed in this reach, and removal effort would shift to the LCR reach.

The taking of life in a sacred location such as the Grand Canyon and the LCR confluence and without beneficial use is a concern of tribes. If this alternative is selected, mitigating measures would likely consist of euthanizing non-native fish that are removed from both reaches and freezing them onsite using generators and electric freezers for storage and later beneficial use. Beneficial use would be for human consumption, or to feed eagles, other raptors, or other captive wildlife, particularly those animals kept and reared by tribes. The advantage of the proposed action is that it conducts removal in two locations, the PBR and LCR reaches. If PBR reach removal proves effective, this would have two key advantages over removal in the LCR reach: the treatment would cost less to implement than removal in the LCR reach, and this treatment would alleviate the concerns expressed by some tribes about conducting removal at the LCR confluence, a place of particular cultural significance to several tribes. However, many tribes have also indicated that any removal in GCNP would be offensive because all of the Grand Canyon is considered a culturally important place, so PBR reach removal alone would not totally alleviate the tribal concerns.

Monitoring is needed both to determine the need for removal efforts and to determine if removal in either the PBR or LCR reach is being effective at keeping trout numbers low in the LCR reach. Monitoring of mainstem fishes would be conducted using electrofishing twice annually, in the spring and fall. If successful, removal actions would continue to be evaluated and refined to meet the management objectives, including the viability of the Lees Ferry trout fishery and recovery of the Grand Canyon population of humpback chub. If unsuccessful, these actions would need to be reevaluated and refined as necessary to achieve the management objectives, and additional actions removed from the EA analysis through the SDM Project may need to be reconsidered. Defining a target level of removal for the proposed action is challenging. Trammel (2005, *in litt.*) reviewed the literature regarding targets for non-native fish removal, and found the following results. Mueller (2005) reported that a 90% reduction in non-native fish abundance is necessary to induce a positive population response by native fishes. Beamesderfer (2000) discussed predator removal in a decision matrix format, and also stated that 10-20% of northern pikeminnow must be removed to benefit salmon smolts. Dudley and Matter (2000) concluded that removing 90% of green sunfish from a small creek did not result in a positive response by Gila chub (*Gila intermedia*). Weidel et al. (2002) showed that removing 43 to 88% of smallmouth bass from a lake in the Adirondacks did result in a positive response by other littoral species.

Pacey and Marsh (1998) included a discussion of 10 case studies illustrating survival, reproduction, and growth of bonytail and razorback sucker in a variety of pond habitats with and without non-native predators. Few of these accounts have been published elsewhere. Six studies were examples of successful survival and reproduction in predator-free pond habitats. Two studies indicated no survival in predator-free habitats, due to environmental conditions. One study, citing unpublished data from Dexter National Fish Hatchery described an experiment with razorback sucker larvae and green sunfish in production ponds at high (874/acre), medium (175/acre), and low (35/acre) predator densities which showed 0 % survival at high density, 72 to 78% survival at medium density and 90-97 % survival at low density. Another study examined the survival of razorback suckers in backwaters and coves of Lake Mohave, Arizona-Nevada, which found that successful survival and reproduction occurred in predator-free habitats, while survival was dramatically reduced or eliminated when non-natives (Pacey and Marsh 1998 cite Marsh and Langhorst 1988, Minckley et al. 1991, Mueller et al. 1993, Mueller 1995, and unpublished data). Marsh and Pacey (1998) found that the goal of complete removal and exclusion of non-native fishes was necessary, and did not recommend partial removal.

A literature review on non-native fish removal conducted for the June Sucker Recovery Program (SWCA 2002) included a few more supporting citations, including Harding et al. (2001) with a non-aquatic model showing that 70-75% of predators must be removed to benefit prey species. Friesen and Ward (1999) found little positive response of salmon smolts to a 12 % reduction in northern pikeminnow.

The conclusion of the Trammel (2005, *in litt.*) review was that reduction in predator abundance required to induce a positive species response is variable, and is likely dependent on the specific environment and species being studied. Efforts to reduce predators resulted in a positive species response with removal of from 12% to 100% in some studies, but in others, similar ranges in reductions did not result in a positive species response. In general, larger proportions of predator removal were more successful at benefitting target prey species, although the precise reduction targets required appear to be site specific.

Hilwig et al. (2010) attempted to define a reduction target for rainbow trout in the LCR reach. While removal in the LCR reach has been found to reduce predation on humpback chub to a large degree (Yard et al. *in press*), efforts have not resulted in definitive results that removal of non-native fish has directly resulted in increases in the adult population of humpback chub (Coggins and Yard 2010). Warmer Colorado River water temperatures during the period of removal efforts was also correlated with both decreased non-native fish abundance (Coggins 2008a) and increases in the humpback chub population (Coggins 2008b; Coggins and Walters, 2009). Considering this, Hilwig et al. (2010) recommended that continued large-scale experimentation be employed to better understand factors benefiting native fish, but that until these mechanisms are better understood, a non-zero target abundance of non-native fish should be defined. Defining a target for when to conduct non-native fish removal in a scientifically credible manner is challenging however because it requires an understanding of the direct and indirect mortality sources on native fish from non-native fish.

Coggins and Yard (2010) found that removal using electrofishing in the LCR reach achieved a level of reduction to approximately 1,200 rainbow trout in the LCR reach. Beyond this level, additional removal effort did not produce measurable reductions in trout abundance. Maintaining this level of trout abundance was estimated to reduce humpback chub predation losses by approximately 6,000-10,000 juvenile humpback chub per year (Yard et al. *in press*). The goal of the proposed action would be to maintain a low level of rainbow trout abundance in the LCR reach, either through removal in the LCR reach or by limiting emigration of trout from Lees Ferry with PBR reach removal. Monitoring would continue to be employed to determine trends in non-native and native fish abundance and recruitment. Removal actions would be implemented based on abundance of trout in the LCR reach as well as abundance and other population parameters of humpback chub, in coordination with the USFWS and other appropriate agencies. Other methods of non-native fish control including the use of dam operations, would continue to be evaluated and may be tested in the future. In this way, non-native fish control would be implemented and evaluated through adaptive management to refine methods to reduce the cost of removal and impacts to cultural resources. This approach is consistent with prior recommendations of scientists on the implementation of non-native fish control in the GCDAMP (U.S. Geological Survey 2008, Hilwig et al. 2010, see also Appendix B).

Valdez and Ryel (1995) and Yard et al. (*in press*) estimated that predation rate of humpback chub by brown trout can be 10 times as high as predation rate by rainbow trout. Yard et al. (2008, *in press*) estimate that about 50% of the total native fish consumed during 2003-4 were by brown trout, although the abundance of brown trout in the LCR reach was lower than that of rainbow trout. Because brown trout are highly piscivorous, relatively small numbers can have a large predation impact on humpback chub. The primary spawning area of brown trout in Grand Canyon is in Bright Angel Creek, and it is believed to be the principal source of fish to the LCR reach. A fish weir placed near the mouth of the creek in fall of 2002 and 2006 was effective at removing large numbers of trout (Leibfried et al. 2003, 2006, Sponholtz et. al. 2008) and could effectively reduce the source of these fish to the LCR reach. Removal of brown trout may need to be implemented only periodically to keep numbers low in the LCR reach. Removal of rainbow and brown trout at Bright Angel Creek, although not part of this alternative, would be ongoing during the life of the project.

Although not assessed in this EA, control mechanisms that target limiting recruitment of rainbow trout in Lees Ferry would continue to be evaluated through adaptive management. Both flow and non-flow experiments focused on the Lees Ferry reach may be conducted in order to experiment on actions that would reduce the recruitment of trout in Lees Ferry, lowering emigration of trout. These actions may also serve to improve conditions of the trout fishery at Lees Ferry. Additional environmental compliance may be necessary for these experiments.

Utilizing Glen Canyon Dam flows to reduce recruitment and emigration rates of trout in Lees Ferry may be more economical and effective over the long-term at mitigating the effects of trout on humpback chub. However, flow options alone also may prove to be ineffective at reducing emigration of trout from the Lees Ferry population. Thus the goal is to use adaptive management to experiment with a variety of options to develop a long-term management strategy that is culturally sensitive and cost effective.

Experimental non-native fish control in Lees Ferry may include several elements if implemented:

- A protocol would be developed to conduct tests of flow and non-flow actions to reduce the recruitment of trout in Lees Ferry and thus reduce the downstream emigration while maintaining adequate catch rates to support a robust recreational fishery.
- A science plan would be developed describing the implementation of short-term experiments to test the efficacy of different actions. This would include a Lees Ferry trout monitoring plan to ensure that flow experiments didn't result in irreversible damage to the sport fishery.
- A robust public process would be implemented in order to take input from interested publics. This would include meetings with stakeholders.
- The science plan would be modified in response to stakeholder concerns and interests.
- Over time these experiments could result in a set of actions whose implementation would likely reduce downstream emigration, make PBR removal more effective, and maintain or improve the Lees Ferry trout fishery.

Although scientists still question what interaction of factors have resulted in recent improvements in the status of humpback chub and other native fishes in GCNP (e.g., are warmer water temperatures or removal of non-native predators more important?), scientists are generally in agreement that non-native fish, trout in particular, limit recovery of humpback chub through predation on juvenile chub, resource competition, and displacement (see Appendix A, Section 6.6 and Table 11). Reclamation has reviewed the best available science, and, using our technical expertise to interpret the science, our conclusion is that the proposed action represents the best option to implement the non-native fish control conservation measure in a way that satisfies our legal commitments and responsibilities under the ESA, and does so in a way that is the least damaging to cultural and other resources.

Appendix C: Biological Assessment

RECLAMATION
Managing Water in the West

Biological Assessment for Non-native Fish Control Downstream from Glen Canyon Dam

U.S. Department of the Interior
Bureau of Reclamation
Upper Colorado Region
Salt Lake City, Utah

January 28, 2011

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1.0 Introduction

1.1 Background

This document serves as the biological assessment for the Bureau of Reclamation's (Reclamation) request for consultation on the operation of Glen Canyon Dam regarding implementation of the conservation measure on non-native fish control (U.S. Fish and Wildlife Service 2008, 2009, 2010). This biological assessment analyzes the effects of the proposed action to implement up to 6 non-native fish removal trips in the Little Colorado River (LCR) reach, river mile (RM) 56 to 66 as measured downstream from Lees Ferry, and up to 10 removal trips in the Paria River to Badger Creek (PBR) reach, RM 1-8, in any one year for the ten-year period of 2011-2020 in the Colorado River downstream of Glen Canyon Dam within Glen Canyon National Recreation Area (GCNRA) and Grand Canyon National Park (GCNP), Coconino County, Arizona (Figure 1). This biological assessment analyzes the effects of the action on the endangered humpback chub (*Gila cypha*), razorback sucker (*Xyrauchen texanus*), Kanab ambersnail (*Oxyloma haydeni kanabensis*), and southwestern willow flycatcher (*Empidonax traillii extimus*).

