RECLAMATION

Managing Water in the West

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

December 30, 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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The Bureau of Reclamation (Reclamation), Upper Colorado Region, proposes to conduct research, monitoring and specific actions 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*), may be contributing to a reduction in 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 and compete with the endangered humpback chub, the U.S. Fish and Wildlife Service (USFWS) 2008 Final Biological Opinion on the Operation of Glen Canyon Dam (2008 Opinion; U.S. Fish and Wildlife Service 2008) 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 Supplement to the 2008 Final Biological Opinion on the Operation of Glen Canyon Dam (2009 Supplement; U.S. Fish and Wildlife Service 2009) and the 2010 Reissuance of the Incidental Take Statement on the 2009 Supplemental Biological Opinion on the Operation of Glen Canyon Dam 2008-2012 (2010 ITS; U.S. Fish and Wildlife Service 2010a).

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 develop further scientific information regarding native and non-native fishes in the Colorado River and take actions to help conserve the endangered humpback chub by controlling numbers of rainbow trout, brown trout, and other non-native fishes, if necessary. 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. A Science Plan to evaluate the proposed action, including a strategy for long-term application and monitoring, is included as an Appendix to this EA (Appendix B).

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. In any one year, 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. Removal in the vicinity of the Little Colorado River would only be conducted if monitoring and modeling data indicate that a trigger has been reached as defined in the 2011 USFWS Final Biological Opinion on the Operation of Glen Canyon Dam including High Flow Experiments and Non-Native Fish Control (2011 Opinion; U.S. Fish and

Wildlife Service 2011). In this way, fish would only be removed if there is a clear necessity to do so (triggers are reached). Fish would also be removed alive and stocked into other waters to satisfy tribal concerns, or, and only if live removal fails, fish removed would be euthanized for other beneficial use. 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. 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 develop further scientific information regarding native and non-native fishes in the Colorado River and take actions 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: Research and Monitoring Plan in Support of the Environmental Assessment Non-Native Fish Control Downstream from Glen Canyon Dam; Appendix C: Biological Assessment for Non-native Fish Control Downstream from Glen Canyon Dam; Appendix D: Supplement to Biological Assessments for Development and Implementation of a Protocol for High-Flow Experimental Releases and Non-native Fish Control Downstream from Glen Canyon Dam, Arizona, 2011 through 2020; Appendix E: Final Biological Opinion on the Operation of Glen Canyon Dam including High Flow Experiments and Non-Native Fish Control.

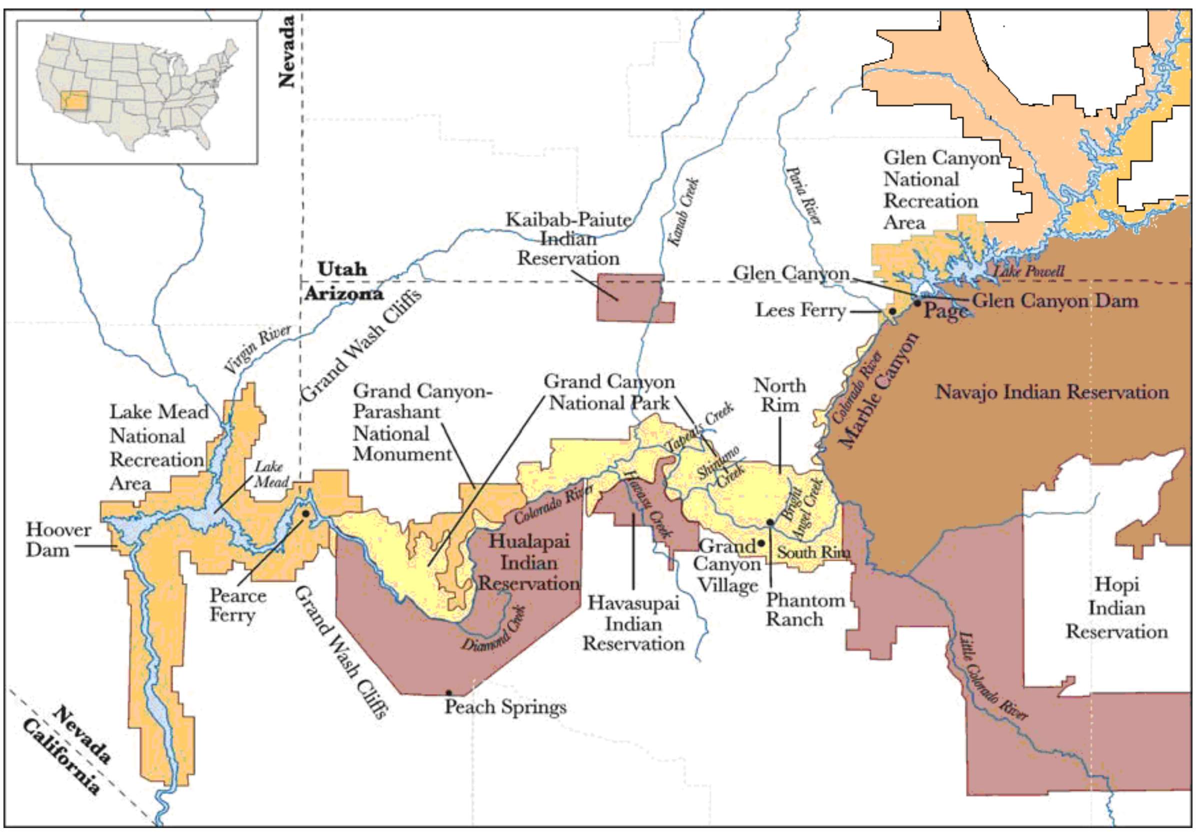


Figure 1. Map of the region that includes the Action Area (courtesy of the U.S. Geological Survey).

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 gain additional scientific information and to reduce the negative impacts of competition and predation by non-native fish on the endangered humpback chub (*Gila cypha*) and its critical habitat in the Grand Canyon. The need for this action is to add to scientific information as part of an adaptive management program and to continue to fulfill the conservation measures and terms and conditions identified in 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 extend to 2020. Starting the action promptly 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) through 2020, described in other sections of this document; as well as the need to address a number of cultural and socioeconomic concerns and issues that are further described in other sections of this EA. 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 implementing a High Flow Experiment Protocol, a separate but related action being evaluated in a separate 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 fish, trout species in particular, 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

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

methods, but only if monitoring and modeling data indicate that a trigger has been reached as defined in the 2011 U.S. Fish and Wildlife Service Final Biological Opinion on the Operation of Glen Canyon Dam including High Flow Experiments and Non-Native Fish Control (U.S. Fish and Wildlife Service 2011). 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 identified through continued tribal consultation. As detailed above, 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 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 Final Environmental Impact Statement (Reclamation 2007), the 2007 Record of Decision (ROD; U.S. Department of the Interior 2007), and the 2007 Final Biological Opinion for the Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mean (2007 Interim Guidelines 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. Annual[2] releases would continue in accordance with prior decisions, including the 2007 Colorado River Interim Guidelines, and including steady flows as identified in the U.S. Fish and Wildlife Service (USFWS) 2008 Final Biological Opinion on the Operation of Glen Canyon Dam (2008 Opinion; U.S. Fish and Wildlife Service 2008) and the USFWS 2009 Supplement to the 2008 Final Biological Opinion on the Operation of Glen Canyon Dam (2009 Supplement; U.S. Fish and Wildlife Service 2009).

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

HFEs may also be implemented during the 10-year period of the proposed action as defined in the Development and Implementation of a Protocol for High-Flow Experimental Releases from Glen Canyon Dam, Arizona, 2011 through 2020 Environmental Assessment (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 1 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 2007 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 volumes as necessary for the following December through February period, or May through August period, respectively while ensuring that the annual volume is not affected, nor are water deliveries under the 2007 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 (this is explained in more detail in Appendix C).

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).

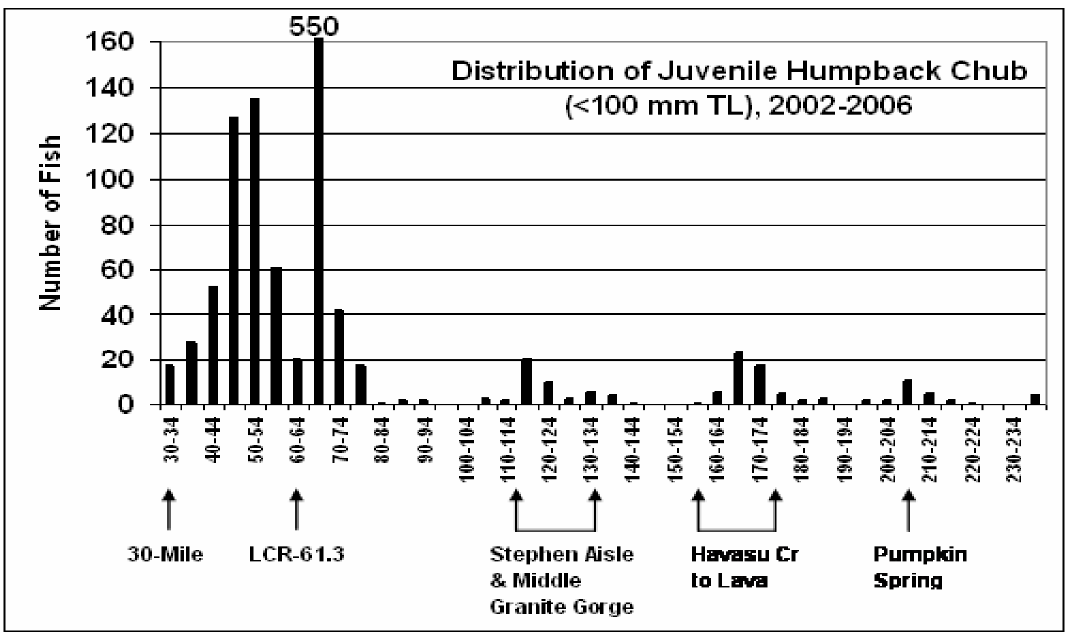


Figure 2. Distribution of juvenile humpback chub<100 mm TL caught during 2002-2006 by 5-mile increments from RM 30 to RM 240. Principal humpback chub aggregations are indicated (data from Ackerman 2008).

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 2008 Opinion (U.S. Fish and Wildlife Service 2008), the 2009 Supplement (U.S. Fish and Wildlife Service 2009), and the 2010 Reissuance of the Incidental Take Statement on the 2009 Supplemental Biological Opinion on the Operation of Glen Canyon Dam 2008-2012 (2010 ITS; U.S. Fish and Wildlife Service 2010a). 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 Interim Guidelines Opinion (U.S. Fish and Wildlife Service 2007). A fourth biological opinion on the cancellation of non-native fish removal trips in 2010, Reinitiation of the 2009 Biological Opinion on the Continued Operations of Glen Canyon Dam without Mechanical Removal of Nonnative Fish in 2010 from the Colorado River, Grand Canyon, Arizona (2010 Cancellation Opinion; U.S. Fish and Wildlife Service 2010b), 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).

Also, implementation of non-native fish control through the GCDAMP by physical removal is part of the proposed action for the operating biological opinion on Glen Canyon Dam operations, the 2011 USFWS Final Biological Opinion on the Operation of Glen Canyon

[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.

Dam including High Flow Experiments and Non-Native Fish Control (2011 Opinion; U.S. Fish and Wildlife Service 2011). The 2011 Opinion replaced all prior biological opinions on the operation of Glen Canyon Dam, including the 2008 Opinion, 2009 Supplement, 2010 ITS, and 2010 Cancellation Opinion.

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, in Grand Canyon (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, 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), and currently populations of both species are high (S. Vanderkoi, GCMRC, pers. comm., 2011). Also, the Grand Canyon population of humpback chub began to improve under the MLFF and prior to many actions and changes in the ecosystem, including removal of non-native fish and warmer river temperatures, beginning approximately in the late 1990s (Coggins and Walters 2009; 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 as an experiment from 2003 to 2006 (see Section 1.9; Coggins et al. 2011; Yard et al. 2011). During this time, a removal and related mitigation program was implemented in the mainstem Colorado River at the Little Colorado River 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, NPS, 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). One removal trip was also conducted in 2009, which prompted concerns from various tribes and ultimately led to preparation of this EA.

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. The Assistant Secretary 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 NPS, the federal agency responsible for managing natural and cultural resources within GCNRA and GCNP, and the 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 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

[4] Because the two park units are not under exclusive federal jurisdiction, state law applies to the management of fish within their boundaries, but only to the extent that it has not been preempted by federal statute, federal regulation, or lawful federal administrative action. In accordance with 43 C.F.R part 24, the NPS must 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"; 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."

addressing some aspect of non-native fish control (e.g. mechanical 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 (defined further in Appendix A). 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.

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 provide further direction to the Secretary 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 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 by the Secretary of the Interior as the required operating regime for Glen Canyon Dam. 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 (Department of the Interior 1996).

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 Final Biological Opinion on the Operation of Glen Canyon Dam (U.S. Fish and Wildlife Service 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 the 2008 Opinion (U.S. Fish and Wildlife Service 2008), which was subsequently supplemented in 2009 (U.S. Fish and Wildlife Service 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 2007 Colorado River Interim Guidelines (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. There are relatively few actions that cumulatively impact the affected environment because the location of the proposed action is the Colorado River in Glen, Marble, and Grand Canyons, almost entirely in national parks, GCNP and GCNRA.

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 Colorado River Interim Guidelines EIS (Bureau of Reclamation 2007) and the associated 2007 ROD (U.S. Department of the Interior 2007). The 1996 Record of Decision implemented the MLFF to govern releases from Lake Powell at monthly, daily, and hourly increments. The 2007 ROD 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 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 without affecting annual releases from Glen Canyon Dam under the 2007 Colorado River Interim Guidelines.

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 2011). 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 GCNP.

- Minimize the impacts of the recreational trout fishery in the Lees Ferry reach to downstream native fisheries in GCNP.

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 Opinion, the 2009 Supplement, and the operating biological opinion, the 2011 Opinion (U.S. Fish and Wildlife Service 2008, 2009, 2011).

- 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 Bright 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. These efforts are a conservation measure of the 2008 Opinion, the 2009 Supplement, and the 2011 Opinion (U.S. Fish and Wildlife Service 2008, 2009).

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. These changes are 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 unlimited take of all sport fish from Navajo Bridge (RM 4) to Separation Canyon (RM 239.5) including all tributaries within Grand Canyon National Park.

- 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 self-determination 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 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 also 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 subsequent studies indicate that the program was conducted at a time when the trout population was undergoing a natural system-wide decline, and other ecosystem changes, including warmer water temperatures, confounded efforts to evaluate the response of native fishes to the control efforts (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[6] 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

[6] A redd is a fish "nest" where spawning occurs and fertilized eggs are buried.

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. (2011) 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 in trout was more likely due to other factors. Possible causes include a system-wide reduction in flow and increases in water temperature due to drought, changes that could have affected the Lees Ferry rainbow trout population by reducing food base and thus creating less suitable conditions for survival and growth.

One non-native removal trip was also conducted in 2009, which provided important information for consideration of non-native fish 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 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 informed by scientists and federal managers in determining the need for non-native fish control and would be based on the numbers and location of non-native fish in the system, as described in section 2 of this document. 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 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 were afforded an opportunity to comment on the plan through the public review process for the 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. (2011) 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) also reported that the 2008 HFE appears to have contributed to an 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 monitoring and modeling data indicate that a trigger has been reached as defined in the 2011 Opinion (see appendix E, U.S. Fish and Wildlife Service 2011). Reclamation proposes to use this trigger for LCR reach removal because this is consistent with the USFWS biological opinion on this action.

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

- The AZGFD, 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.

The draft EA was published on January 28, 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 was circulated again for a two-week public review and comment period on July 5, 2011 in order to provide the interested public the opportunity to review revisions to the previously published draft EA; this public comment period closed on July 26, 2011. There were 15 public comments received during the second comment period which were fully considered in making revisions to the final EA.

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 the Assistant Secretary of the Interior for Water and Science 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.

The Assistant Secretary 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 effects 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 since 2009:

- 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, 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 participated on a discussion panel 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";

- The Assistant Secretary 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 the Assistant Secretary 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.

- Additional tribal consultation meetings with the Pueblo of Zuni were held on January 25, August 30, and December 13, 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 Water Quality Air Quality Sediment Vegetation Terrestrial Invertebrates and Herptofauna Aquatic Food Base **Fish** • **Humpback chub** • **Razorback sucker** • **Other native fishes** • **Trout** • **Other non-native fishes** • **Fish habitat** Birds Mammals	**Historic Properties** **Traditional Cultural Properties** **Sacred Sites**	Hydropower **Recreation (including Public Safety and Sport Fishing)**

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 also required additional ESA section 7 consultation with the USFWS. A biological assessment was prepared, along with a supplement to that biological assessment. The USFWS also completed a biological opinion, the 2011 Opinion, on this action. These documents are attached to the EA as Appendix C, D, and E, respectively.

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."

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

Reclamation has prepared 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 HFEs 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 is transported downstream by river flows. These sand features and associated backwater habitats may provide key wildlife habitat, may 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 further evaluate the control of non-native fish in the Colorado River downstream from Glen Canyon Dam in conserving native fish in GCNP, and is also needed to 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 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 fish 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 fish 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. Also, non-native fish control would be necessary regardless of whether or not the HFE Protocol were implemented. 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 fish 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 an issue, given the post-2008 trout monitoring results, it is clear that both warm and cold-water non-native fish control actions may 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 abundance 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 (geomorphic protection and enhancement of riparian (sandbar) 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 fish 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 HFE 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." 40 CFR § 1508.25(a)(3). 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 GCDAMP since 1996 with the initiation of the Glen Canyon Dam Adaptive Management Program Long Term Experimental and Management Plan (LTEMP; 76 FR 39435-46, July 6, 2011). 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 developed through the non-native fish control addressed in this EA, as well as 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 was published in the Federal Register on July 5, 2011 (76 FR 39435), and a notice to solicit comments and hold public scoping meetings on the LTEMP was published in the Federal Register on October 17, 2011 (76 FR 64104).

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. Such information on the predation and migration patterns of non-native fish would not be available absent implementation of the non-native fish control actions described herein. 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, the Kaibab Band of Paiute Indians, Paiute Indian Tribe of Utah, the Hualapai Tribe, and the Zuni Tribe) 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 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 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 (Yard et al. 2011, Coggins et al 2011). 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; Coggins et al. 2011). 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 although there is compelling evidence that rainbow trout can consume large numbers of young humpback chub, a causal link between non-native trout predation on humpback chub and adult abundance of humpback chub has not been established (Yard et al. 2011).

This issue was considered in 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 rainbow trout eggs and young ("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. 2011), 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 an 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.

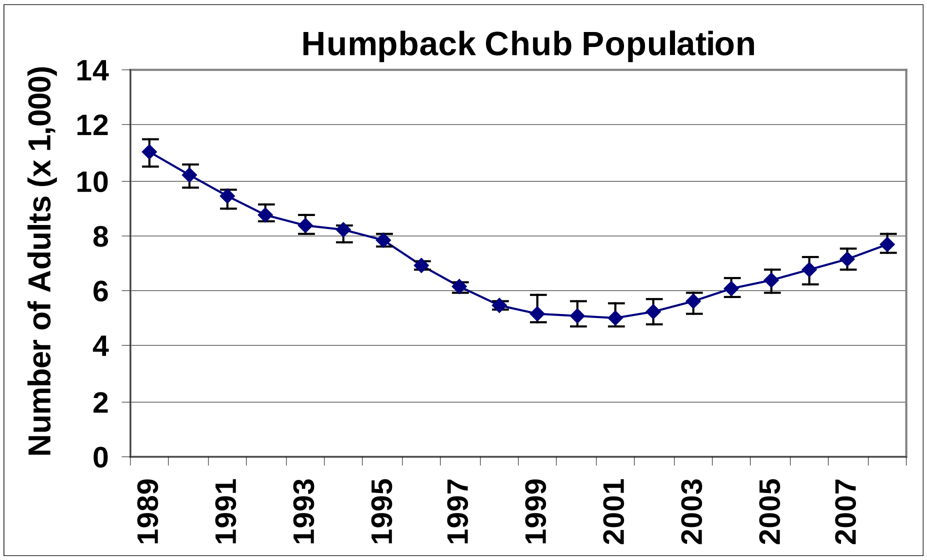
There are a number of other alternative means, including many that have not been tested in this system but have worked in other regulated rivers when applied appropriately. One mechanism that has been tested in the action area and may be effective at controlling non-native fish involves manipulating 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, but also had adverse effects 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.

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.



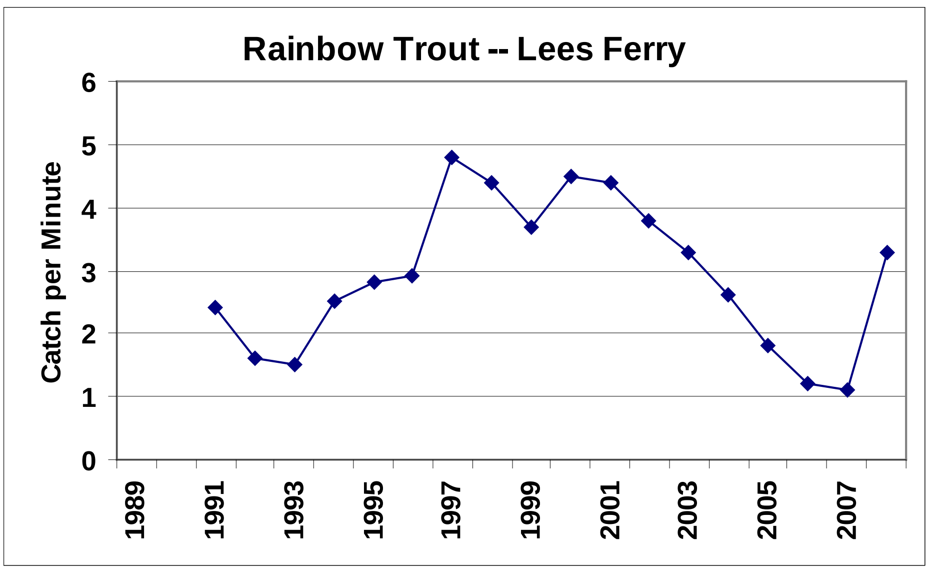


Figure 3. (Top) Annual population estimates of adult humpback chub (age 4+) with an age-structured mark-recapture (ASMR) model, 1989-2008 (Coggins and Walters 2009) (Bottom) Average annual catch rates of rainbow trout in the Lees Ferry reach, 1991-2008 (Makinster et al. 2010)

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 in any one year, and up to 6 LCR reach trips in any one year; LCR reach removal would only occur if monitoring and modeling data indicate that a trigger has been reached as defined in the 2011 Opinion (U.S. Fish and Wildlife Service 2011). 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.

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.

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 Project 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.

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 is part of the proposed action for the operating biological opinion on Glen Canyon Dam operations, the 2011 Opinion (U.S. Fish and Wildlife Service 2011).

Alternatives must also 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 the LTEMP EIS (76 FR 39435-46, July 6, 2011). A number of elements of the GDCAMP, including dam operations, will be fully reviewed and evaluated and accordingly may change when the LTEMP EIS process is completed.

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 2007 Colorado River Interim Guidelines and 1996 and 2007 RODs. Under the current operations, 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 Colorado River Interim Guidelines Opinion and the 2008 Opinion, the 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, and 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. 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 is part of the proposed action for the operating biological opinion on Glen Canyon Dam operations, the 2011 Opinion (U.S. Fish and Wildlife Service 2011).

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 conduct research, monitoring and actions 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 may benefit rainbow trout. 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 first year 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 and modeling data indicate that a trigger has been reached as defined in the 2011 Opinion (U.S. Fish and Wildlife

Service 2011). The proposed action would also include continuing research to refine 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.

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, non-native fish would be removed live and stocked into areas that have an approved stocking plan, unless, and only unless, live removal fails, then fish would be euthanized and used for later beneficial use (such as, 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 Bright 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. Reclamation has committed to working with the NPS to continue to fund and expand this effort as a conservation measure of the 2011 Opinion. 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 be 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 to four 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. Monitoring of mainstem fishes would be conducted by using non-lethal electrofishing periodically in Glen, Marble and Grand canyons. Monitoring may be modified through adaptive management over the life of the proposed action. Removal would be conducted based on monitoring information. 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. This will be the first of multiple reviews of this proposed action to occur periodically over the life of the proposed action.

As described earlier, Reclamation and the NPS are currently engaged in the development of the LTEMP and the LTEMP EIS. 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 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.

2.2.1 *Other Flow and Non-Flow Actions*

Reclamation would also, as part of the proposed action, begin a two-year process with stakeholder involvement to develop other non-native fish control 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. Earlier implementation of elements similar to those in the proposed action were initiated in 2002-2003 as an experiment to test the benefits of non-native fish control to native fish in Grand Canyon. Later beginning in 2008, such actions were included as conservation measures of a USFWS biological opinion. The proposed action has also now been considered by USFWS and a new biological opinion on the proposed action, along with the implementation of the HFE Protocol and the MLFF, is attached as Appendix E (U.S. Fish and Wildlife Service 2011). This new biological opinion includes a number of conservation measures that are related to the proposed action in terms of mitigation. These include: Re-evaluation points, or periodic reviews with the USFWS and other stakeholders to evaluate the effectiveness of the proposed action; Humpback Chub Nearshore Ecology Study, through the Natal Origins Study, Reclamation will, through the GCDAMP, continue research efforts on nearshore habitat use of young humpback chub in the LCR reach; Humpback Chub Refuge, Reclamation will continue to assist FWS in maintenance of a humpback chub refuge population at a federal hatchery; Humpback Chub Monitoring and Mainstem Aggregation Monitoring, Reclamation will, through the GCDAMP, continue to conduct annual monitoring of humpback chub including the eight mainstem aggregations of humpback chub in Marble and Grand Canyon annually and conducting the ASMR on a 3-year schedule; Bright Angel Creek Brown Trout Control, Reclamation will continue to fund efforts of the NPS to remove brown trout from Bright Angel Creek and will work with GCMRC and NPS to expand this effort to be more effective at controlling brown trout in Grand Canyon; High Flow Experiment Assessments, Reclamation will conduct pre- and post-HFE assessments of existing data on humpback chub status and other factors to both determine if a HFE should be conducted and to inform decisions to conduct future HFEs; Dexter National Fish Hatchery Genetic Study, Reclamation will fund an investigation of the genetic structure of the humpback chub refuge housed at the Dexter National Fish Hatchery and Technology Center; Kanab ambersnail (*Oxyloma kanabensis haydenii*), Reclamation will continue, through the GCDAMP, to monitor the population on a periodic basis to assess the health of the population over the life of the proposed action; Conservation of Mainstem Aggregations, Reclamation will also, as part of its proposed action, work within its authority through the GCDAMP to ensure that a stable or upward trend of humpback chub mainstem aggregations can be achieved.

The following additional 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 for later beneficial use 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 and additional scientific information regarding information on non-native fish in the Colorado River below Glen Canyon Dam as well as the effectiveness of actions addressing non-native fish control. Every effort will 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 positive, little or no effect and should be continued, modified or 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 primarily 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. 2011); 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. There are relatively few actions that cumulatively impact the affected environment because the location of the proposed action is the Colorado River in Glen, Marble, and Grand Canyons, almost entirely in national parks, GCNP and GCNRA, areas protected and managed for their natural resources and scenic beauty and thus not likely to be subject to many project impacts.

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). Although there is evidence that the humpback chub spawns in other aggregations, 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 the LCR 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.

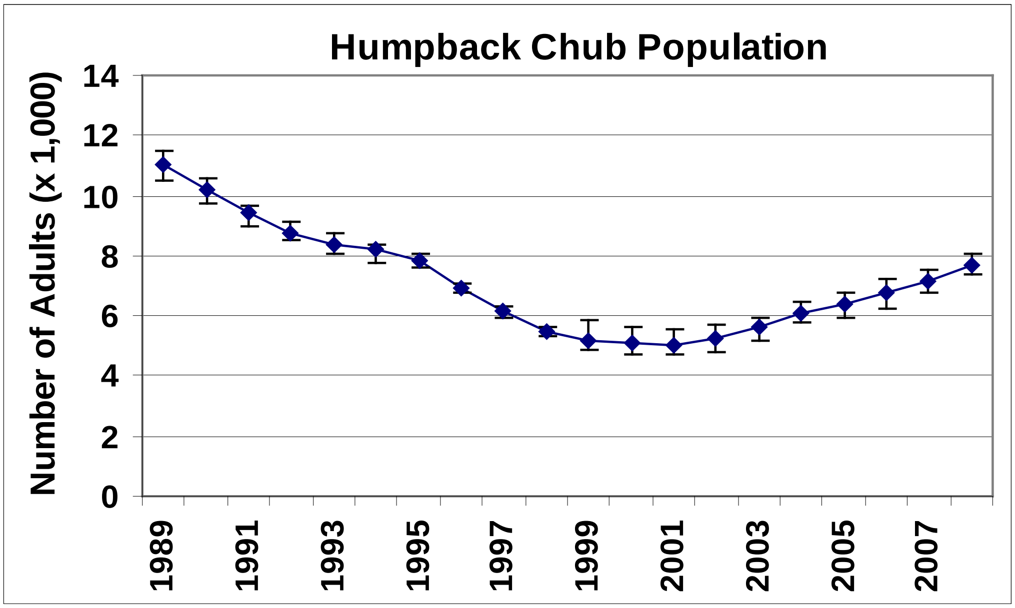


Figure 4. Estimated adult humpback chub abundance (age 4+) from ASMR, incorporating uncertainty in assignment of age. Point estimates are mean values among 1,000 Monte Carlo trials, and error bars represent maximum and minimum 95-percent profile confidence intervals among 1,000 Monte Carlo trials. All runs assume the coefficient of variation of the von Bertalanffy L∞ was CV (L∞) = 0.1 and adult mortality was M∞ = 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 and declines of coldwater salmonids (Ackerman 2008; Andersen 2009). Despite the fact that the warmer water temperatures have somewhat 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).

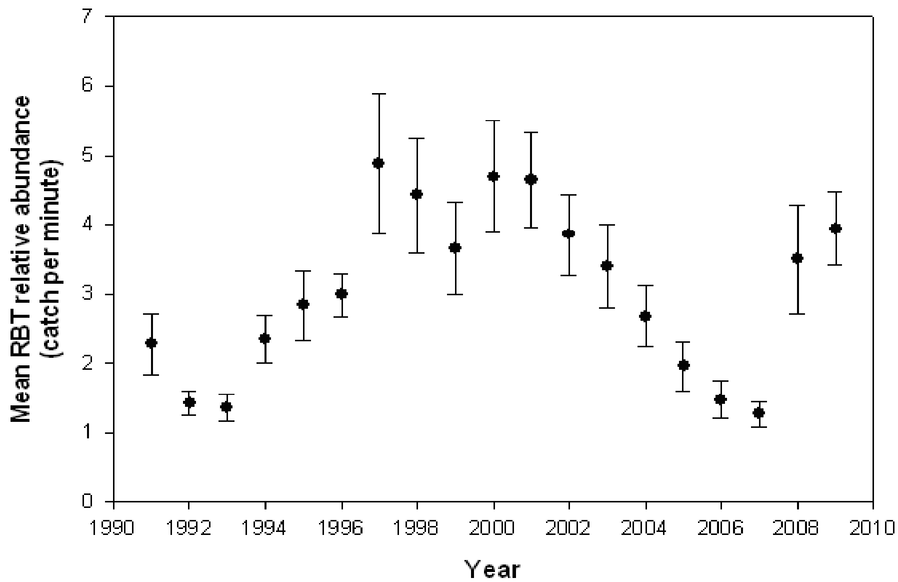


Figure 5. Average annual electrofishing catch rates of rainbow trout in the Lees Ferry reach (Glen Canyon Dam to Lees Ferry) for 1991-2010 (Makinster et al. 2010).

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 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). An even larger increase in trout appears to have occurred in 2011, likely as a result of high steady flow releases under the 2007 Colorado River Interim Guidelines (J. Korman, Ecometric, pers. comm., 2011).

3.2.1.5 Other Non-Native Fishes

Fifteen non-native fish species are currently found in Grand Canyon (Table 2, GCMRC unpublished data; 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 (GCMRC unpublished data), 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 High Flow Experiments on Fishes

Reclamation is developing an the HFE Protocol EA for the purpose of promoting more natural sediment dispersal throughout the Canyon and improving conditions for sediment-derived resources such as camping beaches. The HFE 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 may impact juvenile humpback chub due to the positive effect of HFEs on trout abundance and the negative effect of trout competition and predation on humpback chub and other native fishes. Wright and Kennedy (2011) reported that rainbow trout abundance in the LCR reach increased as a result of the 2008 HFE. 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; 2011) 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; 2011). Korman et al. (2010; 2011) 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; 2011).

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 HFE 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 1-96 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 increase in rainbow trout that apparently resulted from the 2008 spring HFE (Korman et al. 2010, Wright and Kennedy 2011), 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 September and October 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. 2011; Yard et al. 2011). Currently both rainbow trout numbers and humpback chub numbers are high. This suggests that either 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, trout predation ultimately has no effect on the adult humpback chub population, or other factors, such as water temperature or flow volume are also effecting 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. (2011) found that during the 12 removal trips conducted from 2003-2004, 9,326 juvenile 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 survivorship rates of 50-60 percent across 3 years of sampling (2008-2010; S. Vanderkoi, USGS, 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 (2011) 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, there is also evidence 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. 2011). 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.

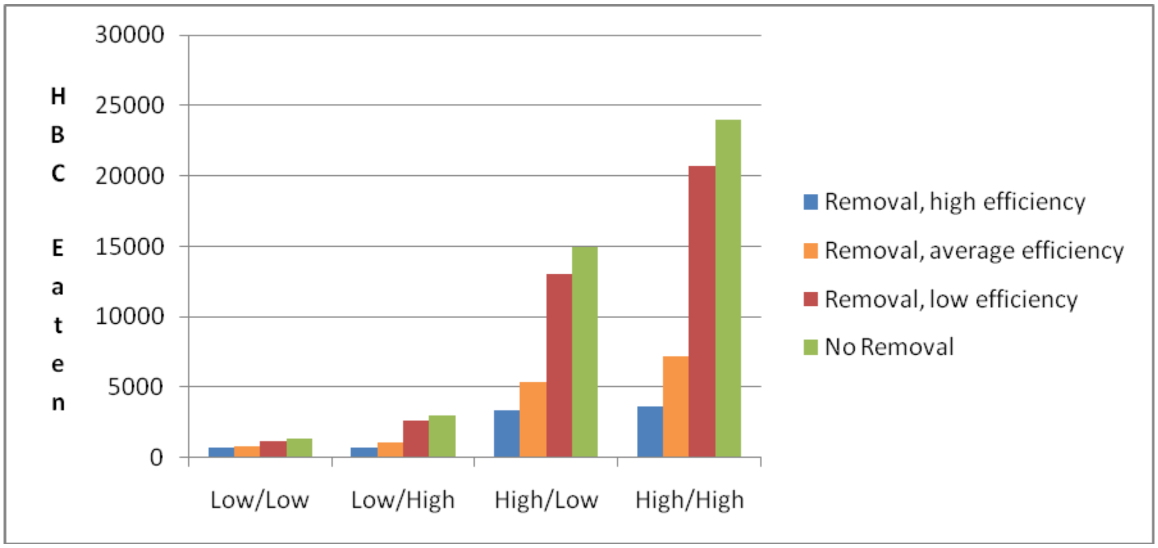


Figure 6. Expected predation of age-0 and subadult humpback chub by trout in the absence of non-native fish removal (green bars) and over a range of removal efficiencies (blue, orange and red bars). X-axis labels refer to assumptions on predator density and piscivory rates. For example, "Low/Low" refers 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 and the 2010 ITS (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.

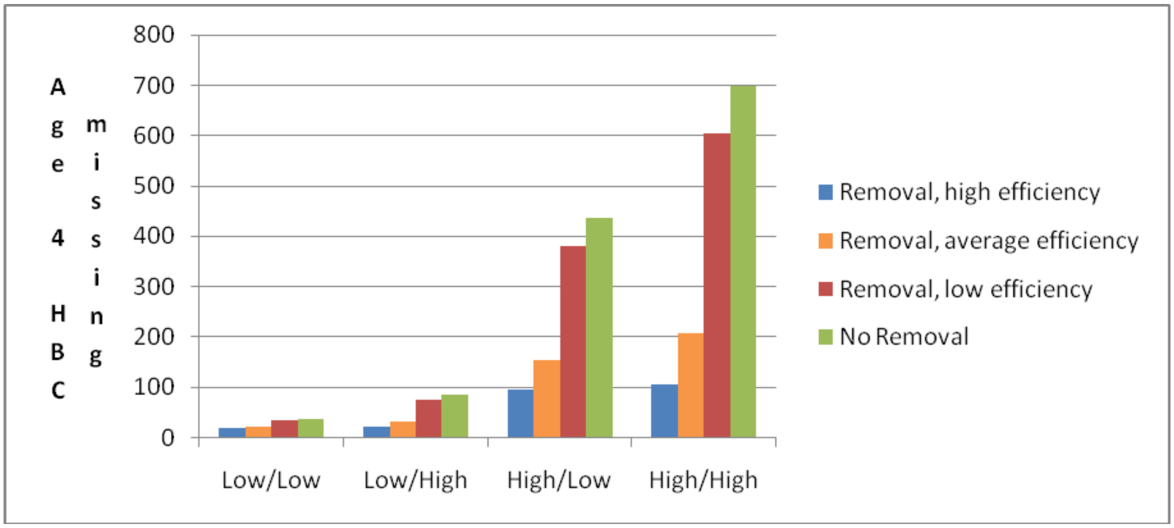


Figure 7. Expected losses of adult humpback chub (age 4+) due to predation by trout in the absence of non-native fish removal (green bars) and over a range of removal efficiencies (blue, orange and red bars, Bureau of Reclamation 2010).

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[7].

[7] 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 if the estimate of the adult humpback chub population dropped below 6,000 fish, using the Age-Structured

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. (2011). 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 Bright 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 of humpback chub translocations.

Other actions that could have a cumulative effect on 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. Also worth considering are various planning documents of the NPS. The CRMP identified the potential of river running activities to adversely affect fishes, primarily from disturbance by recreational boat use, and the fish management plan that NPS is developing could also have direct effects to fishes.

Mark Recapture Model (Coggins and Walters 2009, U.S. Fish and Wildlife Service 2010). This revised ITS was subsequently upheld as in compliance with the ESA by the U.S. District Court.

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* 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 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 B), 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 likely 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, could proliferate to high densities. This effect could potentially be magnified if the HFE Protocol is implemented (Korman et al. 2011). Increases in non-native fish species would lead to increased predation and competition on endangered humpback chub (Yard et al. 2011), resulting in 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 September/October 2011 and 2012, and would also continue in accordance with the 1996 and 2007 RODs and 2007 Colorado River Interim Guidelines. These operations were previously evaluated through prior NEPA compliance, the 1995 EIS and 1996 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 monitoring and modeling data indicate that a trigger has been reached as defined in the 2011 Opinion (U.S. Fish and Wildlife Service 2011).

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 refine 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 would be initiated in the fall in Lees Ferry. Also, three to four downstream monitoring trips in the summer would monitor trout occurrence in Marble Canyon to attempt to detect marked fish from Lees Ferry moving downstream. PBR reach 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 monitoring and modeling data indicate that a trigger has been reached as defined in the 2011 Opinion (U.S. Fish and Wildlife Service 2011). . Removal and research actions in out years would be implemented through adaptive management based on monitoring and research results.

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. This is because removal has never been attempted in this reach. This is why the proposed action also included LCR reach removal in the event the 2011 Opinion trigger is reached. 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.

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 monitoring and modeling data indicate that a trigger has been reached as defined in the 2011 Opinion (U.S. Fish and Wildlife Service 2011). . 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.

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 to 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. Reclamation has also committed to continuing to fund and to help expand this effort as a conservation measure in the 2011 Opinion (U.S. Fish and Wildlife Service 2011)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.

As described in our analysis of no action, other actions that could have a cumulative effect to 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, 2011), as well as NPS implementation of planning documents described in section 1.7.3. 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. Reclamation has committed to continue to support maintenance of this refuge as a conservation measure of the 2011 Opinion (U.S. Fish and Wildlife Service 2011).

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 could still be effects to the 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 PCE 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 which Reclamation will also continue to help fund and implement through the GCDAMP as conservations measures of the 2011 Opinion. 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*

The Grand Canyon of the Colorado is significant for its human history and its ongoing role in the lives and traditions of American Indians of the Colorado Plateau. Cultural resources include historic properties which are defined 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.

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, Hualapai 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, Hualapai 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. The Navajo Nation has indicated that they believe conservation of the humpback chub, including non-native fish control, is essential.

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).

The APE includes two historic districts, one a National Register listed district at Lees Ferry in GCNRA; the other an historic district in GCNP that has been determined eligible to the Register through consensus. Appendix F is the consultation letter with the Arizona State Historic Preservation Officer. Identical letters were sent to other consulting parties.

Application of the criteria of effect and the NPS's policies in National Register Bulletin 15 resulted 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. The Arizona State Historic Preservation Office concurred with Reclamation's determination of eligibility and effect on July 28, 2011.

Consultation to complete a Memorandum of Agreement to resolve adverse effects is underway in accordance with 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.[8] Most of the whitewater boating trips through the Grand Canyon launch from

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

Lees Ferry. Many hiking, fishing, day-use boating, and some camping trips also take place in this reach of the Colorado River.

The AGFD 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).

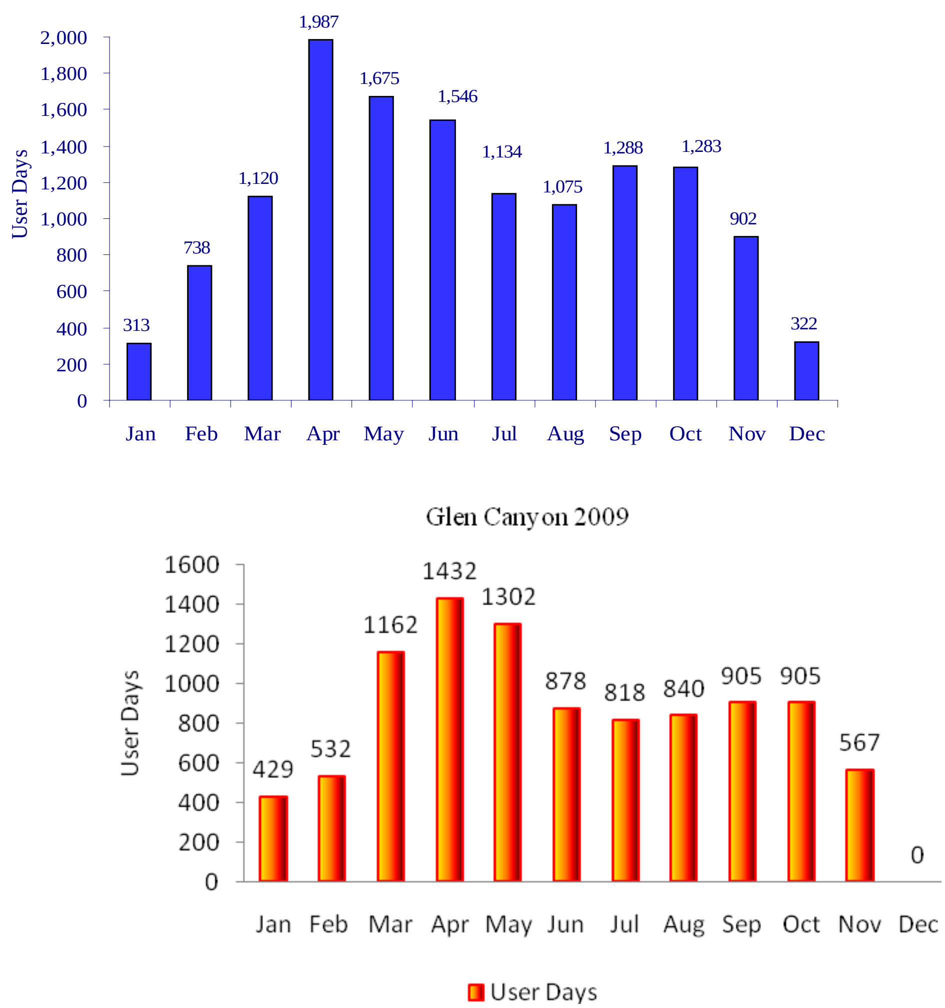


Figure 8. Fishing user days by month in the Lees Ferry reach for 2006 (top) and 2009 (bottom).

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.

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 rafting. No control actions would be implemented.

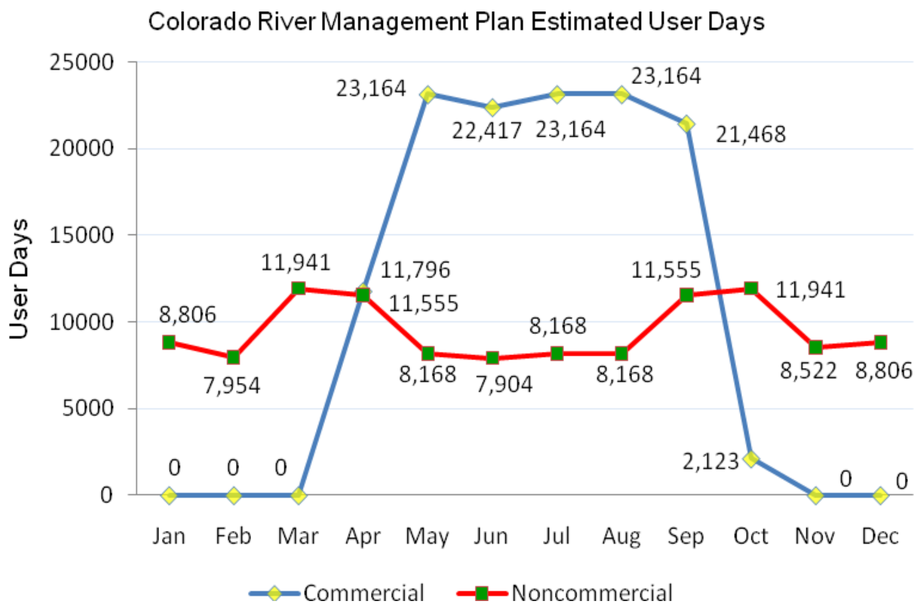


Figure 9. Recreational boating in the Grand Canyon, annual use by month (National Park Service 2006c).

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).[9] 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.[10]

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.

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

[9] 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.

[10] 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.

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). Although the NPS is currently in the process of a new study of nonuse values for the park units along the Colorado River, which will likely update some of the findings of the 1995 study, this study was not completed for use at the time of this EA.

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 could be beneficial to the 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.

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. 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. Live removal in either reach will necessitate more boats and equipment use than would euthanizing fishes, and more activity of boats moving up and down the river, which will add to the disturbance effects described above, and disturbance effects would more noticeable during the non-motor 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 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). But nationwide economic conditions also may have contributed to this decline. 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.

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 and recommended Wilderness designation for approximately 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 be expected to have long-term beneficial effects to wilderness if native fish species are protected.

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 disproportionally 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 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 28, 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 was circulated again for a two-week public review and comment on July 5, 2011 in order to provide the interested public the opportunity to review revisions to the previously published draft EA; this public comment period closed on July 26, 2011. There were 15 public comments received during the second comment period which were fully considered in making revisions to the final 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, aquatic ecosystems, angler use, angler regulations.
Arizona State Historic Preservation Officer	Consult for undertaking, as required by NHPA (16 USC 470).	Concurrence with findings on eligibility and adverse effect under NHPA.
Bodeway-Gap Chapter of the Navajo Nation	Minority community for environmental justice and economic effects.	Data on effects to local economies and tribes.
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.	Data on impacts to local economies.
Hualapai Indian Tribe	Consult regarding land and resource effects, consult with THPO over NHPA.	Information on impacts to cultural resources and local economies.
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.	Information on impacts to cultural resources.
Marble Canyon and Lees Ferry Community	Recreational and economic effects.	Data on impacts to local economies.
National Park Service	Land managing agency for GLCA and GRNP.	Data on visitor use and related impacts in GCNP and GCNRA.
Navajo Nation	Consult regarding land and resource effects, consult with THPO over NHPA. Project might require permits to access land.	Information on impacts to cultural resources and local economies.
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.	Information on impacts to cultural resources.
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.	Information on impacts to cultural resources.
U.S. Geological Survey	Information regarding resources. Figure 1, science plans provided.	Data and analysis on biological, physical, cultural resources.
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, final biological opinion on action.
Western Area Power Administration	Information regarding hydropower and environmental justice.	Data on impacts to hydropower.

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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.

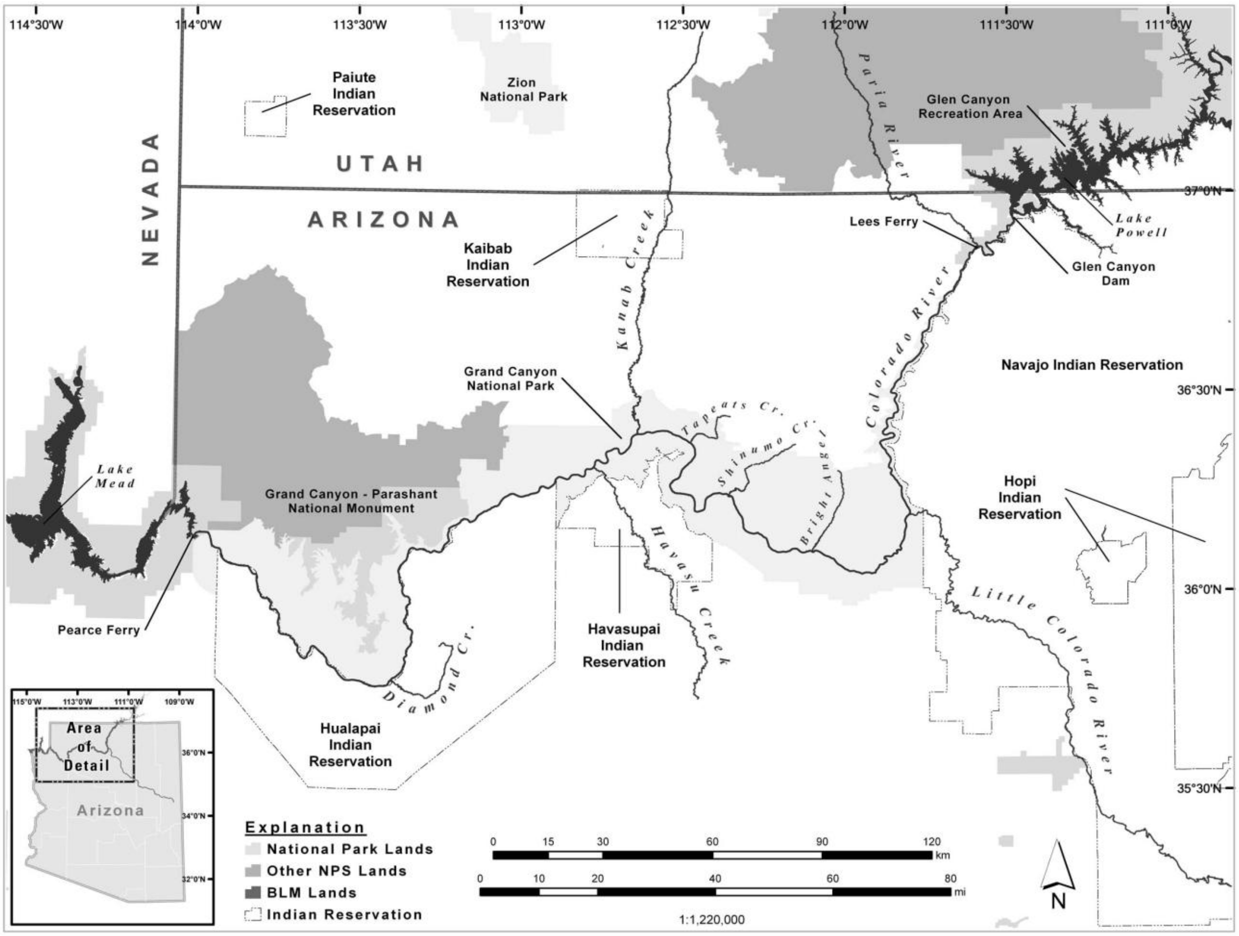

Figure 1. Location map of the Colorado River ecosystem below Glen Canyon Dam, depicting the Glen Canyon Dam Adaptive Management Program project area. The analysis described in this report focuses primarily on the Colorado River from Glen Canyon Dam to Bright Angel Creek. Map credit: Thomas Gushue, U.S.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

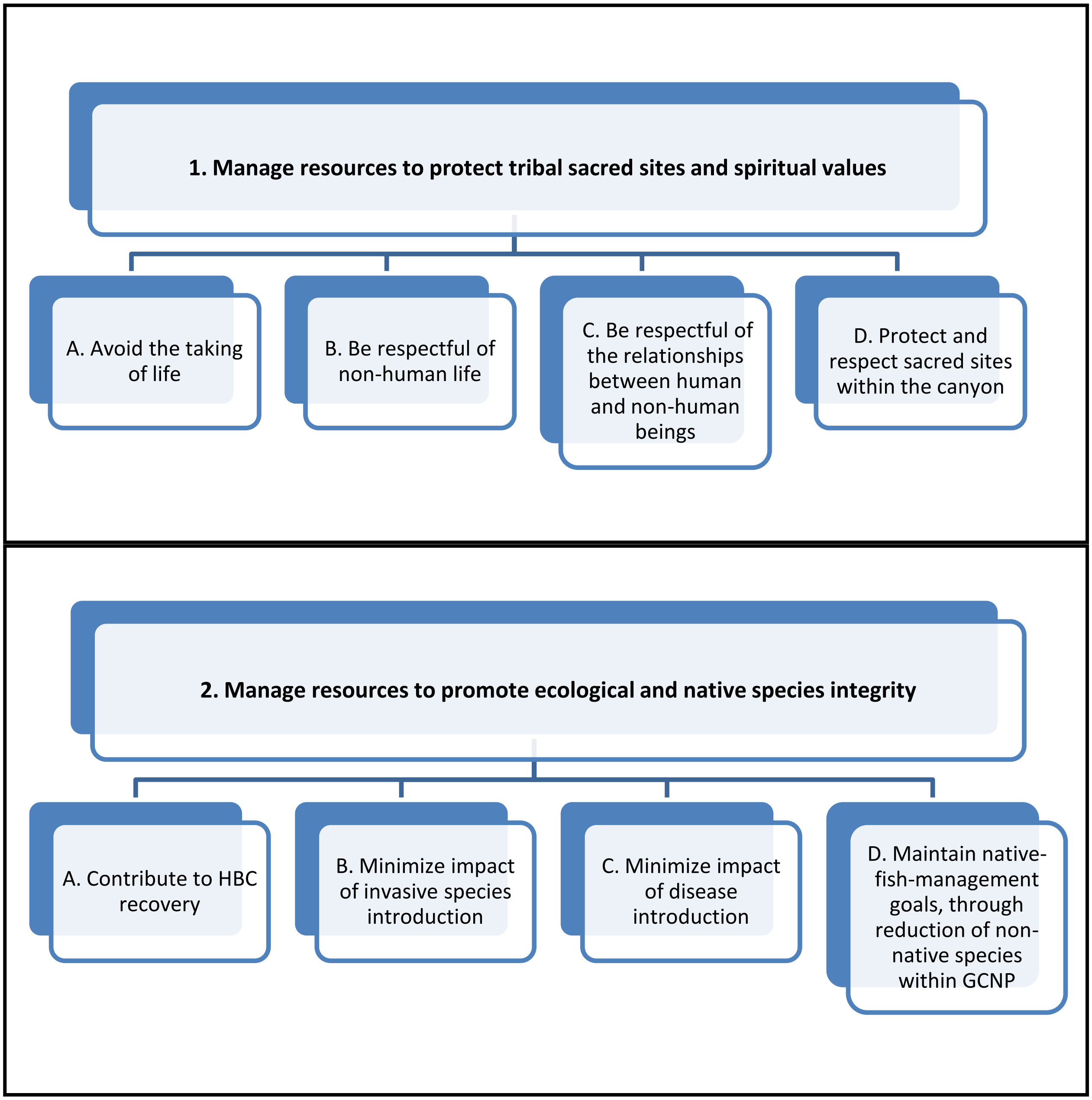

Figure 2. Hierarchy of fundamental objectives for non-native fish control below Glen Canyon Dam. HBC, humpback chub; GCNP, Grand Canyon National Park; GCNRA, Glen Canyon National Recreation Area; Reclamation, Bureau of Reclamation; HFE, high-flow experiment; NHPA, National Historic Preservation Act.

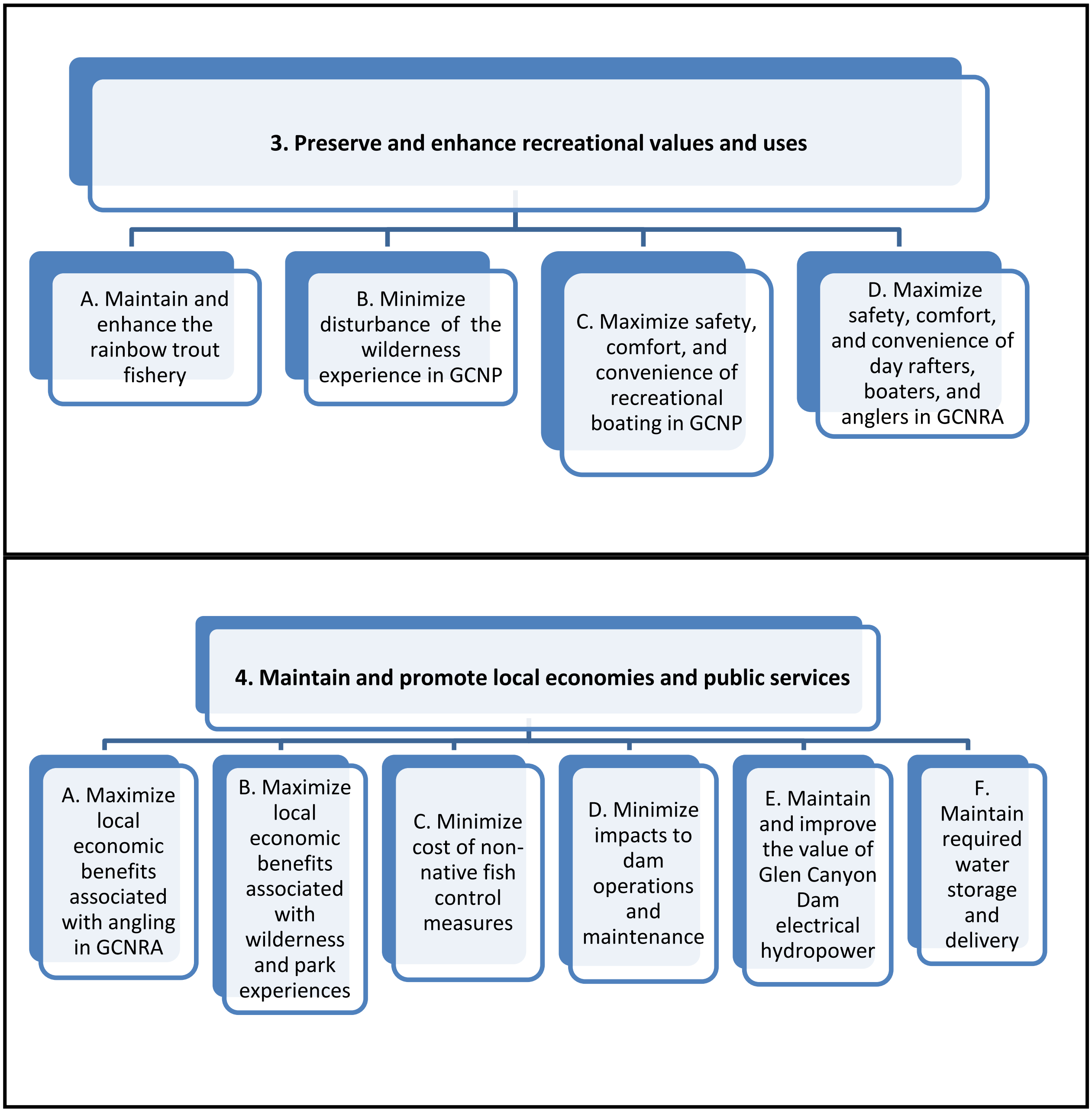

Figure 2. Hierarchy of fundamental objectives for non-native fish control below Glen Canyon Dam.—Continued

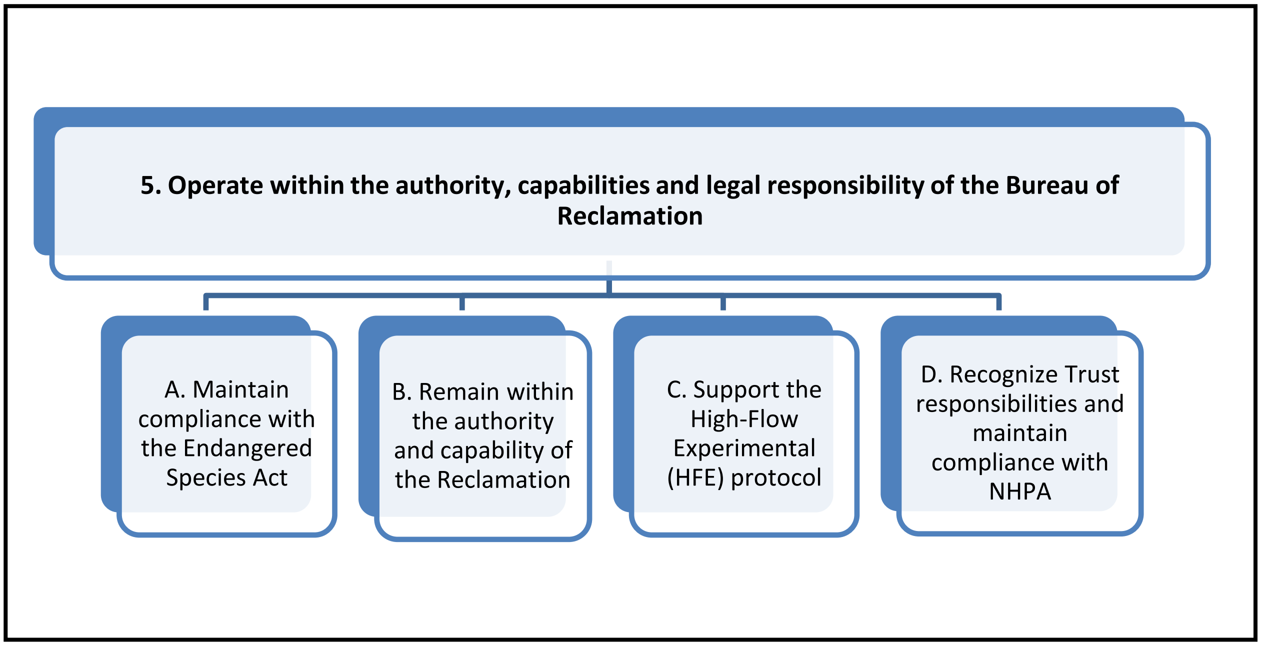

Figure 2. Hierarchy of fundamental objectives for non-native fish control below Glen Canyon Dam.—Continued

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).

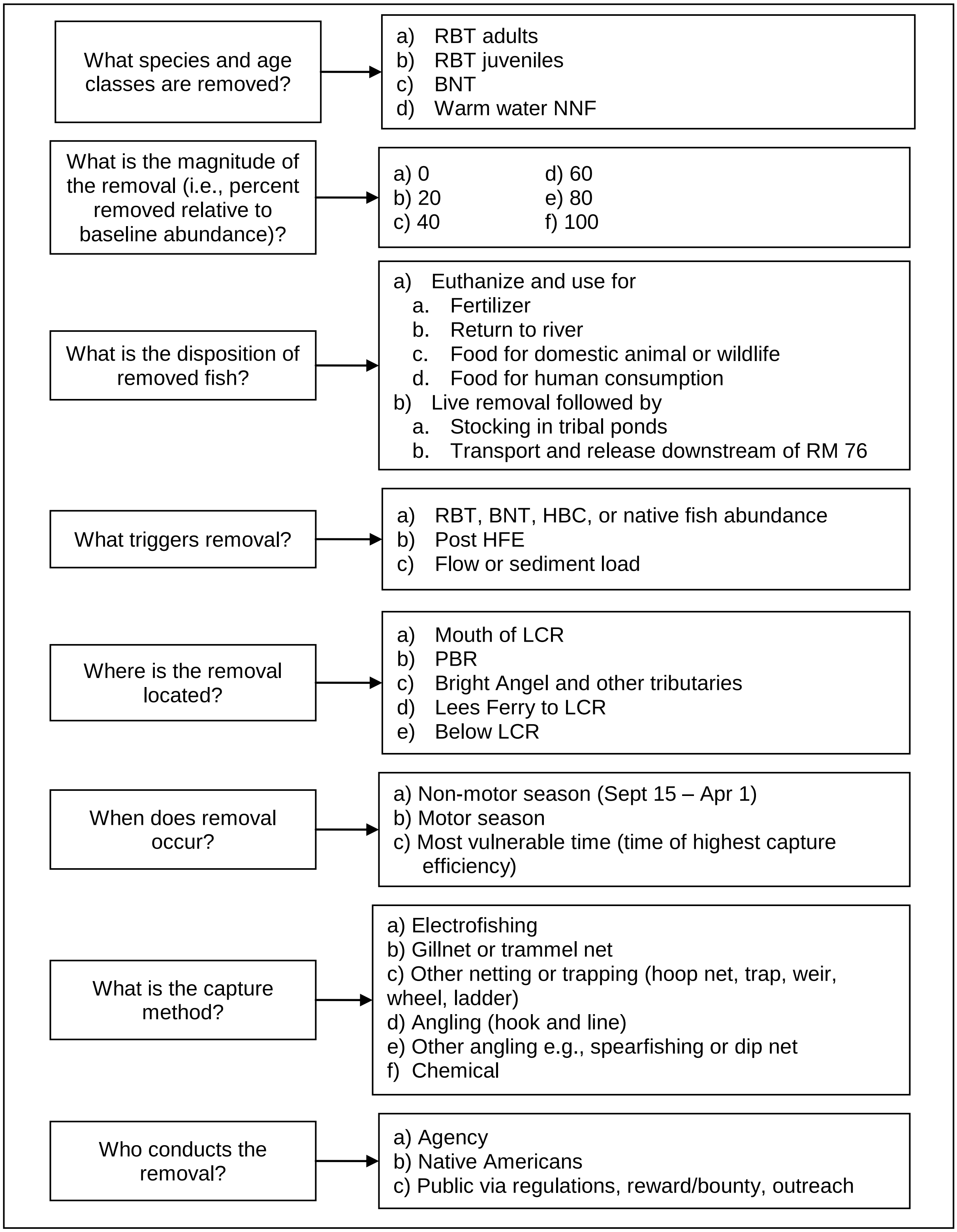

Figure 3. Action elements for alternative control strategies for (A) removal of non-native fish, and (B) suppression of non-native fish or other non-removal actions designed to enhance humpback chub populations in the Colorado River below Glen Canyon Dam.

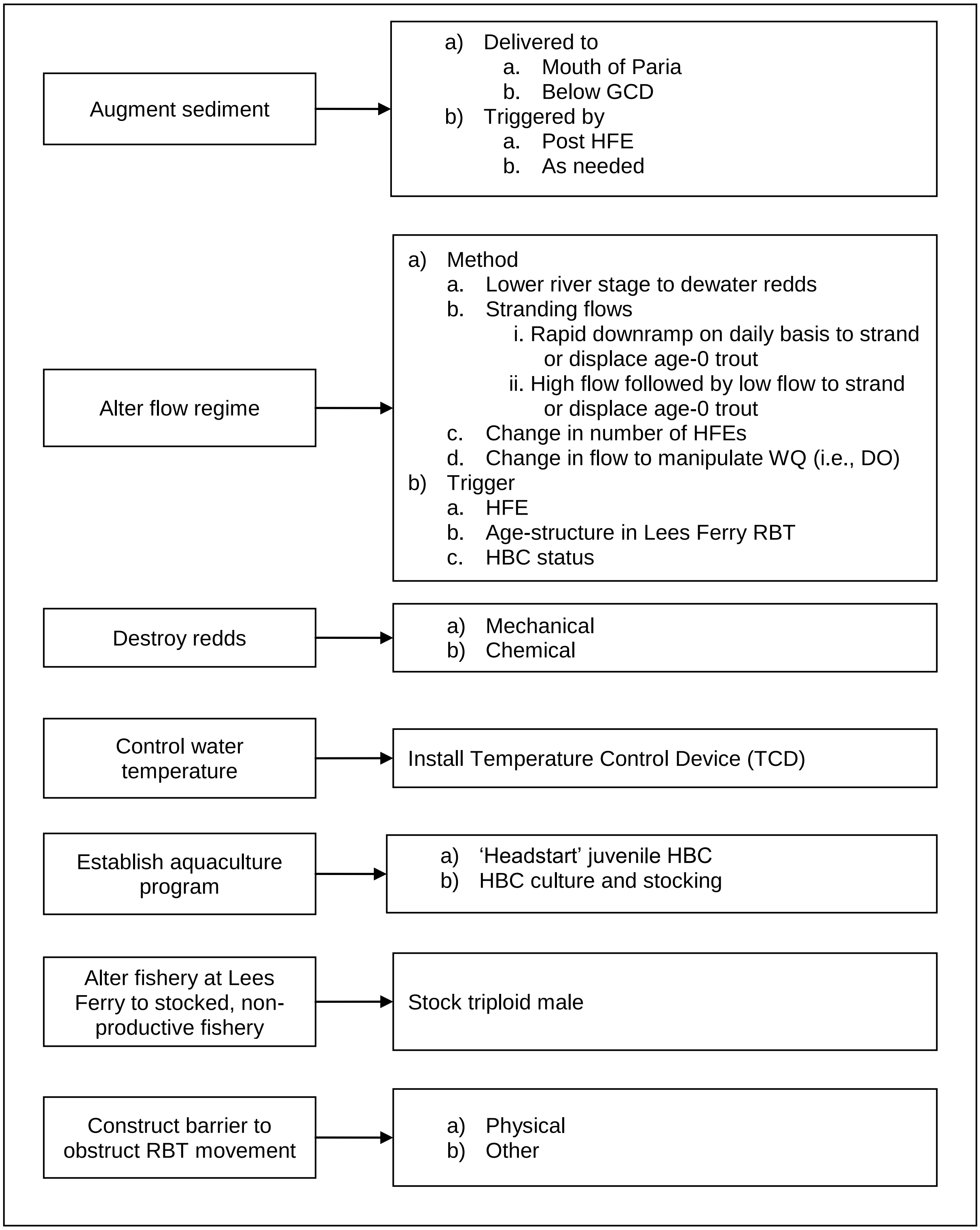

Figure 3. Action elements for alternative control strategies for (A) removal of non-native fish, and (B) suppression of non-native fish or other non-removal actions designed to enhance humpback chub populations in the Colorado River below Glen Canyon Dam.—Continued

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.

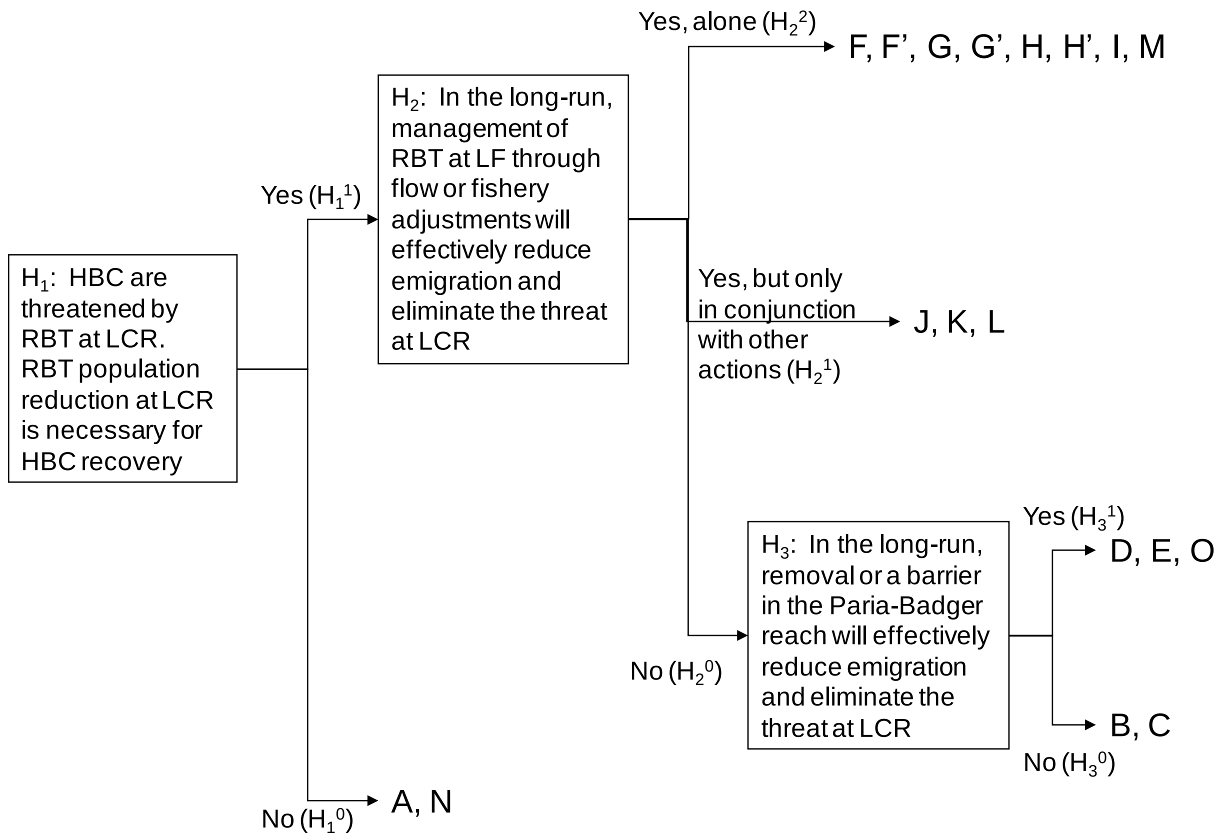

Figure 4. Flowchart showing key uncertainties in predicting the response of rainbow trout and humpback chub populations to management actions. The ends of the flowchart point to the hybrid portfolios (table 3) that are predicated on the series of hypotheses that lead to them. This flowchart is not, however, 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.