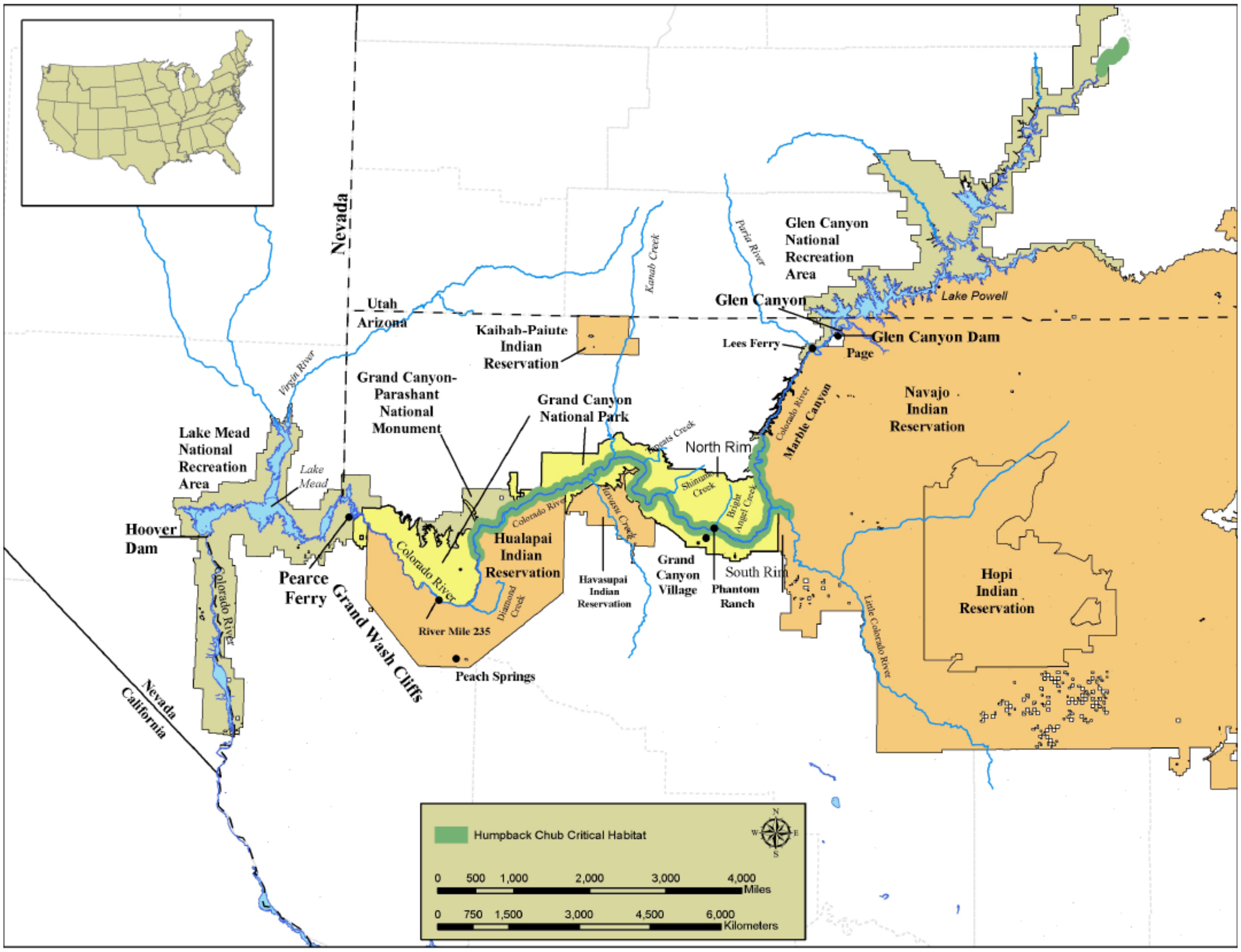

Figure 1. Map of Action Area and humpback chub (*Gila cypha*) critical habitat in the Colorado and Little Colorado Rivers (courtesy of the U.S. Fish and Wildlife Service).

This document was prepared by Reclamation as part of its compliance with the Endangered Species Act of 1973, as amended (ESA; 87 Stat. 884; 16 U.S.C. §1531 *et seq*.). Reclamation has determined that the proposed action may affect, but is not likely to adversely affect the humpback chub and its critical habitat and the razorback sucker and its critical habitat. The Proposed Action will not affect the Kanab ambersnail, or the southwestern willow flycatcher (see Table 1). Take of humpback chub may occur during removal of trout but an ESA Section 10(a)(1)(A) Permit for scientific research to enhance the propagation and survival of the species will be obtained to cover this potential loss.

Reclamation proposes to control non-native fish in the Colorado River downstream from Glen Canyon Dam to ensure that its operation of Glen Canyon Dam does not jeopardize the continued existence of endangered native fish. Non-native fish have long been identified as a threat to native aquatic biota (Cambray 2003, Clarkson et al. 2005), and a specific threat to native fish in the Colorado River and its tributaries in Grand Canyon (Marsh and Douglas 1997; Valdez and Ryel 1995; Minckley 1991). Since passage of ESA and its implementing regulations at 50 CFR 402, Reclamation has consulted with the U.S. Fish and Wildlife Service (USFWS) to ensure that its operations of Glen Canyon Dam do not jeopardize the continued existence of the endangered endemic Colorado River fishes, the humpback chub, razorback sucker, Colorado pikeminnow, and bonytail or destroy or adversely modify their designated critical habitat. This analysis concentrates on the humpback chub because it is the only one of these species that currently occurs in the project area. The Colorado pikeminnow and bonytail are no longer found in this part of the Colorado River and are not included in this assessment. Although the action area or geographic scope of this biological assessment is a 294-mile reach of the Colorado River corridor from Glen Canyon Dam downstream to the Lake Mead inflow near Pearce Ferry, the action will be implemented in two reaches of the Colorado River: the reach from the Paria River to Badger Creek (the PBR reach), River Mile (RM) 1 to 8 (as measured in river miles from Lees Ferry downstream), and in the reach surrounding the Little Colorado River from RM 56-66 (the LCR reach). The proposed action is not anticipated to affect the razorback sucker because it is absent from the action area and unlikely to occupy the area in the reasonably foreseeable future; the reaches where non-native removal will be conducted also are expected to have no effect on the abundance of non-native fishes in Lake Mead, where the species still occurs (Albrecht et al. 2010).

Critical habitat for the humpback chub and the other “big river” fishes was designated by the USFWS in 1994 (50 CFR 17) and includes areas within Marble and Grand Canyons. Humpback chub critical habitat includes 175 miles of the Colorado River from Nautiloid Canyon (river mile, RM 34; with Lees Ferry river mile 0) to Granite Park (RM 209) and the lower 8 miles of the LCR. Critical habitat for razorback sucker extends for 234 miles of the Colorado River from the Paria River confluence (RM 1) to Lake Mead. These reaches of designated critical habitat lie within the boundaries of GCNRA and GCNP and are managed by the National Park Service. The reach of the Colorado River from RM 30 to RM 75 is a principal nursery area for humpback chub (Figure 2), and it is the reach of river downstream from Lees Ferry that has the highest densities of young humpback chub, and thus impacts of predation and competition to humpback chub by non-native fishes are greatest in this reach.

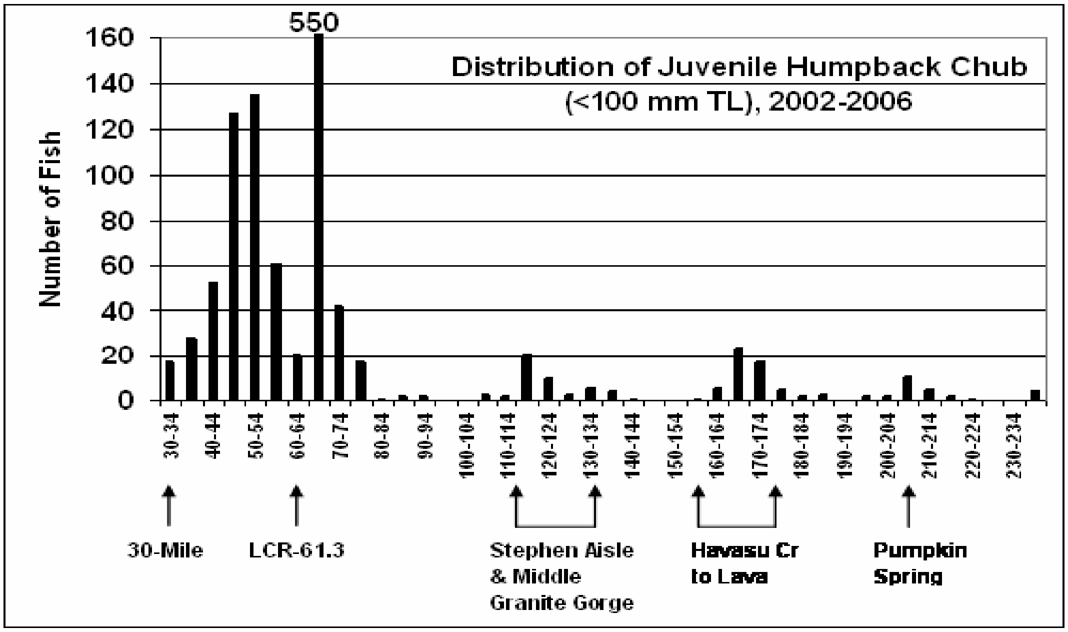

Figure 2. Distribution of juvenile humpback chub<100 mm TL caught during 2002-2006 by 5-mile increments from RM 30 to RM 240. Principal humpback chub aggregations are indicated (data from Ackerman 2008).

The USFWS also identified the need for controlling non-native fish species in the recovery goals for the humpback chub (U.S. Fish and Wildlife Service 2002a)[1]. The focus of non-native fish control in the recovery goals is on controlling the proliferation and spread of non-native fish species that prey on and compete with humpback chub in the mainstem Colorado River. The Recovery Goals identify the need to develop, implement, evaluate, and revise (as necessary through adaptive management) procedures for stocking and other sport fish management actions to minimize out-migration of non-native fish species into the Colorado River and its tributaries through Grand Canyon, and to develop and implement levels of control for rainbow trout, brown trout, and warm water non-native fish species, to minimize negative interactions between non-native fishes and humpback chub (U.S. Fish and Wildlife Service 2002a).

In prior ESA section 7 consultations on the operation of Glen Canyon Dam, Reclamation, and the USFWS have agreed that controlling the numbers of non-native fish that compete with and prey on the endangered fish through the Glen Canyon Dam Adaptive Management Program (GCDAMP) would serve as conservation measures for Reclamation's dam operations planned through the year 2012. Non-native fish control was identified as a conservation measure in the February 27, 2008, Final Biological Opinion on the Operation of Glen Canyon Dam (U.S. Fish and Wildlife Service 2008, consultation number 22410-1993-F-167R1), in the October 29, 2009, Supplement to the 2008 Final Biological Opinion for the Operation of Glen Canyon Dam (U.S. Fish and Wildlife Service 2009, consultation number 22410-1993-F-167R1), and the Reissuance

[1] In 2006, a U.S. District Court ruling set aside the recovery goals, essentially because they lacked time and cost estimates for recovery. The court did not fault the recovery goals as deficient in any other respect. USFWS is in the process of updating the recovery plan and goals for the humpback chub.

of the Incidental Take Statement on the 2009 Supplemental Biological Opinion on the Operation of Glen Canyon Dam 2008-2012 (U.S. Fish and Wildlife Service 2010a, consultation number 22410-1993-F-167R1). Control of non-native fish species in Marble and Grand Canyons through the GCDAMP is also part of the conservation measures identified in the 2007 Biological Opinion for the Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (U.S. Fish and Wildlife Service 2007, consultation number 22410-2006-F-0224). Once Reclamation accepted these conservation measures, implementation of non-native fish control became a part of ongoing operations, with discretion in exactly where, when, and how non-native fish control is conducted. A fourth biological opinion on the cancellation of non-native mechanical removal trips in 2010 was issued on November 9, 2010, and required as a term and condition that Reclamation

> "Resume nonnative control at the mouth of the LCR in 2011. Attempt to implement the program in a manner compatible with the interests of Tribes and other interested stakeholders" and/or "Work with interested Tribes and other parties, expeditiously, to develop options that would move nonnative removal outside of the LCR confluence tribal sacred areas in 2011, with the goal that nonnative removal of trout in sacred areas will be reserved for use only to ensure the upper incidental take level is not exceeded" (U.S. Fish and Wildlife Service 2010b, consultation number 22410-1993-F-167R1).

A panel of independent scientists convened by U.S. Geological Survey (USGS) also concluded that non-fish control should continue to be implemented for conservation of humpback chub in Grand Canyon (U.S. Geological Survey 2008). Rainbow trout and brown trout are not native to the Colorado River Basin and were introduced into the region by federal and state agencies as sport fish before and after the 1963 completion of Glen Canyon Dam (e.g., the Arizona Game and Fish Department (AZGFD) stocked rainbow at Lees Ferry as recently as 1998). These trout species are important competitors and predators of humpback chub, as well as the other native Colorado River fishes (Valdez and Ryel 1995, Yard et al. *in press*). Other species of fish, including the channel catfish (*Ictalurus punctatus*), black bullhead (*Ameiurus melas*), and green sunfish (*Lepomis cyanellus*) also prey upon and compete with the native fishes.

Recent and ongoing investigations show negative impacts from trout on native fish are occurring near the confluence of the Colorado and Little Colorado rivers (RM 56-66), where rainbow trout and brown trout co-inhabit the area with the native humpback chub, flannelmouth suckers (*Catostomus latipinnis*), bluehead suckers (*C. discobolus*), and speckled dace (*Rhinichthys osculus*). The trout species eat juvenile humpback chub and other native fishes and also compete with them for food and space (Yard et al. *in press*). This area of the Colorado River supports the largest aggregation of humpback chub in Grand Canyon, and the nearshore habitat (talus and vegetated shorelines and backwaters) is used as a nursery area by young humpback chub originating from the LCR. Recent and ongoing investigations (Makinster et al. 2010) indicate that rainbow trout in this area likely originate from the Lees Ferry reach (first 15 miles below the dam) and most of the brown trout originate from Bright Angel Creek (RM 88; Liebfried et al. 2003, 2006). Korman et al. (2010) noted that rainbow trout mortality in Lees Ferry and their emigration from Lees Ferry appear to be density dependent. An important aspect of this action is the need test methods to reduce numbers of rainbow trout and brown trout near the confluence of the Colorado and Little Colorado rivers by reducing the numbers of trout emigrating from these population sources in the Lees Ferry reach and Bright Angel Creek.