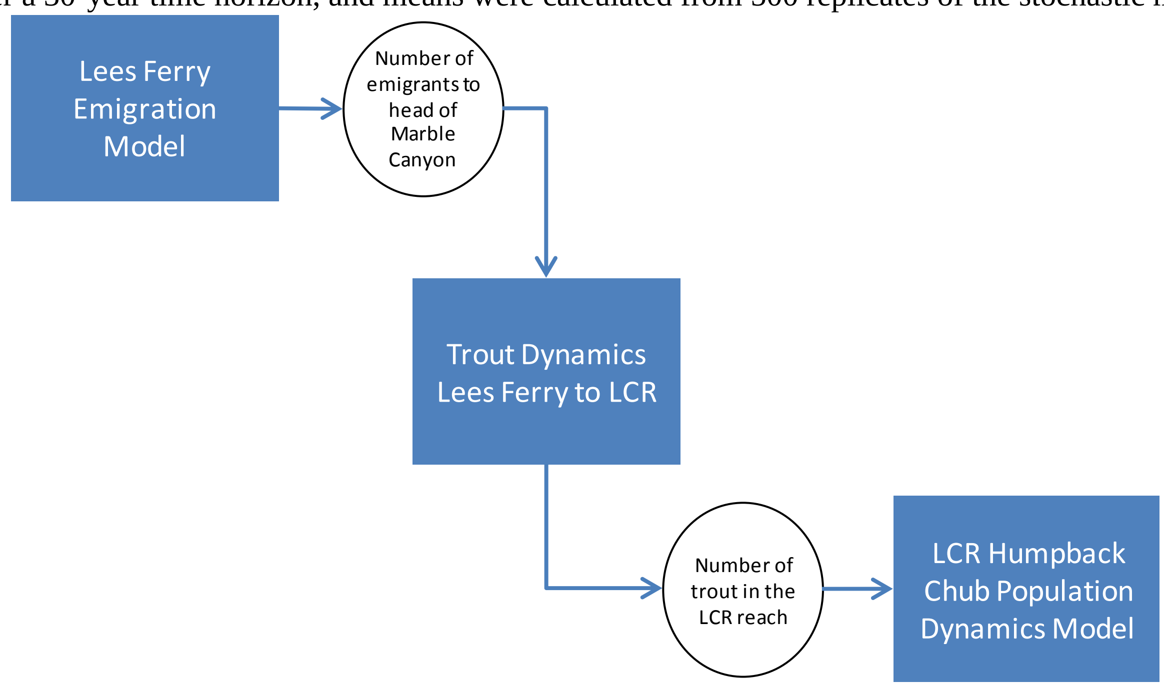

Figure 5. Conceptual model of fish community dynamics in the Colorado River below Glen Canyon Dam (Lew Coggins, Service, written commun., 2010). This provided the basis for a predictive model (Lew Coggins, Service, and Josh Korman, Ecometric Research, Inc., written commun., 2010) to support the decision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

[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).

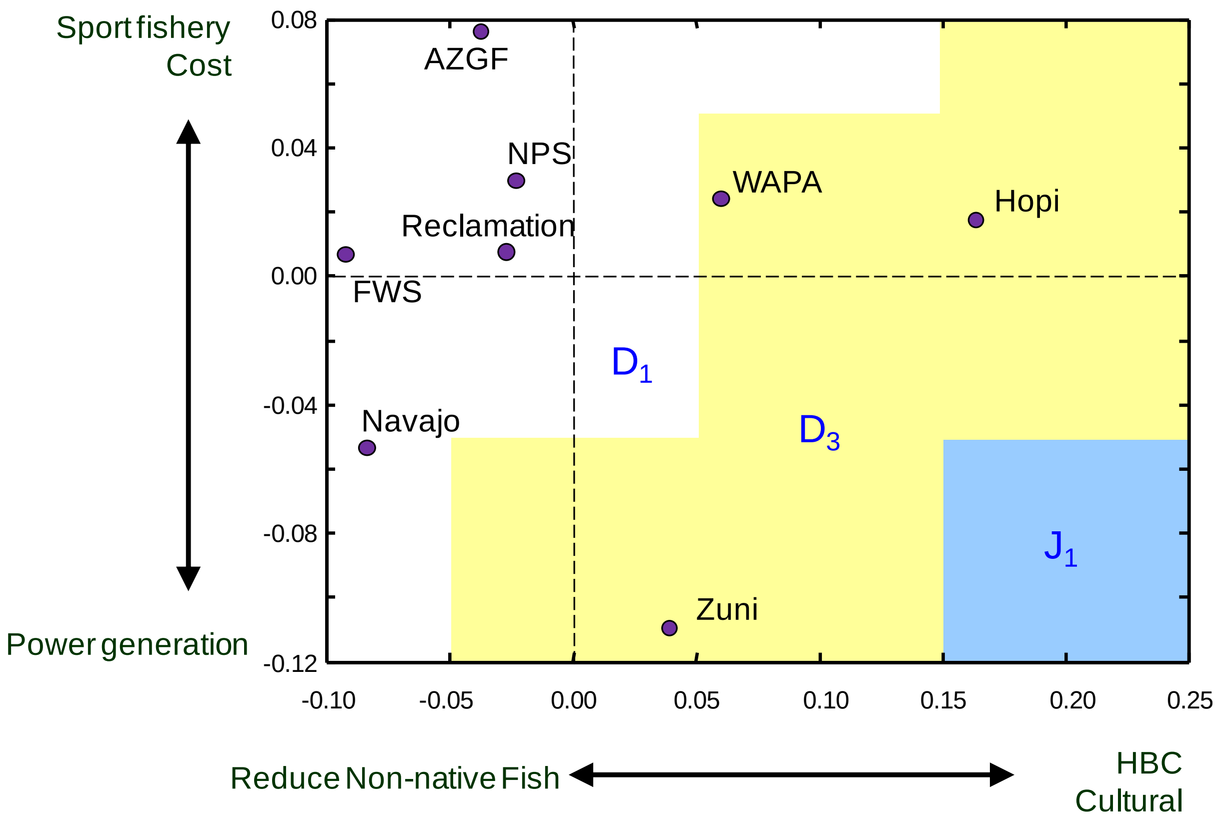

Figure 6. Graph showing principal-components analysis of the objective weights. The first principal component (which explains 47.4 percent of the variation in objective weights across the eight agencies and tribes) is driven positively by the weights on humpback chub recovery (2A) and the cultural objectives (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.

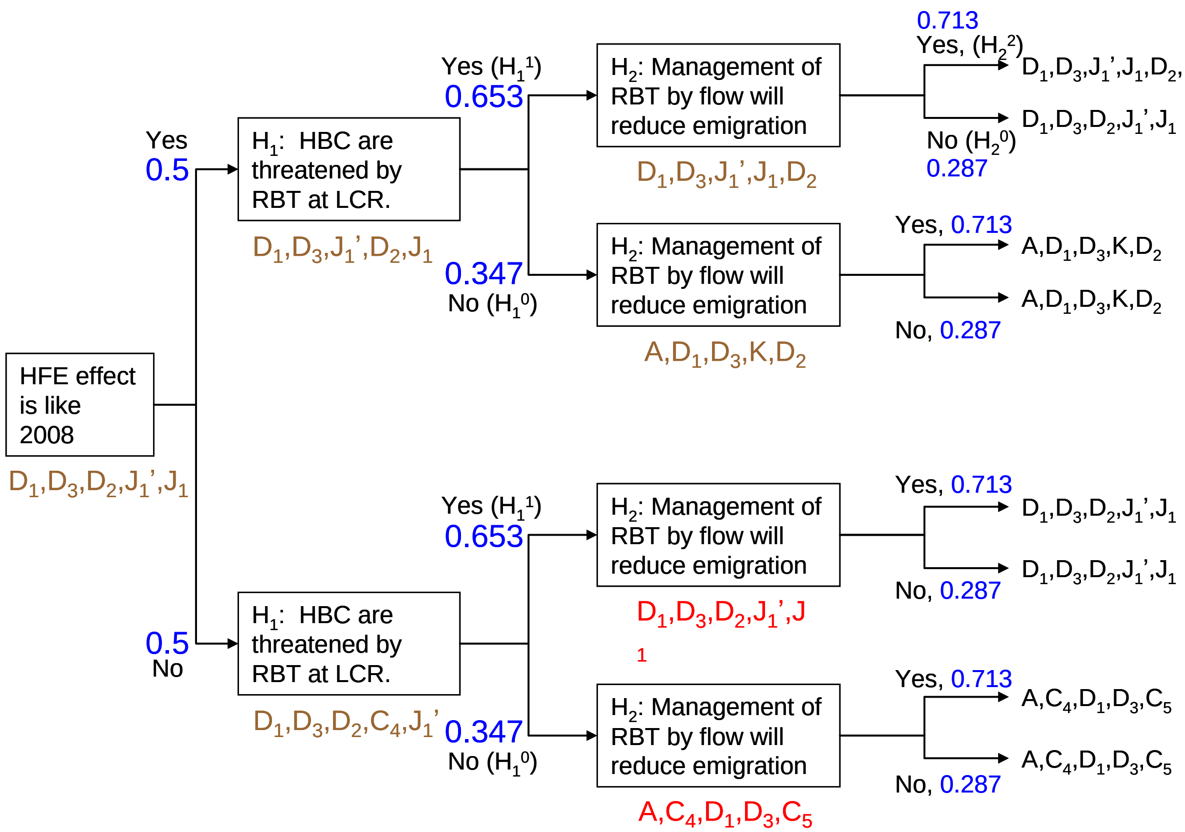

Figure 7. Flowchart showing the preferred alternatives as a function of the underlying hypotheses. The final nodes at the right of the tree show the top-ranked alternatives (in decreasing order) if the uncertainty can be fully resolved on all three hypotheses. For example, if all three hypotheses are 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.

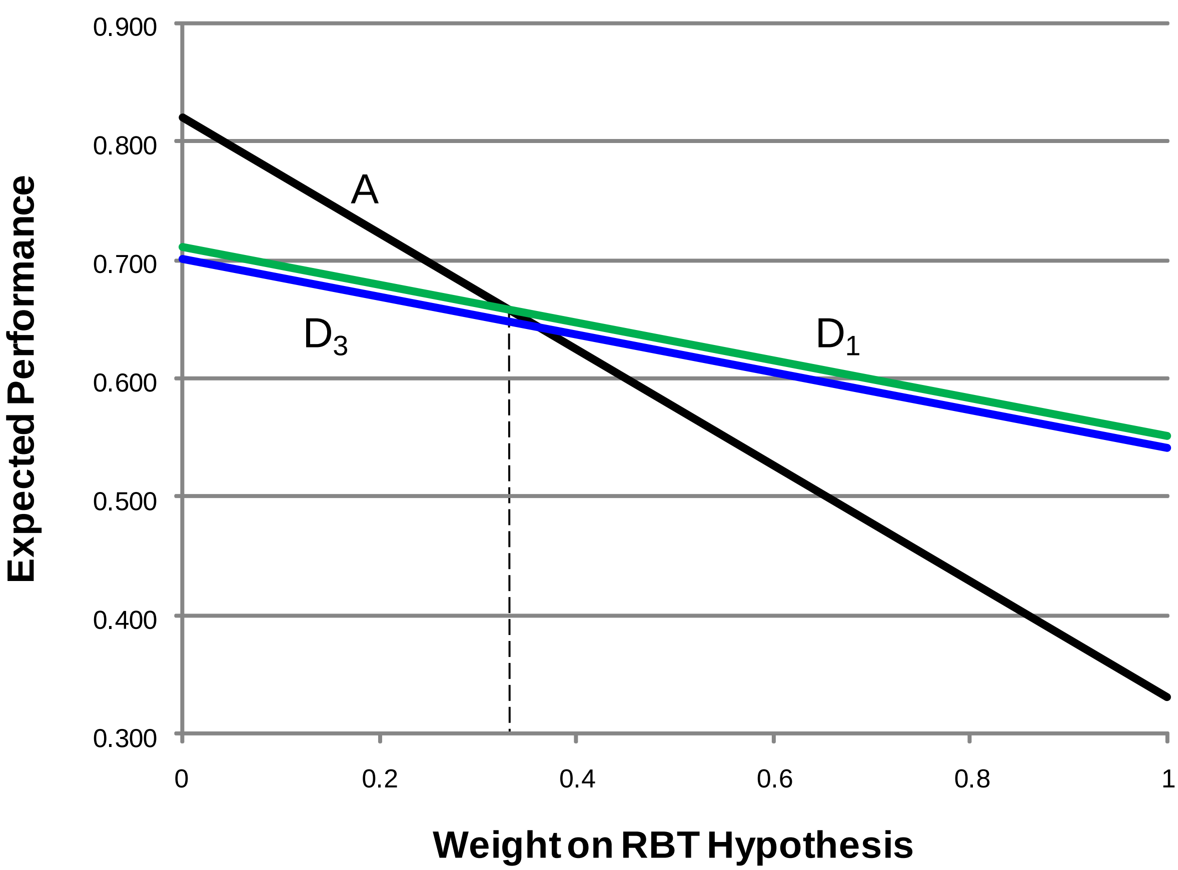

Figure 8. Graph showing expected performance of three hybrid portfolios as a function of the weight on the rainbow trout (RBT) hypothesis. If the weight on the RBT hypothesis is less than 0.33, alternative A (no action) is preferred; otherwise D_1 (removal curtain) is preferred. Note that with the average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

<u>Hybrid Portfolio A:</u> *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.

<u>Hybrid Portfolio B:</u> *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.

<u>Hybrid Portfolios C_1, C_2, C_3, C_4, and C_5:</u> *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

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

December 22, 2011

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

Preface

This research and monitoring plan describes a general framework for evaluating key science questions arising from the **Environmental Assessment for Non-Native Fish Control Downstream from Glen Canyon Dam** (U.S. Department of Interior, Bureau of Reclamation, 2011a). This research and monitoring plan is conceptual and will become more specific as proposed management actions also become more specific. The science activities proposed in this document, and revised in subsequent plans, will also be guided by the information needs of the stakeholders as they identify key management uncertainties surrounding the efficacy of nonnative fish removal to benefit the endangered humpback chub (*Gila cypha*).

Introduction

This science plan has been developed in support of the **Environmental Assessment for Non-Native Fish Control Downstream from Glen Canyon Dam** (hereafter referred to as the NNFC EA). The goal of the proposed action is to minimize the negative effects of nonnative fish on endangered humpback chub (*Gila cypha*) in Grand Canyon. The primary threats imposed by nonnative fish are through competition and predation. The NNFC EA proposes to accomplish this goal by reducing numbers of rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) near the Little Colorado River (LCR) confluence (river mile 61; Figure 1), where humpback chub are most abundant. This goal will be achieved by removal of rainbow trout from the Paria River to Badger Rapid (PBR) reach (river miles 1 to 8; Figure 1), removal of brown trout from Upper Granite Gorge (river miles 83 to 93.5; Figure 1) and Bright Angel Creek (Figure 1), and removal of all nonnative fishes from the LCR reach (river miles 56 to 66; Figure 1). Additionally, management of the trout population in the Lees Ferry reach (river mile -15 to 0; Figure 1) and decreased emigration of these fish further downstream will be accomplished through manipulations of Glen Canyon Dam releases.

Although the proposed action is predicated on documented adverse effects of trout on humpback chub, the significance of those effects at a population level are poorly understood. Thus, key research questions identified in the NNFC EA to be addressed by this science plan focus on quantifying the degree to which humpback chub recruitment and population trends are controlled by nonnative fish, improving understanding of the factors influencing the abundance and distribution of trout in the Colorado River, and identifying the most effective methods of controlling trout populations. This science plan will be implemented through a combination of existing research and monitoring projects and proposed new projects. Given that the proposed action of the NNFC SA will occur over a 10-year period, this research and monitoring plan represents the initial step of an ongoing and evolving science effort.

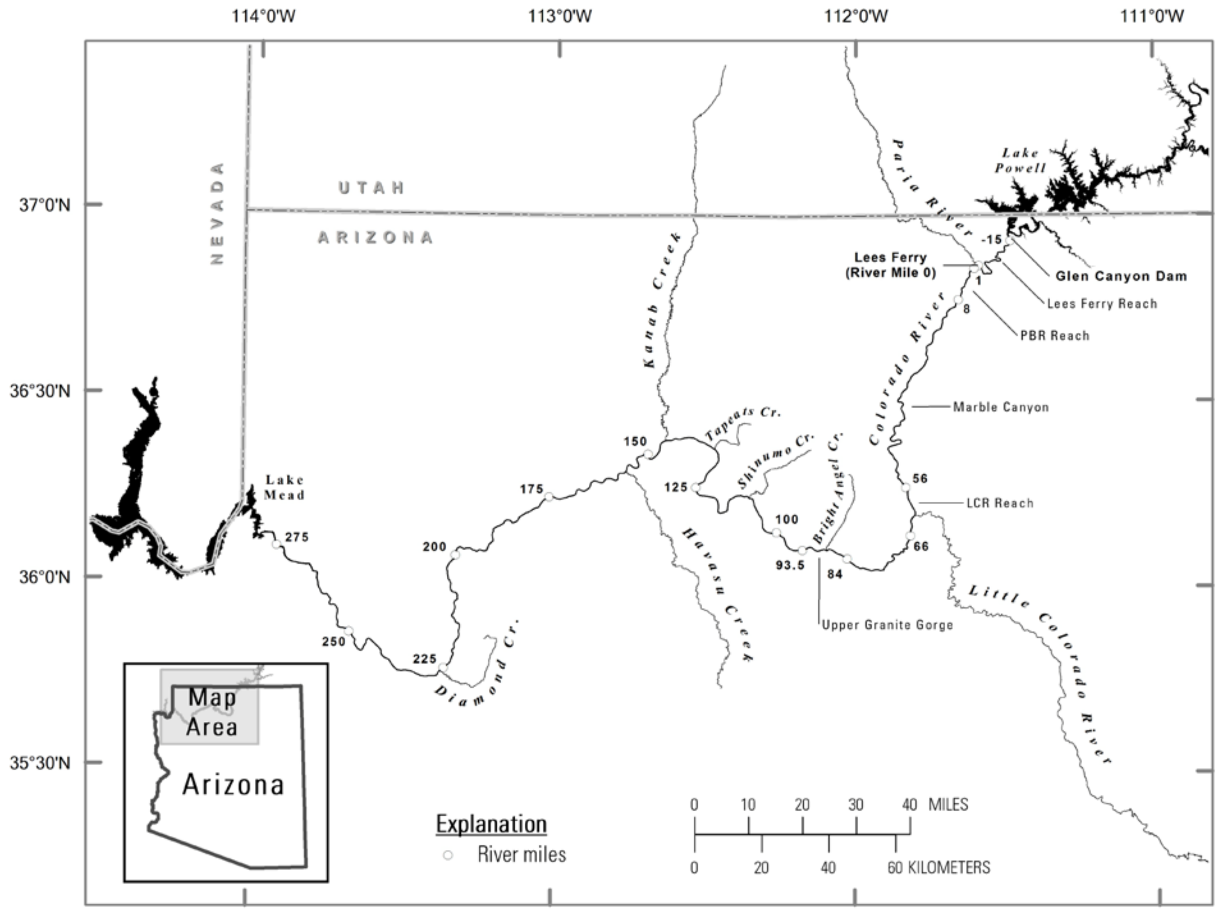

Figure 1. Map of the extent of the study area with river miles identified in 25-mile segments starting at Lees Ferry. The Little Colorado River (LCR) is identified and its confluence is at river mile 61. Key river reaches and associated river miles (RM) are also identified including the Lees Ferry reach (-15 – 0 RM), the Paria River to Badger Rapid (PBR) reach (1 – 8 RM), Marble Canyon (8 – 56 RM), the LCR reach (56 – 66 RM), and Upper Granite Gorge (84 – 93.5 RM).

The nonnative fish control actions described in the NNFC EA are predicated on four fundamental premises. In order of importance, these premises are:

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 Colorado and Little Colorado Rivers;
2. Competition with and/or predation by nonnative fishes, especially rainbow trout and brown trout, significantly limit survival and recruitment of juvenile humpback chub into adult populations in the Colorado River mainstem;
3. Rainbow trout in the LCR reach primarily come from the Lees Ferry reach; brown trout in the LCR reach primarily come from Upper Granite Gorge, mainly from Bright Angel Creek; and
4. Trout abundance in the LCR reach and elsewhere in Grand Canyon, such as near Bright Angel Creek, can be controlled by fish population management activities like removal and flow manipulation.

If all of these premises are correct, then the nonnative fish control actions proposed in the NNFC EA will likely benefit humpback chub populations. However, if the first premise is found to be incorrect, then it negates the relevance of the other premises and the utility of the proposed management actions will be of limited value. For example, if the Colorado River mainstem rearing environment is not contributing significantly to juvenile humpback chub growth, survival, and recruitment, then it is unlikely that any management activity directed at trout removal will have significant positive benefits to humpback chub. On the other hand, if a relatively high proportion of juvenile humpback chub that move or disperse into the mainstem ultimately recruit into the adult population, then trout predation and competition may be limiting humpback chub recruitment in the Colorado River mainstem. Current research and monitoring results (Coggins and others, 2011;Yard and others, 2011; Korman and others, 2011) have identified uncertainty in all of the premises listed above.

Many physical and biological variables vary annually and can have direct effects on humpback chub survival within the LCR. 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 LCR, may also impact the survival of subsequent humpback chub cohorts. In addition, changes in physical attributes of the mainstem Colorado River can also impact survival rates of humpback chub. Changes in mainstem water temperatures impact humpback chub growth rates (Coggins and Pine, 2010) and subsequent swimming ability of native fishes (Ward and others, 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 and others, 2011), and altered mainstem flow regimes may also impact juvenile humpback chub survival. All of these factors can directly affect survival of young humpback chub as well as confound the assessment of the effects that rainbow in the mainstem Colorado River may have on the humpback chub population.

Studies that seek to determine the effect of experimental management actions on humpback chub populations must be of a sufficient duration to allow the effect of experimental manipulation to be separated from natural variability and potential confounding factors. For humpback chub, management actions need to be applied for a duration that approaches or exceeds the generation time of this species—four to six years. Alternatively, inferences regarding the impact of management actions on humpback chub populations can be made using data on how the actions affect juvenile humpback chub growth or survival. Approaches that use these vital rates to make inferences about specific actions will still likely take three to four years to assess due to annual variation in physical and biological factors.

Objectives

The proposed action in the NNFC EA is to control nonnative fish as a means of conserving the endangered humpback chub and other native fishes. This action is predicated on fundamental observations concerning the nature of interactions between humpback chub and trout. As described above, several aspects of these interactions have large scientific uncertainty. Consequently, the proposed action will be pursued in an adaptive management framework such that management actions undertaken in later years will be informed by monitoring and research conducted during the first years of implementation. Thus, the context of this science plan is the effort to reduce uncertainty of management actions and to revise these actions as knowledge is gained throughout the 10-year duration of this EA. The Grand Canyon Monitoring and Research Center (GCMRC) and its science cooperators have identified five key objectives to be addressed to support management decisions associated with the NNFC EA:

1. Understand the relative roles of the LCR and the mainstem Colorado River in juvenile humpback chub survival rates and recruitment into the adult humpback chub population;
2. Determine the linkage between nonnative fish abundance and juvenile humpback chub abundance and survival rates in the LCR reach and elsewhere in Grand Canyon;
3. Determine the natal origins of rainbow trout found in Marble Canyon (river miles 8 to 56) and the LCR reach;
4. Assess the efficacy of nonnative fish removal in the PBR reach for rainbow trout and Upper Granite Gorge for brown trout; and
5. Assess the efficacy of flow manipulations to manage trout populations in the mainstem Colorado River from Lees Ferry to the LCR reach.

Background: Structured Decision Making and Science Planning

Structured decision making (SDM) is an approach that can be used to facilitate management decisions involving multiple competing objectives. A SDM approach (Runge and others, 2011) was used by Reclamation to identify and evaluate alternative non-native fish control actions for application in the NNFC EA (U.S. Department of Interior, Bureau of Reclamation, 2011a). The project consisted of two workshops with representatives of NNFC EA cooperating agencies and tribes. The workshop focused on developing and evaluating a wide range of non-native fish control alternatives considering effectiveness, stakeholder values, costs, and other factors. Trout removal at the PBR, with supplemental 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 downstream to Marble and Grand Canyons. 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 premise in approach 1.

The outcome of the SDM project suggested that the Glen Canyon Adaptive Management Program (GCDAMP) was not driven by learning as a fundamental 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 based on several studies (Coggins and Yard, 2010; Yard and others, 2011) that indicate trout prey upon and compete with humpback chub. In light of ESA mandates to management agencies to take reasonable actions to avoid jeopardy to and promote recovery of humpback chub, approach 1 emerged as the preferred approach by workshop participants. The NNFC EA emphasizes taking appropriate management action to conserve humpback chub by controlling trout while addressing some of the key uncertainties related to the impacts that trout have upon humpback chub recovery.

Several objectives and activities proposed in this science plan were not recommended as outcomes of the SDM project. Since the completion of the SDM workshops, additional information has become available and scientific thinking has evolved. This science plan strives to be inclusive of not only relevant recommendations from the SDM project, but also of the most current thinking of scientists. As the authors of the SDM report note, their conclusions are not meant to be definitive and can best be used as a starting point for the decision making process.

Monitoring and Research Activities

Monitoring and research activities will be organized to meet the five science support objectives identified by GCMRC.

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.

Justification
Although juvenile humpback chub are found in the LCR reach and elsewhere in Grand Canyon, 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 potentially 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 from the LCR reach provides a measurable benefit to humpback chub.

Science Activities
To resolve this key uncertainty concerning the role of the mainstem in humpback chub recruitment, GCMRC recommends a hybrid research project be implemented that incorporates elements of the recently completed Nearshore Ecology (NSE) project, a proposed LCR aquatic food base monitoring program, and ongoing humpback chub monitoring in the LCR and mainstem Colorado River. The overall goals of this hybrid project are to assess the carrying capacity of the LCR to support humpback chub, and to determine the relative importance of mainstem versus LCR rearing to sustaining humpback chub populations. This information would also inform decisions regarding how many humpback chub can be taken from the LCR for translocations to other tributaries, and how translocations upstream from Chute Falls affect humpback chub carrying capacity within the LCR.

Objective 2 – Determine the linkage between nonnative fish abundance and juvenile humpback chub abundance and survival rates in the LCR reach and elsewhere in Grand Canyon.

Justification
Predation of juvenile humpback chub by rainbow trout and brown trout (Yard and others, 2011) clearly demonstrates a negative effect of nonnative fishes on native species at the level of the individual. What remains uncertain is if trout have population level effects on humpback chub. Quantifying population level effects of trout on humpback chub will require continuation and/or expansion of existing monitoring efforts as well as initiation of new research projects.

Science Activities
Continued annual assessments of juvenile humpback chub survival rates and abundance in the mainstem using methods developed in the NSE study is essential since these are the key metrics by which other actions will be measured. This work will continue in 2012 as part of the new Natal Origins study described in Objective 3. The mainstem fish monitoring program will continue because it provides critical information on the relative abundance of rainbow trout and other nonnative fishes in Marble Canyon and Grand Canyon and how they change over time. A proposed expansion of this study to include additional sampling and mark-recapture methods would provide more quantitative information on the status and trends of nonnative fish populations and therefore help reduce uncertainty regarding their effects on humpback chub. Monitoring of humpback chub in the LCR and mainstem must be maintained at a level that allows adult abundance estimates to be generated using the Age-Structured Mark Recapture (ASMR) Model. An effort to revise the ASMR model is currently underway with the goal of developing a more flexible length-based model that will minimize potential bias associated with age-assignment errors that exists in the current model (S. Martell, written communication, 2011). Required sampling levels will be re-evaluated following the revision of the ASMR. Expansion of effort in the mainstem may also be warranted in order to provide a more quantitative assessment of status and trends in these population segments or aggregations as they are commonly called.

Actions proposed in the NNFC EA could also be used in an experimental framework to clarify how trout abundance relates to juvenile humpback chub abundance and survival rates. Trout management actions could be implemented or postponed either as part of a set study design or adaptively as certain biological or environmental conditions occur in an effort to facilitate learning about humpback chub-trout interactions. Specific actions to apply experimentally included in this science plan are the removal activities described in Objective 4 and the flow manipulations proposed in Objective 5.

Objective 3 – Determine the natal origins of rainbow trout found in Marble Canyon and the LCR reach

Justification
Rainbow trout abundance is greatest in the Lees Ferry reach and generally decline downstream, reaching their lowest abundance in western Grand Canyon (Makinster and others, 2010). Sources of rainbow trout in the mainstem downstream from Lees Ferry could include downstream migration of trout from the Lees Ferry reach, trout that spawn in tributaries such as Nankoweap, Bright Angel or Tapeats Creek, or local reproduction in the mainstem. The relative contribution of each of these potential sources to the mainstem population is sufficiently uncertain as to warrant further study. Of particular interest to managers is whether changes in the Lees Ferry reach trout population affect downstream rainbow trout abundance. Though there

is not conclusive evidence linking high rainbow trout abundance in the Lees Ferry reach with high mainstem trout abundance, the patterns of increase between these areas are similar, with generally a one-year lag between pronounced spikes in rainbow trout abundance in the Lees Ferry reach and a comparable increase in rainbow trout abundance downstream (Makinster and others, 2010; Makinster and others, 2011). 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 the Lees Ferry reach. Alternatively, it is possible that scattered local reproduction in Marble Canyon, combined with relatively high growth and survival of juvenile rainbow trout in Marble Canyon, may also contribute sufficient numbers of trout to support observed adult densities (J. Korman, personal communication, 2011). 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 in the LCR reach.

Science Activities

The newly initiated Natal Origins project will quantify the abundance and size classes of rainbow trout in the Lees Ferry reach and estimate what fraction of rainbow trout in Marble Canyon and the LCR reach were spawned and reared in the Lees Ferry reach. Additionally this project will determine if emigration is due to trout production in the Lees Ferry reach, then determine what factors (density dependent versus flows) or interaction of factors are responsible for emigration. This project includes a program of tagging, mark-recapture, and depletion sampling that focuses efforts between Lees Ferry and Badger Rapid. Ongoing downstream monitoring for nonnative fish in the mainstem will sample Marble Canyon and the LCR reach and contribute catch data to inform objectives laid out in this plan. Additionally, any nonnative fish monitoring or removal efforts that may occur will also be used to recapture marked fish.

Objective 4 – Assess the efficacy of nonnative fish removal in the PBR reach for rainbow trout and Upper Granite Gorge for brown trout.

This objective will be addressed through two projects described below.

1. The Paria River to Badger Rapid Sampling and Removal Project

Justification

Understanding rainbow trout population dynamics and movement characteristics in the Lees Ferry reach and the PBR reach is an important first step in being able to assess the potential for successful system-wide control of rainbow trout through actions taken in these reaches. If fish from the Lees Ferry reach are found to be a primary source for rainbow trout downstream, then removing fish in the PBR reach may be less intrusive and more culturally acceptable than control efforts conducted at or near the LCR confluence. Uncertainty remains, however, as to the feasibility of conducting removal in the PBR reach to the degree that it can effectively control rainbow trout abundance in the PBR reach, Marble Canyon, and subsequently in the LCR reach.

Science Activities
This project is proposed as a pilot level effort with two trips to be conducted in FY 2012. The project is intended to estimate age stratified capture probability and abundance of rainbow trout in the Lees Ferry reach and the PBR reach as well as age stratified downstream movement of rainbow trout between these reaches. Additionally, estimates of proportions of marked juveniles will be generated for comparison to proportions established upstream through the Natal Origins marking program. Finally this project will help assess the feasibility of removal in the PBR reach as a means to control trout abundance in the removal and LCR reaches. If rainbow trout move downstream and out of the Lees Ferry reach, then 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 PBR reach. Information from ongoing monitoring of rainbow trout in the Lees Ferry reach will also be incorporated to assess any potential correlation between rainbow trout density in the Lees Ferry reach and potential emigration out of the reach.

2. The Brown Trout Sampling and Removal Project

Justification
Experimental reductions of brown trout populations in Bright Angel Creek and the mainstem Colorado River near its confluence could reduce predation pressure on humpback chub not only in areas where removal occurred, but also in the LCR reach. Bright Angel Creek appears to be the primary spawning area supporting brown trout populations in the mainstem Colorado River including the LCR reach. While brown trout are concentrated in Upper Granite Gorge nearest the confluence of Bright Angel Creek, high catch rates of this species in the LCR reach has corresponded with periods of high abundance in Upper Granite Gorge (Makinster and others, 2011). Any increase in abundance of this predatory fish in the LCR reach would be of concern given the high incidence of piscivory reported for this species (Yard and others, 2011). The concentration of brown trout in Upper Granite Gorge may also be a threat to humpback chub because high levels of predation in this reach may limit dispersion of humpback chub, particularly younger fish, into downstream aggregations, effectively limiting their range within Grand Canyon.

Science Activities
The proposed Brown Trout Sampling and Removal Project is intended to determine efficacy of brown trout removal in the Colorado River mainstem in Granite Gorge and in Bright Angel Creek. Capture probabilities for specific gear used in the study reaches will also be estimated and used in the development of an open population model for estimating size-structured abundance of brown trout. Additionally, densities of native fishes in Bright Angel Creek and areas near its confluence would be monitored. A multi-year, brown trout removal treatment would be applied to both the mainstem Colorado River and Bright Angel Creek with the objective of significantly

reducing brown trout abundance. Proposed removal in the Colorado River mainstem would occur in Upper Granite Gorge using primarily electrofishing depletion methods (See Coggins and others, 2011). This effort is to be conducted in collaboration with the National Park Service's ongoing removal efforts (fish weir and electrofishing) in Bright Angel Creek and potential future efforts (for example, expanded electrofishing, chemical treatments, or rotary screw traps designed for capturing migrating juvenile fish). This project is proposed as an experimental research project to be conducted in FY 2012 with possible extension through FY 2015 to assess the effectiveness of removal in this reach and increase knowledge of humpback chub movement into downstream reaches through recaptures of previously tagged fish.

Any fish removed as part of either of these projects would be put to beneficial use in a manner consistent with the NNFC EA.

Objective 5 – Assess the efficacy of experimental flow manipulations (through dam operations) to manage trout populations in the mainstem Colorado River from Lees Ferry to the LCR reach.