Reclamation is serving as the lead federal agency in this action because it has operational authority over Glen Canyon Dam and it has agreed to address non-native control through the AMP pursuant to the terms of the biological opinions issued by the USFWS (U.S. Fish and Wildlife Service 2007, 2008, 2009, 2010a, 2010b). However, Reclamation's legal authority does not include direct management of Colorado River fishes. That authority rests with the AZGFD, the state resource agency responsible for managing sport fish, and the National Park Service (NPS), the federal land management agency responsible for the management of resources within GCNRA and GCNP.

Native American Concerns

The United States has a unique legal and political relationship with American Indian Tribes, established through and confirmed by the Constitution of the United States, treaties, statutes, executive orders, and judicial decisions. In recognition of that special relationship, pursuant to Executive Order 13175 of November 6, 2000, executive departments, and agencies are charged with engaging in regular and meaningful consultation and collaboration with tribal officials in the development of federal policies that have tribal implications, and are responsible for strengthening the government-to-government relationship between the United States and Native American tribes. Furthermore, the federal government has a general trust responsibility towards the tribes, meaning that it should protect tribal assets and interests. This derives first and foremost from the many treaties entered into by the tribes and the U.S. Government.

Reclamation has a responsibility to recognize Indian Trust rights and maintain compliance with section 106 of the National Historic Preservation Act (NHPA). The Federal government holds Trust responsibilities that recognize the sovereign status and management authority of Tribes, and assures the Tribes that Federal agencies will not knowingly compromise traditional practice and livelihoods in execution of their duties. Executive Order 13007 adds specificity to this principal in stating that Federal agencies "shall avoid adversely affecting the physical integrity of sacred sites," while Secretarial Order 3206 stipulates that within the context of the ESA the "Departments will carry out their responsibilities under the Act in a manner that harmonizes the Federal trust responsibility to tribes." Further, the NHPA requires Federal agencies to take into account the effects of their actions on historic properties, which, through the National Register of Historic Places, includes special provisions for places of cultural and religious importance.

Reclamation consulted with American Indian tribes over the removal of non-native fish in the Grand Canyon in 2002. The Hopi Tribe, the Kaibab Band of Paiute Indians, Hualapai Tribe, and Zuni Tribe objected to the experimental action of removal unless there was a beneficial human use for fish removed. Consultation between these tribes, Reclamation, and the USGS resulted in the identification of a beneficial human use that served to mitigate the tribes' concerns for the experimental action. From 2003 through 2006 and in 2009, a removal and related mitigation program was implemented in the vicinity of the Colorado and Little Colorado rivers confluence (LCR reach). Fish that were removed where euthanized, emulsified, and used as fertilizer on the Hualapai Tribal Gardens. The program was effective at reducing numbers of trout, although the program was conducted at a time that the trout population was undergoing a system-wide decline.

As part of the Annual Work Plan of the Glen Canyon Dam Adaptive Management Program for Fiscal Year 2010-2011, one or two river trips to remove non-native fish were included and tentatively scheduled for May-June 2010 and 2011. Some tribal representatives to the program expressed concern and asked for government-to-government consultation regarding the killing of non-native fish in the vicinity of the confluence of the Little Colorado and Colorado rivers, a location of cultural, religious, and historical importance. The Pueblo of Zuni, in a letter dated June 30, 2009, from expressed the Zuni Tribe's concerns with the "taking of life" associated with non-native fish removal, and their perception that the Bureau of Reclamation and the United States Fish and Wildlife Service had failed to adequately consult with the Zuni Tribe concerning the action, and the Zuni Tribe requested consultation with the Bureau of Reclamation on the issue. In response, DOI representatives attended a meeting with Zuni tribal leaders to hear their concerns on September 15, 2009. DOI's approval of the work plan acknowledged tribal concerns for removal of non-native fish and expressly noted that as a result of tribal concerns, DOI would work to examine and evaluate "different locations for carrying out the mechanical removal" and noted that "tribal consultation regarding non-native fish control is underway."

A meeting of DOI and tribal representatives was held on January 12-13, 2010, where all of the GCDAMP tribes requested government-to-government consultation on the proposed removal. Tribal concerns were also expressed in February 2010, as part of a 2-day series of GCDAMP-related public meetings in Phoenix, Arizona. The Pueblo of Zuni sent a letter to Assistant Secretary of the Interior for Water and Science Anne Castle on February 19, 2010, in which the Governor of Zuni expressed his dissatisfaction with the nature and content of consultation that had occurred thus far regarding non-native fish control. Assistant Secretary Castle met with Pueblo of Zuni Governor Norman J. Cooeyate and the Tribal Council on August 5, 2010 during which time the Pueblo presented Zuni Tribal Council Resolution No. M70-2010-C086 to Assistant Secretary Castle. This document and formal position statement generated by the Executive and Legislative Branches of the Zuni Government stated the position of the Zuni Tribe and religious leaders concerning the adverse affects to the Pueblo from the removal of non-native fish in Grand Canyon and also explained that the Zuni Tribe believes the Grand Canyon and Colorado River are Zuni Traditional Cultural Properties eligible to the National Register of Historic Places.

Government-to-government consultation was initiated with the Havasupai Tribe, Hopi Tribe, Hualapai Tribe, Kaibab Band of Paiute Indians, Paiute Indian Tribe of Utah, San Juan Southern Paiute Tribe, Las Vegas Paiute Tribe, Moapa Band of Paiutes, Navajo Nation, the Yavapai Apache Nation, the Pueblo of Jemez, and Pueblo of Zuni regarding the proposed action, and consultation is continuing. The following government-to-government tribal consultation, informal tribal consultation, and cooperating agency (CA) meetings were held:

- Government-to-government tribal consultation meetings were held with the Zuni Tribe at the Pueblo of Zuni at Zuni, New Mexico, on September 15, 2009, and on March 24 and June 4, 2010;

- Government-to-government tribal consultation meetings were held with the Hopi Tribe (March 4 and April 22 2010, January 27, 2011), Navajo Nation (June 9, 2010, and January 26, 2011), Hualapai (March 6, 2010, and January 8, 2011), Havasupai (March 15, 2010), Kaibab Pauite Tribe (March 18, 2010, and January 20, 2011), and the Paiute Indian Tribe of Utah (December 13, 2010);

- Reclamation served on a discussion panel about this issue at the 2010 Native American Fish and Wildlife Society Southwest Conference;

- Assistant Secretary Anne Castle and other representatives from DOI and Reclamation met with the Governor and Tribal Council, Zuni Cultural Resource Advisory Team, and the Zuni public at Zuni, New Mexico, to discuss removal and the objection of the Zuni people to the killing of rainbow trout on August 5, 2010.

- The Pueblo of Zuni sent Reclamation the Zuni Tribal Council Resolution No. M70-2010-C086 regarding their concerns with removal and the request that Grand Canyon be included as a TCP eligible for listing on the National Register. This resolution was given to Assistant Secretary Castle at the August 5, 2010 meeting.
- A CA and tribal meeting was held in Flagstaff on August 20, 2010; and,

- CA conference calls were conducted on September 2, 9, 16, 23, 30, and November 4 and 21, 2010, and on January 5, 2011. These often included the tribes that participated as cooperating agencies, the Pueblo of Zuni and Hualapai Tribe.

- SDM Workshops were conducted on October 18-20, November 8-10, 2010, and representatives from three of the five tribes (the Navajo, Hopi, and Zuni tribes) participated in these.

- A tribal consultation meeting with the Pueblo of Zuni was held on January 25, 2011, during which the tribe indicated that they would prefer, if fish are to be killed, to be used for human consumption as a beneficial use.

Reclamation is committed to ongoing consultation with concerned Native American tribes with assistance from the USFWS, NPS, BIA, and U.S. Geological Survey, on non-native fish removal, including the option of continued non-native control near and within the LCR confluence.

Assistant Secretary Castle determined it was not appropriate to precede with the planned removal trips in spring 2010 until additional meaningful tribal consultation was completed and any necessary environmental compliance responsibilities under applicable law were undertaken, including, but not limited to, the National Historic Preservation Act. In March 2010 Reclamation requested reinitiation with the USFWS to stay in compliance with ESA. Reclamation produced a Biological Assessment; *Proposed Action to Cancel Non-native Fish Mechanical Removal in the Colorado River, Grand Canyon, Scheduled for May-June 2010* that documents the details of this decision. A Biological Opinion from the USFWS followed on November 9, 2010 that required Reclamation to resume non-native control at the mouth of the

LCR in 2011 and attempt to conduct it in a manner compatible to the tribes and other stakeholders (Section 1.2.6).

1.2 Related Consultation History

Reclamation has consulted with the USFWS under section 7 of the ESA for various projects that could have had effects on ESA listed species and designated critical habitat within the action area, leading to the definition of the current environmental baseline. Since 1995, Reclamation has consulted with the USFWS on a total of five important experimental actions, and undertaken a sixth experimental action that did not require separate ESA consultation. The current baseline is a result of these consultations and their effects on ESA-listed species and designated critical habitat within the action area. This history is provided in the 2008 Biological Opinion and the two relevant consultations are described below:

1.2.1 2002 Biological Opinion on experimental flows and non-native fish control

In 2002, Reclamation, the NPS, and the USGS consulted with the USFWS on: (1) experimental releases from Glen Canyon Dam, (2) mechanical removal of non-native fish from the Colorado River in an approximately 9-mile reach in the vicinity of the mouth of the Little Colorado River to potentially benefit native fish, and (3) release of non-native fish suppression flows having daily fluctuations of 5,000-20,000 cfs from Glen Canyon Dam during the period January 1-March 31. Implicit in experimental flows and mechanical removal was the recognition that modification of dam operations alone likely would be insufficient to achieve objectives of the GCDAMP, which include removal of jeopardy from humpback chub and razorback sucker.

In their biological opinion, the USFWS concluded the proposed action was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail, bald eagle, razorback sucker, California condor, and southwestern willow flycatcher. The December 2002 biological opinion included incidental take of up to 20 humpback chub during the non-native fish removal efforts and the loss of up to 117m^2 of Kanab ambersnail habitat.

Two conservation measures were included in the USFWS biological opinion. The first measure included relocation of 300 humpback chub above Chute Falls in the LCR to increase the likelihood of humpback chub surviving in the lower LCR, reduce predation, and other inclement environmental conditions. The second conservation measure consisted of temporary removal and safeguard of approximately 29m^2 – 47m^2 (25 to 40 percent) of Kanab ambersnail habitat that would be flooded by the experimental release. The relocated habitat and ambersnails would be replaced once the high flow was complete to facilitate re-establishment of vegetation.

1.2.2 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead, Final EIS

The December 2007 biological opinion on the Shortage Record of Decision (ROD) included the geographic scope of this biological assessment, Glen Canyon Dam to Lake Mead (U.S. Bureau of Reclamation 2007a). The Shortage ROD specified reduction of consumptive uses below Lake Powell during times of low reservoir conditions and modification of the annual release volumes from Lake Powell through 2026. The Shortage ROD, as adopted on December 13, 2007, established annual release volumes from Glen Canyon Dam, but did not, in any manner, alter the constraints imposed by the 1996 ROD or as adopted in the 1997 Glen Canyon Dam Operating Criteria (discussed in Section 1.4.2). Since many of the potential resource impacts identified in that final EIS were being investigated in the GCDAMP, the biological opinion made use of this institutional arrangement as a key mechanism for addressing these impacts. With respect to the listed species in Grand Canyon the USFWS determined that implementation of the Guidelines is not likely to jeopardize the continued existence of the humpback chub, the southwestern willow flycatcher, or the Kanab ambersnail, and is not likely to destroy or adversely modify designated critical habitat for the humpback chub or the southwestern willow flycatcher. Conservation measures under this consultation included non-native fish control, humpback chub refuge establishment, examining habitat for the potential reintroduction of razorback sucker in the lower Grand Canyon, support for a genetic biocontrol symposium, sediment research, parasite monitoring, and other monitoring and research. Regarding non-native fish control, Reclamation is to work with other GCDAMP members and through the GCDAMP to continue efforts to control both cold- and warm-water non-native fish species in the mainstem of Marble and Grand canyons, including determining and implementing levels of non-native fish control as necessary. Control of these species using mechanical removal and other methods would help to reduce this threat.