Justification
Past efforts to control trout populations in the LCR reach by lethal removal appear to have resulted in temporary reductions that were likely only successful due to a concurrent system-wide decline in trout abundance (Coggins and others, 2011). Given that trout populations appear to be increasing (Korman and others, 2011; Makinster and others, 2011; GCMRC unpublished data) and the possible limitations of removal as a population control tool, future efforts at trout management should include experimentation to develop other approaches. One approach that warrants investigation is identifying flows or flow regimes that limit trout reproduction and/or survival of fertilized eggs, larvae, or juveniles in the Lees Ferry reach. Flow manipulation as a trout population control measure is attractive as it would target the most vulnerable life stages of rainbow trout at their likely source using a method that has the potential of affecting high proportions of the population. Some experimentation with flows to manage trout populations was conducted from 2003 through 2005 (Korman and others, 2011; also see USGS Fact Sheet 2011-3002 available at http://www.usgs.gov). The range of daily releases from Glen Canyon Dam was increased from January through March to promote rainbow trout spawning in high elevation areas that would subsequently be dewatered, thus increasing mortality rates of eggs and young fish. While survival rates of these early life stages were lowered, age 0 abundance did not decrease likely due to compensatory increases in survival rates among survivors (Korman and others, 2011). These results demonstrate flows can affect survival of some trout early life stages, but also make it clear that the factors controlling trout recruitment need to be understood and accounted for when designing future experiments.

Science Activities
An experimental approach would be used to determine which flows (volumes, duration) or flow regimes (fluctuating, rapid ramp rates) would be best suited to managing mainstem trout populations by limiting available spawning or rearing habitat, de-watering redds, stranding young fish, or displacing young fish to sub-optimal habitats.

Linkages to Existing Monitoring and Research Projects

As part of the GCDAMP there are five existing long-term monitoring projects 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.M2.11, 12) – Ongoing status of the Lees Ferry trout fishery (adult and juvenile fish);
2. Monitoring Mainstem Fishes (BIO 2.M4.11, 12) – Ongoing monitoring of the documented humpback chub aggregations in the mainstem and downstream monitoring of native and nonnative fish distribution and relative abundance in the mainstem (includes sampling downstream of Diamond Creek);
3. Stock Assessment of Native Fish in Grand Canyon (BIO 2.R7.11, 12) – Age-structured mark recapture recruitment modeling update for adult humpback chub (Age- 4+);
4. Little Colorado River Humpback Chub Monitoring (BIO 2.R1.11, 12) – Annual point estimates for humpback chub population in the lower 13.57 km; and
5. Natal Origins (BIO 2.E18. 11, 12) – Determine the natal origins of rainbow trout found in Marble Canyon and the LCR reach and assess humpback chub survival and abundance and trout abundance downstream of the LCR confluence.

These projects are described in more detail in the Glen Canyon Dam Adaptive Management Program Biennial Budget and Work Plan—Fiscal Years 2011-12 (FY 2011-12 BWP). Other research and reporting efforts that are part of FY 2011-12 BWP projects associated with the mainstem and its tributaries will also help inform the adaptive decision-making process. These include:

1. Annual Nonnative Fish Workshop (see BIO 2.R17.11, 12) – conduct a workshop with scientists and managers to review current data and findings and adapt the program as needed; and
2. Continued ecosystem modeling (see PLAN 12.P1.11, 12) – collaborate with GCMRC's Senior Ecologist and other cooperators to employ novel approaches to link study results into conceptual and quantitative models of responses of the Colorado River aquatic ecosystem to management actions.

Linkages to High Flow Experimental Protocol EA and Monitoring and Research Plan

The NNFC EA and this science plan were developed concurrently with another Environmental Assessment, **Development and Implementation of a Protocol for High-Flow Experimental Releases from Glen Canyon Dam, Arizona, 2011 through 2020** (HFE EA; U.S. Department of

Interior, Bureau of Reclamation, 2011b), and its associated science plan. Although the HFE EA and the NNFC EA are separate documents, they are interrelated. The actions described in each not only overlap geographically and temporally, but also contain elements that interact and affect one another. Of particular relevance to this science plan are the effects High Flow Experiments (HFEs) may have on native and nonnative fishes. Past HFEs may have positively affected nonnative trout populations. The spring 2008 HFE was followed by a dramatic increase in rainbow trout abundance, a result thought to be related to high flow releases (Korman and others, 2010; also see USGS Fact Sheet 2011-3002 available at http://www.usgs.gov). For native fishes, including humpback chub, effects of HFEs may be negative through mechanisms such as increases in predation and competition associated with more abundant nonnative fish (Wright and Kennedy, 2011).

Understanding the effects of HFEs on both physical and biological resources in the Colorado River will be essential for managers to make fully informed decisions regarding operations of Glen Canyon Dam. Several ongoing or proposed monitoring and research projects described above will help determine the biological effects of any HFEs that occur during the period this science plan is in place. The effects of HFE timing and frequency on rainbow trout population dynamics and outmigration will be evaluated by activities proposed in Objectives 2, 3, and 4. The influence of HFEs on humpback chub habitat use, predation risk, and competitive interactions will be evaluated through activities proposed in Objective 2. Other aspects of HFEs and their effects on biological resources that have not been addressed in this science plan are those that relate to the Lees Ferry recreational trout fishery. As noted above, HFEs can result in high trout abundance in the Lees Ferry reach. Under these conditions, high levels of competition for limited food resources can limit the numbers of larger and, presumably, more desirable trout available to anglers. HFE induced changes in the trout population structure like these may in turn affect recreational experience quality. This is of concern as maintaining this important trout fishery has been identified as a priority for the GCDAMP. As part of the FY 2011-12 BWP, the GCMRC has proposed to conduct a recreation experience valuation study for the Lees Ferry reach of the Colorado River (REC 9.R4.11, 12). The objective of this study is to provide a foundation for evaluating how different dam operations, including future HFEs, affect the biological and physical attributes of the Lees Ferry reach that visitors value and consider to be important for maintaining high quality recreation experiences there.

Annual Reporting

Annual reporting is proposed to occur in December or January either as part of the GCMRC's Annual Fish Cooperators Meeting or another planning 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 reach trout abundance estimates and total fish catch and removal numbers (if removal occurs), 4) PBR reach trout abundance estimates and total fish catch and removal numbers (if removal occurs), and 5) Lees Ferry reach age-0 trout marking numbers and recaptures in the Lees Ferry reach, the PBR reach, Marble Canyon, and the LCR reach.

Budget

The GCMRC anticipates that the monitoring and research activities described above will be funded as part of ongoing monitoring and research projects included in the approved FY 2011-12 BWP, including use of experimental funds as described in that work plan. Continuation of the tasks described here, or the addition of any other tasks that may be needed to provide information about actions implemented beyond 2012, will be developed through ongoing planning efforts between the GCMRC and the GCDAMP, starting with development of the draft FY 2013-14 Biennial Work Plan during 2012.

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Appendix C: Biological Assessment

United States Department of the Interior

BUREAU OF RECLAMATION
Upper Colorado Regional Office
125 South State Street, Room 6107
Salt Lake City, UT 84138-1102

IN REPLY REFER TO:

UC-700
ENV-7.0

JAN 28 2011

MEMORANDUM

To: Field Supervisor, U.S. Fish and Wildlife Service, 2321 West Royal Palm Road, Suite 103, Phoenix, AZ 85021
Attn: Steve Spangle

From: Larry Walkoviak
Regional Director

Subject: Transmittal of Bureau of Reclamation Biological Assessment Regarding Non-native Fish Control Downstream From Glen Canyon Dam

Pursuant to Section 7(a)(2) of the Endangered Species Act (ESA), 16 U.S.C. § 1531 et seq. and the implementing regulations at 50 C.F.R. 402.16, Reclamation is requesting initiation of formal consultation with the U. S. Fish and Wildlife Service regarding Non-native Fish Control Downstream from Glen Canyon Dam, Coconino County, Arizona.

This request is to analyze the effects of non-native fish control that may affect listed species including Kanab ambersnail (*Oxyloma haydeni kanabensis*), humpback chub (*Gila cypha*), razorback sucker (*Xyrauchen texanus*), and southwestern willow flycatcher (*Empidonax traillii extimus*), or designated critical habitat for humpback chub and razorback sucker. Our effects analysis is described in detail in the attached Biological Assessment.

The proposed action will be for a period of 10 years, 2011-2020. We anticipate that the underlying dam operation for this period will be as defined in your 2008 Biological Opinion on the Operation of Glen Canyon Dam and its 2009 Supplement through 2012. After 2012, we anticipate that the underlying dam operation will be the Modified Low Fluctuating Flow.

The attached Biological Assessment was prepared by Reclamation staff and contractors as described in 50 C.F.R 402.12. The Biological Assessment incorporates results of onsite inspections, updated information on listed species and designated critical habitats based on the views of recognized experts, reviews of the literature, and reaches findings about the effects of the proposed action on listed species and critical habitat in the action area below the dam. The findings are that the proposed action, as described in the attached Biological Assessment:

- May affect, but is not likely to adversely affect, the humpback chub, due to beneficial effects to the species from the reduction in predation and competition to humpback chub from non-nonnative fish species, predominantly rainbow trout, through non-native fish removal. Potential take of individuals of this species resulting from the implementation of non-native fish control utilizing boat-mounted electrofishing near the mouths of the Paria and Little Colorado rivers will be covered under U. S. Fish and Wildlife Service ESA section 10(a)(1)(A) recovery permits.

- We have determined that the proposed action may affect, but is not likely to adversely affect, the razorback sucker. Although the primary beneficial effects of removing non-native fish species will likely have no effect on razorback sucker where they now occur downstream in Lake Mead, removal will benefit aspects of its unoccupied habitat in the Grand Canyon.

- We have determined that the proposed action will not affect the Kanab ambersnail or the southwestern willow flycatcher because the proposed action will not occur in areas occupied by these species or result in indirect effects to these species, and thus not affect the numbers, distribution, or breeding, feeding, or shelter of these species.

In assessing effects on designated critical habitats at issue, the proposed action:

- Is not likely to result in destruction or adverse modification of designated critical habitat for the endangered humpback chub or razorback sucker.

- The critical habitat for the humpback chub and razorback sucker will be beneficially affected by the removal of non-native fish species; specifically, the biological environment Primary Constituent Element will be enhanced through the removal of non-native fish predators and competitors.

In compliance with section 9 of the Endangered Species Act, although the action is designed to benefit humpback chub by reducing competition and predation from non-native fish species, Reclamation anticipates the potential take of individual humpback chub. The form of take is expected to be from potential harm and harassment to humpback chub resulting from electrofishing and handling stress. However, we request that this take be covered separately through ESA section 10(a)(1)(A) recovery permits.

We appreciate your expedited consideration of this request for reinitiation of consultation in light of the proposal to undertake non-native fish control this spring or summer. If you have any questions regarding the Biological Assessment, please contact Glen Knowles at 801-524-3781.

Attachment

cc: UC-413, UC-438, UC-600, UC-720
(each w/attach)

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*).

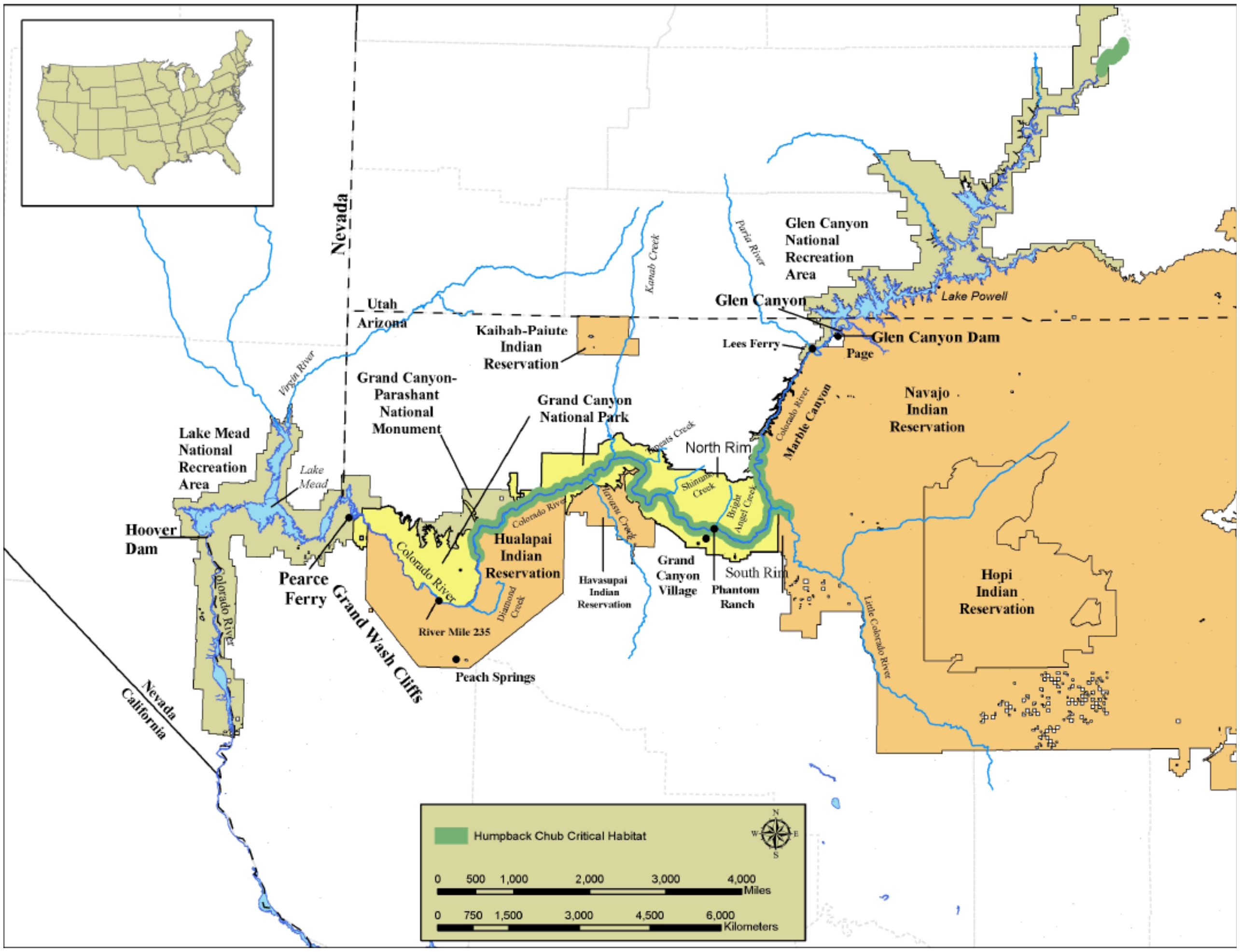

Figure 1. Map of Action Area and humpback chub (*Gila cypha*) critical habitat in the Colorado and Little Colorado Rivers (courtesy of the U.S. Fish and Wildlife Service).

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.

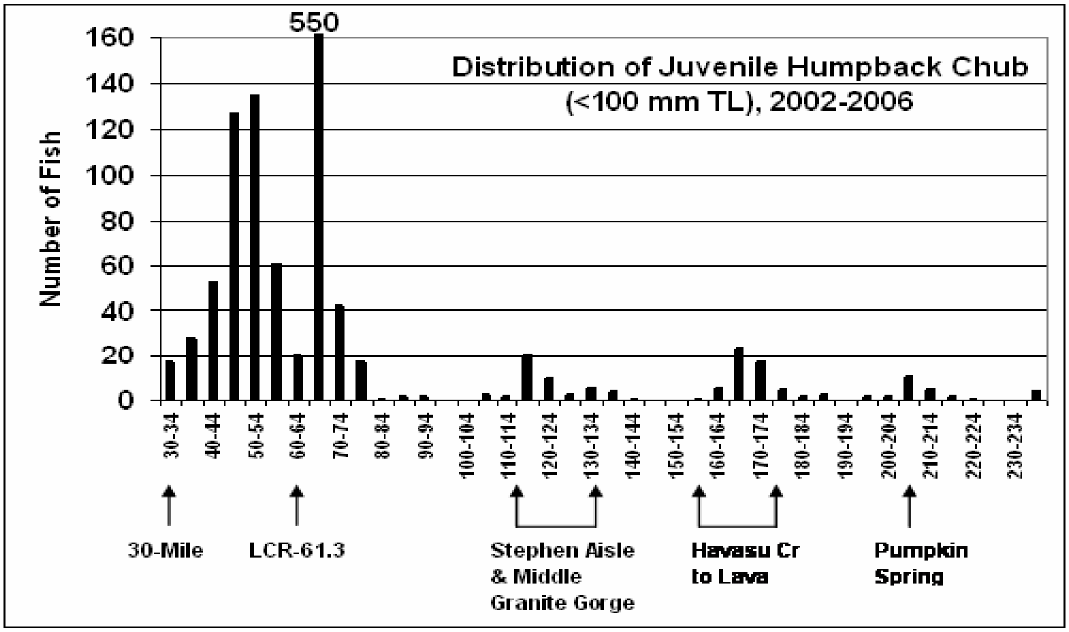

Figure 2. Distribution of juvenile humpback chub<100 mm TL caught during 2002-2006 by 5-mile increments from RM 30 to RM 240. Principal humpback chub aggregations are indicated (data from Ackerman 2008).

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 $117 m^2$ 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 $29 m^2 – 47 m^2$ (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.

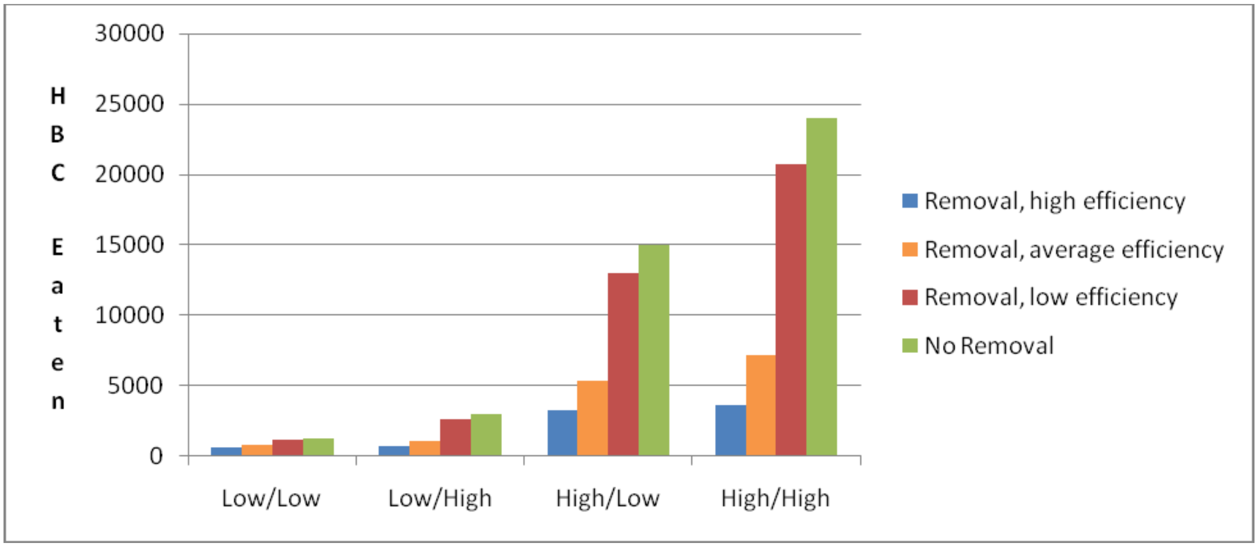

Figure 3. Expected predation of young-of-year fry and subadult humpback chub by trout in the absence of non-native fish removal (green bars) and over a range of mechanical removal efficiencies (blue, orange and red bars). X-axis labels refer to assumptions on predator density and piscivory rates. For 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).

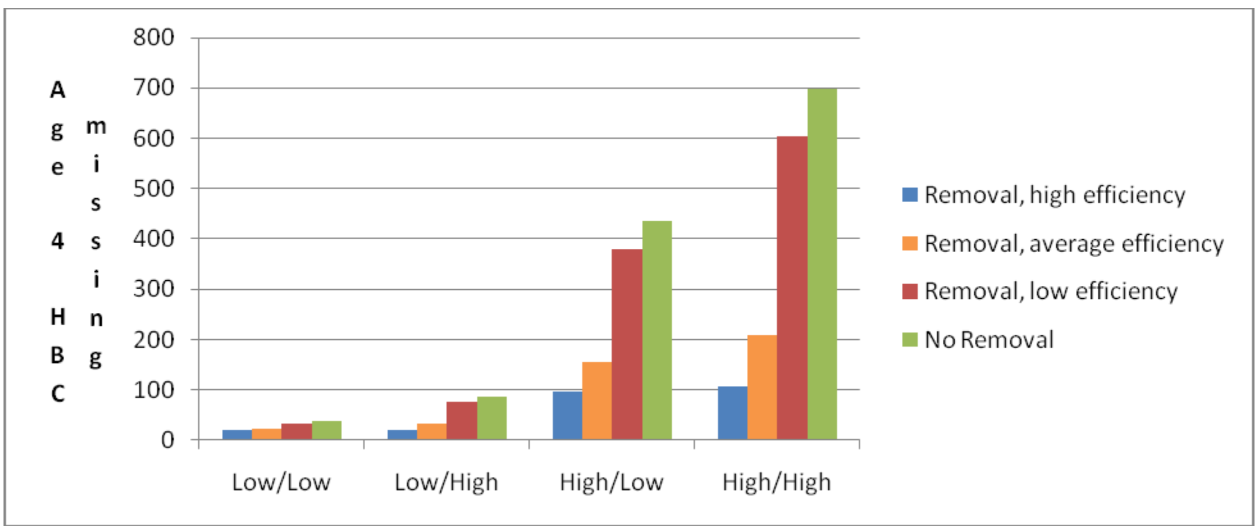

Figure 4. Expected losses of adult humpback chub (age 4) due to predation by trout in the absence of non-native fish removal (green bars) and over a range of mechanical removal efficiencies (blue, orange and red bars).

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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Appendix D: Supplement to Biological Assessment

United States Department of the Interior

BUREAU OF RECLAMATION
Upper Colorado Regional Office
125 South State Street, Room 6107
Salt Lake City, UT 84138-1102

IN REPLY REFER TO:
UC-700
ENV-7.0

JUL 13 2011

MEMORANDUM

To: Field Supervisor, U.S. Fish and Wildlife Service, 2321 West Royal Palm Road, Suite 103, Phoenix, Arizona 85021
Attn: Steve Spangle

From: Larry Walkoviak Anamarie Gold
Regional Director

Subject: Supplement to Biological Assessments for Development and Implementation of a Protocol for High-Flow Experimental Releases and Non-native Fish Control Downstream from Glen Canyon Dam, Arizona, 2011 through 2020

Pursuant to Section 7(a)(2) of the Endangered Species Act (ESA), 16 U.S.C. § 1531 et seq. and the implementing regulations at 50 C.F.R. 402.16, the Bureau of Reclamation is providing additional information to you for formal consultation with the U.S. Fish and Wildlife Service regarding Development and Implementation of a Protocol for Conducting High Flow Experimental Releases from Glen Canyon Dam, and Non-native Fish Control Downstream from Glen Canyon Dam in Coconino County, Arizona.

Reclamation has recently provided biological assessments (BAs) and draft Environmental Assessments (EAs) to the USFWS for these proposed federal actions:

- Development and Implementation of a Protocol for High-Flow Experimental Releases from Glen Canyon Dam, Arizona, 2011 through 2020, and;

- Non-Native Fish Control Downstream from Glen Canyon Dam.

As part of the protocol for high-flow experimental releases (HFEs), the numbers of rainbow trout (*Oncorhynchus mykiss*) in the Lees Ferry reach are expected to increase as an unintended consequence of the action. An increase in this population could result in greater downstream dispersal of trout into reaches of the Colorado River that are occupied critical habitat of the humpback chub (*Gila cypha*) where the trout prey upon and compete with this endangered species.

Predation by rainbow trout and brown trout (*Salmo trutta*) has been identified as a source of mortality for juvenile humpback chub that potentially reduces recruitment and possibly the overall size of the population of humpback chub. The purpose of this memorandum and the attached BA supplement is to identify and clarify actions being undertaken and proposed by

Reclamation to offset and mitigate unanticipated effects of the proposed HFE protocol, which could include increased rainbow trout production and hence negative effects to the humpback chub in Grand Canyon. Additional analysis that supplements the two BAs you have already received is provided in the attached BA supplement, as well as a summary of the anticipated effectiveness of actions to mitigate these effects.

In addition, we are also including in this supplement an analysis of the effects to ESA-listed species of implementing the modified low fluctuating flow (MLFF) for 10 years through 2020. As identified in our previous BAs, the underlying dam operations for these proposed actions would be the MLFF as defined in the 1995 Environmental Impact Statement and 1996 Record of Decision on the operation of Glen Canyon Dam. We are clarifying that our proposed action will include implementation of the MLFF through 2020, and request your biological opinion on the implementation of these actions with regard to the effects to listed species, in particular, the humpback chub, the razorback sucker (*Xyrauchen texanus*) and their critical habitat, the Kanab ambersnail (*Oxyloma kanabensis haydenii)*, and the southwestern willow flycatcher (*Empidonax traillii extimus*). All other aspects of the proposed action remain the same as described in the previously released BAs, and updated proposed actions in the July 5, 2011 drafts of the Non-native Fish Control EA and HFE Protocol EA.

Please also note that, in compliance with section 9 of the ESA, as previously explained in our January 28, 2011, request for consultation, Reclamation anticipates the potential take of individual humpback chub from implementation of non-native fish control and other aspects of the proposed actions. The form of take is expected to be from potential harm and harassment to humpback chub resulting from electrofishing and handling stress and other science-related activities. However, we request that this take be covered separately through ESA section 10(a)(l)(A) recovery permits.

We appreciate your expedited consideration of this request for consultation in light of the proposal to implement the HFE Protocol and undertake non-native fish control this calendar year. We look forward to working with the USFWS and Glen Canyon Dam Adaptive Management Program partners in reaching a balance among American Indian tribes' concerns, non-native fish control, sediment conservation, and conservation of the endangered humpback chub in Grand Canyon. If you have any questions regarding this request, please contact Glen Knowles at 801-524-3781.

Attachment

cc: UC-413, UC-438, UC-600, UC-720, UC-731
(each w/att)

RECLAMATION

Managing Water in the West

Supplement to Biological Assessments for Development and Implementation of a Protocol for High-Flow Experimental Releases and Non-native Fish Control Downstream from Glen Canyon Dam, Arizona, 2011 through 2020

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

July 8, 2011

Introduction

The Bureau of Reclamation (Reclamation) is in the process of completing NEPA compliance for two separate but related actions: Development and Implementation of a Protocol for High-Flow Experimental Releases (HFEs) from Glen Canyon Dam, Arizona, 2011 through 2020 (HFE Protocol); and Non-native Fish Control Downstream from Glen Canyon Dam, Arizona (Non-native Fish Control). Reclamation completed biological assessments (BAs) on these actions and submitted them to U.S. Fish and Wildlife Service (USFWS) with requests for Endangered Species Act (ESA) section 7 consultation on effects of these actions on listed species. These requests were submitted to USFWS on January 21, 2011 (HFE Protocol) and January 28, 2011 (Non-native Fish Control).

A recent finding of HFE analysis is that HFEs, and particularly those conducted in the spring, result in increases in the numbers of rainbow trout (*Oncorhynchus mykiss*) in the Lees Ferry reach (Korman et al. 2011). These increases, and in particular those resulting from the March 2008 HFE, also result in increases in downstream dispersal of rainbow trout into reaches of the Colorado River that are occupied critical habitat of the humpback chub (*Gila cypha*), where the trout prey upon and compete with this endangered species. A more detailed description of the relationship of high flows to trout and humpback chub is provided in Appendix A, as well as the Non-native Fish Control and HFE Protocol EAs and BAs (Bureau of Reclamation 2011a, 2011b, 2011c, 2011d).

Predation by rainbow trout and brown trout (*Salmo trutta*) has been identified as a source of mortality for juvenile humpback chub (Yard et al. 2011) that potentially reduces recruitment and possibly the overall size of the population of humpback chub (Coggins 2008, Coggins et al. 2011). The purpose of this BA supplement is to identify and clarify actions being undertaken and proposed by Reclamation including those to offset and mitigate unanticipated effects of the proposed HFE protocol, which could include increased rainbow trout production and hence negative effects to the humpback chub in Grand Canyon. Additional analysis that supplements the two BAs you have already received is provided, as well as a summary of the anticipated effectiveness of actions to mitigate these effects.

In addition, we are also including in this supplement an analysis of the effects to ESA-listed species of implementing the modified low fluctuating flow (MLFF) for 10 years through 2020. As identified in our previous biological assessments, the underlying dam operations for these proposed actions would be MLFF as defined in the 1995 Environmental Impact Statement (1995 EIS) and 1996 Record of Decision (1996 ROD) on the operation of Glen Canyon Dam (Bureau of Reclamation 1995, 1996). We are hereby clarifying our proposed actions to include implementation of the MLFF through 2020, and provide here an analysis of the implementation of MLFF in combination with these actions with regard to the effects to listed species and their critical habitat in the action area: the humpback chub, the razorback sucker (*Xyrauchen texanus*), the Kanab ambersnail (*Oxyloma kanabensis haydenii)*, and the southwestern willow flycatcher (*Empidonax traillii extimus*). All other aspects of the proposed actions remain the same as described in the prior EAs and BAs.

Changes to the Proposed Actions

The Modified Low Fluctuating Flow

The proposed action in the BAs includes MLFF as the background Glen Canyon Dam operation through 2020, as well as steady flows previously scheduled (and consulted upon) for September and October 2011 and 2012. The MLFF is a set of dam operations defined in the 1995 EIS and 1996 ROD, and we hereby incorporate those documents by reference. Under the MLFF, minimum daily flow releases are limited to a minimum of 5,000 cubic feet per second (cfs) and maximum to 25,000 cfs (although this can be exceeded for emergencies or during extreme hydrological conditions). Minimum flow during the day from 7:00 am to 7:00 pm is further limited to 8,000 cfs. Daily fluctuation limit is 5,000 cubic feet per second (cfs) for months with release volumes less than 0.6 million acre feet (maf), 6,000 cfs for monthly release volumes of 0.6 maf to 0.8 maf, and 8,000 cfs for monthly volumes over 0.8 maf. Ramp rates must not exceed 4,000 cfs per hour ascending and 1,500 cfs per hour descending (Table 1). Operations under the MLFF are typically structured to generate hydropower in response to electricity demand, with higher monthly volume releases in the winter and summer months, and daily fluctuations in release volume.

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

Glen Canyon Dam Release Constraints		
Parameter	**Release Volume (cfs)**	**Conditions**
Maximum Flow[1]	25,000	
Minimum Flow	5,000	Nighttime
	8,000	7:00 a.m. to 7:00 p.m.
Ramp Rates		
Ascending	4,000	Per hour
Descending	1,500	Per hour
Daily Fluctuations[2]	5,000 to 8,000	

1 May be exceeded for emergencies and during extreme hydrological conditions.

2 Daily fluctuation limit is 5,000 cubic feet per second (cfs) for months with release volumes less than 0.6 maf; 6,000 cfs for monthly release volumes of 0.6 maf to 0.8 maf; and 8,000 cfs for monthly volumes over 0.8 maf.

Non-Native Fish Control

Mechanical removal of trout from the Colorado River has been shown to be effective at reducing abundance of trout in areas occupied by humpback chub (Coggins et al. 2011).

The proposed action has been modified with regard to non-native fish control as follows for the 10-year period (2011-2020) of the two proposed federal actions identified above:

1. Paria River to Badger Creek (PBR) reach (RM 0-8; Figure 1): Up to 10 removal trips per year.

2. Little Colorado River (LCR) reach (RM 56.3-65.7; Figure 1): Up to six removal trips per year **only** if adult (age 4 years or more) humpback chub abundance drops below 7,000 adults as determined using the Age Structured Mark Recapture Model (ASMR; Coggins and Walters 2009).

All non-native fish removed would be removed live, transported, and stocked into areas with approved stocking plans, or would be euthanized for later beneficial use such as human consumption or as food for wildlife at wildlife rehabilitation facilities.

Proposed Non-Native Fish Research Activities

The following specific research and monitoring activities are proposed in the initial years of the proposed action. In future years, implementation of these actions will be based on the outcome of these research activities. These activities include:

1. Lees Ferry reach (RM +15-0): One rainbow trout marking trip in October.

2. Paria to Badger reach (RM 0-8): Two monitoring/live removal trips during November-January period.

3. Marble Canyon (RM 0 – 62): Three monitoring trips (no trout removal), one each in July, August, and September to detect downstream movement of rainbow trout and conduct nearshore ecology work on juvenile humpback chub at the LCR confluence.

4. Conduct research, through a continuation of the Nearshore Ecology Study to develop triggers for juvenile humpback chub abundance and survivorship to consider in implementing LCR reach removal, to investigate the relative importance of habitats in the LCR and mainstem Colorado River in humpback chub recruitment, and to investigate the effect of high flows on displacement loss of young-of-year and/or juvenile humpback chub.

5. Reclamation will undertake development, with stakeholder involvement, of additional non-native fish suppression options for implementation in the first two years of the proposed action to reduce recruitment of non-native rainbow trout at, and emigration of those fish from, Lees Ferry. 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.

6. Undertake a review in 2014 of the first two years of implementation of the two proposed actions through a workshop with scientists to assess what has been learned. Based on the results of this workshop, the proposed action may be altered in coordination with the FWS to better meet the intent of the conservation measure.

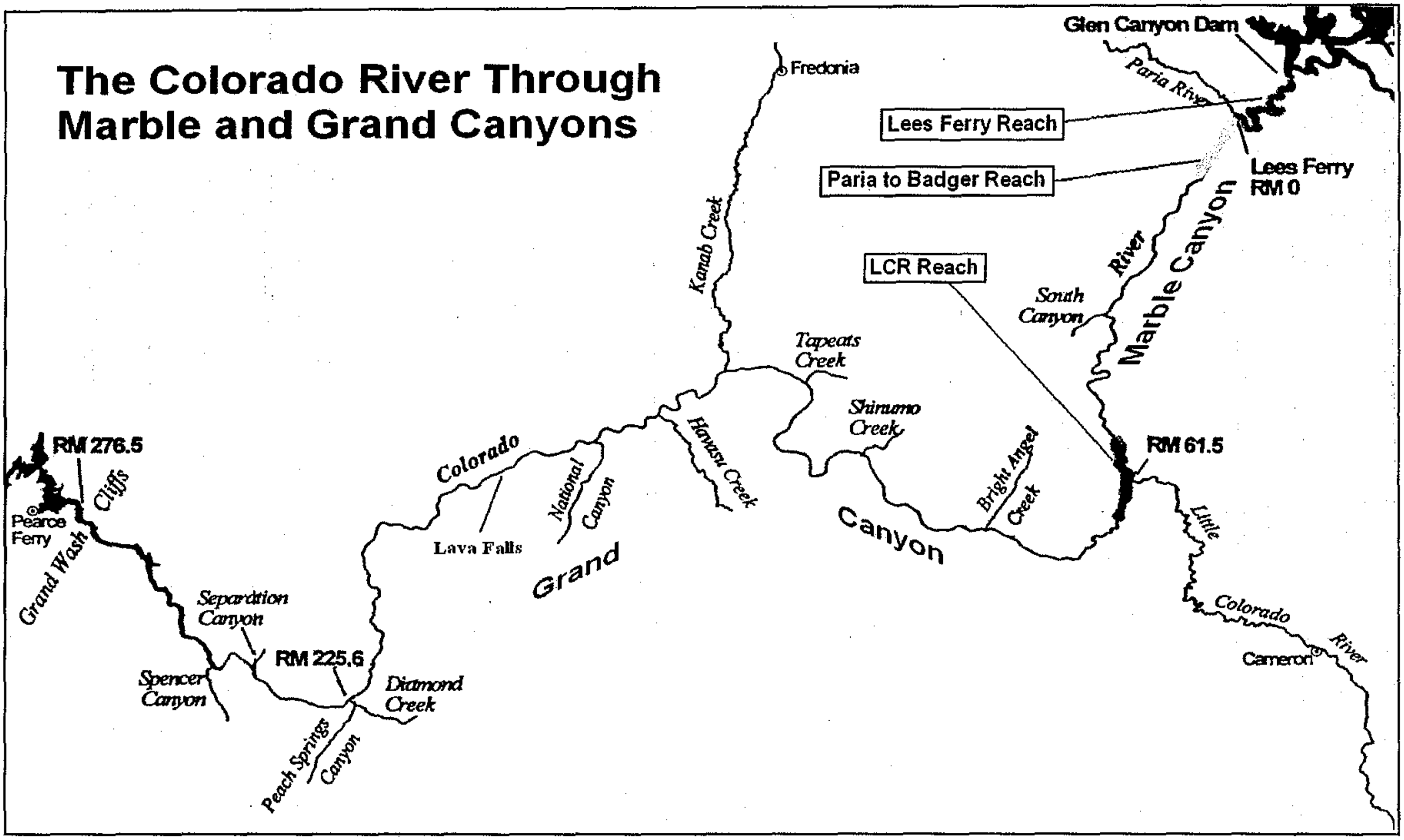

Figure 1. Map of the Colorado River from Glen Canyon Dam to Pearce Ferry in upper Lake Mead. The Lees Ferry, Paria to Badger reach (PBR), and Little Colorado River (LCR) reach are identified.

Rationale for Proposed Action

The focus of the proposed action is to explore new methods of non-native fish control that alleviate concerns of the American Indian tribes within the Glen Canyon Dam Adaptive Management Program (GCDAMP) regarding the taking of life in an area of cultural importance to the tribes, and to incorporate research to better understand the effect of predation by non-native fish on humpback chub, but to do so in a way that also does not result in undue adverse effects to the humpback chub. The 10-year period of the non-native fish control action is appropriate to establish and extend a long-term and important conservation measure for non-native fish control in a manner that is consistent with several USFWS biological opinions and with ongoing consultation on the prospective operation of Glen Canyon Dam. USFWS ESA section 10(a)(1)(A) scientific collecting permits would be obtained to cover incidental take of listed species resulting from implementation of non-native fish control actions.

The High Flow Experimental Protocol is a related EA that contains a concurrent 10-year proposed federal action, and non-native fish control is needed as a means to offset the possible effects of increased trout abundance that has been shown to accompany spring HFEs (Wright and Kennedy 2011). Some of these control activities have already been implemented as conservation measures outlined in the 2007 and 2008 Biological Opinions and the 2009 Supplement (e.g., fish research and monitoring, and limited mechanical removal in the Colorado River and its tributaries including Shinumo and Bright Angel creeks; USFWS 2007, 2008, 2009, 2010). HFEs also may have the potential to displace young-of-year and/or juvenile humpback chub or other native fish. The proposed action includes research that builds on the Nearshore Ecology Study to, in part, assess the potential for displacement of these age classes by HFEs, which will serve as important information for consideration in the HFE decision-making process.

The following provides a rationale for each of the non-native fish removal and research activities identified above:

Paria to Badger Reach (PBR) Removal.—Reclamation is proposing to test the ability to reduce the source of fish preying on humpback chub by intercepting and removing rainbow trout migrating downstream from Lees Ferry through the PBR reach. Removal of trout from the PBR would be tested starting in 2011 with up to 10 removal trips per year. Boat electrofishing has been shown to be the most effective means of removing these fish (Coggins 2008), although other methods may be considered and employed. The goal of this removal is to better understand: (1) the degree to which rainbow trout emigrating from the Lees Ferry reach result in increased trout abundance in the LCR reach (leading to humpback chub predation), and (2) the efficacy of removing rainbow trout in the PBR reach (if emigration is occurring on a large scale) to reduce the number of trout preying on or competing with humpback chub in the LCR reach. PBR removal would utilize rainbow trout tagging trips in the Lees Ferry reach in the fall to help detect and quantify downstream movement of trout from Lees Ferry. To alleviate the tribal concerns, in FY 2012, fish would be removed alive and stocked into waters with approved stocking plans to test the efficacy of live removal.

PBR Monitoring/Removal.—Two monitoring/removal trips would be conducted during the November-January period to determine the extent of emigration of trout from the Lees Ferry reach, based on marked fish from that reach, and evaluate the efficacy of PBR reach removal.

LCR Reach Removal.—Up to six removal trips would be conducted per year in the LCR reach if adult humpback chub abundance drops below 7,000 adults based on the ASMR. In addition, Reclamation will conduct research to develop other triggers, such as abundance of juvenile humpback chub (discussed below). Reclamation would coordinate with the USFWS to determine the need to implement LCR reach removal. Fish removed would be removed alive and stocked into offsite waters with approved stocking plans or would be euthanized for later beneficial use.

Marking of Trout in Lees Ferry.—Marking of rainbow trout with PIT tags in the Lees Ferry reach would begin in fall 2011 to start to track emigration from the Lees Ferry reach downstream through Marble Canyon and to answer questions on natal origins of trout that occupy the LCR reach.

Marble Canyon Monitoring.—Monitoring trips would be conducted in the initial years of the proposed action through Marble Canyon in July, August, and September to detect downstream movement of rainbow trout, to better understand the degree to which rainbow trout emigrating from the Lees Ferry reach result in increased trout abundance in the LCR reach, and to help evaluate the efficacy of removing rainbow trout in the PBR reach. Trout would not be removed during these trips. These monitoring trips would also stop at the LCR reach and conduct research and monitoring as an extension of the Nearshore Ecology Study to better understand habitat use by juvenile humpback chub in the LCR and in the mainstem and improve estimates of abundance of juvenile humpback.

Research to Develop Triggers.—Because of the sensitivity to American Indian tribes, removal of trout from the LCR reach would be implemented only when necessary to alleviate losses of humpback chub to trout predation. The proposed criteria for implementing trout removal in the LCR reach is the "HBC Trigger," such that when the estimated abundance of humpback chub falls below 7,000 adults based on the ASMR, removal of trout from the LCR reach would be triggered and implemented. The age-structured mark-recapture model (ASMR; Coggins and Walters 2009) would be used to assess adult humpback chub abundance periodically. If the estimate drops below 7,000 adults, removal of trout from the LCR reach could be implemented. Additionally, research would be implemented to refine and further develop triggers based on juvenile humpback chub abundance and survivorship. This research would seek to identify and quantify the different sources of mortality for young humpback chub, including but not limited to thermal shock, diseases/parasites, downstream displacement, stranding, food starvation, and fish predation.

Feasibility of Flow Releases.—Reclamation will begin working with stakeholders to develop and assess the feasibility of possible flow and non-flow actions to reduce Lees

Ferry rainbow trout recruitment for potential implementation in the next 1-2 years. Some flow-related actions have been tested and evaluated as possible control methods for trout in the Lees Ferry reach (Korman et al. 2011). Flow releases may be proposed, pending additional NEPA and ESA compliance, to provide for additional means to control recruitment of rainbow trout in Lees Ferry, both to reduce predation on native fishes downstream and to improve aspects of the Lees Ferry fishery.

Continuance of Assessing Young-of-Year and Juvenile Humpback Chub.
Reclamation will provide sufficient funding to continue monitoring of young-of-year and juvenile humpback chub in the area downstream of the LCR-mainstem confluence so that managing agencies can assess recruitment after high flow events. This will be used to assist managing agencies in determining future high flows by providing indirect information as to recruitment over multiple years of high flows.

Scientific Review.—Reclamation will also undertake a thorough scientific review in 2014 through a workshop with scientists and managers to assess what has been learned through implementation of non-native fish control as proposed here, in particular, on the ultimate effect of trout predation on adult humpback chub abundance. If results indicate that rainbow trout are causing substantial unanticipated impacts to humpback chub, Reclamation will reinitiate consultation with the FWS.

Relationship to Existing Biological Opinions.—Reclamation believes that the proposed action satisfies its responsibilities under the existing biological opinions while also addressing the concerns of American Indian tribes. The proposed action was refined from that identified in the Draft Non-Native Fish Control EA to further balance implementation of non-native fish control measures with minimization of actions that have generated American Indian tribal concerns. To mitigate the adverse affects of the MLFF and the HFE Protocol, Reclamation also intends to continue conservation measures identified in previous biological opinions (U.S. Fish and Wildlife Service 2008, 2009) through 2020 as warranted, based on continued consultation and coordination between Reclamation and USFWS.

Removal of trout from the LCR reach will be based on humpback chub status, as described above. The decision to implement LCR reach trout removal will be based on evidence from monitoring and the ASMR that humpback chub are declining, and that implementing LCR reach removal is necessary to avoid exceeding levels of incidental take defined in previous biological opinions (U.S. Fish and Wildlife Service 2010a). To address tribal concerns and to insure beneficial use of removed fish, Reclamation will either remove fish live for translocation and stocking into waters with approved stocking plans, or the fish will be euthanized for later beneficial uses, such as food for human consumption or to feed wildlife.

Relationship of Proposed Action to Incidental Take

The current incidental take statement for the humpback chub in Grand Canyon is based on the September 1, 2010 Reissuance of the 2009 Supplement to the 2008 Final

Biological Opinion for the Operation of Glen Canyon Dam (USFWS 2010a). According to that reissuance, incidental take is exceeded if the humpback chub population drops below 6,000 adults within the 95% confidence interval based on the ASMR. The proposed non-native fish control action is also designed to minimize the chances of violating this incidental take. Additionally, information gathered from removal activities, scientific research, and the scheduled 2014 workshop will help to better inform and possibly refine the anticipated level of take for the humpback chub in Grand Canyon.

The proposed non-native fish removal action described in this BA supplement is designed to reduce losses of young humpback chub due to trout predation. The estimated number of young humpback chub lost to predation can be gauged from an existing incidental take statement that anticipates between 1,000 and 24,000 y-o-y or juvenile humpback chub would be lost to predation by trout as a result of cancelling non-native fish removal from the LCR reach for a 13-month period (USFWS 2010b). The adopted incidental take of 10,817 humpback chub (mostly age-0 and age-1) for this 13-month period is the estimate provided in the April 2010 BA (Reclamation 2010), based on minimum and maximum predation rates calculated by Yard et al. (2008) (1.7 and 7.1 prey/rainbow trout/year, and 18.2 to 106 prey/brown trout/year). Since the issuance of the BA and BO, these rates of piscivory have been revised by Yard et al. (2011) and the new values range from 4 to 10 fish/rainbow trout/year, and 90 to 112 fish/brown trout/year. The estimated prey fish consumed (27.3% were humpback chub) remained the same. Using the new predation rates, the estimated take of humpback chub is revised to 16,215 fish, which is still within the anticipated range of take of 1,000 to 24,000 fish.

Changes to Effects Analysis

The effects determinations for both the HFE Protocol and Non-native Fish Control actions remain the same as determined in the previous biological assessments (Table 2), and we hereby incorporate by reference those documents (Bureau of Reclamation 2011a, 2011b). We provide here additional analysis to support these effects determinations in consideration of implementation of MLFF through 2020 and to further evaluate the combined effects of these actions.

Table 2. Effects determinations to ESA-listed species for the implementation of MLFF through 2020 in conjunction with implementation of the HFE Protocol and Non-Native Fish Control actions through 2020.

Species	Effects Determination	Basis for Determination
Humpback Chub	May affect, likely to adversely affect species and critical habitat	• Take could occur from downstream displacement of young into unsuitable habitat, especially during fall HFEs. Effects of displacement, if it occurs, are largely unknown. • Direct short-term reductions in near-shore habitat could occur in the vicinity of the LCR with changes in flow stage, but long-term benefit is expected from sand redeposition that rebuilds and maintains near-shore and backwater nursery habitats. • Direct short-term reductions in food supply could

		occur with scouring and changes in flow stage, but long-term benefit is expected from stimulated food production. • Increased predation from expanded population of rainbow trout is expected, especially with spring or multiple HFEs. • Non-native fish control actions would provide a beneficial effect to the species and its critical habitat. • MLFF would affect the species and its critical habitat through physical habitat manipulation; releases have a cooling effect on water temperatures and may result in reduced quality of sediment-formed habitats such as backwaters through erosion and daily fluctuations of MLFF may disrupt nearshore habitats, reducing food base and increasing energetic requirements or predation risk of young humpback chub. • MLFF would result in colder temperatures that could result in reduced growth rate and survival of young humpback chub, although results of recent research are contradictory, indicating relatively high survivorship and growth rates that are at times relatively high. • The cooling effect of MLFF on mainstem fish habitat likely inhibits non-native fish in the same ways it inhibits native fish. This is likely a benefit to humpback chub by disadvantaging non-native predators and competitors with the species.
Razorback Sucker	May affect, likely to adversely affect species and critical habitat	• In general, HFEs, non-native fish control, and the MLFF are unlikely to affect the species because it apparently no longer occurs in the action area, although a small reproducing population occurs downstream in Lake Mead, but possible effects include: • Short-term beneficial impacts to food supply from large influx of organic material during HFEs. • Short-term beneficial effect from inundated vegetation and increased turbidity as protective cover from predators. • Potential displacement of young in Lake Mead inflow by spring HFEs, but possible creation of productive nursery habitats from increased reservoir level and reshaping of near-shore deposits. • Potential short-term burial of spawning bars and other habitats by fine sediment during HFEs. • Non-native fish control actions would provide a beneficial effect to the species and its critical habitat. • MLFF would affect the species critical habitat through physical habitat manipulation; releases have a cooling effect on water temperatures and result in reduced quality of sediment-formed habitats such as backwaters through erosion. • Cooling effect of MLFF on mainstem fish habitat likely inhibits non-native fish in the same ways it inhibits native fish. This likely benefits razorback

		sucker through reduced numbers of non-native fish predators and competitors with the species.
Kanab Ambersnail	May affect, likely to adversely affect; no critical habitat designated	• Up to 119.4 m² (17 percent in 1996) of potential habitat may be inundated by 45,000 cfs. • Proportionally less habitat area scoured and fewer numbers of snails would be displaced by lower magnitude HFEs. • Sequential HFEs could reinundate and scour primary habitat prior to full recovery from previous HFE. • Non-native fish control actions would not affect this species. • MLFF at high releases of over 17,000 cfs can inundate and scour up to 10 percent of available habitat, but the habitat is of low quality and contains few snails. • Critical habitat has not been designated for the species.
Southwestern willow flycatcher	May affect, not likely to adversely affect; critical habitat not in area of proposed action	• Birds will not be present during spring HFEs, and nesting and feeding sites are not expected to be adversely affected. • Birds will be off nests by Sept-Oct, but birds will be foraging and there could be some indirect effect to their food supply. • Non-native fish control actions would not affect this species. • MLFF would have only limited effects of southwestern willow flycatcher. Nesting habitat occurs at stage elevations above 45,000 cfs, and normal operations below 25,000 cfs are unlikely to affect habitat for the species. Southwestern willow flycatcher critical habitat does not occur in the action area.

Effects of MLFF through 2020 on Humpback Chub and its Critical Habitat

The MLFF is a set of dam operations that results in hourly, daily, and monthly variations in flow from Glen Canyon Dam. The MLFF is implemented by Reclamation through the GCDAMP as defined in the 1995 EIS and 1996 ROD (Bureau of Reclamation 1995, 1996). The variations in flow resulting from MLFF affect many aspects of the ecosystem below Glen Canyon Dam downstream some 250 miles or so to Lake Mead. Effects are on the abiotic aspects of the ecosystem (e.g., water temperature, turbidity, sediment transport, riverine habitat formation) and on the biotic aspects (e.g. food base dynamics, fish species abundance and composition, fish growth, fish predation rates, prevalence of disease or parasites). Many of these effects are poorly understood at best, and adding to the complexity is the fact that few if any affects can be analyzed separately because they interact.

Water temperature is an important aspect of the physical ecosystem for humpback chub that is affected by dam operations. Humpback chub require temperatures of 16-22 °C for successful spawning, egg incubation, and survival of young (Hamman 1982, Valdez and

Ryel 1995). Since closure of the dam and filling of Lake Powell, water temperatures in the mainstem Colorado River at the LCR inflow have been about 8-10 °C on average (Valdez and Ryel 1995). Water temperature of downstream releases from Glen Canyon Dam is affected by release temperature, which is a function of reservoir elevation, temperature and volume of inflow, and air temperature. Downstream warming of the river is a function of Glen Canyon Dam release temperatures, release volumes, and volume fluctuations, and warming is also along a longitudinal gradient that varies with air temperature, such that warming increases as water moves downstream and more so in the hotter months than in cooler months (Wright et al. 2008a).

Water releases under MLFF are designed to produce hydropower during months when power demand is greatest, releasing more water in the winter months of December-February and summer months of June-August. Increasing releases in the winter months has little effect on warming of the river because air temperatures and release water temperatures are cold. In summer, however, the effect of increasing monthly releases to meet electricity demand (within the constraints of MLFF) has a measurable effect on water temperature. Lower release volume results in greater downstream warming (Wright et al. 2008a). This is most evident from the 2000 low summer steady flow. Releases during the summer months (June 1 – September 1) were limited to 8,000 cfs, and mainstem temperatures warmed somewhat more than at higher releases. The mainstem water temperature at the LCR inflow in June 2000 was 13.3 °C; release temperature at the dam was 9.5 °C, so releases had warmed 3.8 °C; June temperatures for the previous six years at the LCR inflow ranged from 10.3 °C to 11.8 °C and had warmed an average of 2.3 °C (Vernieu 2000). Structuring monthly release volumes to generate hydropower under a fluctuating regime has a cooling effect on downstream water temperature, which likely results in, or contributes to, mortality to humpback chub eggs and juvenile fish due to cold temperatures (Hamman 1982, Marsh 1985), or death of juvenile humpback chub from cold shock or increased predation due to cold shock (Berry 1988, Berry and Pimentel 1985, Lupher and Clarkson 1994, Valdez and Ryel 1995, Marsh and Douglas 1997, Robinson et al. 1998, Clarkson and Childs 2000, Ward et al. 2002).

MLFF also modifies the hydrograph (the timing of water delivery in the river). Monthly flows under MLFF produce a hyrdrograph with the highest flows in the winter and summer months. Humpback chub evolved with a historically variable hydrograph in Grand and Marble Canyons, but with consistently high flows in the spring following snow melt and low flows in the summer (Topping et al. 2003). Muth et al. (2000) recommend releases from Flaming Gorge Dam mimic this natural pattern in the Green River to benefit humpback chub by providing high flows in the spring and base flows in other seasons. But at Glen Canyon Dam, the maximum release at powerplant capacity (31,500 cfs) is likely too low to provide any benefit to native fishes (Valdez and Ryel 1995), but flows that utilize the outlet works such as the March 2008 high flow test do provide some of these positive benefits to humpback chub, such as by rearranging sand deposits in recirculating eddies, effectively reshaping reattachment bars and eddy return current channels. The proposed action also includes September and October steady flow releases through 2012 to determine if these flows benefit humpback chub without undue risk from benefiting non-native species. In 2013, flows in September and October will be determined by annual hydrological conditions, the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead and related legal mandates, and the MLFF restrictions (U.S. Department of the Interior 1996, 2007).

Fluctuating daily volume to meet power demand may have direct and indirect effects to humpback chub, and in particular to juvenile humpback chub, because this life stage prefers nearshore habitats where the effects of fluctuations are concentrated (Valdez and Ryel 1995, Robinson et al. 1998, Stone and Gorman 2006, Korman and Campana 2009). Daily variation in discharge can result in a variety of adverse affects due to lateral movement of the shoreline, such as the direct effect of stranding juvenile fish (Cushman 1985). Ongoing research referred to as the Nearshore Ecology study (NSE) into the use of nearshore habitats in the Colorado River mainstem near the LCR has provided some interesting insight into these effects. Juvenile humpback chub appear to have relatively high survival rates in these mainstem habitats based on mark-recapture monitoring. Also, juvenile humpback chub in the mainstem at times exhibit higher growth rates than fish in the LCR, indicating potentially better food availability, higher water temperatures, or both (B. Pine, Univ. of Florida, pers. comm., 2011).

Fluctuations also result in a cooling effect to nearshore habitats such as backwaters, which may be important nursery areas for juvenile humpback chub. Daily fluctuations cause mixing of warm waters contained in backwaters with cold mainchannel water (Arizona Game and Fish Department 1996, Grand et al. 2006). Hoffnagle (1996) found that mean, minimum, maximum and diel temperature range of backwaters were higher under steady versus daily fluctuating flows, with mean daily temperatures (14.5 °C) under steady flows about 2.5 °C greater than those under fluctuating flows. Differences in the mainchannel temperatures during steady and fluctuating flows were also statistically significant, but mean temperatures differed by only 0.5 °C. Trammell et al. (2002) found backwater temperatures during the 2000 low steady summer flow experiment to be 2-4 °C above those during 1991-1994 under fluctuating flows. Korman et al. (2006) found warmer backwater temperatures under steady flow conditions, concluding that backwaters were cooler during fluctuations because of the daily influx of cold main channel water. Although fluctuations would thus likely be expected to result in some increased mortality to humpback chub eggs and juvenile fish due to colder temperatures (Hamman 1982, Marsh 1985), recent work through the NSE on use of these habitats appears to contradict this, with juvenile humpback chub exhibiting relatively high survival rates in these habitats, and humpback chub growth rates appeared to be higher in the mainstem in some months (B. Pine, Univ. of Florida, pers. comm., 2011).

Daily variation in discharge can also result in a variety of adverse sub-lethal effects due to colder water and lateral movement of the shoreline and potential displacement effect as fluctuations dewater these habitats daily, which can result in reduced growth rates, increased stress levels, predation risk, energy expenditure, or reduced feeding opportunities (Cushman 1985). Korman et al. (2006) hypothesized that fluctuation effects on nearshore habitats pose an ecological trade-off for fish utilizing these areas;

fish may choose to exploit the warmer temperatures of the fluctuating zone on a daily basis and simply sustain any bioenergetic disadvantages of acclimating to rapidly changing discharge, or they may choose to remain in permanently wetted zones that are always wetted, but colder than the immediate nearshore margin. Korman et al (2005) found that young rainbow trout in the Lees Ferry maintained their position as flows fluctuated rather than follow the stream margin up slope, indicating that the bioenergetic cost of changing stream position with fluctuations in discharge perhaps outweighs the benefits of exploiting the slightly warmer stream margins. If humpback chub chose to utilize warmer backwaters, movement into and out of these habitats as stage changes with fluctuation will be required. Korman and Campana (2009) found that, for rainbow trout in Lees Ferry, growth appeared to increase during stable flows, based on evidence of a distinctive line on the ototlith (inner ear bone) representing increased growth that corresponded to juvenile trout's increased use of immediate shoreline areas on Sundays (the only day of the week with steady flows), where higher water temperatures and lower velocities provided better growing conditions. If humpback chub are similarly affected, fluctuating flows could result in lower growth rates, or perhaps death of juvenile humpback chub from cold shock or increased predation due to cold shock, as well as increased predation risk due to increased movement (Berry 1988, Berry and Pimentel 1985, Lupher and Clarkson 1994, Valdez and Ryel 1995, Marsh and Douglas 1997, Robinson et al. 1998, Clarkson and Childs 2000, Ward et al. 2002). Results of the NSE seem to contradict these expected findings; juvenile humpback chub survival rates appear high in the mainstem, and growth rates can exceed those in the LCR.

Structuring releases (within the MLFF constraints) to meet electricity demand also increases erosion of sandbars and backwaters, which could result in a reduction in habitat quality for juvenile humpback chub. Lovich and Melis (2007) hypothesized that the MLFF's annual pattern of monthly volumes released from the dam (with the greatest peak daily flows during the summer sediment input months of July and August) is a key factor in preventing accumulation of new sand inputs from tributaries over multi-year time scales. Also, the amount of sand exported is dependent on antecedent conditions, but if the supply of sand is sufficient, the amount transported by the river is exponentially proportional to flow volume (i.e., the rate of increase in sand load is much greater than the rate of increase in flow). As a result, daily flow fluctuations will transport more sediment than steady flows of the same daily average volume because the fluctuating flows are at a higher volume flow than steady flows during part of each day (U.S. Bureau of Reclamation 1995). Wright et al. (2008b) evaluated Glen Canyon Dam releases relative to existing sediment supply from tributary inputs to determine if any operational regime could rebuild and maintain sandbars, and found that a "best case" scenario for Glen Canyon Dam operations to build and retain sandbars would be to utilize high flow tests followed by equalized monthly volumes, at the lowest volume allowable under the Law of the River, with a constant steady flow, because export increases with both volume and fluctuations. And Wright et al. (2008b) acknowledged that "The question remains open as to the viability of operations that deviate from the best-case scenario that we have defined." Thus varying flow seasonally and daily to meet electricity demand is not optimal for retaining sand in the system for use in maintaining sand bars and backwaters because it results in increased erosion. However, the degree to which dam operations may be able to deviate from this best case and still retain enough sediment to meet resource needs using high flow tests remains a research question (Wright et al. 2008b) which is currently being evaluated by research and monitoring of the effects of the 2008 high flow test, and would be further tested through the implementation of the HFE Protocol.

Fluctuations and seasonal variation in flow volume to meet electricity demand also affects the food base available for fishes. As flow volume increases, Valdez and Ryel (1995) documented increasing densities of chironomids and simuliids in the drift on the descending limb of the diurnal hydrograph, and McKinney et al. (1999) documented a similar response for *G. lacustris*. Chironomids and simulids are important food items for adult humpback chub (Valdez and Ryel 1995), thus flow fluctuations may make these prey items more available in the drift. Flow fluctuations may have a negative effect on food availability in nearshore habitats, reducing food base of juvenile humpback chub. In a study conducted in the upper Colorado River basin (middle Green River, Utah), Grand et al. (2006) found that the most important biological effect of fluctuating flows in backwaters is reduced availability of invertebrate prey caused by dewatered substrates (see also Blinn et al. 1995), exchange of water (and invertebrates) between the mainchannel and backwaters, and (to a lesser extent) reduced temperature. As the magnitude of within-day fluctuations increases, so does the proportion of backwater water volume influx, which results in a net reduction in as much as 30 percent of daily invertebrate production (Grand et al. 2006). Early results of the NSE suggest that there may be little effect on food base in nearshore mainstem habitats near the LCR based on high juvenile humpback chub survivorship and relatively high growth rates at times in these habitats (B. Pine, Univ. of Florida, pers. comm., 2011).

The effect of flows in Grand Canyon on non-native fishes is not well understood, but in general, effects are similar to those described for humpback chub. The most relevant effect of dam operations on non-native fishes for humpback chub conservation is how operations benefit or disadvantage non-native fishes. This presents a tradeoff to managers that has been recognized since the 1970s (U.S. Fish and Wildlife Service 1978) and was discussed briefly in the 1995 USFWS biological opinion on the operation of Glen Canyon Dam: operations that benefit humpback chub are likely to also benefit non-native fishes that prey on and compete with humpback chub. Because predation and competition from non-native fishes is such a serious threat to humpback chub, any operations that disadvantage non-native fishes could potentially be an advantage to humpback chub. For example, the 2000 low summer steady flow appeared to benefit all fish species as abundances for size classes < 100 mm TL (3.9 inches) of all species increased during the steady flow period compared to previous years (Trammell et al. 2002, Speas et al. 2004). There is also evidence that non-native fish including fathead minnow and largemouth bass spawned in the mainstem above Diamond Creek during the low summer steady flow, and there was no record of largemouth bass reproducing above Diamond Creek prior to this (Trammel et al. 2002). Changes in hydrology likely benefitted non-native species in the Yampa River, and this appears to have led to increased predation on humpback chub and the collapse of that humpback chub population. A similar scenario occurred in Desolation and Gray canyons (Jackson and Hudson 2005, Finney 2006, Fuller 2008, R. Valdez, pers. comm., 2009).

The MLFF affects humpback chub critical habitat in many of the same ways it affects the species itself as described above. Critical habitat for humpback chub in the action area consists of the lowermost 8 miles (13 km) of the LCR to its mouth with the Colorado River, and a 173-mile reach of the Colorado River in Marble and Grand Canyons from Nautiloid Canyon (RM 34) to Granite Park (RM 208). The primary constituent elements of critical habitat are: Water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, turbidity, etc) that is delivered to a specific location in accordance with a hydrologic regime that is required for the particular life stage for each species; Physical Habitat, areas for use in spawning, nursery, feeding, and movement corridors between these areas; and Biological Environment, food supply, predation, and competition (Maddux et al. 1993a, 1993b, U.S. Fish and Wildlife Service 1994).

The MLFF directly affects water temperature, a primary constituent element (PCE) of humpback chub critical habitat (U.S. Fish and Wildlife Service 1994) by cooling mainstem water temperatures. The MLFF does this by increasing the monthly volume of releases in the winter and summer months to meet increased electricity demand. By releasing greater volumes in the summer, when air temperatures and solar insolation could warm lower volume releases, the MLFF cools the mainstem (Wright et al. 2008a). Operations under the MLFF also cool the water temperature of nearshore habitats because release volume often fluctuates over the course of the day to meet electricity demand. This significantly cools mainstem nearshore habitats by alternately flooding and dewatering nearshore habitats, especially during warm seasons, when warm air temperatures and solar insolation greatly warm these habitats (Arizona Game and Fish Department 1996, Korman et al. 2006, Wright et al. 2008a). This cooling effect is additive to the already cold temperatures of the hypolimnetic releases coming out of Glen Canyon Dam, and limits the suitability of the mainstem to provide for successful spawning and rearing of humpback chub in the mainstem (Valdez and Ryel 1995), although as discussed previously, there is evidence of mainstem spawning and recruitment (Ackerman et al. 2008, Andersen et al. 2009, 2010), and new evidence of survival and growth of early life stages of humpback chub in the mainstem (B. Pine, University of Florida, pers. comm., 2011).

The MLFF also affects the timing and volume of water delivery, directly affecting PCEs of critical habitat, and specifically, the quantity of water that is delivered to a specific location in accordance with a hydrologic regime that is required for the particular life stage for each species. Operations under MLFF alter the hydrograph to deliver more water during months with higher electricity demand in the winter and summer. Historically, humpback chub evolved with a variable hydrograph in Grand and Marble canyons, but with consistently high flows in the spring following snow melt and low flows in the summer (Topping et al. 2003). As discussed earlier, the maximum release from Glen Canyon Dam at powerplant capacity (31,500 cfs) is likely too low to provide any benefit to humpback chub in terms of providing high spring flows to clean spawning substrates and rework sediment-formed habitats (Valdez and Ryel 1995). But flows that utilize the outlet works, such as HFEs of 40,000 cfs or more, do provide some of these positive benefits to humpback chub, such as rearranging sand deposits in recirculating eddies, effectively reshaping reattachment bars and eddy return channels, creating and enlarging backwaters. The post-dam hydrograph also likely no longer provide sufficiently high flows to constitute a physical spawning cue (Valdez and Ryel 1995); despite this, humpback chub continue to spawn in the mainstem based on the persistence of mainstem aggregations and presence of juvenile and young of year humpback chub at mainstem aggregations (Andersen, M., GCMRC, pers. comm., 2007, Ackerman et al. 2008). Valdez and Ryel (1995) hypothesized that humpback chub in the mainstem now rely on photoperiod as a physical cue for spawning, noting that gonadal maturation appears normal and timed to correspond to either suitable LCR conditions (March-May) or historic mainstem conditions (May-July).

Critical habitat for humpback chub also includes PCEs for Physical Habitat, including areas for use in spawning, nursery, feeding, or corridors between these areas, such as river channels, bottomlands, side channels, secondary channels, oxbows, backwaters, and other areas in the 100-year floodplain, which when inundated provide spawning, nursery, feeding and rearing habitats, or access to these habitats. The MLFF primarily affects the quality of nursery and feeding habitats. Backwaters may be important nursery habitat for native fish due to low water velocity, warm water and high levels of biological productivity. There is a strong need for additional research on the relationship between backwaters and fish habitat suitability and humpback chub survival and recruitment. Converse et al. (1998) identified shoreline habitats used by subadult humpback chub and related spatial habitat variability with flow regulation. Most juvenile humpback chub utilized talus, debris fans or vegetated shorelines in shallow areas of low current velocity, and backwaters were a relatively rare, and rarely used, habitat type.

The MLFF affects the formation of physical habitat and has an adverse affect of eroding sediment out of the system, which results in a continual loss of sediment downstream to Lake Mead (Lovich and Melis 2007, Wright et al. 2008b). Continual erosion and a lack of flood flows may not affect the total number of backwater habitats available as much as the flow volume at any given time, but likely does reduce the size and quality of sediment-formed habitats such as backwaters (Stevens and Hoffnagle 1999, Goeking et al. 2003) that may be important rearing habitat for young humpback chub (Arizona Game and Fish Department 1996). High flow tests, timed to utilize tributary sediment inputs, can reset the system, creating sand bars and sediment formed habitat, but the degree to which this is effective in counterbalancing the erosion loss of MLFF is unclear (Wright et al. 2008b); implementation of the HFE Protocol will provide a long-term test of this hypothesis.

The MLFF's fluctuations also dewater nearshore habitats daily. Because juvenile humpback chub prefer nearshore habitats (Valdez and Ryel 1995, Robinson et al. 1998, Stone and Gorman 2006), they are especially susceptible to the adverse effects that fluctuating flows have on these habitats. Daily fluctuations in discharge can result in a variety of adverse affects due to lateral movement of the shoreline, such as stranding of juvenile fish, or sub-lethal effects related to increased stress levels, predation risk, energy expenditure, or reduced feeding opportunities (Cushman 1985) as well as decreased growth rates (Korman and Campana 2009). MLFF may likely adversely affect PCEs from the displacement effect of fluctuations, but this is not known with certainty.

The biological environment PCEs of food base, predation and, competition are also affected by the MLFF, although in complex ways that are not fully understood. As described earlier, as flow volume increases, Valdez and Ryel (1995) documented increasing densities of chironomids and simuliids on the descending limb of the diurnal hydrograph, and McKinney et al. (1999) documented a similar response for G. lacustris. Chironomids and simulids are important food items for adult humpback chub (Valdez and Ryel 1995), thus flow fluctuations may make these prey items more available in the drift, and this seems supported by data provided by Hoffnagle (2000) that found adult humpback chub condition factor was higher in the mainstem than in the LCR.

Flow fluctuations may have a negative effect on food availability in nearshore habitats, reducing food base of juvenile humpback chub. In a study conducted in the upper Colorado River basin (middle Green River, Utah), Grand et al. (2006) found that the most important biological effect of fluctuating flows in backwaters was reduced availability of invertebrate prey caused by dewatered substrates (see also Blinn et al. 1995), exchange of water (and invertebrates) between the mainchannel and backwaters, and (to a lesser extent) reduced temperature. As the magnitude of within-day fluctuations increases, so does the proportion of backwater water volume influx, which results in a net reduction in as much as 30 percent of daily invertebrate production (Grand et al. 2006). However, preliminary results of the NSE study indicate that survivorship of juvenile humpback chub in mainstem nearshore habitats is high, and growth rates in these habitats can at times be higher than LCR growth rates (B. Pine, Univ. of Florida, pers. comm., 2011).

The MLFF likely negatively affects the abundance and distribution of non-native fish species, an aspect of the biological PCEs for humpback chub, because MLFF results in a net cooling effect on mainstem river temperatures and mainstem nearshore habitats (Trammel et al. 2002, Korman et al. 2005, Valdez and Speas 2007, Wright et al. 2008a). Lower and steady mainstem flows, such as the seasonally adjusted steady flow (SASF) (see U.S. Bureau of Reclamation 1995) would lead to an increase in water temperatures that may promote spawning and minimize exposure of incubating and early larval stages of fishes, which appears to benefit non-native fishes as well as native fish species (Trammell et al. 2002). Because MLFF has the effect of cooling mainstem waters, it may benefit humpback chub by disadvantaging non-native fish species that prey on, and compete with, humpback chub including common species such as channel catfish, common carp, rainbow trout, and brown trout, as well as potential invaders, such as largemouth bass, smallmouth bass, and green sunfish (Valdez and Speas 2007). This is likely also true for small-bodied non-native fishes; for example, Trammel et al. (2002) found a significant increase in fathead minnow abundance during the 2000 Low Summer Steady Flow experiment, apparently due to the habitat stability and increases in water temperatures resulting from the flow experiment. Climatologists predict that the southwest will experience extended drought due to global climate change, and lower Lake Powell Reservoir elevations and warmer release temperatures are predicted (Seager et al. 2007, U.S. Climate Change Science Program 2008a, b). Warmer water conditions will benefit warm-water non-native fishes, result in invasions of new species, and cause greater proliferation of existing non-native fish species (Rahel et al. 2008). Thus operations that disadvantage warm-water non-native fish species may become an increasingly important tool in conservation of humpback chub.

In summary, operations under the MLFF manipulate the Colorado River hydrograph in Marble and Grand Canyons on a daily and monthly scale that has important effects to humpback chub and its critical habitat. MLFF results in a cooling effect to the mainstem Colorado River and to nearshore areas. This negatively affects water temperature PCEs, and likely results in some loss of humpback chub spawning and rearing habitat. The MLFF hydrograph also no longer provides seasonal flooding and its benefits, although Glen Canyon Dam has only a limited capability to flood the system relative to pre-dam conditions. The daily fluctuations of the MLFF may result in stranding of juvenile humpback chub, as well as sub-lethal effects from displacement, although these effects are poorly understood. The MLFF may have both beneficial and adverse effects on food base, but may adversely affect food base in nearshore habitats. The MLFF erodes sediment-formed habitats such as backwaters that may be important to juvenile humpback chub; high flow tests can offset this, but the degree to which erosion effects can be offset, and the importance of sediment-formed habitats to humpback chub, are research questions. Steady flows likely improve spawning and rearing habitat for both non-native fishes as well as native fish species, thus MLFF may have an important beneficial effect in suppressing non-native fishes. The status of the Grand Canyon population of humpback chub, in terms of both recruitment and adult abundance, has improved since the implementation of MLFF (Coggins and Walters 2009), an indication that the MLFF, originally designed to benefit native fishes, may have improved conditions for humpback chub relative to pre-MLFF flows.