1.2.3 2008 Biological Opinion

On February 27, 2008, the USFWS issued a biological opinion on the operation of Glen Canyon Dam for the period 2008-2012 (2008 Opinion) that implementation of the March 2008 high flow test and the five-year implementation of Modified Low Fluctuating Flow (MLFF) with steady releases in September and October, as proposed, was not likely to jeopardize the continued existence of the humpback chub or the Kanab ambersnail, and is not likely to destroy or adversely modify designated critical habitat for the humpback chub. The Incidental Take Statement in the 2008 Opinion states that incidental take would be exceeded if the proposed action results in detection of more than 20 humpback chub mortalities during the high flow test of March 2008 and is attributable to the high flow test. The 2008 biological opinion identified eight conservation measures for the humpback chub, including a Humpback Chub Consultation Trigger, a Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon, Humpback Chub Translocation, Non-native Fish Control, Humpback Chub Nearshore Ecology Study, Monthly Flow Transition Study, Humpback Chub Refuge, and Little Colorado River Watershed Planning.

On May 26, 2009, the District Court of Arizona, in response to a lawsuit brought by the Grand Canyon Trust, ordered the USFWS to reevaluate the conclusion in the 2008 Opinion that the MLFF does not violate the Endangered Species Act of 1973 (16 U.S.C. 1531-1544), as amended (Act) (Case number CV-07-8164-PHX-DGC). The Court ordered the USFWS to provide an analysis and a reasoned basis for its conclusions in the 2008 Opinion, and to include an analysis of how MLFF affects critical habitat and the functionality of critical habitat for recovery purposes by October 30, 2009.

1.2.4 2009 Supplement to the 2008 Biological Opinion

On October 29, 2009, the USFWS issued a Supplement to the 2008 Final Biological Opinion for the Operation of Glen Canyon Dam, as a result of the Court Order of May 26, 2009, and concluded that the action was not likely to jeopardize the continued existence of the humpback chub or the Kanab ambersnail, and was not likely to destroy or adversely modify designated critical habitat for the humpback chub. The Incidental Take Statement in the 2009 Supplement states that incidental take would be exceeded if the proposed action causes the conditions of the consultation trigger to be met. The consultation trigger was identified in the 2008 Opinion as a conservation measure, and states in the 2009 Supplement that "Reclamation and USFWS agree to specifically define this reinitiation trigger relative to humpback chub, in part, as being exceeded if the population of adult humpback chub (≥200 mm [7.87 in] TL) in Grand Canyon declines significantly, or, if in any single year, based on the age-structured mark recapture model (ASMR; Coggins 2007), the population drops below 3,500 adult fish within the 95 percent confidence interval." Based on the recommendation of the Protocol Evaluation Panel (PEP), the decision was made to employ the ASMR model once every three years. Hence, the ASMR would not be utilized annually, but only employed to test the humpback chub consultation trigger if other data, such as annual mark-recapture based closed population estimates of humpback chub abundance in the Little Colorado River (Van Haverbeke and Stone 2008, 2009), indicate that the population is declining to the abundance level defined in the trigger.

1.2.5 Reissuance of the Incidental Take Statement on the 2009 Supplemental Biological Opinion on the Operation of Glen Canyon Dam 2008-2012

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is defined to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. "Harass" is defined as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns that include, but are not limited to, breeding, feeding or sheltering (50 C.F.R. § 17.3). Under the terms of section 7(b)(4) and section 7(o)(2), "take" that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA, provided that such taking is in compliance with the terms and conditions of the Incidental Take Statement. Section 10(a)(1) of the ESA authorizes the Secretary to permit any taking of listed species otherwise prohibited by section 9(a)(1)(B) if such taking is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity.

Incidental Take Statements were issued in the 2008 Opinion and the 2009 Supplement relative to experimental operations of Glen Canyon Dam and were designed to mitigate estimated "take" resulting from experimental dam operations. In response to the court order, the USFWS issued a revised ITS on September 1, 2010, for the 2009 Opinion, which changed the amount of incidental take authorized to "if monitoring detects a decrease in the adult chub population below an estimate of 6,000 adult chub using the Age-Structured Mark Recapture model (ASMR, Coggins and Walters 2009) that is not attributable to other factors (such as parasites or diseases), that decrease is reasonably indicative of higher than expected levels of juvenile mortality caused by the proposed action." The USFWS cited as its reasoning for this, numbers of chub estimated by the ASMR at the time the 2008 biological opinion on Glen Canyon Dam operations was issued is an appropriate surrogate for take "because it represents the species' ability to reproduce, survive, and recruit during the life of the project which provides information on the health of the overall population."

1.2.6 Reinitiation of the 2009 Biological Opinion on the Continued Operations of Glen Canyon Dam without Mechanical Removal of Non-native Fish in 2010 from the Colorado River, Grand Canyon, Arizona

On March 5, 2010, Reclamation requested reinitiation of formal consultation (2009 Supplemental Opinion) to accommodate a modification of the 5-year experimental non-native fish removal efforts planned for May and June 2010. Concerns were expressed by Native American Tribes over the killing of fish as loss of life in sacred areas. A draft biological opinion was submitted by USFWS to Reclamation on October 14, 2010, evaluating the cancellation of non-native mechanical removal in 2010.

The focus of this consultation was the cancellation of two non-native removal trips scheduled for May and June 2010. All other aspects of the proposed action remained the same as described in the 2009 Supplemental Opinion described above.

On November 9, 2010, the USFWS issued a biological opinion on the Reclamation's cancellation of non-native mechanical removal trips in 2010. They determined that the proposed action of not removing trout would adversely affect the humpback chub and its critical habitat and critical habitat for the razorback sucker. All other effects determinations remained the same as for the 2008 and 2009 Opinions for the razorback sucker, Kanab ambersnail, and southwestern willow flycatcher. The Service required as a term and condition that Reclamation "[r]esume non-native control at the mouth of the LCR in 2011" and "[a]ttempt to implement the program in a manner compatible with the interests of Tribes and other interested stakeholders" (U.S. Fish and Wildlife ServiceService 2010b, consultation number 22410-1993-F-167R1). The incidental take statement for the biological opinion acknowledged that the September 1, 2010, revised ITS, but added that "we anticipate that between 1,000 and 24,000 young of year or juvenile humpback chub will be lost to predation by trout as a result of the modified proposed action during this 13-month period. We adopt the incidental take estimate provided in the April 2010 BA, of 10,817 humpback chub for this 13-month period."

2.0 Description of the Proposed Action

2.1 Purpose and Need for Action

The federal action analyzed in this Biological Assessment is the control of non-native fish in the Colorado River downstream from Glen Canyon Dam within Glen Canyon National Recreation Area and Grand Canyon National Park, Coconino County, Arizona. The purpose of the action is to reduce the negative impacts of competition and predation by rainbow trout and brown trout on the endangered humpback chub and its critical habitat in Grand Canyon while supporting public recreation in GCRA and GCNP. The need for this action is to fulfill the conservation measures and terms and conditions of several U.S. Fish and Wildlife biological opinions, to contribute to the recovery of humpback chub by helping to maintain high juvenile survival and recruitment rates resulting in an increasing adult population, to continue to provide quality recreational opportunities in GCRA and GCNP, and to address concerns expressed by Native American Indian Tribes over the killing of trout in the Grand Canyon, a location of cultural, religious, and historical importance to several tribes.

Reclamation, in response to the USFWS biological opinion, proposes that this action start in 2011 and extend to 2020. The necessity to implement non-native fish control in 2011 is a consequence of cancelled efforts in 2010 that allowed and likely increased the ongoing threat to the humpback chub from predation and competition.

2.2 Proposed Action

As part of the National Environmental Policy Act Environmental Assessment for the proposed action, Reclamation, in partnership with the U.S. Geological Survey, conducted a Structured Decision Making Project (SDM) to develop and provide substantive input to Reclamation and provide a forum for the diverse cooperating agencies and Tribes to discuss, expand, and articulate their respective values, to develop and evaluate a broad set of potential control alternatives using the best available science and to indicate how they would individually prefer to manage the inherent trade-offs in this non-native fish control problem (Runge et al. 2011). The proposed action is the top ranking alternative that resulted from the SDM Project. The proposed action combines a strategy of removing rainbow trout in the LCR reach to reduce the extant threat of rainbow trout in the LCR reach (RM 56 to 66) with a strategy of testing removal of RBT in the PBR reach (RM 1 to RM 8) to reduce or eliminate emigration of rainbow trout from Lees Ferry downstream to the LCR reach Up to 6 LCR reach removal trips and up to 10 PBR reach removal trips will be conducted in any one year for the ten-year period of 2011-2020 depending on trout abundance (see below). In the short term (one to several years), the focus will be to reduce trout at the LCR reach because they are currently abundant there. If abundance of trout can be reduced at the LCR using removal there, and removal in the PBR reach proves effective at limiting emigration of trout from the Lees Ferry area, effort would be concentrated at the PBR.

Removal of rainbow and brown trout from Bright Angel Creek with a fish weir in fall of 2002 effectively removed large numbers of trout (Leibfried et al. 2003, 2006). The NPS Bright Angel Creek removal project is ongoing and expected to reduce what is considered to be the primary source of brown trout to the LCR reach, but is not part of the proposed action. NPS already has a biological opinion from NPS on this action.

Removal of trout will be conducted as it was done in 2004-2006 and 2009 (Coggins 2008a; Coggins and Yard 2010), in which trout were removed near the LCR confluence during multiple trips each year. One to six removal passes would be conducted in each trip, as described in Coggins (2008a). Removal will be conducted with boat-mounted electrofishing and will remove all non-native fish captured. The number of removal trips conducted depends on numbers of trout in each reach. Effort is focused on the LCR reach when trout numbers are high, but shifts to the PBR reach when trout numbers are low in the LCR reach. If trout numbers are low in both reaches, removal may not be necessary.

Removal in the PBR reach is anticipated to be most efficient during the fall or early spring (suspected emigration periods) but multiple trips throughout the year may be necessary in order to be effective. Seasonal movement by young trout from the Lees Ferry reach and the time that emigrating fish reside in the PBR reach is unknown. If residence time in this reach is short, only a small fraction of downstream migrants would be removed using removal. Fish removal downstream as far as Badger Creek Rapid (RM 8) will enable boats to return upstream to Lees Ferry in the same day and avoid expensive trips through the entire Grand Canyon.

The number of trips in any given year would not exceed 6 LCR reach trips and 10 PBR reach trips. Methods would be similar to Coggins (2008a) and would include up to 6 passes with a boat-mounted electrofisher in a single trip. The number of trips implemented in a given year would depend on the abundance of non-native fish in these reaches and other considerations through adaptive management and in coordination with the USFWS and other agencies. The abundance and other population parameters of humpback chub will also be considered, and a recovery plan that is currently in development by the U.S. Fish and Wildlife Service should provide guidance in this regard when it becomes available. As more information about removal is gathered as the proposed action is implemented, effort may be shifted between reaches to maximize reductions and minimize cost. Also, Reclamation will continue to work with the GCDAMP to design and test additional flow and non-flow non-native fish control actions over the life of the proposed action. Additional environmental compliance may be necessary for these actions.

The taking of life in a sacred location without beneficial use is a spiritual concern to Native American tribes. The proposed action will include euthanizing and freezing fish removed for later beneficial use to address these concerns. Acceptable uses of the frozen fish are being explored in government-to-government tribal consultation. Potential uses include use for human consumption or as feed for wildlife in zoos or other captive wildlife facilities.

Based on past and ongoing consultation and communication with interested tribes, relevant regulatory authorities, and other stakeholders, Reclamation has reluctantly concluded that live removal is not a viable option at this time for removal of non-native fish. The potential for spreading whirling disease, which was detected in rainbow trout in Lees Ferry in 2007, to unaffected areas by transfer of live fish, and the unknown effects to endangered and threatened species by this action, have been raised as substantive objections and require additional study.