Effects of MLFF through 2020 on Razorback Sucker and its Critical Habitat

The MLFF would affect razorback sucker in much the same ways as it affects humpback chub. The MLFF modifies physical habitat by cooling the water temperatures of downstream releases, particularly in the summer months. Physical habitats, backwaters formed by fine sediment in particular, are eroded by MLFF. The cooling effect of MLFF likely provides a benefit in disadvantaging non-native fish species and fish parasites such as Asian fish tapeworm. However, because razorback sucker appear to be extirpated from the action area, although they do still occur as a small reproducing population downstream in Lake Mead (Albrecht et al. 2007), none of these effects would likely actually occur to the species. Razorback sucker critical habitat does occur in the action area and 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. Razorback sucker critical habitat PCEs are exactly the same as those for humpback chub and would be affected in essentially the same ways as described above. In general, MLFF impacts critical habitat primarily through a cooling effect on water temperature, with some likely additional affects from shoreline erosion, and physical habitat manipulation through daily fluctuation. The

MLFF may benefit the biological PCEs of razorback sucker critical habitat because its cooling effect on water temperatures disadvantages non-native fishes that prey on and compete with the species.

Effects of MLFF through 2020 on Kanab Ambersnail

Kanab ambersnail habitat can be adversely affected by scouring at Colorado River flows exceeding 17,000 cfs. MLFF has been implemented since 1991, and flows have consistently scoured Kanab ambersnail habitat, removing habitat and snails below about the 25,000 cfs flow level. The MLFF includes flows up to 25,000 cfs (and beyond in emergency situations; up to 33,200 cfs may be released at power plant capacity, plus 15,000 cfs from the river outlet works, and 208,000 cfs from the spillways). Flows in excess of 25,000 cfs rarely occur, only in wettest years, although if the HFE Protocol is implemented, could occur as often as twice a year if conditions are met (up to 45,000 cfs). Nevertheless some loss of habitat and snails would occur as MLFF flows in excess of about 17,000 cfs scour the vegetation at Vaseys Paradise and carry the snails downstream. But the amount of habitat that is subjected to this effect, which is usually incremental and continuous (as opposed to the high magnitude, short duration, and relatively instantaneous effect of a HFE), is a small proportion of habitat available to Kanab ambersnail at Vaseys Paradise. Meretsky and Wegner (2000) found that at flows from 20,000 to 25,000 cfs, only one patch of snail habitat is much affected (Patch 12), and a second patch to a lesser extent at flows above 23,000 cfs (Patch 11). The largest these patches have been recently was in July 1998 when the area of both patches was 28.68 m^2 (308.7 ft^2) (Meretsky and Wegner 2000). Total habitat available in July 1998 (minus two patches that were not included in the total measurement) was 276.82 m^2 (2,979.7 ft^2). Thus patches 11 and 12, even in a good year, constitute less than 10 percent of total habitat available. Also, very few Kanab ambersnail have been found in patches 11 and 12 historically, and these patches are of low habitat quality for Kanab ambersnail (Sorensen 2009). Currently the amount of habitat loss at the 25,000 cfs flow level due to scour would be low, and is estimated to be about 300-350 ft^2 (27.9-32.5 m^2) or less (Meretsky and Wegner 2000). Thus the scouring effect of MLFF is predicted to have little effect on the overall population of Kanab ambersnail at Vaseys Paradise because scouring would occur infrequently, would affect only a small proportion of overall habitat available, habitat lost would be of low quality, and is expected to contain few snails.

The proposed action will have no effect on the water flow from the side canyon spring that maintains wetland and aquatic habitat at Vaseys Paradise. Kanab ambersnail at Elves Chasm would be unaffected by MLFF because the snails and their habitat are located up the chasm well above the Colorado River and the influence of dam operations on flow. No critical habitat has been designated for Kanab ambersnail, thus none would be affected.

Effects of MLFF through 2020 on Southwestern Willow Flycatcher

The southwestern willow flycatcher can be adversely affected by high flows through scouring and destruction of willow-tamarisk shrub nesting habitat or wetland foraging habitat, or conversely, through a reduction in flows that desiccate riparian and marsh vegetation. However, willow flycatcher nests in Grand Canyon are typically above the 45,000 cfs stage, and thus would not be affected by the highest typical Glen Canyon Dam releases (Holmes et al. 2005). Flycatchers nest primarily in tamarisk shrub in the lower Grand Canyon (Sogge et al. 1997), which is quite common, and can tolerate very dry and saline soil conditions, and thus is capable of surviving lowered water levels (Glenn and Nagler 2005). Therefore, maximum flows of the MLFF of 25,000 cfs and minimum flows of 5,000 cfs are neither expected to scour or significantly dewater habitats enough to kill or remove tamarisk, and no loss of southwestern willow flycatcher nesting habitat from flooding or desiccation is anticipated.

An important element of flycatcher nesting habitat is the presence of moist surface soil conditions (U.S. Fish and Wildlife Service 2002d). Moist surface soil conditions are maintained by overbank flow or high groundwater elevations supported by river stage, and provide nesting habitat of riparian trees, and habitat for insects that contribute to the food base for flycatchers. The MLFF flows have been implemented since 1991, and given the typical range of daily fluctuations, groundwater elevations adjacent to the channel are not expected to decline enough to significantly desiccate nesting habitat. Thus the proposed action will likely have little effect on the abundance or distribution of southwestern willow flycatcher in the action area or regionally.

Ability of Non-native Fish Control Actions to Offset Increases in Non-native Fish

Non-native fish control may be an important conservation measure in offsetting and mitigating adverse effects of dam operations, both the MLFF and HFEs. As explained previously, the proposed non-native fish control actions are designed to utilize research to improve the fundamental understanding of the effect of predation and competition on native fish, in particular humpback chub, but to do so in a way that minimizes impacts to cultural resources, and protects the humpback chub from excessive losses of individuals from non-native fish predation. The effectiveness of the proposed non-native fish control activities over the 10-year period of the proposed action, including implementation of MLFF and the HFE Protocol, was evaluated predicatively with a model (Coggins and Korman, unpublished). The model was originally designed and used to help evaluate various alternatives of non-native fish control through a structured decision-making process (Runge et al. 2011). The model contains three submodels: (1) Submodel 1 estimates the numbers of age-0 trout emigrating downstream from Lees Ferry based on a specified proportion of recruits; (2) Submodel 2 tracks the monthly numbers of age-0 trout emigrating downstream through Marble Canyon, together with specified numbers already in the main channel, and incorporates specified levels of removal in the PBR and LCR reaches, and includes incorporation of a "HBC Trigger" to implement removal in LCR reach only when the humpback chub population drops below 7,000 adults; and (3) Submodel 3 is an age-structured stock recruitment model ("HBC Shell") that evaluates the effect of different trout numbers resulting from Submodel 2 on annual modeled estimates of adult humpback chub abundance in the LCR reach.

Five scenarios were used to determine the probability that, under predation from various trout numbers, the population of humpback chub would remain greater than 5,000; 6,000; 7,000; or 10,000 adults (Figure 2; Tables 1, 2, and 3). The range of 5,000 to 10,000 adults represents a range of possible humpback chub population size. The level of 6,000 adults corresponds to the previous incidental take statement for humpback chub, and the level of 7,000 adults corresponds to the "HBC Trigger" that would cause removal of trout in the LCR to be implemented.

The five scenarios are based on the number of age-0 rainbow trout recruits in Lees Ferry; i.e., 10,000; 25,000; 50,000; 75,000; and 100,000. These numbers represent a range of possible recruitment numbers based on the best available scientific information (Korman et al. 2010). Each of these five scenarios was evaluated for three levels of existing trout numbers in the 62-mile reach between Lees Ferry and the LCR; i.e., 4,500; 45,000; and 75,000. These numbers are within the range of estimated population estimates from a low of 2,131 rainbow trout (July 2006) to a high of 10,571 rainbow trout (March 2003) reported from an 8.1-mi "control reach" (RM 44-52.1) by Coggins (2008). Assuming uniform distribution, these numbers of trout expand to a range of 16,311 to 80,914 trout for the 62-mile reach.

Three levels of trout removal were evaluated for each of the five scenarios; no removal, PBR only removal, and PBR and LCR removal. PBR only removal means that mechanical removal of trout would occur only in the 8-mi reach from the Paria River to Badger Creek Rapid. Removal in the LCR reach would be implemented in the 9.4-mi reach of the Colorado River (RM 56.3-65.7) used for removal during 2003-2006 (Coggins 2008). Removal in the LCR reach was triggered and implemented in the model only when the humpback chub population dropped below 7,000 adults. The model also always implements removal in the LCR in combination with removal in the PBR reach. The proposed action differs from the model in that removal could be implemented in either reach based on extant conditions.

The computed probabilities are based on annual estimates of adult humpback chub determined from monthly abundances of trout for 100 years, each simulated 100 times.

Scenario 1: 10,000 Rainbow Trout in Lees Ferry

Scenario 1 evaluates a base Lees Ferry recruitment of 10,000 age-0 trout, with 550 emigrating downstream. For a main-channel population equilibrium of 4,500 trout (Table 1, Figure 2), there is a 0.89, 0.92, and 0.93 probability that the adult population of humpback chub will remain above 6,000 adults (incidental take level) for no removal, PBR only removal, and PBR and LCR removal, respectively. For a main-channel population equilibrium of 45,000 trout (Table 2), the probability that the adult population of humpback chub will remain above 6,000 adults is 0.86, 0.91, and 0.89, respectively. These results show that at a low Lees Ferry recruitment level of 10,000 age-0 trout, the probability of maintaining a humpback chub population of above 6,000 adults is better than 0.90 with or without trout removal. As a comparison, the probability of maintaining the adult humpback chub population above 6,000 with no trout present is 0.93. At much higher main-channel numbers of 75,000 trout, the probability of maintaining the humpback chub population above 6,000 adults is 0.66, 0.70, and 0.67 for no removal, PBR only removal, and PBR and LCR removal, respectively. This drop in probability indicates that the numbers of trout present in the main channel strongly affects the ability of trout removal to maintain the population above 6,000 adults.

Scenario 2: 25,000 Rainbow Trout in Lees Ferry

Scenario 2 increases the number of Lees Ferry recruits to 25,000 age-0, with 1,080 emigrating downstream. At a low main-channel population equilibrium of 4,500 trout (Table 1, Figure 2), the probability of the humpback chub population remaining above 6,000 adults is 0.84, 0.93, and 0.92 for no removal, PBR only removal, and PBR and LCR removal, respectively. For a main-channel population equilibrium of 45,000 trout, the probability of >6,000 adults is 0.77, 0.88, and 0.90, respectively. This scenario reveals little difference in the probability of maintaining the humpback chub population above 6,000 adults for PBR only removal compared to PBR and LCR removal. As with the scenario 1, removal of trout at the PBR keeps the probability for more than 6,000 adult humpback chub at about 90%. At much higher main-channel numbers of 75,000 trout, removal at the PBR and LCR reaches provides a probability of about 0.70, confirming that the numbers of trout already in the main channel strongly affects the ability of trout removal to maintain the humpback chub population above 6,000 adults.

Scenario 3: 50,000 Rainbow Trout in Lees Ferry

Scenario 3 tests a greater number of Lees Ferry recruits of 50,000 age-0 trout, with 1,950 emigrating downstream. This is the first scenario that shows a marked difference between no trout removal and trout removal. With no trout removal, the probability of maintaining more than 6,000 adult humpback chub is 0.57 and 0.00 for 4,500 and 45,000 trout in the main channel. Furthermore, the probability for more than 6,000 adults does not differ by more than 0.01 between PBR-only removal and PBR and LCR removal for 4,500 main-channel trout (0.91 and 0.89) and 45,000 main-channel trout (0.88 and 0.89). In other words, if the number of Lees Ferry recruits is 50,000 age-0 trout, removal at PBR is sufficient to maintain more than 6,000 adult humpback chub at a probability of about 0.90. At the much higher main-channel numbers of 75,000 trout, however, removal at the PBR and LCR reaches provides a probability of only up to about 0.67.

Scenario 4: 75,000 Rainbow Trout in Lees Ferry

Scenario 4 tests a number of Lees Ferry recruits of 75,000 age-0 trout, with 2,830 emigrating downstream. As with Scenario 3, the difference between no removal and removal of trout is dramatic for the probability of maintaining the humpback chub population above 6,000 adults. For no removal, PBR removal, and PBR and LCR removal, the respective probabilities are 0.23, 0.82, and 0.81 for 4,500 main-channel trout and 0.00, 0.89, and 0.87 for 45,000 trout. This scenario illustrates the effect of trout removal on maintaining the humpback chub population at higher main-channel trout abundances, and also indicates that LCR removal does not appear to improve humpback chub survival beyond the PBR-only removal. At higher main-channel numbers of 75,000 trout and 75,000 Lees Ferry recruits, removal at the PBR and LCR reaches provides a probability for >6,000 adults of only up to about 0.66.

Scenario 5: 100,000 Rainbow Trout in Lees Ferry

Scenario 5 tests a number of Lees Ferry recruits of 100,000 age-0 trout, with 3,700 emigrating downstream. As with Scenarios 3 and 4, the difference between no removal and removal of trout is dramatic for the probability of maintaining the humpback chub population above 6,000 adults. For no removal, PBR removal, and PBR and LCR removal, the respective probabilities are 0.01, 0.69, and 0.68 for 4,500 main-channel trout and 0.00, 0.88, and 0.89 for 45,000 trout. This scenario also illustrates the effect of trout removal on maintaining the humpback chub population, and also indicates that LCR removal does not appear to improve humpback chub survival beyond the PBR-only removal. At higher main-channel numbers of 75,000 trout and 100,000 Lees Ferry recruits, removal at PBR and LCR provides a probability for >6,000 adults of up to about 0.70.

Trout Removal and HBC Trigger

The average number of trout removed per month (1 trip of 4 passes) was estimated with the model for the PBR and LCR reach, as well as the percentage of months in which the HBC Trigger for LCR reach removal occurred (Tables 1, 2, and 3). For a rainbow trout population equilibrium of 4,500, the estimated average number of trout removed at the PBR per month ranged from 634 to 1,988. At a main-channel equilibrium of 45,000 trout, estimated numbers removed ranged from 993 to 3,568, and at an equilibrium of 75,000 trout, monthly removal ranged from 1,001 to 3,876. Coggins (2008) reported a range of 66 to 3,605 rainbow trout captured with electrofishing from the LCR mechanical removal reach in March 2006 (4 passes) and January 2003 (5 passes), respectively. The striking similarity between the maximum number of fish captured monthly by Coggins (i.e., 3,605 when the expanded Marble Canyon trout population was 80,914) and the highest monthly PBR removal estimate by the model (i.e., 3,876 with an Marble Canyon population of 75,000) provides confidence in the model estimates.

The HBC Trigger for LCR reach removal (adult humpback chub <7,000) occurred in 10-28% of months for 4,500 main-channel trout; 12-13% for 45,000 trout; and 28-29% for 75,000 trout. When the trigger occurred, estimated monthly removal in the LCR reach was 205-880 for 4,500; 19-22 for 45,000; and 32-35 for 75,000 trout. These low removal numbers in the LCR reach reflect an estimated capture probability in the PBR that intercepts most of the trout moving downstream. The model shows that removal can keep up with emigration of large numbers of trout from the Lees Ferry reach, as long as the number of trout in Marble Canyon is low to moderate (i.e., 4,500-45,000).

Unknowns and Uncertainties

The model results described above and provided in Tables 1-3 and Figure 2 reflect estimated system responses based on model parameters with different levels of uncertainty. Many of the parameters used in the model have not been thoroughly evaluated and validated. The research activities described above are designed to provide a better understanding of the relationship of trout and humpback chub and to better inform these model parameters, as well as other uncertainties.

Caution is advised in the use of the model and interpretation of results beyond general relationships and approximate responses because of the uncertainty associated with some model parameters. The model is a valuable tool in providing insight into likely probabilities of maintaining the humpback chub population above certain levels under different trout abundances. More importantly, the model helps to identify the most sensitive parameters and those that need further investigation.

The following is a list of unknowns and uncertainties associated with the proposed non-native fish activities and with the model used to evaluate mechanical removal:

1. The current size and trend of the rainbow trout population in the Lees Ferry reach, as well as in Marble Canyon, are not known with certainty; from 2001 to 2007, the population in Lees Ferry showed a continued decline (see Figure A-3), but abundance in 2008 and 2009 increased dramatically to a level similar to the highest abundance reported by Coggins (2008) (i.e., 10,571 rainbow trout in the 8.1-mi "control reach" in March 2003).

2. The anticipated positive response of the Lees Ferry trout population to an HFE is based primarily on information derived from a fall (2004) and spring (2008) event; different investigations of the spring 1996 HFE indicate a similar beneficial response by trout to the 2008 HFE, and no response from the 2004 HFE.

3. The proportion of trout recruitment in the Lees Ferry reach that emigrates downstream to the LCR reach is not known with certainty.

4. The effectiveness of trout removal in the PBR reach has not been implemented and evaluated.

5. The distribution of trout in Marble Canyon is assumed in the model to be uniform, but preliminary data indicate decreasing numbers downstream of Lees Ferry.

6. The extent of trout reproduction in Marble Canyon is not known, although length data indicate no young trout are hatched downstream of Lees Ferry.

7. Emigration of trout downstream of Lees Ferry is not known with respect to timing, fish size, or numbers of fish.

8. Movement of trout in Marble Canyon is not known; the model assumes uniform downstream movement and no upstream movement.

9. Various sources of mortality to humpback chub are not identified and segregated, and the role of trout predation in total mortality is not known.

Summary of Anticipated Effects of Actions

Model results indicate that mechanical removal in the 8-mi Paria River to Badger Creek reach (PBR) is a viable approach to reducing the abundance of trout in Marble Canyon and for maintaining the population of humpback chub above the 6,000-adult level of incidental take. The model also shows that at low to moderate numbers of trout in Marble Canyon (i.e., 4,500-45,000), removal in the PBR reach alone may be sufficient and may not necessitate removal in the LCR reach.

Removal of trout from the PBR reach has several advantages: (1) trout are intercepted before they move downstream to the LCR reach, (2) PBR removal could reduce the source of trout to the LCR reach and lead to continued and long-term downstream trout reduction (assuming little or no trout production in Marble Canyon), (3) crews could be based at Lees Ferry where fish could be processed or further transported, and (4) labor and cost are greatly reduced with PBR removal when compared to trips through the entire 225-mi reach to Diamond Creek or further downstream to Pearce Ferry.

At higher Marble Canyon trout abundances (i.e., 45,000+ trout), it may be necessary to implement removal in both the PBR and LCR reaches. Trout abundance indices for the Lees Ferry reach for 2008-2009 show a similar abundance level to 2003 (see Figure A-3) when Coggins (2008) reported the highest estimated abundance of 10,571 rainbow trout for the 8.1-mi "control reach." This equates to about 81,000 fish for the 62-mile Marble Canyon reach, assuming uniform distribution, and represent the current condition of rainbow trout abundance in Marble Canyon. At this higher Marble Canyon trout abundance, 10 monthly PBR removal trips and 6 monthly LCR removal trips provide a probability of about 0.60 of maintaining the humpback chub population above 6,000 adults. It may be necessary, at the higher Marble Canyon trout abundances, to implement a short-term removal effort in the LCR reach in order to bring main-channel numbers down to a level where PBR removal only can control trout numbers. However, LCR removal would only occur if adult humpback chub numbers drop below 7,000 fish based on the ASMR.

The model shows that removal can keep up with emigration of large numbers of trout from the Lees Ferry reach (up to 100,000), but it is necessary to first reduce the Marble Canyon trout abundance. The model suggests that if trout abundance is high in the mainstem through Marble Canyon, maintaining a humpback chub population of >6,000 adults with a probability >0.60 will likely require more than 10 PBR removal trips, and could also require more than 6 LCR removal trips.

The unknowns and uncertainties listed above help to identify those elements of non-native fish control activities and model parameters that need to be addressed. The investigations identified in this BA supplement, together with ongoing investigations, and monitoring and evaluation being conducted in compliance with conservation measures and biological opinions will help to provide a sound scientific basis for this need. The workshop scheduled for 2014 will help to bring scientists and managers together to assess and evaluate available information and proceed with reasonable and prudent actions.

Conclusions

The proposed action will implement 10 years worth of the MLFF, multiple HFEs, and experimentation and implementation of non-native fish control to mitigate the adverse effects of these dam operatoins. There is uncertainty about how these actions will interact over the 10-year period. Reclamation is proposing to implement these actions in such a way that adaptive management principles will be utilized to both learn as much as possible about these resource management actions, but also to learn in a way that poses the least possible risk to the suite of resources identified in the Grand Canyon Protection Act that are under the GCDAMP's authority.

MLFF tends to cool mainstem habitat for humpback chub and erode sediment-formed habitats such as backwaters. The cooling effect likely adversely affects humpback chub through inhibited growth and cold shock, but also benefits humpback chub by helping to suppress non-native fish predators. Recent findings by the NSE study indicate survival and growth of humpback chub in mainstem nearshore habitats is much better than expected, and effects to the species in the mainstem from MLFF may not be as adverse as previously thought. Humpback chub status has improved in the 20-years since the MLFF was implemented, which is perhaps not surprising, because it was intended to improve conditions for native fish.

HFEs would potentially be conducted twice a year for the 10-year period of the proposed action. Although the existing information indicates that this will likely benefit sediment conservation in the action area, as well as related resources such as camping beaches, and sediment-formed habitats that may be important for native fish, there is also the potential that biological resources such as humpback chub could be adversely affected by increases in the trout population resulting from HFE implementation (Wright and Kennedy 2011).

Model predictions for the effectiveness for using rainbow trout removal in the PBR and LCR reaches to offset increases in trout that result from HFEs indicate that the success of this approach in maintaining the humpback chub population depends on the numbers of trout already in the mainstem in Marble Canyon and the number of trout emigrating from Lees Ferry. Korman et al. (2010) documented numbers of age-0 rainbow trout in Lees Ferry and found that abundance of age-0 trout in the Lees Ferry reach increased in spring as fish emerged from the gravel and recruited to the sampled population, peaking by mid-July, and then declined as losses owing to mortality and possibly downstream dispersal or movement to offshore habitat in the Lees Ferry reach that was not sampled. The rate of decline in abundance decreased in fall, and abundance was generally stable through winter. Most of this decrease is thought to be from mortality, as opposed to emigration to other habitats or downstream, but emigration is thought to occur, and likely occurs in the fall (J. Korman, Ecometric, pers. comm., 2011). Given this, and numbers of age-0 trout documented in past years by Korman et al. (2010), the scenarios of 10,000 to 50,000 rainbow trout recruits seems more likely than 75,000 or 100,000. Although the numbers of rainbow trout currently in Marble Canyon could be about 80,000 based on past results (Coggins et al. 2011), this assumes uniform distribution, which is unlikely. Also, Coggins et al. (2011) found that, even at these densities, mechanical removal in the LCR reach was successful in reducing abundances back down to the 4,500 level for the Marble Canyon reach. In other words, under any conditions, based on prior LCR reach removal results, LCR reach removal can, if necessary, create the 4,500 mainstem trout condition in the LCR reach. Given these assumptions and monitoring results, the proposed action seems likely to be able to maintain the humpback chub population above 6,000 adults for the duration of the proposed action. In other words, the moderate recruitment and adult trout abundance scenarios evaluated with the model seem like the most probable, and under these conditions probability of maintaining the adult humpback chub population above 6,000 adults is relatively high, although enough uncertainty exists that only testing these assumptions will reduce existing uncertainty.

The proposed action is expected to have both beneficial and adverse effects to humpback chub and to humpback chub and razorback sucker critical habitat, but Reclamation believes the net result will be positive for these species. 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.

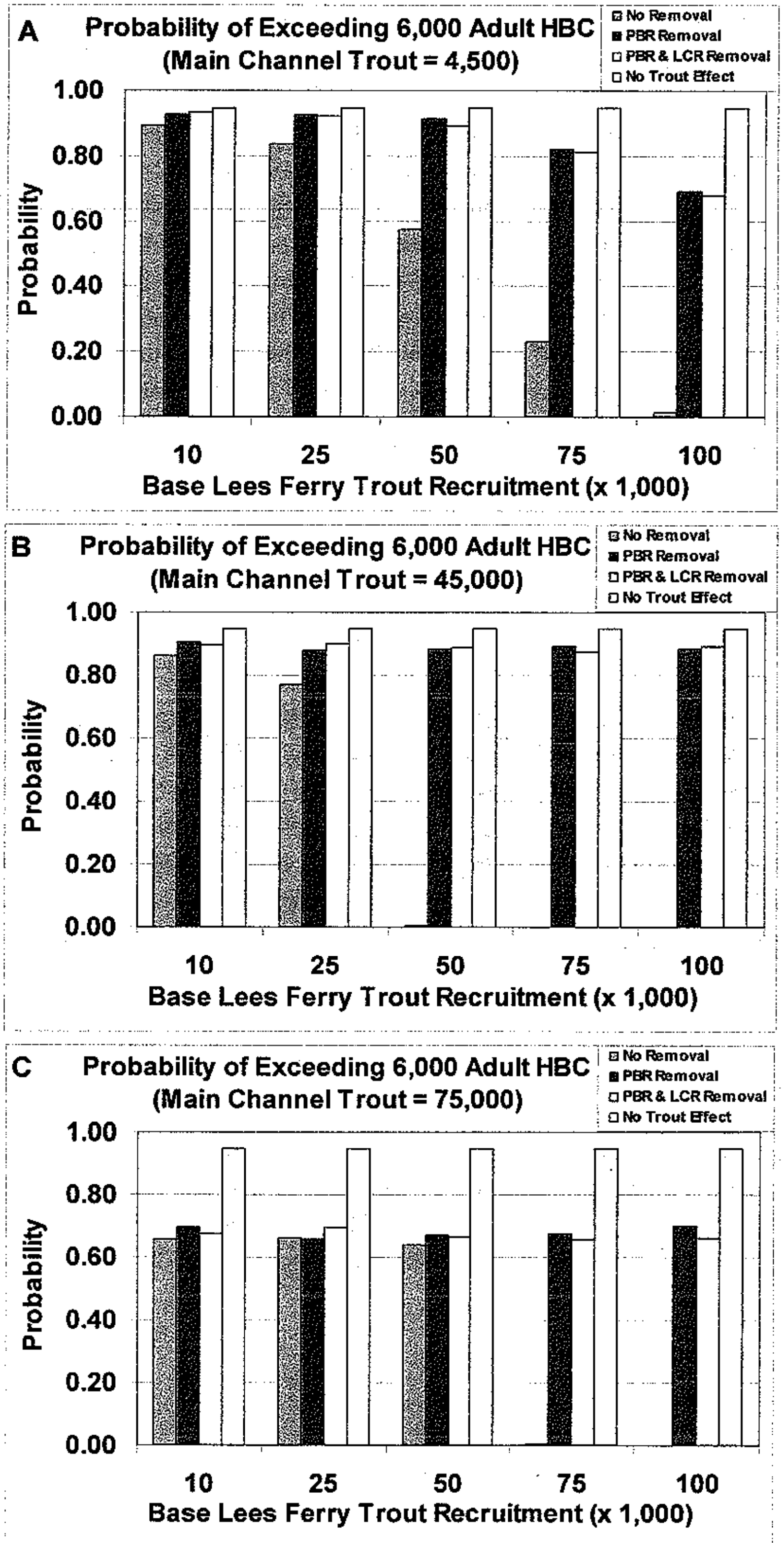

Figure 2. Probability of exceeding 6,000 adult humpback chub with main channel trout equilibriums of (A) 4,500, (B) 45,000, and (C) 75,000. Comparisons are made for no removal of trout, PBR removal only, PBR and LCR removal, and no trout effect (i.e., no trout present in the system).

Table 1. Probabilities of exceeding 5,000; 6,000; 7,000; and 10,000 adult humpback chub for combinations of (A) base recruitment of rainbow trout at Lees Ferry, (B) recruitment/emigration rate, (C) main-channel rainbow trout population equilibrium of 4,500, (D) PBR removal, and (E) LCR removal. Estimated numbers of trout removed per month and percentage of months in which the HBC Trigg occurred are also provided. Probabilities are based on 100 model simulations for 100 years each. Model parameters are described in table footnotes.

Model Parameters	No Trout Effect	Scenario 1			Scenario 2			Scenario 3			Scenario 4			Scenario 5		
A. Base LF Recruit (1,000s age-0 RBT)	0	10	10	10	25	25	25	50	50	50	75	75	75	100	100	100
B. Recruit/Emigration Rate	0	0.55	0.55	0.55	1.08	1.08	1.08	1.95	1.95	1.95	2.83	2.83	2.83	3.7	3.7	3.7
C. MC RBT Pop Equilibrium	0	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500
D. PBR Removal Sched (trips, 4 passes)	0	0	10	10	0	10	10	0	10	10	0	10	10	0	10	10
E. LCR Removal Sched (trips, 4 passes)	0	0	0	6	0	0	6	0	0	6	0	0	6	0	0	6
Probability of Exceeding Adult HBC Numbers																
>5,000	0.99	0.96	0.98	0.98	0.93	0.96	0.98	0.85	0.96	0.96	0.48	0.94	0.93	0.08	0.88	0.87
>6,000 (Incidental Take)	0.93	0.89	0.92	0.93	0.84	0.93	0.92	0.57	0.91	0.89	0.23	0.82	0.81	0.01	0.69	0.68
>7,000 (HBC Trigger)	0.90	0.72	0.81	0.82	0.64	0.75	0.80	0.39	0.72	0.71	0.07	0.61	0.61	0.01	0.43	0.43
>10,000	0.48	0.19	0.30	0.33	0.14	0.26	0.29	0.04	0.19	0.19	0.00	0.11	0.12	0.00	0.03	0.04
Trout Removed and HBC Trigger																
Ave No. Trout Removed/Month (PBR)	--	--	634	634	--	832	834	--	1,192	1,192	--	1,587	1,590	--	1,987	1,988
Ave No. Trout Removed/Month (LCR)	--	--	0	205	--	0	311	--	0	500	--	0	690	--	0	880
% of Months HBC Trigger Occurred	--	--	0	10%	--	0	10%	--	0	15%	--	0	21%	--	0	28%

A. Base LF Recruit (1,000s age-0 RBT: The number of age-0 rainbow trout recruiting at Lees Ferry; 10,000; 25,000; 50,000; 75,000; and 100,000 (see Figure A-2.

B. Recruit/Emigration Rate: The model provides three "Recruitment-Emigration Relationships" (WLR, WLR0.4, NoLR). The output on this table is from WLR only (i.e., with specified trout recruitment from Lees Ferry); the number 1.95 means that for age-0 trout recruitment of 50,000, a total of 1,950 emigrate downstream. The other models are not relevant to these scenarios.

C. MC RBT Pop Equilibrium: This sets the numbers of trout already in the main channel downstream from Lees Ferry, set proportional to seven river reaches from Lees Ferry (RM 0) to the LCR (RM 62). Specified numbers of 4,5 45,000; and 75,000 are equivalent to a range of trout numbers in a "control reach" of 690 RBT/mi (July 2006) to 3,424 RBT/mi (March 2003) (Coggins 2008).

D. PBR Removal Sched (trips, 4 passes): This parameter provides the option of no removal at the PBR or any specified number of removal trips and passes; table output is based on 4 passes in each of 10 monthly removal trips

E. LCR Removal Sched (trips, 4 passes): This parameter provides the option of no removal at the LCR or any specified number of removal trips and passes if the HBC population drops below 7,000 adults (i.e., "HBC Trigger"); ta output is based on 4 passes in each of 6 monthly removal trips.

Table 2. Probabilities of exceeding 5,000; 6,000; 7,000; and 10,000 adult humpback chub for combinations of (A) base recruitment of rainbow trout at Lees Ferry, (B) recruitment/emigration rate, (C) main-channel rainbow trout population equilibrium of 45,000, (D) PBR removal, and (E) LCR removal. Estimated numbers of trout removed per month and percentage of months in which the HBC Trigger occurred are also provided. Probabilities are based on 100 model simulations for 100 years each. Model parameters are described in table footnotes.

Model Parameters	No Trout Effect	Scenario 1			Scenario 2			Scenario 3			Scenario 4			Scenario 5		
A. Base LF Recruit (1,000s age-0 RBT)	0	10	10	10	25	25	25	50	50	50	75	75	75	100	100	100
B. Recruit/Emigration Rate	0	0.55	0.55	0.55	1.08	1.08	1.08	1.95	1.95	1.95	2.83	2.83	2.83	3.7	3.7	3.7
C. MC RBT Pop Equilibrium	0	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
D. PBR Removal Sched (trips, 4 passes)	0	0	10	10	0	10	10	0	10	10	0	10	10	0	10	10
E. LCR Removal Sched (trips, 4 passes)	0	0	0	6	0	0	6	0	0	6	0	0	6	0	0	6
Probability of Exceeding Adult HBC Numbers																
>5,000	0.99	0.97	0.97	0.96	0.91	0.96	0.96	0.01	0.97	0.97	0.01	0.97	0.96	0.00	0.97	0.96
>6,000 (Incidental Take)	0.93	0.86	0.91	0.89	0.77	0.88	0.90	0.00	0.88	0.89	0.00	0.89	0.87	0.00	0.88	0.89
>7,000 (HBC Trigger)	0.90	0.74	0.74	0.73	0.58	0.72	0.73	0.00	0.73	0.74	0.00	0.75	0.75	0.00	0.77	0.73
>10,000	0.48	0.20	0.23	0.21	0.12	0.21	0.21	0.00	0.22	0.21	0.00	0.22	0.23	0.00	0.23	0.21
Trout Removed and HBC Trigger																
Ave No. Trout Removed/Month (PBR)	--	--	999	993	--	1,379	1,384	--	2,118	2,111	--	2,855	2,854	--	3,570	3,568
Ave No. Trout Removed/Month (LCR)	--	--	0	22	--	0	20	--	0	22	--	0	19	--	0	21
% of Months HBC Trigger Occurred	--	--	0	13%	--	0	12%	--	0	13%	--	0	11%	--	0	12%

A. Base LF Recruit (1,000s age-0 RBT: The number of age-0 rainbow trout recruiting at Lees Ferry; 10,000; 25,000; 50,000; 75,000; and 100,000 (see Figure A-2.

B. Recruit/Emigration Rate: The model provides three "Recruitment-Emigration Relationships" (WLR, WLR0.4, NoLR). The output on this table is from WLR only (i.e., with specified trout recruitment from Lees Ferry); the number 1.95 means that for age-0 trout recruitment of 50,000, a total of 1,950 emigrate downstream. The other models are not relevant to these scenarios.

C. MC RBT Pop Equilibrium: This sets the numbers of trout already in the main channel downstream from Lees Ferry, set proportional to seven river reaches from Lees Ferry (RM 0) to the LCR (RM 62). Specified numbers of 4,500; 45,000; and 75,000 are equivalent to a range of trout numbers in a "control reach" of 690 RBT/mi (July 2006) to 3,424 RBT/mi (March 2003) (Coggins 2008).

D. PBR Removal Sched (trips, 4 passes): This parameter provides the option of no removal at the PBR or any specified number of removal trips and passes; table output is based on 4 passes in each of 10 monthly removal trips.

E. LCR Removal Sched (trips, 4 passes): This parameter provides the option of no removal at the LCR or any specified number of removal trips and passes if the HBC population drops below 7,000 adults (i.e., "HBC Trigger"); table output is based on 4 passes in each of 6 monthly removal trips.

Table 3. Probabilities of exceeding 5,000; 6,000; 7,000; and 10,000 adult humpback chub for combinations of (A) base recruitment of rainbow trout at Lees Ferry, (B) recruitment/emigration rate, (C) main-channel rainbow trout population equilibrium of 75,000, (D) PBR removal, and (E) LCR removal. Estimated numbers of trout removed per month and percentage of months in which the HBC Trigger occurred are also provided. Probabilities are based on 100 model simulations for 100 years each. Model parameters are described in table footnotes.