2.3 Action Area

The action area or geographic scope of this environmental assessment is a 294-mile reach of the Colorado River corridor from Glen Canyon Dam downstream to the Lake Mead inflow near Pearce Ferry (Figure 1). Glen Canyon Dam impounds the Colorado River about 16 miles upstream from Lees Ferry, Coconino County, Arizona. This action area includes GCNRA in a 16-mile reach from Glen Canyon Dam to the Paria River; and GCNP, a 277-mile reach from the Paria River downstream from Lees Ferry to the Grand Wash Cliffs near Pearce Ferry. In terms of geomorphic features, Glen Canyon encompasses a 16-mile reach from the dam to the Paria River; Marble Canyon is a 61-mile reach from the Paria River to the LCR; and Grand Canyon is a 217-mile reach from the LCR to near Pearce Ferry. The Glen Canyon segment of the action area is also commonly referred to as the Lees Ferry reach. Additional description of the action area and its associated resources can be found in Gloss et al. (2005).

2.4 Relevant Statutory Authority

The Secretary of the Interior (Secretary) is vested with the responsibility to manage the mainstream waters of the Lower Colorado River Basin pursuant to applicable federal law. The responsibility is carried out consistent with a body of documents commonly referred to as the Law of the River. While there is no universally accepted definition of this term, the Law of the River comprises numerous operating criteria, regulations, and administrative decisions included in federal and state statutes, interstate compacts, court decisions and decrees, an international treaty, and contracts with the Secretary. Notable among these documents include the Colorado River Compact of 1922; the 1944 Treaty (and subsequent minutes of the International Boundary and Water Commission); the Upper Colorado River Basin Compact of 1948; the Colorado River Storage Project Act of 1956 (CRSPA); the 1963 United States Supreme Court Decision in Arizona v. California; the 1964 US Supreme Court Decree in Arizona v. California ; the Colorado River Basin Project Act of 1968 (CRBPA); the Colorado River Basin Salinity Control Act of 1974; and the Grand Canyon Protection Act of 1992. In compliance with ESA section 7(a)(2) and its implementing regulations, Reclamation is responsible for defining the extent of its discretionary authority with respect to this action.

Reclamation’s authority does not extend to direct management of native and non-native fish. Those authorities rest with the federal land management agency, the National Park Service, the state fish and wildlife agency, the Arizona Game and Fish Department, and, on tribal lands, the designated fish and wildlife agency for the given tribe. These agencies, either directly or through commissions or councils, make decisions on stocking procedures, set bag limits, and determine other actions to increase or limit the distribution and abundance of species under their authority. Where species listed under the ESA are potentially affected by a proposed action, the primary regulatory authority for those species is held by the USFWS.

2.5 Glen Canyon Dam Adaptive Management Program

The 1996 ROD directed the formation and implementation of an adaptive management program to assist in monitoring and future recommendations regarding the impacts of Glen Canyon Dam operations. The GCDAMP was formally established in 1997 to implement the Grand Canyon Protection Act (GCPA), the 1995 Operation of Glen Canyon Dam Final Environmental Impact Statement, and the 1996 ROD. The GCDAMP provides a process for assessing the effects of current operations of Glen Canyon Dam on downstream resources and using the results to develop recommendations for modifying dam operations and other resource management actions. This is accomplished through the Adaptive Management Work Group (AMWG), a federal advisory committee to the Secretary. The Secretary's Designee serves as the chair of the AMWG and provides a direct link between the AMWG and the Secretary.

The AMWG consists of stakeholders from federal and state resource management agencies, the seven Basin States, Native American Indian tribes, hydroelectric power marketers, environmental and conservation organizations and recreational and other interest groups. The duties of the AMWG are an advisory capacity only. Coupled with this advisory role is long-term monitoring and research that provides a continual record of resource conditions and new information to evaluate the effectiveness of the operational modifications to Glen Canyon Dam and other management actions.

The Technical Work Group (TWG) translates AMWG policy into information needs, provides questions that serve as the basis for long-term monitoring and research activities, and conveys research results to AMWG members. The USGS Grand Canyon Monitoring and Research Center (GCMRC) provides scientific information on the effects of the operation of Glen Canyon Dam and related factors on natural, cultural, and recreational resources along the Colorado River between Glen Canyon Dam and Lake Mead. The independent review panels provide independent assessments of the GCDAMP to assure scientific validity. Academic experts in pertinent areas make up a group of Science Advisors.

2.6 Regulatory Context

Past consultations have evaluated the impact of proposed actions on the threatened and endangered species that live in the Colorado River and its floodplain between Glen Canyon Dam and Separation Canyon, near the inflow area of Lake Mead, Coconino and Mohave counties, northern Arizona. This biological assessment focuses on the LCR and PBR reaches, although the impacts of trout removal could extend downstream and upstream of these areas in the action area, depending on movement potential and limiting temperature requirements of non-native fish, primarily rainbow trout and brown trout. The anticipated area of effect lies within the State of Arizona and in Grand Canyon National Park. The area is bordered by, or is in proximity to the Navajo Nation, Hopi, Pueblo of Zuni, Paiute and Hualapai tribal lands.

2.7 Effects of Climate Change

The Fourth Assessment Report (Summary for Policymakers) of the Intergovernmental Panel on

Climate Change (IPCC 2007), presented a selection of key findings regarding projected changes in precipitation and other climate variables as a result of a range of unmitigated climate changes projected over the next century. Although annual average river runoff and water availability are projected to decrease by 10-30 percent over some dry regions at mid-latitudes, information with regard to potential impacts on specific river basins is not included. Recently published projections of potential reductions in natural flow on the Colorado River Basin by the mid 21st century range from approximately 45 percent by Hoerling and Eischeid (2006), to approximately 6 percent by Christensen and Lettenmaier (2006), but, as documented in the Shortage EIS (U.S. Bureau of Reclamation 2007b), these projections are not at the spatial scale needed for CRSS, the model used to project future flows.

The hydrologic model, CRSS, used as the primary basis of the effects analysis does not project future flows or take into consideration projections such as those cited above, but rather relies on the historic record of the Colorado River Basin to analyze a range of possible future flows. Using CRSS, projections of future Lake Powell reservoir elevations are probabilistic, based on the 100- year historic record. This record includes periods of drought and periods with above average flow. However, studies of proxy records, in particular analyses of tree-rings throughout the upper Colorado River Basin indicate that droughts lasting 15-20 years are not uncommon in the late Holocene. Such findings, when coupled with today's understanding of decadal cycles brought on by El Niño Southern Oscillation and Pacific Decadal Oscillation (and upstream consumptive use), suggest that the current drought could continue for several more years, or the current dry conditions could shift to wetter conditions at any time (Webb et al. 2005). Thus, the action period may include wetter or drier conditions than today. An analysis of hydrologic variability and potential alternative climate scenarios is more thoroughly discussed in the Shortage EIS (Reclamation 2007b) and is incorporated by reference here.

Although precise estimates of the future impacts of climate change throughout the Colorado River Basin at appropriate spatial scales are not currently available, these impacts may include decreased mean annual inflow to Lake Powell, including more frequent and more severe droughts. Such droughts may decrease the average storage level of Lake Powell, which could correspondingly increase the temperature of dam releases. Increased release temperatures have been cited as one potential factor in the recent increase of juvenile humpback chub (Andersen 2009) but concerns also exist that warmer aquatic habitat will also increase the risk of warm water non-native fish predation. To allay this risk if such warming occurs, in the 2007 Opinion Reclamation committed to the monitoring and control of non-native fish as necessary, in coordination with other Department of the Interior agencies and working through the GCAMP (U.S. Fish and Wildlife Service 2007).

3.0 Listed Species and Critical Habitat in the Action Area

3.1 Species Identified for analysis

Four species are identified as endangered within or near the area affected by the proposed action, including the humpback chub, razorback sucker, Kanab ambersnail, and the southwestern willow flycatcher. Only the humpback chub and razorback sucker may be affected by the proposed action and are addressed in detail in this biological assessment.

3.1.1 Humpback Chub

The humpback chub is currently listed as "endangered" under the ESA. The humpback chub recovery plan was approved on September 19, 1990 (U.S. Fish and Wildlife Service 1990) and Recovery Goals were developed in 2002 (U.S. Fish and Wildlife Service1 2002). Designated critical habitat exists in two reaches near the action area (U.S. Fish and Wildlife Service 1994); the lower 8 miles of the LCR and 173 miles of the Colorado River and its 100-year floodplain in Marble and Grand Canyons from Nautiloid Canyon (RM 34) to Granite Park (RM 208). Primary threats to the species include streamflow regulation and habitat modification (including cold-water dam releases and habitat loss), competition with and predation by non-native fish species, parasitism, hybridization with other native *Gila*, and pesticides and pollutants (U.S. Fish and Wildlife Service 2002).

The humpback chub is a moderately large cyprinid fish endemic to the Colorado River system (Miller 1946). It is surmised from various reports and collections that the species presently occupies about 68 percent of its historic habitat of about 470 miles of river (U.S. Fish and Wildlife Service 2002). Range reduction is thought to have been caused primarily by habitat inundation from reservoirs, cold-water dam releases, and non-native fish predation. Six humpback chub populations are currently known—all from canyon-bound reaches (U.S. Fish and Wildlife Service 2002). Five are in the upper Colorado River Basin and the sixth is located in Marble and Grand Canyon's of the lower basin. Upper basin populations range in size from a few hundred individuals to about 5,000 adults. The lower basin population is found in the Little Colorado River and the Colorado River in Marble and Grand canyons and is currently at between 6,000 and 10,000 (most likely estimate at 7,650 adults; Coggins and Walters 2009) and is the largest of the extant populations.

Young and juvenile humpback chub are found primarily in the LCR and the Colorado River near the LCR inflow, although many are found upstream of the LCR (Figure 2), presumably from spawning near warm springs (Valdez and Masslich 1999). Reproduction by humpback chub occurs annually in spring in the LCR, and the young fish either remain in the LCR or disperse into the Colorado River. Dispersal of these young fish has been documented as nighttime larval drift during May through July (Robinson et al. 1998), as density dependent movement during strong year classes (Gorman 1994), and as movement with summer floods caused by monsoonal rain storms during July through September (Valdez and Ryel 1995). Survival of these young fish in the mainstem is thought to be low because of cold mainstem temperatures (Clarkson and Childs 2000; Robinson and Childs 2001), but fish that survive and return to the LCR contribute to recruitment in this population. Predation by rainbow trout and brown trout in the LCR confluence area has been identified as an additional source of mortality affecting survival and recruitment of humpback chub (Coggins 2008a; Marsh and Douglas 1997; Valdez and Ryel 1995; Yard et al. 2008).

3.1.2 Razorback Sucker

The razorback sucker was listed as endangered under the Endangered Species Act of 1973, as amended, on October 23, 1991 (56 FR 54957). Designated critical habitat includes the Colorado River and its 100-year floodplain from the confluence with the Paria River (RM 1) downstream to Hoover Dam, a distance of nearly 500 miles, including Lake Mead to the full pool elevation. A recovery plan was approved on December 23, 1998 (U.S. Fish and Wildlife Service 1998) and Recovery Goals were approved on August 1, 2002 (U.S. Fish and Wildlife Service 2002b). Primary threats to razorback sucker populations are streamflow regulation and habitat modification and fragmentation (including cold-water dam releases, habitat loss, and blockage of migration corridors); competition with and predation by non-native fish species; and pesticides and pollutants (Bestgen 1990; Minckley 1991; U.S. Fish and Wildlife Service 2002b).

The razorback sucker is endemic to the Colorado River system. Historically, it occupied the mainstem Colorado River and many of its tributaries from northern Mexico through Arizona and Utah into Wyoming, Colorado, and New Mexico. Distribution and abundance of razorback sucker declined throughout the 20th century over all of its historic range, and the species now exists naturally only in a few small, disconnected populations or as dispersed individuals. The razorback sucker has exhibited little natural recruitment in the last 40–50 years and wild populations are comprised primarily of aging adults, with steep declines in numbers.

Razorback sucker in the lower Colorado River basin persist primarily in reservoirs, including Lakes Mohave and Mead (Minckley 1983). Currently, the group of razorback sucker in Lake Mohave is the largest remaining in the entire Colorado River system. Estimates of the wild stock in Lake Mohave, now old and senescent, have dropped precipitously in recent years from 60,000 in 1989 (Marsh and Minckley 1989) to 25,000 in 1993 (Holden 1994; Marsh 1993) and to about 9,000 in 2000 (personal communication, T. Burke, U.S. Bureau of Reclamation). A second razorback sucker population of approximately 500 individuals occurs in Lake Mead. The Lake Mead population is the only known recruiting population of razorback sucker in the Lower Colorado River Basin (Holden et al. 2000; Abate et al. 2002; Albrecht and Holden 2006). The majority of the fish are found in Las Vegas Bay and Echo Bay, where spawning has been documented over alluvial deposits and rock outcrops.

In the spring of 2010, larval sampling in the Colorado River inflow area (presently in the Gregg Basin region of Lake Mead) resulted in the capture of seven larval razorback sucker, one larval flannelmouth sucker (*Catostomus latipinnis*), and four larval fish thought to be either flannelmouth sucker or hybrid flannelmouth x razorback sucker (Albrecht et al. 2010). Although catch per unit effort was low, the identification of larval razorback sucker in the Colorado River inflow area helped confirm the presence of spawning adult razorback sucker and documented successful spawning in 2010. Moreover, Albrecht et al. (2010) reported that trammel netting in the inflow area yielded three wild razorback sucker, four razorback x flannelmouth sucker hybrids, and 52 flannelmouth sucker. Of these fish one hybrid and five flannelmouth sucker were recaptured. All three razorback sucker were males expressing milt, which helped confirm spawning activities. Two of these individuals were 6-years old and one was 11-years old.

The razorback sucker has not been reported from Grand Canyon since 1990, and only 10 adults were reported between 1944 and 1995 (Valdez 1996; Gloss and Coggins 2005). Carothers and Minckley (1981) reported four adults from the Paria River in 1978-1979. Maddux et al. (1987) reported one blind female razorback sucker at Upper Bass Camp (RM 107.5) in 1984, and Minckley (1991) reported five adults in the lower Little Colorado River from 1989-1990.

4.0 Effects Analysis

An analysis of the effects of the proposed action on the endangered humpback chub is confounded by various management actions or studies coincident with changing environmental conditions. Abundance of the principal predator considered in this action—the rainbow trout—increased in the Lees Ferry reach below Glen Canyon Dam during 1992-2001, but abundance in this reach steadily fell during 2002-2006 (Makinster 2007). Simultaneously, reservoir elevations of Lake Powell dropped steadily from 2000 to 2005 and the temperature of water released at the dam increased from a daily maximum of about 10 °C to about 15.5 °C. During this same time period, releases from Glen Canyon Dam included the low steady summer flow experiment of 2000, and the high flow experiments of November 2004 and March 2008. To an unknown extent, these independent events likely interacted to affect the various fish populations, including rainbow trout, brown trout, and humpback chub. When non-native fish removal was implemented from 2003 through 2006, environmental factors had already begun to influence the target fish populations. In 2010 non-native fish removal was cancelled and the rainbow trout population was allowed to increase. Wright and Kennedy (*in press*) now report that rainbow trout numbers have increased 3,800 percent since 2006 in the LCR reach. Any effects analysis of the proposed action cannot be singly attributable to the action described in this biological assessment.

4.1 Scientific Basis for Non-native Fish Removal

The scientific basis for non-native fish removal of non-native fishes in Grand Canyon is well documented. Predation by non-native fish species is considered a primary threat to numerous native fish species worldwide and particularly in the southwestern United States (Cambray 2003, Clarkson et al. 2005). Non-native fish in Grand Canyon prey on and compete with humpback chub, and predation may result in the loss of large numbers of young-of-year humpback chub in some years (Valdez and Rye1 1995, Marsh and Douglas 1997, Yard et al. *in press*). Because low survivorship of young humpback chub and concomitant reductions in recruitment are the primary factors limiting recovery (Coggins 2008b; Coggins and Walters 2009), ameliorating this threat is a primary strategy in recovery of humpback chub (U.S. Fish and Wildlife Service 2002a). Mechanical removal, which for fisheries means using electrofishing, nets, and other gear types to physically remove fish from an ecosystem, is recognized as a potentially viable option for addressing this threat (Clarkson et al. 2005, Simberloff et al. 2005), although in practice, mechanical removal of non-native fishes in the mainstem Colorado River has not been well evaluated and has achieved varying degrees of success (Mueller 2005).

Mueller (2005) recommended a success criteria of 80 percent reduction for non-native fish removal programs. He implied that lesser levels of removal are likely ineffective, but there are limited results from controlled studies to confirm or reject this criterion. Mechanical removal of non-native fish species in Grand Canyon was tested at the LCR inflow reach (LCR, RM 56.3-65.7) from 2003 to 2006 (Coggins 2008a). The LCR inflow reach is the area of the mainstem with the highest densities of young humpback chub in the Grand Canyon population, and thus the clear choice of location for targeting removal of non-native fishes. Relying primarily on electrofishing, mechanical removal proved especially effective at removing both rainbow and brown trout, with rates up to 90 percent in removal reaches (Coggins 2008a, Yard et al. *in press*).

Stomach analysis of removed trout revealed that while the predation rate by rainbow trout was low, numbers of humpback chub lost to rainbow trout were very high due to the high densities of the predator in the removal reach (Yard et al. 2008, *in press*). In a hypothetical modeling scenario developed using trout diet information obtained from these removal efforts, Yard et al. (2008, *in press*) assessed the impact removed trout might have had on humpback chub had they not been removed. Assuming that trout captured during removal were not removed, and fish abundance and catchability conditions remained the same during the period of the trout diet study from January 2003 through September 2004, the number of humpback chub that could have been consumed by these trout had they not been removed during the 12 removal trips was 12,169 young-of-year fry and subadults (Hilwig et al. 2010).

4.2 Justification for Non-native Fish Control

An external scientific review panel conducted in 2007 by the USGS to recommend experimental actions to the GCDAMP reviewed the data resulting from the 2003¬2006 removal efforts. They recommended continued removal in Grand Canyon to maintain low levels of rainbow trout in the LCR confluence reach (U.S. Geological Survey 2008). Hilwig et al. (2010) also reviewed the existing information and scientific literature and recommended removal targets of 10-20 percent of 2003 abundance levels of rainbow trout in the removal reach, which would achieve the 80 percent reduction recommended by Mueller (2005).

Despite the conventional wisdom on the need to continue removal, the GCMRC acknowledges that the link between non-native fish predation and humpback chub adult abundance has not been firmly established, and other variables in the ecosystem apart from reductions in non-native predators, such as the warmer mainstem water temperatures caused by the recent drought, may have contributed to the recent improvement in humpback chub recruitment observed over the last decade (Andersen 2009; Coggins and Walters 2009; Hilwig et al. 2010).

4.3 Results of Mechanical Removal Study

The mechanical removal study of 2003-2006 demonstrated that rainbow trout can be effectively reduced in numbers within a 9.4-mile removal area around the confluence of the Colorado and Little Colorado rivers (Coggins 2008a). It also illustrated the rate of immigration of trout, presumably from upstream sources, and the offsetting effect on removal. During the period of removal, the humpback chub population stabilized and increased, suggesting that removal had enabled higher survival, and hence recruitment, by humpback chub (Andersen 2009; Coggins 2008a; Coggins and Walters 2009). The coincidental effect of warmer temperature releases from Glen Canyon Dam, the result of lowered reservoir elevations in Lake Powell, confounded the results of removal as a beneficial action for humpback chub.

The decline of rainbow trout abundance observed in the control reach was likely precipitated by at least two factors. First, rainbow trout abundance in the Lees Ferry reach of the Colorado River increased during approximately 1992-2001 and abundance in this reach steadily fell during 2002-2006 (Makinster 2007). The 2002-2006 decrease took place during the period of mechanical removal, and suggests there was a system-wide decrease in rainbow trout not attributable to removal. With the exception of limited spawning activity in select tributaries of the Colorado River in Grand Canyon, rainbow trout reproductive activity appears to be limited mainly to the Lees Ferry reach (Korman et al. 2005). The second major factor likely influencing these distributional patterns is sediment delivery from tributaries and the subsequent effects of elevated turbidity in the Colorado River on food availability and feeding behavior of sight feeders, such as trout.

One non-native removal trip was also conducted in 2009, which provided important information for consideration of non-native control efforts (Makinster et al. 2009a). Results from the 2009 trip indicated that rainbow trout populations rebounded since declines in 2006-2007, a trend first documented in 2008 (Coggins 2008a). AGFD estimates that the population in the LCR inflow reach was about 2,300 - 3,300 prior to the 2009 removal, which removed about 1,873 rainbow trout. The numbers of rainbow trout in 2009 in the LCR inflow reach were approaching those seen in 2002 and 2003 when numbers were among the highest recorded for that reach. Roughly 500 -1,500 rainbow trout were thought to remain in the LCR inflow reach at the end of the trip, which is approximately the 10-20 percent of 2003 levels recommended by Hilwig et al. (2010), or 600-1,200 adult rainbow trout.

The number of trout in the inflow reach following removal appears dependent on numbers of trout immigrating into the reach, plus trout reproduction in the reach which is thought to be very low (Coggins 2008a). Hilwig et al. (2010) used immigration rates observed by Coggins (2008a) to estimate potential numbers of trout in the inflow reach, relative to hypothetical scenarios of 1, 2, or 3 removal trips conducted per year. At the lowest immigration rate of 50 fish per month, two removal trips per year appears sufficient to keep trout numbers below 1,200 rainbow trout in the reach. However, at higher immigration rates of 300 fish per month, even 3 trips per year appears insufficient to achieve the 600-1,200 fish target for much of the year (Hilwig et al. 2010).

4.4 Effects of HFEs on Trout and other Fishes

In separate NEPA process, Reclamation is developing an Environmental Assessment concerning high-flow experimental releases from Glen Canyon Dam for the purpose of promoting more natural sediment dispersal throughout the Canyon. A high flow protocol is being developed with the intention to allow for multiple high flow tests over a period of 10 years. The SDM Project analysis results suggested that there is a close relationship between the decision to conduct high flow experiments and to implement non-native fish control because of the apparent effect that HFE flows have on trout recruitment in Lees Ferry. The coupled trout-chub models developed as part of the SDM Project assessment provided some valuable predictions about the effects of HFEs (see Appendix A, Table 7). Wright and Kennedy (*in press*) also concluded available evidence indicates that HFEs can substantially impact humpback chub population levels due to the positive effect of HFEs on trout abundance and the negative effect of trout completion and predation on humpback chub and other native fishes. Wright and Kennedy reported that rainbow trout abundance in the LCR reach increased approximately 3,800 percent since 2006. They attribute this increase to downriver migration of the large 2008 rainbow trout cohort spawned in the Lees Ferry tailwater reach immediately after the 2008 HFE, together with local recruitment along downriver sections.

Results from the 1996 and 2008 HFEs indicate that high flow experiments have the potential to increase numbers of rainbow trout in Lees Ferry and likely influence the abundance of rainbow trout throughout Grand Canyon due to several factors. Korman et al. (2010) found multiple lines of evidence indicating that the March 2008 HFE resulted in large increases in abundance of rainbow trout in Lees Ferry due to improved habitat conditions for young-of-year rainbow trout. Numbers of young-of-year rainbow trout in July of 2008 were four-fold greater than would be expected based on numbers of eggs produced during the 2008 spawn based on stock-recruitment analysis. Survivorship was also greater for fish that hatched after the HFE based on hatch-date analysis, also indicating that habitat conditions were improved after the HFE. Growth rates of young-of-year rainbow trout were also as high as has been recorded in Lees Ferry, despite the fact that abundance was also much greater than previous years, suggesting a greater carrying capacity for young trout in Lees Ferry following the HFE (Korman et al. 2010). Korman et al. (2010) speculate that the 2008 HFE (41,500 cfs for 60 hours) resulted in these effects because the high flow increased interstitial spaces in the gravel bed substrate and food availability or quality, resulting in higher early survival of young-of-year rainbow trout, as well as improved growth of young trout. This improved habitat effect of the 2008 HFE also apparently carried over into 2009; trout abundance in 2009 was more than twofold higher than expected from egg counts (Korman et al. 2010).

Although there is less data from the 1996 and 2004 HFEs, those events appeared to have effects to rainbow trout as well. Trout abundance in Lees Ferry appeared to increase following the 1996 event which was conducted in April (Makinster et al. 2009b). During a three-week period that spanned the November 2004 HFE, abundance of age-0 trout, estimated to be approximately 7 months old at that time, underwent a three-fold decline; a two-fold decline was also observed in November-December 2008 (Korman et al. 2010). The decline observed during the 2004 HFE may have been due to either increased mortality or displacement/disbursal as a result of the higher flow (Korman et al. 2010). However, long-term trout monitoring data indicated that trout started to decline system-wide in 2001/2002 and declined through the period of the 2004 HFE and only began to recover in about 2007 (Makinster 2009b). Also, key monitoring programs to detect ecosystem pathways that affect rainbow trout in Lees Ferry were not in place at the time of the 2004 HFE (Wright and Kennedy *in press*). Higher water temperatures and lower dissolved oxygen in fall 2005 also may have increased mortality and reduced 2006 spawning activity (Korman et al. 2010). Thus the overall effect of fall HFEs on rainbow trout abundance is unclear.