Model Parameters	No Trout Effect	Scenario 1			Scenario 2			Scenario 3			Scenario 4			Scenario 5		
A. Base LF Recruit (1,000s age-0 RBT)	0	10	10	10	25	25	25	50	50	50	75	75	75	100	100	100
B. Recruit/Emigration Rate	0	0.55	0.55	0.55	1.08	1.08	1.08	1.95	1.95	1.95	2.83	2.83	2.83	3.7	3.7	3.7
C. MC RBT Pop Equilibrium	0	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000
D. PBR Removal Sched (trips, 4 passes)	0	0	10	10	0	10	10	0	10	10	0	10	10	0	10	10
E. LCR Removal Sched (trips, 4 passes)	0	0	0	6	0	0	6	0	0	6	0	0	6	0	0	6
Probability of Exceeding Adult HBC Numbers																
>5,000	0.99	0.86	0.90	0.88	0.87	0.86	0.89	0.86	0.87	0.87	0.01	0.87	0.87	0.00	0.90	0.87
>6,000 (Incidental Take)	0.93	0.66	0.70	0.67	0.66	0.66	0.70	0.64	0.67	0.67	0.00	0.68	0.66	0.00	0.70	0.66
>7,000 (HBC Trigger)	0.90	0.40	0.44	0.43	0.41	0.42	0.45	0.39	0.43	0.41	0.00	0.42	0.41	0.00	0.43	0.41
>10,000	0.48	0.02	0.03	0.04	0.03	0.04	0.04	0.02	0.04	0.03	0.00	0.03	0.04	0.00	0.03	0.03
Trout Removed and HBC Trigger																
Ave No. Trout Removed/Month (PBR)	--	--	1,001	1,003	--	1,393	1,396	--	2,168	2,173	--	3,025	3,025	--	3,876	3,874
Ave No. Trout Removed/Month (LCR)	--	--	0	35	--	0	34	--	0	36	--	0	32	--	0	35
% of Months HBC Trigger Occurred	--	--	0	29%	--	0	30%	--	0	30%	--	0	30%	--	0	28%

A. Base LF Recruit (1,000s age-0 RBT: The number of age-0 rainbow trout recruiting at Lees Ferry; 10,000; 25,000; 50,000; 75,000; and 100,000 (see Figure A-2.

B. Recruit/Emigration Rate: The model provides three "Recruitment-Emigration Relationships" (WLR, WLR0.4, NoLR). The output on this table is from WLR only (i.e., with specified trout recruitment from Lees Ferry); the number 1.95 means that for age-0 trout recruitment of 50,000, a total of 1,950 emigrate downstream. The other models are not relevant to these scenarios.

C. MC RBT Pop Equilibrium: This sets the numbers of trout already in the main channel downstream from Lees Ferry, set proportional to seven river reaches from Lees Ferry (RM 0) to the LCR (RM 62). Specified numbers of 4,50 45,000; and 75,000 are equivalent to a range of trout numbers in a "control reach" of 690 RBT/mi (July 2006) to 3,424 RBT/mi (March 2003) (Coggins 2008).

D. PBR Removal Sched (trips, 4 passes): This parameter provides the option of no removal at the PBR or any specified number of removal trips and passes; table output is based on 4 passes in each of 10 monthly removal trips.

E. LCR Removal Sched (trips, 4 passes): This parameter provides the option of no removal at the LCR or any specified number of removal trips and passes if the HBC population drops below 7,000 adults (i.e., "HBC Trigger"); tabl output is based on 4 passes in each of 6 monthly removal trips.

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APPENDIX A: Relationship of High Flows to Trout and Humpback Chub

High releases from Glen Canyon Dam, especially in the spring, are expected to increase survival and recruitment of young rainbow trout in the Lees Ferry reach and increase their abundance (Korman et al. 2010). Figure A-1 illustrates the relationship of high-flow releases to rainbow trout and humpback chub. The increase in trout abundance is expected to result in emigration of some young trout downstream into designated critical habitat occupied by the endangered humpback chub near the LCR confluence.

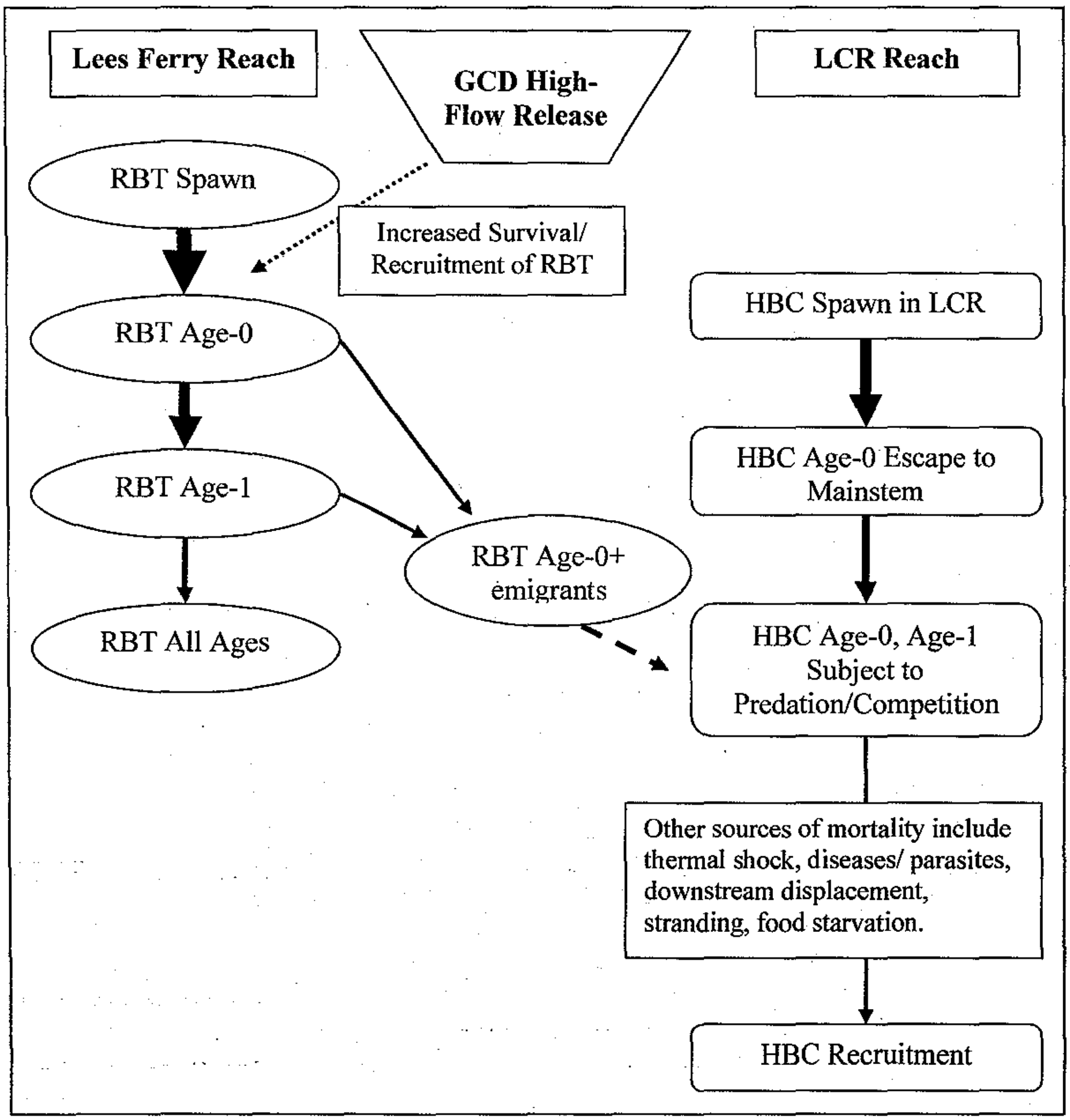

Figure A-1. Relationship of a high-flow release to rainbow trout and humpback chub.

Humpback chub in their first and second years of life use nearshore habitats as nursery areas (Converse et al. 1998), where they are susceptible to predation by rainbow trout and brown trout. Rates of piscivory ranged from 4 to 10 fish/rainbow trout/year, and 90 to 112 fish/brown trout/year (Yard et al. 2011). Of prey fish consumed, an estimated 27.3% were humpback chub.

The greatest concentration of young humpback chub occurs in the LCR reach, about 70-80 mi downstream from Glen Canyon Dam. This reach is the principal nursery area for young humpback chub that originate from spawning primarily in the LCR, but may also come from a small amount of mainstem spawning as far upstream as warm springs near RM 30 (Valdez and Masslich 1999; SWCA 2008), where there is evidence of overwinter survival in some years (Andersen et al. 2010).

Evidence of Trout Response to a High-Flow Release

Evidence for a potential increase in abundance of rainbow trout from a high-flow release is based on measured survival rates of young trout in the Lees Ferry reach before and after high-flow releases (HFEs) in November 2004 and April 2008 (Figure A-2, Korman et al. 2010). A stock-recruitment analysis showed that survival rates of early life stages increased more than fourfold following the March 2008 HFE compared to survival rates before the experiment. Fry abundance in 2009 was more than twofold higher than expected, given the estimated number of viable eggs deposited that year, but fry abundance in 2010 was similar to levels between 2003 and 2007.

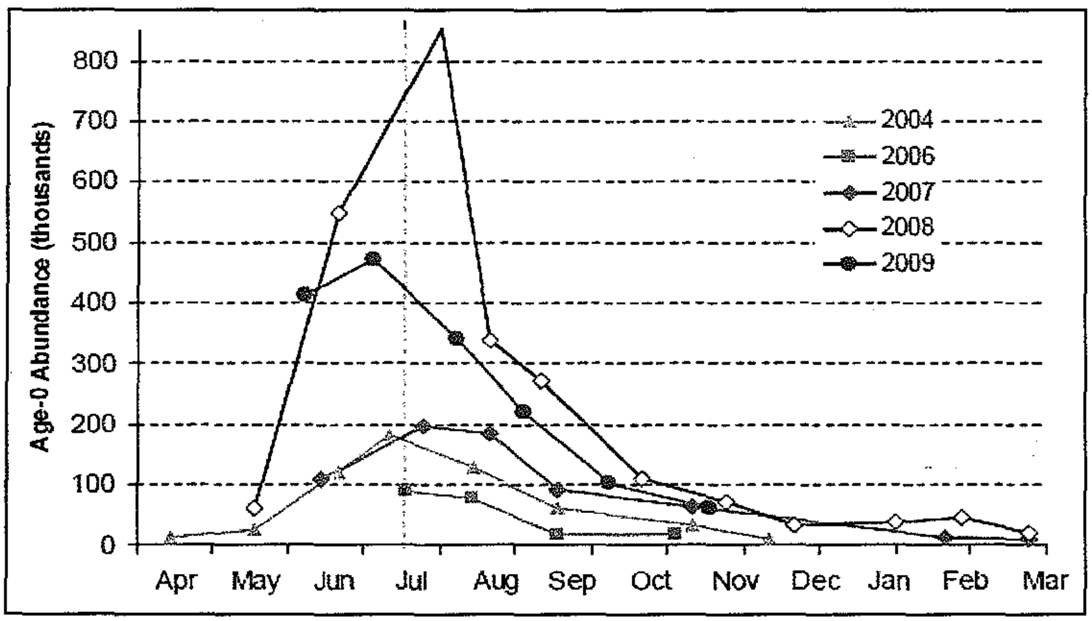

Figure A-2. Trends in the abundance of age-0 rainbow trout in the Lees Ferry reach through the year for several different brood years (years in which the eggs that produced the fish were fertilized). The vertical dashed line represents July 15, the date used as a standard time for the annual recruitment values in the stock-recruitment analysis (from Korman et al. 2010).

This pattern indicates that the effect of an HFE on early life stages of trout declines through time, with increased survival rates lasting for as long as 2 years (Korman and Melis 2011). Increased abundance of fry in 2008 eventually led to increased abundance of 1-year-old trout in 2009 in the Lees Ferry reach, and some of these fish likely moved downstream to the area near the confluence with the Little Colorado River (Makinster et al. 2010a) used by humpback chub. In contrast, the November 2004 HFE resulted in lower apparent survival of rainbow trout compared to that observed during more typical dam operations. Although the cause of this effect was not clear, it may be that spring HFEs benefit trout by increasing egg and fry survival, whereas fall HFEs may scour overwinter food sources and detrimentally affect trout survival.

The rainbow trout population in the Lees Ferry reach underwent a dramatic increase from 1991 to 1997 most likely because of increased minimum flows and reduced daily discharge fluctuations (Figure A-3). After 2001, there was a steady decline in the Lees Ferry population until 2007; a similar decline occurred below the Paria River (Makinster et al. 2010a). The 2001–2007 decline is attributed less to increased daily fluctuations (trout suppression flows) during 2003-2005 and more to increased water temperatures (associated with low reservoir elevations) and increased trout metabolic demands coupled with a static or declining foodbase, periodic oxygen deficiencies and nuisance aquatic invertebrates; e.g., New Zealand mudsnail (*Potamopyrgus antipodarum*) (Behn et al. 2010). The dramatic increase in 2008, as previously discussed is attributed to the April 2008 HFE.

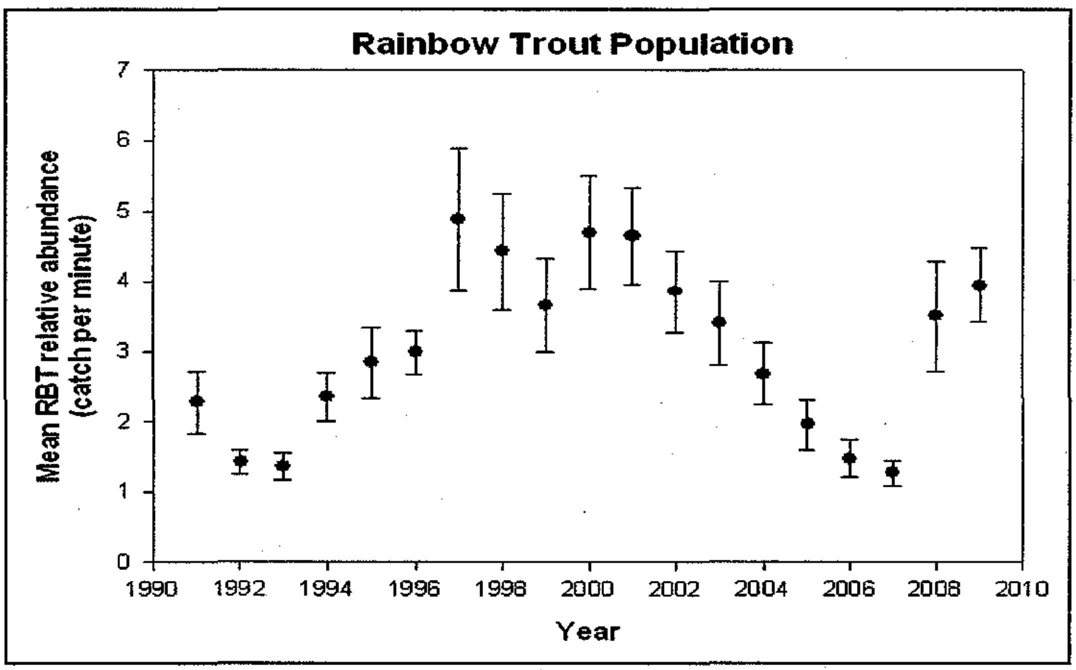

Figure A-3. Average annual electrofishing catch rates of rainbow trout in the Lees Ferry reach (Glen Canyon Dam to Lees Ferry) for 1991–2010 (from Makinster et al. 2010a).

The population of humpback chub for the period 1991 to 2007 (Figure A-4) appears to be inversely related to the abundance of rainbow trout. The chub population was lowest in 2000 and 2001 when the rainbow trout density was highest.

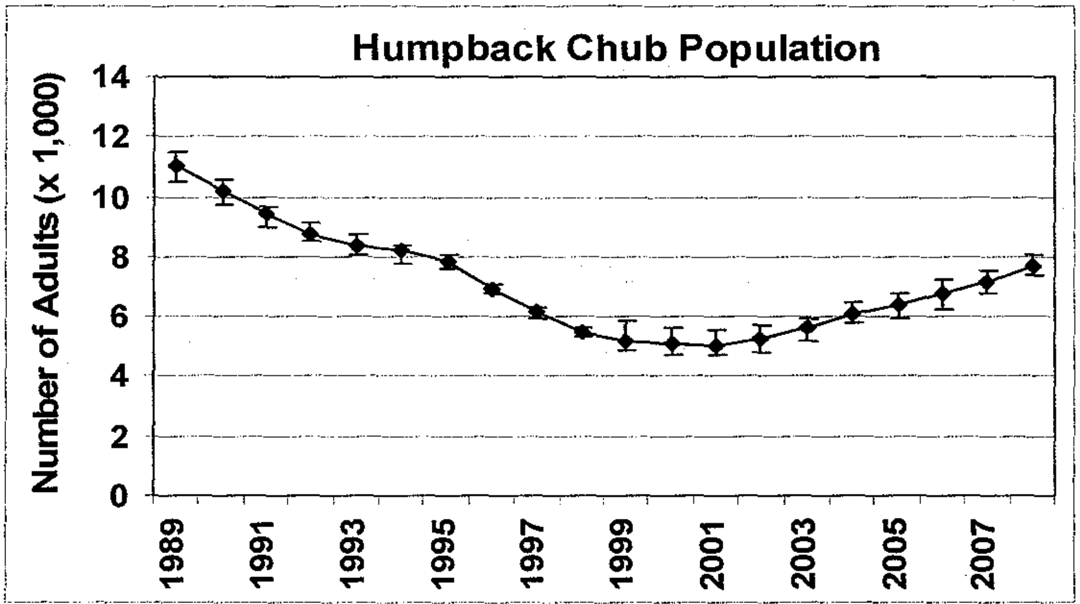

Figure A-4. Estimated adult humpback chub abundance (age 4+) from ASMR, incorporating uncertainty in assignment of age. Point estimates are mean values among 1,000 Monte Carlo trials, and error bars represent maximum and minimum 95-percent profile confidence intervals among 1,000 Monte Carlo trials.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

Effects of Past Removal Activities

From 2003 through 2006, over 36,500 non-native fish of 15 species were removed from a 9.4-mi reach of the Colorado River (RM 56.3-65.7) in the vicinity of the LCR; 82% were rainbow trout and 1% was brown trout (Coggins 2008). The estimated abundance of rainbow trout in the entire removal reach ranged from a high of 6,446 (95% credible interval (CI) 5,819-7,392) in January 2003 to a low 617 (95% CI 371-1,034) in February 2006; a 90% reduction over this time period. Between February 2006 and the final removal effort in August 2006, the estimated abundance increased by approximately 700 fish to 1,297 (95% CI 481-2,825).

An average of 1,765 rainbow trout and 36 brown trout were captured during each trip (2-5 passes per trip; 2 nights per pass) from the LCR reach when the trout population was highest in 2003 (Table A-1). Assuming that these numbers of fish can be removed in a single trip from the LCR reach during each of six proposed trips, a total of 10,590 (1,765 x 6) rainbow trout and 216 (36 x 6) brown trout could be removed in one year. It is recognized that fewer fish would be removed with lower numbers of trout. In a given year, therefore, with these levels of mechanical removal and high levels of trout abundance we would expect to save 11,564—28,911 chub from predation by rainbow trout (i.e., numbers removed times HBC/predator/year) and between 5,307 and 6,604 chub from predation by brown trout. These numbers were derived from rates of piscivory of 4 to 10 fish/rainbow trout/year, and 90 to 112 fish/brown trout/year, and the estimation that 27.3% of prey fish consumed were humpback chub (Yard et al. 2011).

Table A-1. Average numbers of rainbow trout (RBT) and brown trout (BNT) captured in the LCR reach each year from 2003 through 2006. Data from Coggins (2008).

Year	Trips	Passes	Average per Trip	
			RBT	BNT
2003	6	2-5	1,765	36
2004	6	4-6	908	32
2005	6	4	364	6
2006	5	4	160	5

Appendix E: Biological Opinion

United States Department of the Interior
U.S. Fish and Wildlife Service
Arizona Ecological Services Office
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Phoenix, Arizona 85021-4951
Telephone: (602) 242-0210 FAX: (602) 242-2513

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

December 23, 2011

Memorandum

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

From: Field Supervisor

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

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

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

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

Table of Contents

Consultation history

January 14, 2011

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

January 28, 2011

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

March 17, 2011

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

June 6, 2011

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

July 18, 2011

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

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

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

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

August 24, 2011 and
August 25, 2011

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

August 31, 2011

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

September 2, 2011

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

September 6 - 8, 2011

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

October 4, 2011

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

October 27, 2011

Reclamation sent revised Conservation Measures to FWS.

November 8, 2011 and
November 18, 2011

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

November 25, 2011

FWS sent draft biological opinion to Reclamation for agency review.

November 30, 2011

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

December 6, 2011

Second revised draft Opinion provided to Reclamation for review.

December 8, 2011

Reclamation responded to second draft Opinion.

December 14, 2011

Third draft Opinion provided to Reclamation for review.

December 20, 2011

Conference call between FWS and Reclamation. Reclamation provides comments on the third draft document.

December 21, 2011 and
December 22, 2011

Reclamation and FWS discuss final draft biological opinion.

BIOLOGICAL OPINION

DESCRIPTION OF THE PROPOSED ACTION

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

<u>HFEs</u>

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

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[1] On February 27, 2008, the Service issued to Reclamation a biological opinion on the operation of Glen Canyon Dam for the period 2008-2012 (2008 Opinion). On May 26, 2009, the District Court of Arizona, in response to a lawsuit brought by the Grand Canyon Trust, ordered the Service to reevaluate the conclusion in the 2008 Opinion that the Modified Low Fluctuating Flow (MLFF) does not violate the Endangered Species Act (Case number CV-07-8164-PHX-DGC). The Court ordered the Service to provide an analysis and a reasoned basis for its conclusions in the 2008 Opinion, and to include an analysis of how MLFF affects critical habitat and the functionality of critical habitat for recovery purposes. The court noted that other portions of the biological opinion, the two components analyzing Reclamation's proposed action for steady flow releases in September and October 2008-2012 and the 2008 experimental high flow test, were adequate and would remain in effect. The court further ordered that "Reclamation may continue operating the Dam in accordance with the 2008 Experimental Plan" in the interim. The Service published a supplement to the 2008 Opinion (2009 Supplemental Opinion) in response to the Court Order. It provided a revised analysis of the effects of MLFF on endangered humpback chub and its critical habitat, and the endangered Kanab ambersnail. It also provides an explanation for why MLFF does not destroy or adversely modify humpback chub critical habitat and addressed whether MLFF will advance or impede chub recovery. On June 29,

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

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

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

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

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

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

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

Non-native fish control

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

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

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

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

OR

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

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

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

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

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

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

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

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

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

Modified Low Fluctuating Flows

This portion of the proposed action includes the continuation of the MLFF alternative as described in the 1995 Environmental Impact Statement and adopted in the 1996 ROD on Glen Canyon Dam operations for the 10-year period for fiscal years 2011-2020. MLFF is also considered in the Environmental Baseline section of this opinion because MLFF has been in effect since 1996. Previously scheduled steady flows will continue in September and October 2012 as part of the proposed action that is subject of this consultation. Under the MLFF, daily flow releases are limited to a minimum of 5,000 cfs and maximum of 25,000 cfs (although this can be exceeded for emergencies or during extreme hydrological conditions). Minimum flow during the day from 7:00 am to 7:00 pm is further limited to 8,000 cfs. Daily fluctuation limit is 5,000 cfs for months with release volumes less than 0.6 million acre feet (maf), 6,000 cfs for monthly release volumes of 0.6 maf to 0.8 maf, and 8,000 cfs for monthly volumes over 0.8 maf. Ramp rates must not exceed 4,000 cfs per hour ascending and 1,500 cfs per hour descending (Table 1). Operations under the MLFF are typically structured to generate hydropower in response to electricity demand, with higher monthly volume releases in the winter and summer months, and daily fluctuations in release volume.

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

Glen Canyon Dam Release Constraints		
Parameter	**Release Volume (cfs)**	**Conditions**
Maximum Flow[1]	**25,000**	
Minimum Flow	**5,000**	**Nighttime**
	8,000	**7:00 a.m. to 7:00 p.m.**
Ramp Rates		
Ascending	**4,000**	**Per hour**
Descending	**1,500**	**Per hour**
Daily Fluctuations[2]	**5,000 to 8,000**	

1 May be exceeded for emergencies and during extreme hydrological conditions.

2 Daily fluctuation limit is 5,000 cubic feet per second (cfs) for months with release volumes less than 0.6 maf; 6,000 cfs for monthly release volumes of 0.6 maf to 0.8 maf; and 8,000 cfs for monthly volumes over 0.8 maf.

Conservation Measures

As explained in the 2008 Opinion and 2009 Supplemental Opinion, we are confident that Reclamation will implement the following conservation measures because of their continued demonstration of effectiveness in implementing past and ongoing conservation measures. Essentially all of the ongoing conservation measures are currently being implemented by Reclamation. It is important to note that Reclamation's continuing implementation of these measures is in marked contrast to conditions at the time of the 1995 jeopardy biological opinion when none of these elements were funded and implemented at that time, although some had been identified as potential actions. Based on new information, Reclamation in coordination with Glen Canyon Dam Adaptive Management Program (GCDAMP) has updated some of the conservation measures as described below.

Re-Evaluation Points – Pursuant to 50 CFR § 402.16 (c), reinitiation of formal consultation is required and shall be requested by the Federal agency or by the FWS where discretionary Federal involvement or control over the action has been retained or is authorized by law and if new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered. Reclamation and FWS agree to meet at least once every 3 years to specifically review the need for reinitiation based on humpback chub status and other current and relevant information. Reclamation will undertake a review in 2014 of the first two years of implementation of the proposed action through a workshop with scientists to assess what has been learned, which will also serve as the first re-evaluation point. Reclamation will also produce a written report of each evaluation and either FWS or Reclamation may require reinitiation of formal consultation on the proposed action to reevaluate the effects of the action.

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

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

Humpback Chub Refuge – Reclamation will continue to assist FWS in maintenance of a humpback chub refuge population at a Federal hatchery (Reclamation has assisted the FWS in creating a humpback chub refuge at Dexter National Fish Hatchery and Technology Center) (DNFHTC) or other appropriate facility by providing funding to assist in annual maintenance (including the collection of additional humpback chub from the Little Colorado River for this purpose). In the unlikely event of a catastrophic loss of the Grand Canyon population of humpback chub, a humpback chub refuge will provide a permanent source of sufficient numbers of genetically representative stock for repatriating the species.

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

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

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

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

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

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

Ongoing Research

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

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

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

Action Area

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

STATUS OF THE SPECIES AND CRITICAL HABITAT

Humpback chub

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The Lower Basin currently hosts the largest population of humpback chub and is commonly referred to as the Grand Canyon population. Mark-recapture methods have been used since the late 1980s to assess trends in adult abundance and recruitment of the LCR aggregation, the primary aggregation constituting the Grand Canyon population. These estimates indicate that the adult population declined through the 1980s and early 1990s but has been increasing for the past decade (Coggins et al. 2006a, Coggins 2008a, Coggins and Walters 2009). Coggins (2008a) summarized information on abundance and analyzed monitoring data collected since the late 1980s and found that the adult population had declined from about 8,900- 9,800 in 1989 to a low of about 4,500-5,700 in 2001, increased in 2006 to approximately 5,300-6,700, and further increased to 7,650 adults in 2008. Current methods for assessment of humpback chub abundance rely on the ASMR (Coggins et al. 2006b, Coggins and Walters 2009). Although Coggins and Walters (2009) caution that the ASMR has limited capability to provide abundance estimates, the most important finding in their report is that the population trend in humpback chub is increasing. They also concluded that "considering a range of assumed natural mortality-rates and magnitude of ageing error, it is unlikely that there are currently less than 6,000 adults or more than 10,000 adults" and estimate that the current adult (age 4 years or more) Grand Canyon population is approximately 7,650 fish (Coggins and Walters 2009).

Translocation of juvenile humpback chub from near the mouth of the LCR upstream to above Chute Falls was undertaken in 2008 - 2011 as a conservation measure of the 2008 Opinion. The purposes of the conservation measure are to extend the range of the species upstream in the LCR into reaches previously unoccupied (presumably due to the presence of the falls), to improve the survivorship of juvenile humpback chub by moving juveniles to areas of the LCR with better nursery habitats, and to glean information on the life history of the species. Monitoring of this upstream reach was also conducted every year since 2008. Monitoring of humpback chub in the mainstem Colorado River has documented the persistence of small aggregations, although no population estimates are available (W. Persons, USGS, written comm. 2011a). Young-of-year humpback chub were also translocated into Shinumo Creek and Havasu Creek in an effort to broaden the distribution of humpback chub in the action area. Translocation is further discussed in the Environmental Baseline section.

Humpback Chub Critical Habitat

Critical habitat for humpback chub was designated in 1994 (59 FR 13374; USFWS 1994). Seven reaches of the Colorado River system were designated for a total river length of 379 miles in the Yampa, Green, Colorado, and Little Colorado rivers in Arizona, Colorado and Utah. "Critical habitat," as defined in Section 3(5)(A) of the ESA, means: (i) the specific areas within the geographical area occupied by the species at the time it is listed, on which are found those physical and biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by a species at the time it is listed upon a determination by the Secretary that such areas are essential for the conservation of the species. The term "conservation," as defined in Section 3(3) of the ESA, means: the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this ESA are no longer necessary. Therefore, in the case of critical habitat, conservation represents the areas required to recover a species to the point of delisting (i.e., the species is recovered and is removed from the list of endangered and threatened species). In this context, critical habitat preserves options for a species' eventual recovery.

In our analysis of the effects of the action on critical habitat, we consider whether or not the proposed action will result in the destruction or adverse modification of critical habitat. In doing so, we must determine if the proposed action will result in effects that appreciably diminish the value of critical habitat for the recovery of a listed species (see p. 4-34, U.S. Fish and Wildlife Service and National Marine Fisheries Service 1998). To determine this, we analyze whether the proposed action will adversely modify any of those physical or biological features that were the basis for determining the habitat to be critical. The physical or biological features that determine critical habitat are known as the primary constituent elements (PCEs). PCEs are provided by the final rule designating critical habitat and three supporting documents (USFWS 1994, Maddux et al. 1993a, 1993b. To determine if an action results in an adverse modification of critical habitat, we must also evaluate the current condition of all designated critical habitat units, and the PCEs of those units, to determine the overall ability of all designated critical habitat to support recovery. Further, the functional role of each of the critical habitat units in recovery must also be considered, because, collectively, they represent the best available scientific information as to the recovery needs of the species.

Recovery for the humpback chub is defined by the FWS Humpback Chub Recovery Goals (Recovery Goals) (67 FR 55270) (FWS 2002a). In 2006, a U.S. District Court ruling set aside the Recovery Goals, because they lacked time and cost estimates for recovery. The court did not fault the recovery goals as deficient in any other respect, thus the FWS, the GCDAMP, and the Upper Colorado River Endangered Fish Recovery Program (UCRRP), the program that addresses conservation of all of the upper Colorado River basin populations of humpback chub, continue to utilize the underlying science in the Recovery Goals. In our 2009 Supplemental Opinion we referenced the draft 2009 revisions to the Recovery Goals document because that document provided updates on species biology and distribution, and represented the best available scientific information at that time. The draft 2009 revisions to the Recovery Goals included the same demographic criteria found in the 2002 Recovery Goals. Thus, we are using the demographic criteria found in both the 2002 Recovery Goals and 2009 draft recovery goals. The FWS' 2011 Humpback Chub 5-Year Review relies on the information provided in the recovery goals and provides supplemental information on the species' distribution and status. That supplemental information, as well as the demographic criteria found in the Recovery Goals have been considered in this biological opinion and are summarized here**.** The Recovery Goal demographic criteria for downlisting (endangered to threatened) are:

Upper Basin Recovery Unit

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

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

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

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

Lower Basin Recovery Unit

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

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

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

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

The Recovery Goal demographic criteria for delisting are:

Upper Basin Recovery Unit

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

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

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

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

<u>Lower basin Recovery Unit</u>

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

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

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

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

The Recovery Goals consist of actions to improve habitat and minimize threats. The success of those actions is measured by the status and trend (i.e. the demographic criteria) of the population. We have evaluated the contribution of each critical habitat unit to recovery by examining how the PCEs are, or are not, serving to achieve the demographic criteria. In some cases, population-dynamics information is not statistically adequate to evaluate the demographic criteria as defined in the Recovery Goals. In those cases, we rely on existing data to make an informed, evaluation of the PCEs in a critical habitat unit.

Primary Constituent Elements (PCEs)

In accordance with section 3(5)(A)(i) of the ESA and regulations at 50 CFR 424.12, in determining which areas to propose as critical habitat, we are required to base critical habitat determinations on the best scientific data available and to consider those PCEs that are essential to the conservation of the species, and that may require special management considerations and protection. These include, but are not limited to: space for individual and population growth and for normal behavior; food, water, air, light, minerals, or other nutritional or physiological requirements; cover or shelter; sites for breeding, reproduction, and rearing (or development) of offspring; and habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of a species. The general primary constituent elements required of humpback chub critical habitat are listed below, and the current conditions of PCEs in individual critical habitat reaches, the factors responsible for these conditions, and the conservation roles of individual critical habitat reaches are described, based on FWS (1994), Maddux et al. (1993a), and Maddux et al. (1993b), and updated with the most current scientific information.

General PCEs of Critical Habitat

Critical habitat was listed for the four big river fishes (Colorado pikeminnow [*Ptychocheilus lucius*], humpback chub, bonytail [*Gila elegans*], and razorback sucker) concurrently in 1994, and the PCEs were defined for the four species as a group (FWS 1994). However, note that the PCEs vary somewhat for each species on the ground, particularly with regard to physical habitat, because each of the four species has different habitat preferences.

Water--Consists of water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, turbidity, etc.) (W1) that is delivered in sufficient quantity to a specific location in accordance with a hydrologic regime that is required for the particular life stage for each species (W2).

Physical Habitat--This includes areas of the Colorado River system that are inhabited by fish or potentially habitable for use in spawning (P1), nursery (P2), feeding (P3), or corridors between these areas (P4). In addition to river channels, these areas include bottomlands, side channels, secondary channels, oxbows, backwaters, and other areas in the 100-year floodplain, which when inundated provide spawning, nursery, feeding, and rearing habitats, or access to these habitats.

Biological Environment--Food supply (B1), predation (B2), and competition (B3) are important elements of the biological environment and are considered components of this constituent element. Food supply is a function of nutrient supply, productivity, and availability to each life stage of the species. Predation, although considered a normal component of this environment, is out of balance due to introduced fish species in some areas. This is also true of competition from non-native fish species.

The PCEs are all integrally related and must be considered together. For example, the quality and quantity of water (PCEs W1 and W2) affect the food base (PCE B3) directly because changes in water chemistry, turbidity, temperature, and flow volume all affect the type and quantity of organisms that can occur in the habitat that are available for food. Likewise, river flows and the river hydrograph have a significant effect on the types of physical habitat available. Changes in flows and sediment loads caused by dams may have affected the quality of nearshore habitats utilized as nursery areas for young humpback chub. Increasingly the most significant PCE seems to be the biological environment, and in particular PCEs B2 and B3, predation and competition from non-native species. Even in systems like the Yampa River, where the water and physical PCEs are relatively unaltered, non-native species have had a devastating effect on the ability of that critical habitat unit to support conservation (Finney 2006, Fuller 2009). In fact, as we will describe in more detail, the conservation of humpback chub in the future may depend on our ability to control non-native species, and manipulating the water and physical PCEs of critical habitat to disadvantage non-natives may play an important role.

Specific Critical Habitat Reaches and PCEs

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

The most northerly segment of humpback chub critical habitat is a 44-mile (70.8-km) long reach of the Yampa River in Moffat County, Colorado, in Dinosaur National Monument. The boundaries are from T6N, R99W, section 27 (6th Principal Meridian) to the confluence with the Green River in T7N, R103W, section 28 (6th Principal Meridian); land ownership is NPS, with 1 percent private ownership. The reach is dominated by steep canyon walls and low current velocities. Occasional boulder fields create rapids, but the predominant substrate is gravel/cobble with patches of sand. In the lower portion of the canyon the river meanders through soft sandstone cliffs. The Yampa River exits the canyon at Echo Park, where it meets the Green River (Maddux et al. 1993b). This critical habitat unit contains the Yampa population, one of the five populations of humpback chub in the upper basin. This population of humpback chub has declined precipitously in recent years, likely due to increasing predation and competition from non-native fish species (Finney 2006, USFWS 2011a).