The high flow experiment protocol currently under development by Reclamation would provide for the opportunity to conduct multiple high flows over a 10-year period of from 31,500 cfs to 45,000 cfs. Proposed time frames are March/April and October/November, periods following the primary sediment-input season are of late Summer/early fall and winter. High flows conducted in the March/April period likely will result in improved conditions for rainbow trout based upon observations from the 1996 and 2008 HFEs. Given that a 3,800 percent increase in rainbow trout from what appears to be downstream density-driven emigration to the LCR Reach resulting from the 2008 Spring HFE (Korman et al. 2010; Wright and Kennedy *in press*), multiple HFEs over a 10-year period would reasonably be predicted to increase rainbow trout abundance system-wide including in the LCR Reach. Under the no action alternative, losses of young humpback chub to predation by rainbow trout would also be expected to increase, even exceeding previously observed levels (Yard et al. *in press*).

Under the proposed action, removal will take place, including up to 10 removal trips in the PBR Reach and up to 6 removal trips in the LCR reach. PBR removal may serve to limit emigration of young trout from Lees Ferry. LCR reach removal is predicted to be effective at removing trout in that reach to address this threat if conditions warrant this action. In this way, the proposed action should serve to offset the adverse impacts of multiple HFEs on rainbow trout abundance and the concomitant increased predation and competition to humpback chub.

4.5 Humpback Chub Effects Analysis

4.5.1 LCR Reach Removal Effects to the Population

We evaluated impacts of the proposed action by first comparing the predicted amount of predation by rainbow and brown trout (henceforth referred to as "trout") on humpback chub across a range of mechanical removal effort by electrofishing, including: (1) No removal effort; (2) Removal effort assuming a low level of capture efficiency; (3) Removal effort assuming a high level of capture efficiency; and (4) Removal effort assuming an average level of capture efficiency. Second, we considered population level impacts of these four alternatives on the adult humpback chub population by estimating number of juvenile and age-4 (first year adults) humpback chub that would be absent to the population as a whole because of predation by rainbow trout.

We had to make several simplifying assumptions in conducting this analysis but made every attempt to assure that these assumptions remained conservative. The overriding assumptions of this analysis are that the actual levels of predation under any alternative will vary with:

1) The actual number of trout remaining in the LCR reaches since March 2009 (the last time an effort was taken to mechanically remove rainbow trout and estimate their numbers).

2) The immigration rate of trout into the LCR inflow reach since March 2009 (the last time an effort was taken to mechanically remove rainbow trout and estimate their numbers).

3) The total number of trout in the inflow reach would be removed at a rate which varies among those observed in the recent literature (no action alternative; Coggins 2008a; Coggins and Yard 2010; Yard et al. *in press*).

4) Predation rates in this analysis are assumed to vary directly and positively with prey density; in other words, high predation rates are commensurate with high prey density and vice-versa (Yard et al. *in press*).

5) Electrofishing total effort was assumed to be two LCR reach trips with methods as described by Makinster et al. 2009. Note that the proposed action allows for up to 6 river trips in the LCR reach and 10 river trips in the PBR reach, but we have no data to quantitatively evaluate the effects of PBR reach removal.

6) Mortality of humpback chub due to electrofishing is negligible compared to decreased mortality due to reduced predation and competition.

We estimated predation rates of trout on humpback chub for a period of one year and evaluated effects on the adult population several years later. We calculated our predictions using minimum and maximum parameter estimates if they were available. By most statistical distributions, the probability of minimum and maximum values actually occurring is relatively small, but these distributions serve to provide a limit on the range of possible outcomes. Estimated rainbow trout remaining in the LCR reach after the last removal effort in March 2009 was 427 to 1,427 fish (Makinster et al. 2009). Estimates of brown trout abundance in the LCR inflow reach in 2009 were not available, so brown trout predation was based on values ranging from zero to 245 fish, which was the maximum observed by Yard et al. (*in press*).

Immigration rates of rainbow trout into the LCR inflow reach were assumed to vary between 50 and 300 fish/month (Hilwig et al. 2010). Brown trout immigration rates were not available but were estimated by regressing brown trout against rainbow trout captures (effort was constant for both species; Coggins 2008a) and applying that relationship to rainbow trout immigration rates. Mean immigration rate was used to model immigration rates during 2010-2011 for the sake of simplicity; however we feel this did not influence the range of predicted outcomes significantly. Minimum and maximum predation rates calculated by Yard et al. (*in press*) were applied to the predicted number of predators during 2010-2011 (1.7 and 7.1 prey/rainbow trout/year, and 18.2 to 106 prey/brown trout/year). Of prey fish consumed, we assumed that 27.3% were humpback chub as reported in Yard et al. (*in press*). Reduction in predator numbers by mechanical removal (serial pass electrofishing; Coggins 2008a) was calculated according to high, average and low rates of removal efficiency, or 35, 18 and 2 percent of fish in the LCR inflow reach removed per electrofishing pass; we assumed four electrofishing passes/trip would be conducted as was the protocol in previous years (Coggins 2008a; Hilwig et al. 2010). Capture probabilities were assumed to be the same for both trout species.

As the number of humpback chub available to predation in the mainchannel is unknown at this time, we assumed it to be unlimited for the sake of computing and comparing estimates among alternatives across the range of variables described above. We also assumed that the overwhelming majority of humpback chub are comprised of young-of-year fry and subadults (Yard et al. 2008). Calculation of age-0 and age-1 humpback chub abundance in the LCR is currently in its infancy, and it is unknown how many of these fish would actually inhabit the main channel at any given time.

Evaluation of population level effects was conducted by converting losses of age-1 humpback chub to losses of adult humpback chub, which is the metric identified in the Recovery Goals (U.S. Fish and Wildlife 2002a) and the incidental take statement from the 2009 Supplemental Biological Opinion and the 2010 Reissued Incidental Take Statement (U.S. Fish and Wildlife Service 2009, 2010). We applied published survival rates for humpback chub (Valdez and Ryel

1995; Coggins et al. 2006) to estimate numbers of preyed-upon humpback chub as described above. We then compared these losses to the minimum population size contained in the incidental take statement (6,000 adult humpback chub; U.S. Fish and Wildlife Service 2010b).

The proposed action would have only beneficial effects to humpback chub. Depending on electrofishing efficiency, two electrofishing removal trips could reduce predation pressure by rainbow trout substantially (Figure 3). Under worst case conditions (i.e., low efficiency), total humpback chub predation would be reduced by 10-14% depending on immigration rates and individual trout predation rates. Assuming average electrofishing efficiency, total humpback chub predation would be reduced by 41-70%, and 49-85% under high efficiency conditions depending on immigration rates and individual trout predation rates. Similarly, 129-3,292 humpback chub would be theoretically saved from predation under the low efficiency scenario, 532-16,851 humpback chub in the average efficiency scenario and 637 to 20,384 humpback chub in the high efficiency scenario.

The aforementioned savings of age-0 and age-1 humpback chub due to reduced predation from 2 electrofishing trips would theoretically translate into a substantial savings of adult fish (Figure 4). Four to 96 fish would survive due to reduced predation in the low efficiency scenario, 15 to 491 fish in the average efficiency scenario, and 19 to 594 humpback chub in the high efficiency scenario. The grand mean of estimated fish saved from predation across all variables (predation and immigration rates as well as electrofishing efficiency) is 169 fish. Note that this estimate is for two LCR reach removal trips. Additional removal trips would likely not result in a linear increase in adult humpback chub saved, but would result in substantial additional increases in fish saved.

Another potential effect to humpback chub is increased competition between adult humpback chub and nonnative fishes, in particular adult rainbow and brown trout. Valdez and Ryel (1995) found that simulids, chironomids, and *Gammarus* were the three most prevalent diet items in 158 adult humpback chub stomachs sampled by gastric lavage in the mainstem Colorado River in Grand Canyon. Yard et al. (*in press*) also found that these same three types of aquatic invertebrates were important components of both rainbow and brown trout diets, often accounting for 40 to 90 percent of the proportion of diet by weight over a 1.75 year study from 2003-2004. The degree to which competition occurs between humpback chub and rainbow trout is a function of food availability, which is not currently well understood (Hilwig et al. 2010). The ongoing GCDAMP food base research project should provide insight into the effect of competition from nonnative fishes on humpback chub in light of food availability within the Colorado River ecosystem, and the Nearshore Ecology Study may also provide information about feeding ecology of fishes in nearshore environments (U.S. Bureau of Reclamation and U.S. Geological Survey 2009). Because of these uncertainties, no additional losses of humpback chub were attributed to competition from nonnative fish.

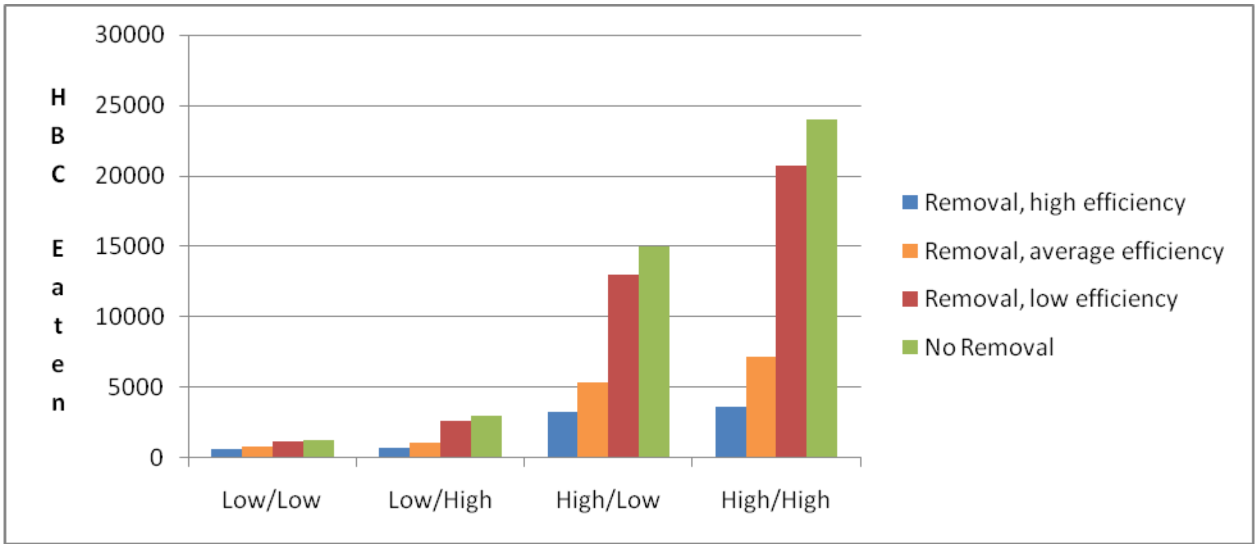

Figure 3. Expected predation of young-of-year fry and subadult humpback chub by trout in the absence of non-native fish removal (green bars) and over a range of mechanical removal efficiencies (blue, orange and red bars). X-axis labels refer to assumptions on predator density and piscivory rates. For example, "Low/Low" refers to low levels of predatory density (as a function of trout immigration rates) and low piscivory rates (Yard et al. 2008).

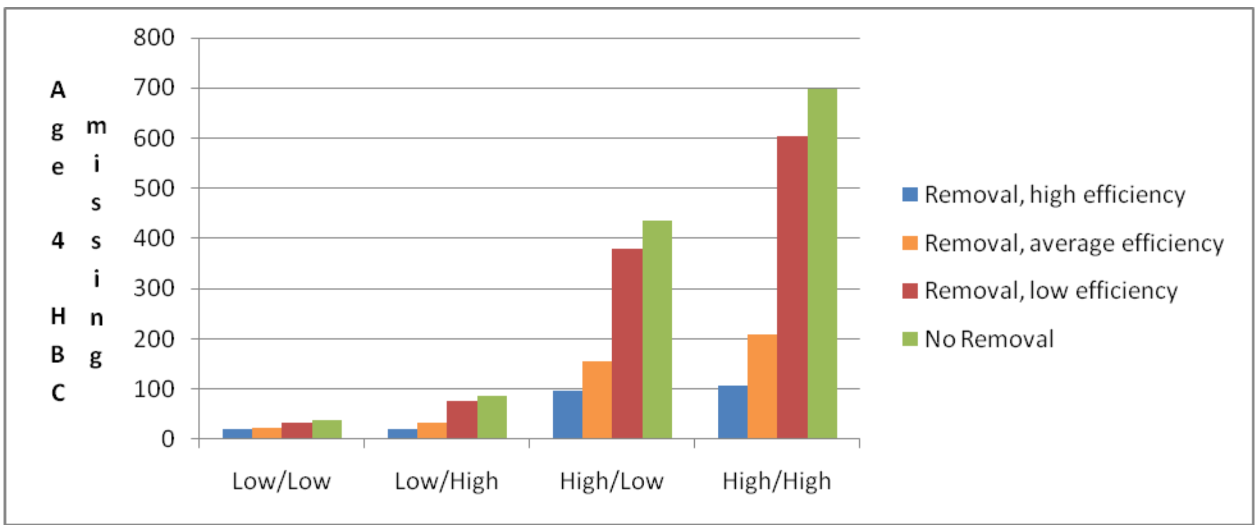

Figure 4. Expected losses of adult humpback chub (age 4) due to predation by trout in the absence of non-native fish removal (green bars) and over a range of mechanical removal efficiencies (blue, orange and red bars).

4.5.2 PBR Reach Removal Effects to Population

Effects of removal in the PBR reach to humpback chub are uncertain due to lack of information on the timing, magnitude and other controls on migration rates of rainbow trout from Lees Ferry. A study plan for the proposed action provided by GCMRC will help guide monitoring and research associated with implementing removal actions in this reach.

4.5.3 Effects to Critical Habitat

Critical habitat for humpback chub occurs in two reaches in the action area (U.S. Fish and Wildlife Service 1994): the lower 8 miles of the LCR and 173 miles of the Colorado River in Marble and Grand Canyons from Nautiloid Canyon (RM 34) to Granite Park (RM 208). A more detailed description of critical habitat and its primary constituent elements (PCEs) is provided in the original rule designating critical habitat and in the 2009 Supplemental Biological Opinion (U.S. Fish and Wildlife ServiceService 1994, 2009a).

The effect to humpback chub critical habitat from changes to the proposed action would be from implementing 1-6 removal trips at the LCR in 2011-2020 and implementing up to 10 removal trips per year in the PBR reach to reduce downstream emigration. This would result in removing several thousands of rainbow trout and other non-native fish species in the LCR confluence reach and in the PBR reach, and result in reduced predation on and competition to humpback chub from non-native fish species.

From a critical habitat perspective, this change would affect the biological primary constituent element of critical habitat, which includes three specific elements--food supply (B1), predation from non-native fish species (B2), and competition from non-native fish species (B3).

Food supply is a function of nutrient supply, productivity, and availability of food to each life stage of the species. One potential effect to humpback chub is decreased competition between adult humpback chub and non-native fishes, in particular adult rainbow and brown trout. Valdez and Ryel (1995) found that simulids, chironomids, and *Gammarus* were the three most prevalent diet items in 158 adult humpback chub stomachs sampled by gastric lavage in the mainstem Colorado River in Grand Canyon. Yard et al. (*in review*) also found that these same three types of aquatic invertebrates were important components of both rainbow and brown trout diets, often accounting for 40 to 90 percent of the proportion of diet by weight over a 1.75 year study from 2003-2004. The degree to which competition occurs between humpback chub and rainbow trout is a function of food availability, which is not currently well understood (Hilwig et al. 2010). The ongoing GCDAMP food base research project should provide insight into the effect of competition from non-native fishes on humpback chub in light of food availability within the Colorado River ecosystem, and the Nearshore Ecology Study may also provide information about feeding ecology of fishes in nearshore environments (Reclamation and U.S Geological Survey 2009).

Predation and competition are normal components of the ecosystem, but are out of balance due to introduced fish species within these critical habitat units, particularly in Reach 7. As described above, the effect of the proposed action would be to decrease predation and competition from non-native fishes, potentially increasing the food supply available to humpback chub, thus all three aspects of the biological environment constituent element would be positively affected by the proposed action for 2011-2020.

The Recovery Goals (U.S. Fish and Wildlife Service 2009b) identify the need to develop and implement levels of control of non-native fish species. The GCDAMP has demonstrated that successful removal of non-native trout is possible, and may benefit humpback chub (Yard et al. *in review*; Coggins and Walters 2009). The degree to which these removal efforts have improved the PCEs B1, B2, and B3 is still a research question. However, as described above, Yard et al. (*in review*) presented some preliminary results indicating that the 2003-2006 removal of rainbow and brown trout contributed significantly in reducing predation losses of juvenile humpback chub. This evidence, along with information from the most recent 2009 removal effort (Makinster et al. 2009), provides a good indication of what affect the proposed action is likely to have on humpback chub critical habitat, although the overall effect on recovery is less clear.

Non-native fish removal has been identified by several authors as a likely cause of improved status of humpback chub (Andersen 2009, Coggins and Walters 2009, Van Haverbeke and Stone 2009), but a definitive link between removal and improvement in humpback chub status is still lacking (Coggins and Yard 2010). However, Reclamation's proposed action should continue to refine methods of controlling non-native fish species, and may ultimately improve the effectiveness of the conservation measure in the long-term, which would directly address this recovery need for the B2 and B3 PCEs of Reach 7 and, to a lesser extent, Reach 6. Overall, the proposed action should provide a substantial beneficial effect to humpback chub and its critical habitat.

4.6 Razorback Sucker Effects Analysis

The only effect to razorback sucker from the proposed action would be from conducting non-native fish removal trips in 2011 to 2020. This would result in removing thousands of rainbow trout and other non-native fish species in the LCR confluence reach. However removal in both the LCR and PBR reaches is anticipated to have no effect to razorback sucker because of its absence in the areas where removal actions will be occurring and the distance from the removal areas, over 300 miles, to where razorback sucker occur in Lake Mead.

The nearest population of razorback sucker to the proposed action area is in Lake Mead at Echo Bay and near the Virgin River and Muddy River inflows into the lake. These groups of fish are reproducing and evidently self-sustaining. These razorback suckers are located about 300 miles downstream of removal reaches of the action area and it is highly unlikely that individuals would move upstream into the action area.

Critical habitat for razorback sucker occurs throughout the Colorado River in Grand Canyon from the Paria River to Hoover Dam, including Lake Mead (U.S. Fish and Wildlife Service 1994). Best available scientific information indicates that the habitat of the Colorado River and its tributaries within Grand Canyon is currently unoccupied by razorback sucker. Although the proposed action will likely have little if any effect on razorback sucker, the unoccupied reaches of its critical habitat that overlap with the removal reaches, the LCR and PBR reach, will benefit in the same way that humpback chub critical habitat will benefit.

4.7 Limitation on Commitment of Resources

Section 7(d) of the ESA provides that after initiation of consultation required under subsection 7(a)(2), the Federal agency and the permit or license applicant shall not make any irreversible or irretrievable commitment of resources with respect to the agency action which has the effect of foreclosing the formulation or implementation of any reasonable and prudent alternative measures which would not violate subsection 7(a)(2). Reclamation is in compliance with Section 7(d) and no irretrievable investment of resources has been made on this action.

4.8 Effects Determinations

A summary of effects determinations for the four listed species is presented in Table 1. Analysis of effects determination are based 50 CFR 402.02, in which "Effects of the action refers to the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process."

Effects on critical habitat in this biological assessment relied on 50 CFR 402.02, in which "Destruction or adverse modification means a direct or indirect alteration that appreciably diminishes the value of critical habitat for both the survival and recovery of a listed species. Such alterations include, but are not limited to, alterations adversely modifying any of those physical or biological features that were the basis for determining the habitat to be critical." In its determination on destruction or adverse modification of critical habitat, Reclamation has relied on the 9th Circuit Court ruling of August 6, 2004 (Gifford Pinchot Task Force v. U.S. Fish and Wildlife Service, 378 F.3d 1059), to consider whether the action appreciably diminishes the value of critical habitat for <u>either</u> the survival <u>or</u> recovery of a listed species.

Based on the analysis of effects of predation by trout on humpback chub (See Section 3.2), Reclamation has determined that the proposed action may affect, but is not likely to adversely affect the humpback chub and its critical habitat in the Colorado River within Grand Canyon. This determination is due to the overall beneficial effect to humpback chub from the proposed action. Conducting removal of non-native fishes, predominately rainbow trout, from 2011-2020 will reduce losses of humpback chub to predation and likely increase recruitment into the adult population. We have also determined that the removal action is likely to appreciably increase the value of critical habitat for survival and recovery of the humpback chub by positively affecting the biological principal constituent elements of critical habitat by not allowing known predators of humpback chub to remain in an area used by part of the population for rearing.

However, we acknowledge that here is incomplete knowledge of the complexity of survival rates associated with a large number of variables that would translate to adult recruitment. These include: the uncertainty of numbers and sizes of chubs eaten by trout, various annual densities of juvenile chubs depending on year class strength, relationship of predator and prey densities, and the levels of mainstem chub survival. To place the effect of the new action in context of the

Grand Canyon population of humpback chub, investigators have surmised that most of the young humpback chub that recruit to the adult population are reared in the LCR where trout predation is not a problem because of unsuitable water quality conditions for the trout (e.g., Coggins et al. 2006; Valdez and Ryel 1995;Van Haverbeke and Stone 2008, 2009). Furthermore, the mechanical removal in 2003-2006 was implemented in only a 9.4-mile reach of the Colorado River, but removal of predators has not been conducted elsewhere in Grand Canyon. In some years, there can be substantial numbers of juvenile humpback chub in reaches upstream of the LCR (see Figure 1), where trout are present, but predation rates there are unknown. The effects determination in this biological assessment is for the action of removing predators from a 9.4-mile reach of the Colorado River near the LCR confluence and an 8 mile reach in the PBR, where predation is one of five possible sources of mortality for humpback chub (i.e., cold-water shock, starvation, cannibalism, diseases and parasites, and downstream transport to less suitable habitat).

Reclamation has determined that the action may affect, but is not likely to adversely affect the razorback sucker or its critical habitat in the Colorado River within Grand Canyon. This determination is based on current scientific information that indicates an absence of the endangered razorback sucker from the action area or its proximity (the nearest capture of razorback sucker in the last decade is over 200 miles downstream). Reclamation also determined that the action is not likely to directly or indirectly alter critical habitat in a manner that appreciably diminishes the value of critical habitat for either the survival or recovery of the razorback sucker. The action does not adversely affect the survival of the species because of its absence from the action area, and it does not adversely affect the recovery of the species because Grand Canyon is not specifically identified as a recovery unit in the Razorback Sucker Recovery Goals (U.S. Fish and Wildlife Service 2002b) and the prospect for the species to return to this area is currently thought to be low. This determination is also based on the dynamic nature of the predator trout population in the action area and the unpredictable duration of the effect of predation. There is also uncertainty of effects on razorback sucker if the species was to somehow gain access to the action area or to be intentionally reintroduced into the area. In the case of reintroduction, any augmentation action would need to comply with the ESA and a reevaluation of critical habitat would be done at that time.

We have determined that the proposed action will not affect the Kanab ambersnail. This determination is based on the absence of the ambersnail from the project area and the lack of a relationship to trout; i.e., trout are not known to prey on Kanab ambersnail. We have also determined that the new action will not affect the southwestern willow flycatcher. This determination is based on the lack of any relationship between trout and their removal on the flycatcher or of indirect effects on the flycatcher from the action. NPS and GCRMC conduct monitoring of flycatchers in Grand Canyon. If their status should change in Grand Canyon or monitoring detect that there are effects to the species from the proposed action, reinitiation of consultation may be necessary.

Table 1. Summary of effects determinations for the four listed species.

Species	Determination	Basis for Determination
Humpback chub	May affect, not likely to adversely affect	Predation and competition by trout would be reduced as a result of conducting removal trips for 2011 to 2020; biological primary constituent element of critical habitat would be beneficially affected by removing predators to humpback chub.
Razorback sucker	May affect, not likely to adversely affect	Species not present in action area or likely to be affected by action; biological primary constituent element of critical habitat would be beneficially affected.
Kanab ambersnail	No affect	Species not present in action area or likely to be affected by action; no critical habitat is designated.
Southwestern willow flycatcher	No affect	Species not likely to be affected by action; no critical habitat is affected by action.

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