As the Yampa River has minimal water development compared to other rivers in the basin, the current hydrograph reflects flows which are usually representative of historical volume and timing, and habitat of the Yampa River has not been as extensively affected by streamflow regulation as in other rivers of the basin (Roehm 2004, Johnson et al. 2008). Flow recommendations have been developed that specifically consider flow-habitat relationships in habitats occupied by humpback chub in Yampa Canyon (Roehm 2004). Yampa River flows also have been identified as critical for maintaining native fish habitat in the Green River below the confluence (Roehm 2004, Muth et al. 2000). There are water diversions upstream which can impact flow, especially during very dry years such as 2002-2003 when flows were very low; however, evidence of juvenile humpback chub indicates that successful spawning continues to occur (Finney 2006). Water temperatures in this portion of the Yampa River have not been altered to any significant degree by human activities and remain suitable for native fishes, although temperature is a function of streamflow, and at low flows, temperatures can become more suitable for non-native fishes such as smallmouth bass (Fuller 2009). No chronic problems with water quality have been identified. Although upstream diversions have some impact on the water PCE W2, both the necessary quality and quantity appear to be provided by this unit (Roehm 2004, Modde et al. 1999).

This reach of the Yampa also provides some areas of adequate physical habitat (FWS 1990, Karp and Tyus 1990, Finney 2006). Yampa Canyon within Dinosaur National Monument is typical of the deep canyon habitat preferred by the species (FWS 1990). This reach provides the humpback chub habitat characteristics of fast current, deep pools, shoreline eddies, and runs (Holden and Stalnaker 1975, Tyus and Karp 1989, USFWS 1990). The Yampa reach of critical habitat remains relatively unaltered from pre-development times in terms of hydrology and geomorphology (Roehm 2004, Modde et al. 1999), and we believe that all aspects of appropriate physical habitat (P1, P2, P3 and P4) are available.

Nutrient inputs and food sources for humpback chub are present within the reach. The relatively unmodified nature of the Yampa River system likely results in foods similar to predevelopment, thus PCE B1 continues to be met. The introduction of non-native fishes is probably the greatest alteration to the historical Yampa system. Non-native fish species abundance has increased significantly in recent years (Fuller 2009). From 2001-2003 a rapid increase in numbers of smallmouth bass was followed by a decline in humpback chub (Finney 2006, Johnson et al. 2008). A Strategic Plan for Non-native Fish Control was developed for the Upper Colorado River Basin and implemented by the UCRRP in 1997 (Fuller 2009). The UCRRP identified smallmouth bass (*Micropterus dolomieu*) and channel catfish (*Ictalurus punctatus*) as the principal predators of humpback chub (USFWS 2009a). Efforts to control smallmouth bass and channel catfish have met with mixed success, although efforts to control northern pike (*Esox luscious*) have been successful (Fuller 2009, R. Valdez, pers. comm., 2009).

Channel catfish numbers have actually increased despite non-native removal efforts, although the average size of channel catfish in the Yampa reach has decreased, which may help reduce predation (Fuller 2009). A combination of cold high flows and mechanical removal may have suppressed smallmouth bass production in 2007-2008, and numbers of native fish have increased (Fuller 2009). The ability of this critical habitat unit to fully function in humpback chub conservation in the future will depend on the success of efforts to remove smallmouth bass and channel catfish (Johnson et al. 2008, Fuller 2009). Given the best available information, the predation and competition aspects of the biological environment PCE (B2 and B3) are not currently met for this species, which prevents this unit from providing for recovery at this time.

The Yampa illustrates that if non-native species are abundant (i.e. B2 and B3 are not met), good condition of other aspects of critical habitat (water and physical PCEs) may not be sufficient to provide for the recovery of the species. Water temperatures in the Yampa River during the summer of 2002 were much warmer than typical, and a longer growing season in 2002 appears to have facilitated recruitment of smallmouth bass in 2003 (Fuller 2009), resulting in a precipitous decline in the humpback chub population. In the mid-2000s, cold high flows may have suppressed smallmouth bass production (along with removal efforts), and numbers of y-o-y humpback chub have increased. So not only does flow affect the water PCE of necessary hydrology and water quality for critical habitat for humpback chub, but it is also directly linked to the biological environment PCEs of predation and competition from non-native fish species. Because of this relationship between the physical and biological PCEs, efforts focused on restoring physical attributes of critical habitat, in places such as the Grand Canyon could have the unintended consequence of benefiting non-native species, offsetting any gains from habitat improvement.

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

This unit is a 38-mile (61.2-km) reach in Uintah County, Utah, and Moffat County, Colorado, from the confluence with the Yampa River in T7N, RI03W, section 28 (6th Principal Meridian) to the southern boundary of Dinosaur National Monument in T6N., R24E, section 30 (Salt Lake Meridian). The land ownership of the unit is predominantly NPS in Dinosaur National Monument, except for about 4.5 percent of privately-owned lands. The Green River enters Echo Park at its confluence with the Yampa River as a wide, deep, and slow moving stream. Substrate is a mixture of sand and silt with some large gravel and cobble riffles. After a short distance, the river passes through Whirlpool Canyon, an area of steep cliffs, large pools, deep eddies, rapids, and large boulders. The substrate in the canyon is boulder/bedrock, but large deposits of sand exist in eddies. After leaving the canyon, the Green River meanders through Island and Rainbow Parks. The river in this area is shallow and side channels are common. Further downstream, the river enters Split Mountain Canyon. This stretch contains large boulder fields, swift waters, and major rapids. Some significant sandbars exist in the slower moving parts of this reach (Maddux et al. 1993b).

Humpback chub have never been common in this reach, despite what appears to be suitable habitat except for the abundance of non-native fishes. Only eight humpback chub were captured in Whirlpool Canyon from 2002 to 2004 (Bestgen et al. 2006), although young of year chub were collected from Island Park which may be humpback chub (T. Jones, FWS, pers. comm., 2009). The area is considered to be part of the Yampa River population along with the Yampa River upstream, but this critical habitat unit does not appear to currently support humpback chub.

Flows in this reach are primarily a product of the flows released from Flaming Gorge Dam and flows from the Yampa River. During an average hydrologic year, a spring peak of at least 13,000 cfs should occur in this reach. Because of the distance between this reach and the dam and unregulated flows of the Yampa River, water temperatures in this reach approach historical levels. However, when releases during summer and fall from the dam are greater than historical, water temperatures may be lower than under normal conditions. Water quantity and quality needs (PCEs W1 and W2) are believed met for the species, and the UCRRP has completed and implemented flow recommendations for the Green River below Flaming Gorge Dam, including specific seasonal flow recommendations, that should serve to meet the needs of humpback chub in this reach of critical habitat (Muth et al. 2000). All four physical variables also appear to be present (PCEs P1-4), and young of year *Gila* found in 2008 may be an indication that spawning is occurring, although at low levels (T. Jones, FWS, pers. comm., 2009).

This portion of the Green River has large numbers of red shiner (*Cyprinella lutrensis*), channel catfish, smallmouth bass, and common carp, all of which are known to compete with and/or prey upon native fishes. The recent invasion of smallmouth bass has likely greatly reduced the value of this PCE for humpback chub (Finney 2006). Because water and physical PCEs appear to be met for humpback chub in this reach of critical habitat, the presence of non-native fishes (PCEs B2 and B3) may be the primary factor limiting the capability of this critical habitat unit to meet recovery needs.

Humpback Chub Critical Habitat Reach 3 - Green River - Desolation and Gray Canyons

The Green River in Desolation and Gray Canyons contains one of the five upper basin populations of humpback chub. The 73-mile (117.4 km) reach of critical habitat in the Green River is in Uintah and Grand Counties, Utah, from Sumners Amphitheater in T12S, R18E, section 5 (Salt Lake Meridian) to Swasey's Rapid in T20S, R16E, section 3 (Salt Lake Meridian). The reach is about 50 percent Tribal ownership, 49 percent Bureau of Land Management (BLM), and 1.0 percent private. Desolation Canyon is a deep canyon of the Green River with many rapids. Habitats include eddies, rapids, and riffles, with some deep pools. Boulders make up the primary substrate within Desolation Canyon. This canyon is followed by Gray Canyon which contains larger and deeper pools than are found in Desolation Canyon. Other habitats within the canyon include eddies, rapids, and riffles, side channels and backwaters. Substrate in Gray Canyon is composed mainly of boulder/rubble with some gravel (Maddux et al. 1993b).

Population estimates for Desolation/Gray Canyon in 2001-2003 show the population was composed of 1,254 individuals in 2001, 2,612 individuals in 2002, and 937 individuals in 2003 (Jackson and Hudson 2005). However, a significant decline has occurred recently; the first adult abundance estimate in Desolation/Gray Canyons in 2001, 1,254 fish declined to a low in 2007 of about 300 fish (Figure 2; USFWS 2011a). Because of water depletions which occur above this reach, historic water levels are seldom if ever obtained, and thus flooding of bottomlands is infrequent (Muth et al. 2000). However, water quantity and quality needs (PCEs W1 and W2) are believed met for the species; and the UCRRP has completed and implemented flow recommendations for the Green River below Flaming Gorge Dam, including specific seasonal flow recommendations, that should serve to meet the needs of humpback chub in this reach of critical habitat (Muth et al. 2000). This canyon reach contains both deep, swift areas and low-velocity eddies that are associated with steep cliffs and large boulders. Spawning habitat is available based on consistent evidence of recruitment and collection of juvenile fish (Jackson and Hudson 2005). Physical habitat parameters (PCEs P1-4) also appear to be sufficient in this reach of critical habitat.

Little is known on the quantity or quality of the food supply in this reach. Sources of input include the river above and washes and side channels. The flooded bottomlands along this reach were probably once sources of food input into the system, but are now not as extensively flooded. Common non-native fishes include red shiner, channel catfish, smallmouth bass, common carp, and fathead minnow (*Pimephales promelas*) (Jackson and Hudson 2005). Similar to the scenario seen in the Yampa River, an increase in smallmouth bass over the 2001-2003 period co-occurred with a decline in humpback chub over the same period, although Jackson and Hudson (2005) felt the decline in humpback chub was likely too soon to have been solely caused by increases in smallmouth bass. Much as in other critical habitat reaches, water and physical PCEs appear met, but biological PCEs B2 and B3 are not, and limit the capability of this critical habitat unit to meet recovery needs.

Humpback Chub Critical Habitat Reach 4 - Colorado River - Black Rocks/Westwater Canyon

The Black Rocks and Westwater populations of humpback chub occur in this 30-mile (48.3-km) reach of critical habitat. The reach extends from Black Rocks (RM 137) in T1S, R104W, section 25 (6th Principal Meridian) in Mesa County, Colorado, downstream to Fish Ford River (RM 106) in T21S, R24E, section 35 (Salt Lake Meridian) in Grand County, Utah. Land ownership is 66.6 percent BLM, 33.4 percent private. Historically, the largest known concentrations of humpback chub in the upper basin have been found at Black Rocks and Westwater Canyons (Valdez and Clemmer 1982, USFWS 2009a), and this is still the case currently.

Population estimates for humpback chub using mark-recapture estimators began in 1998 with the Black Rocks and Westwater Canyon populations, and were conducted during 1998-2000 and 2003-2005. These estimates showed the Black Rocks population between about 1,000 and 2,000 adults in 2000 (age 4+) and the Westwater Canyon population between about 1,800 and 4,700 adults in 2003 (McAda 2006, Hudson and Jackson 2003, Eleverud 2007, Jackson 2010). But levels of both populations have declined as of the most recent estimates in 2008 to a few hundred in Black Rocks and approximately 1,500 in Westwater Canyon (Figure 2; USFWS 2011a). Levels of both populations appear to have declined further since that time, as evidenced by a few hundred reported by Francis and McAda (2011) in 2011. However, while the estimates are low, they fall within the confidence intervals of earlier abundance estimates, so we cannot conclude an additional decline.

Black Rocks occurs near the Colorado-Utah state line where the Colorado River flows through a mile of upthrust black metamorphic gneiss rock. Some five miles downstream the river again flows through upthrust gneiss for 14 miles (22.5-km) through Westwater Canyon. The geology forms narrow, deep, canyon-bound channels with rapids, strong eddies, and turbulent currents. In both canyons, habitat consists of deep runs, eddies, and pools, with few backwaters, although gravel bars, floodplains, and backwaters do occur above and below the canyons (Maddux et al. 1993b). Habitats have been altered by water use that altered the natural flow regime. Annual peak flows of the Colorado River immediately upstream of the Black Rocks and Westwater Canyon populations decreased by 29–38 percent due mainly to the presence of dams upstream (Van Steeter and Pitlick 1998). However, Black Rocks and Westwater Canyon continue to provide deep eddies, pools, runs, and rapids, with strong turbulent currents. The quantity and quality of water in this reach (PCEs W1 and W2) are presently sufficient. This reach provides deep pools, eddies, and runs for feeding and movement corridors, and spawning and rearing habitat are available as evidenced by successful recruitment. Flow recommendations have been developed that specifically consider flow-habitat relationships in habitats occupied by humpback chub in Black Rocks and Westwater Canyon (McAda 2003). All physical habitat PCEs (P1-4) are met based on the stability of the population and evidence of recruitment (McAda 2006, Hudson and Jackson 2003, Eleverud 2007). Red shiner, channel catfish, black bullhead (*Ameiurus melas*), and largemouth bass (*Micropterus salmoides*) all occur here, but because these canyons are very narrow, and large floods are fairly frequent, flooding generally keeps numbers of non-native fishes low (R. Valdez, pers. comm., 2009), and there currently is no non-native fish control effort in this unit. All PCEs are fully functional, and this critical habitat unit is functioning in support of recovery. But, as with other reaches, there appears to be a correlation between low water years and increases in non-native species; climate change and operations under the Interim Guidelines could lead to an increase in low water years and non-native fishes, challenging the ability of this unit to support recovery (Reclamation 2007, Rahel et al. 2008, R. Valdez, pers. comm., 2009).

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

A 13-mile (20.9 km) reach of critical habitat in Cataract Canyon on the Colorado River upstream of Lake Powell contains the most southerly population of humpback chub occurring in the upper basin. The reach extends along the Colorado River from Brown Betty Rapid in T30S, R18E, section 34 (Salt Lake Meridian) to Imperial Canyon in T31S, R17E, section 28 (Salt Lake Meridian) in Garfield and San Juan counties, Utah. Land ownership is 100 percent NPS. Lake Powell likely eliminated the majority of the habitat that humpback chub utilized in this section of the Colorado River historically, leaving only about 13 miles (20.9 km) of suitable river habitat when Lake Powell is at full pool. Comprehensive surveys for humpback chub did not begin until about 1980, shortly after Lake Powell had filled. Although the population of humpback chub in the Colorado River in Cataract Canyon above the inflow area to Lake Powell has never been large since consistent surveys began in the 1980s, historically it may have been much larger (R. Valdez, SWCA pers. comm., 2009).

The Cataract Canyon population of humpback chub has declined to approximately 100 individuals and currently is too small to monitor through mark-recapture analysis (USFWS 2011a). Badame (2008) estimated the adult population, using closed point estimates, at 126 individuals in 2003, 91 in 2004, and 70 in 2005. Population estimates based on fish density and total amount of available habitat were 468-262 over the period. Evidence of successful spawning has been inferred from several size classes present in past surveys (Valdez 1990), but no juvenile humpback chub were encountered in the 2003-2005 surveys, and the smallest humpback chub encountered was 195 mm TL (7.7 inches). It is not known if juvenile humpback chub are not encountered because they are not present, or because survey techniques do not detect them, but electrofishing is employed, a technique that reliably captures juvenile humpback chub elsewhere (Badame 2008). Young humpback chub may also be lost to some extent to downstream movement into Lake Powell (D. Elverud, Utah Division of Wildlife Resources, pers. comm., 2009).

The Colorado River in Cataract Canyon cuts deeply through steep canyons and talus slopes, and is characterized by deep, swift runs, large eddies and pools, with a few shallow runs, riffles, and backwaters. Large angular rock and steep gradient have created approximately 13 miles (20.9 km) of rapids before the river flows into the upper end of Lake Powell where it resembles a large, deep, slow-flowing river with high sandstone walls (Maddux et al. 1993b). River flows in Cataract Canyon are greater than in other reaches in the Upper Basin because of the numerous upstream tributaries which enter the Colorado River as a result of its location low in the system. While all life stages of humpback chub were captured in this reach in surveys in the late 1980s (Valdez 1990), indicating adequate habitat for successful reproduction, recent surveys have not located any young humpback chub, indicating possible recruitment failure (Badame 2008), although there is no indication this is due to recent changes in water quality or quantity, and PCEs W1 and W2 of humpback chub critical habitat appear to be functional.

Causes of the apparent current lack of recruitment of the population do not appear to be due to changes in the physical habitat PCEs. Valdez (1990) reported humpback chub of all age classes in Cataract Canyon (indicating a reproducing population) and the presence of preferred physical habitats; there appear to be no changes to the physical habitat since that time that would explain the current lack of recruitment. Cataract Canyon has many non-native fish species, with channel catfish, black bullhead, and red shiner being the most common (D. Elverud, Utah Division of Wildlife Resources, pers. comm., 2009, R. Valdez, pers. comm. 2009), and striped bass (*Morone saxatilis*) were captured in past surveys (Valdez 1990). The water and physical PCEs appears to be met, but the presence of Lake Powell likely eliminated much of the historical habitat, and provides a robust population of non-native fish species. It is not clear if the remaining habitat since Lake Powell filled would have sufficient carrying capacity to support a large population of humpback chub, but the high numbers of non-native species has resulted in the lack of the biological environment PCEs B2 and B3 and this is likely the reason this unit is not functioning currently in humpback chub recovery.

Humpback Chub Critical Habitat Reach 6 - Little Colorado River

Critical habitat in the LCR includes the lowermost eight miles from T32N, R6E, section 12 (Salt and Gila River Meridian) to the confluence with the Colorado River in T32N, R5E, section 1 (Salt and Gila River Meridian) Coconino County, Arizona. Land ownership is 81.3 percent Tribal (Navajo Tribe), and 18.8 percent NPS (Grand Canyon National Park). The Grand Canyon population of humpback chub occurs in both critical habitat reaches 6 and 7. The Grand Canyon population is the largest population of humpback chub, the only population in the lower basin, and constitutes the lower basin recovery unit (Coggins and Walters 2009, USFWS 2009a). While the vast majority of spawning of humpback chub in Grand Canyon occurs in the LCR, humpback chub utilize the mainstem Colorado River also, and condition factor[3] of adult humpback chub in the mainstem has been reported to be better than that of adults in the LCR (Hoffnagle et al. 2006). Additionally eight other spawning aggregations occur in the mainstem Colorado River, all of which, including the LCR, constitute what is considered a single reproducing population (Douglas and Douglas 2007).

Perennial flows in the LCR are maintained through a series of springs, the largest of which is Blue Spring approximately 13 miles (20.9 km) upstream from the mouth of the Colorado River.

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

The LCR above Blue Spring was once perennial, but is now intermittent throughout most of its 356-mile (572.9-km) length, flowing only during floods from spring thaws or summer rain events (Colton 1937, Miller 1961, Valdez and Thomas 2009). Flows during floods can be between 500-2000 cfs. Base flow of the lower reach containing critical habitat is about 225 cfs (Cooley 1976). Water from these springs is high in chloride salts, relatively constant in flow, warm (20°C), highly charged with carbon dioxide, and saturated with calcium carbonate (Gorman and Stone 1999). This water chemistry forms the mineral travertine, layered deposits of hard, dense calcite. Travertine deposition in the LCR is an ongoing process, forming extensive reefs, terraces, and dams throughout the lower 14.5 miles (23.3-km). Large boulders and cobble fallen from canyon walls or transported by debris flows from side canyons are common in the stream channel (Gorman and Stone 1999). The unique geology forms a complex habitat matrix of pools, shallow runs, and races. Uncemented calcium carbonate particles form part of the stream bottom and contribute to the mild turbidity of the river at base flow (Kubly 1990), and flood flows are extremely turbid. Because of the reduced flow levels from Glen Canyon Dam, only the lower portion of the LCR is ponded by flows from the dam, where approximately 10 to 25% of the adult humpback chub are likely to occur (P. Sponholtz, FWS, pers. comm., 2011). The other adults will be in the mainstem Colorado River or in the upper reaches of the Little Colorado River in areas not affected by the operations of Glen Canyon Dam.

Flows in the LCR maintain acceptable habitat for all sizes and age classes of humpback chub. The historical hydrograph has been altered by the reduction in flows coming into the reach from the watershed, but seasonal variations remain (Valdez and Thomas 2009). Fluctuating flows in the Colorado River affect the lowermost portion of the reach by raising and lowering water levels and altering temperatures, but this affects less than a quarter mile (0.40 km) of the reach. Water quality has not been significantly altered by changes in flow from the historical condition; however salinity levels may be higher now during low-flow periods when there are no additional flows in the Little Colorado to dilute the inflow from the springs. Temperatures in the upper portion of the reach may have changed slightly in response to altered seasonal water levels, but water temperature in the LCR is suitable for spawning and egg and larval development (Gorman and Stone 1999). Although flows have changed in the LCR with development throughout the basin (Valdez and Thomas 2009) and the shift to intermittency upstream of Blue Spring, humpback chub continue to occupy and thrive in this reach of critical habitat (Coggins and Walters 2009, Van Haverbeke and Stone 2008, 2009). Thus PCEs W1 and W2 are present, although threats exist, as described in the Environmental Baseline.

Humpback chub utilize a variety of habitat types in the reach. Larval to juvenile humpback chubs have been found in shallow shoreline areas, sand-bottomed runs, and silt-bottomed backwaters with low-current velocities (USFWS 1990, Robinson et al. 1998). Adult humpback chub in the LCR utilize shoreline areas, pools and eddies, quiet waters under rock ledges, areas below travertine dams, and the deeper water at the confluence (Minckley et al. 1981). Spawning humpback chub have been found over rapidly flowing water among large angular boulders and shoreline outcrops or along shoreline eddy habitats of moderate depth with swirling currents and sand and boulder substrates (Gorman and Stone 1999). Although humpback chub larvae are common in midstream drift, larvae do appear to actively seek out calmer nearshore habitats as they age (Robinson et al. 1998). Stone and Gorman (2006) found that humpback chub undergo an ontogenesis from diurnally active (active during the day), vulnerable, nearshore-reliant y-o-y (30–90 mm, 1.2-3.5 inches TL) into nocturnally active, large-bodied adults (>180 mm TL [3.5 inches]). Adult humpback chub reside in deep mid-channel pools during the day, and move inshore at night (Stone and Gorman 2006). All aspects of the physical habitat PCEs (P1, P2, P3, and P4) are present in Reach 6, based upon the current status of the population (Van Haverbeke and Stone 2008, Coggins and Walters 2009).

Information from stomach contents and other observations indicate that food resources utilized by humpback chub in the LCR include bottom-dwelling invertebrates such as *Gammarus lacustris* and chironomid larvae, planktonic crustaceans, terrestrial invertebrates, and algae such as *Cladophora glomerata* (Minckley 1979, Minckley et al. 1981, Valdez and Ryel 1995). Foods utilized in the Little Colorado River are in different proportions than those utilized in the mainstem, reflecting food availability (Kaeding and Zimmerman 1983, Valdez and Ryel 1995). The extent of competition by non-native fishes is unknown, but predation has been documented by rainbow trout, channel catfish, and black bullhead (Marsh and Douglas 1997). Numbers of non-native fish make up a small proportion of the fish community in the LCR, comprising only 7 percent of total catch in 2007 monitoring (Van Haverbeke and Stone 2008). While relatively small proportions of certain non-native species (e.g., channel catfish) could be problematic for humpback chub in the LCR, the most common non-native fish in 2010 was fathead minnow (Van Haverbeke et al. 2011). All of the PCEs are provided for in the Little Colorado Reach of critical habitat, although significant threats exist which are discussed in the Environmental Baseline.

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

The 173-mile (278.4-km) reach of critical habitat in the Colorado River in Marble and Grand Canyons extends from Nautiloid Canyon (RM 34) in T36N, R5E, section 35 (Salt and Gila River Meridian) to Granite Park (RM 208) in T30N, RI0W, section 25 (Salt and Gila River Meridian). Land ownership is 87.8 percent NPS and 12.2 percent Tribal (Navajo Nation). As discussed above, Reaches 6 and 7 constitute critical habitat occupied by the Grand Canyon population of humpback chub. While the vast majority of adult humpback chub in Grand Canyon occur in the LCR Inflow aggregation (at RM 57.0-65.4), humpback chub also occur at other aggregations in the mainstem Colorado River throughout Marble and Grand canyons, and there is some movement of humpback chub between the aggregations (Paukert et al. 2006). All nine aggregations constitute what is considered a single reproducing population (Douglas and Douglas 2007). According to Paukert et al. 2006, approximately 85% (12,508 of 14,674) of the humpback chub were captured and recaptured in the LCR, whereas only 241 (1.6%) were captured and recaptured in the mainstem Colorado River within the LCR confluence area. In 2006, concurrent estimates of the LCR and LCR inflow population were determined and represented 14,526 fish (or 99.0% of the recaptures) demonstrating the species' disproportionate reliance on the LCR. There is, however, evidence of some fish travelling among and adding to the mainstem aggregations (Paukert et al. 2006, W. Persons, USGS, written communication, 2011b).

The eight other spawning aggregations are (per Valdez and Ryel 1995): 1) 30-mile (RM 29.8 to 31.3); 2) Lava to Hance (RM 65.7-76.3); 3) Bright Angel Creek Inflow (RM 83.8-93.2); 4) Shinumo Creek Inflow (RM 108.1-108.6); 5) Stephen Aisle (RM 114.9-120.1); 6) Middle Granite Gorge (RM 126.1-129.0); 7) Havasu Creek Inflow (RM 155.8-156.7); and 8) Pumpkin Spring (RM 212.5-213.2). As stated in the 2008 and 2009 Supplemental Opinions, monitoring continues to confirm the persistence of these aggregations (Trammell et al. 2002), although few humpback chub have been caught at the Havasu inflow and Pumpkin Spring aggregations since

2000 (Ackerman 2008). Humpback chub have also been caught infrequently downstream of Pumpkin Spring (Valdez and Masslich1999). The LCR Inflow is the largest aggregation, which is in the lower 15 km (9.3 miles) of the LCR and the adjoining 15 km (9.3 miles) of the Colorado River (RM 57.0-65.4) (Valdez and Ryel 1995). The LCR aggregation has been expanded upstream of Chute Falls through translocation (Stone 2009, Van Haverbeke et al. 2011).

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

The Colorado River in Grand Canyon has a restricted channel with limited floodplain development. Channel widths vary from 180 to 390 feet (54.9-118.9 meters [m]) (Valdez and Ryel 1995). Gradients are often high, resulting in areas of rapids separated by long pools and runs. Steep, rocky shorelines, talus slopes with alluvial boulder fans, and undercut ledges border the channel. Substrates range from boulders to cobbles, gravels, and sand. Numerous small tributaries enter the Colorado River in the canyon. These are of two types: (1) perennial tributaries such as the LCR, and Bright Angel, Kanab, Shinumo, and Havasu creeks provide varying amounts of base flow to the river that create shallow water habitats for use by native fish with substrates that tend to be more rocky with fewer fine materials; and (2) the ephemeral tributaries which provide flows during flood periods and contribute significant amounts of sediment to the river. Alluvial fans form at the mouth of these ephemeral streams, contributing to the formation of rapids (Maddux et al. 1993b, Valdez and Ryel 1995). Cobble is the most productive habitat for invertebrates (highest biomass and production), perhaps because sediment thickness is lowest there (T. Kennedy, USGS, written comm. 2011).

Water releases from Glen Canyon Dam vary between 5,000 and 25,000 cfs and will continue in this way as described by the MLFF regime adopted by the Secretary of the Interior in 1996. The dam blocks the primary sediment inflow to the river in the canyon, limiting the sediment load to the amount contributed by the tributaries. The HFE protocol is designed to maximize the tributary inputs by producing high flows to deposit sand on beaches and nearshore habitats. Constant scouring of sediment from the canyon has continually eroded beaches and other sand-formed habitats such as backwaters since dam closure. The greatly reduced sediment load of the Colorado River post-dam increased water clarity, which increased primary productivity, especially in Marble Canyon, and algae and associated invertebrates dominate upstream reaches (Maddux et al. 1993b).

Water temperatures were altered significantly by the completion of Glen Canyon Dam and are cold (8.9 °C) year round when the reservoir is full (Reclamation files). Water temperatures downstream warm seasonally and with increasing distance from the dam due to solar insolation. However, fluctuations in water flow and associated stage change carry cold water continually into nearshore habitats extending the range of cold water influence. Between 2003 and 2006 when Lake Powell levels were low, water temperatures were able to warm up to 17 º C, the warmest temperature recorded since Lake Powell filled in 1980 and near the minimum temperature at which successful humpback chub spawning is initiated (Hamman 1982). This along with increased sediment levels from Paria River and other tributaries and mechanical removal of non-native fish contributed to the creation of water temperatures and habitat parameters that allowed overwintering of young-of-year humpback chub (Andersen et al. 2010). Water years since 2006, and in particular in 2011, have also been unusually warm with water temperatures at Lees Ferry at 13.5 ºC and 14.5 ºC at the LCR (Figure 4; USGS unpublished data). As a result of the different water temperatures available to humpback chub, there can be great variability in growth rates of humpback chub depending on the amount of time fish spend in the mainstem versus time spent in the tributaries.

Non-native fish species, most notably rainbow trout, channel catfish, brown trout, and carp, are established in the river in Marble and Grand canyons (Maddux et al. 1993b, Valdez and Ryel 1995) and prey upon and compete with native fish. Of the native fish species that historically occurred in the Grand Canyon, two have been extirpated. Extirpated species include the bonytail and Colorado pikeminnow. Reproducing populations include the humpback chub, bluehead sucker (*Catostomus discobolus*), flannelmouth sucker (*Catostomus latipinnis*), and speckled dace (*Rhinichthys osculus*). As discussed later in the document, the razorback sucker still occurs in the lower Grand Canyon but is very rare.

Flow fluctuations occur on daily, weekly, and monthly cycles based on needs for power generation and downstream water deliveries instead of the natural seasonal extreme flows of pre-dam years. Water depths and velocities are altered by the change in flows. The humpback chub in the mainstem is mostly found in backwaters, shoreline areas, and eddies, all areas of low-current velocity (Valdez and Ryel (1995). These areas may expand or contract in response to changes in flows. Existing water quality is adequate to support aquatic communities; however, changes in turbidity and temperature due to existence of Glen Canyon Dam and its operations have had effects on the suitability of the mainstem Colorado River for humpback chub, with resulting effects to reproduction, predation, and foraging behavior (Glen Canyon Dam Adaptive Management Program 2009). The degree to which the water PCEs (W1 and W2) provide for recovery in this reach of critical habitat is an ongoing research question.

The Colorado River in this reach provides a variety of main channel habitats, including eddies, shorelines, and backwaters. The confluence of the Colorado and LCRs is an important habitat area. Access to both systems provides both adult and juvenile humpback chubs with a variety of physical habitat conditions (water depth, velocity, turbidity, temperature, and substrate). Habitats formed by fine substrates such as backwaters that may be important nursery habitats are negatively impacted by the reduction in sediment supply and constant scour caused by periodic changes in flow volume (Glen Canyon Dam Adaptive Management Program 2009). The physical habitat PCEs are at least partially met. In the 2008 and 2009 Supplemental Opinion, we concluded that the suitability of spawning and rearing habitats (PCEs P1 and P2) to fully function in meeting recovery needs was unknown. Converse et al. (1998) documented a preference for vegetated shorelines in subadult (< 200 mm TL [(7.9 inches]) humpback chub in the area below the LCR. The Near Shore Ecology (NSE) study has demonstrated that all PCEs appear to be met in the limited area of the mainstem where their study occurs 1,500 m (0.93 mile), downstream of the LCR confluence. Reclamation has committed to expand the information and understanding of mainstem aggregations through improved monitoring to support humpback chub distribution throughout the action area as a new conservation measure. Monitoring will be expanded beyond the small NSE study area to better understand the population dynamics of the mainstem aggregations of humpback chub, including yearly trips to try and generate population estimates for these aggregations.

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

There are fewer numbers of non-native fish species established in the Colorado River in Reach 7 than in other reaches of critical habitat, due in part to the harsh physical conditions present. The cold mainstem water temperatures in particular have likely limited the invasion and expansion of warm-water species (such as fathead minnows or smallmouth bass). As discussed earlier, providing warmer water through flow manipulations or dam modifications, or warmer water due to climate change and the Interim Guidelines, could improve the W1 PCE for humpback chub, but would need to be carefully monitored so as to not degrade the B2 and B3 PCEs of critical habitat by increasing predation and competition from non-native fish warm water species. All of the PCEs may be provided for in this reach of critical habitat, although significant questions exist about water temperature (W1), spawning habitat (P1), nursery habitat (P2), and non-native fish predation and competition (B2 and B3); these are discussed in detail in the Environmental Baseline.

Previous consultations on humpback chub

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

Razorback Sucker and its Critical Habitat

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Recovery for the razorback sucker is currently defined by the FWS Razorback Sucker Recovery Goals (USFWS 2002b). The Recovery Goals define recovery as specific demographic criteria that must be attained, and recovery factors that must be met to achieve downlisting and delisting of razorback sucker. The recovery factors were derived from the five listing threat factors under ESA section 4(a), and state the conditions under which threats are minimized or removed sufficient to achieve recovery; a list of site-specific management actions and tasks (e.g. the development and implementation of non-native fish control programs) is also provided. They include the need to identify, implement, evaluate, and revise (as necessary through adaptive management) flow regimes to benefit razorback sucker for all the rivers in which the species occurs. Essentially, the goals identify actions needed to maintain the habitat features (i.e. the physical and biological features of critical habitat) to accomplish recovery. But the measures of whether or not actions are working with regard to recovery, and the basis for altering management actions through adaptive management, are the demographic criteria. The site-specific recovery actions, as well as the demographic Recovery Goals, are provided in USFWS (2002b). We summarize here the Recovery Goal demographic criteria for downlisting (there are no delisting criteria) as follows (population demographics in both recovery units must be met in order to achieve downlisting):

Upper basin recovery unit

Green River Subbasin

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

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

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

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

Upper Colorado River and San Juan River Subbasins

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

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

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

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

Lower basin recovery unit

Lake Mohave

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

Rest of basin

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

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

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

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

General PCEs of Critical Habitat

Critical habitat was listed for the four big river fishes (Colorado pikeminnow, humpback chub, bonytail, and razorback sucker) concurrently in 1994, and the PCEs were defined for the four species as a group in two biological support documents and the final rule designating critical habitat (Maddux et al. 1993a, 1993b, USFWS 1994). The general PCEs are the same as these discussed previously for humpback chub and are not repeated here. However, note that the PCEs vary somewhat for each species on the ground, particularly with regard to physical habitat, because each of the four species has different habitat preferences.

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

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

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

Previous consultations

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

Kanab ambersnail

The Kanab ambersnail was listed as endangered in 1992 (57 FR 13657) with a recovery plan completed in 1995 (USFWS 1995a). No critical habitat is designated for this species. Unpublished results of an ongoing taxonomy study indicate that the Kanab ambersnail may actually be part of a much more widespread and abundant taxon (Culver et al. 2007).

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

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

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

ENVIRONMENTAL BASELINE

The environmental baseline includes past and present impacts of all Federal, State, or private actions in the action area, the anticipated impacts of all proposed Federal actions in the action area that have undergone formal or early section 7 consultation, and the impact of State and private actions which are contemporaneous with the consultation process. The environmental baseline defines the current status of the species and its habitat in the action area to provide a platform to assess the effects of the action now under consultation.

Glen Canyon Dam has operated under MLFF since the Record of Decision was signed in 1996. Generally, the MLFF is a set of flow constraints that results in hourly, daily, and monthly variations in flow from Glen Canyon Dam. The MLFF is implemented by Reclamation through the GCDAMP as defined in the 1995 EIS and 1996 ROD (Reclamation 1995, 1996). The variations in flow resulting from MLFF affect many aspects of the ecosystem from Glen Canyon Dam to Lake Mead. Effects are on the abiotic aspects of the ecosystem (e.g., water temperature, turbidity, sediment transport, riverine habitat formation) and on the biotic aspects (e.g. food base dynamics, fish species abundance and composition, fish growth, fish predation rates, prevalence of disease or parasites). Many of these effects are poorly understood, and adding to the complexity is the fact that few if any effects can be analyzed separately because they interact. The proposed action will continue the MLFF and add NNFC and HFE Releases.

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

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

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

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

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

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

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

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

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

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

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

Humpback chub

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

As stated in our 2008 and 2009 Supplemental Opinion, the population dynamics information for humpback chub is much improved since the 1995 opinion, with much more available information on humpback chub recruitment and abundance as a result of ongoing monitoring of the GCDAMP and the development of the ASMR (Coggins and Walters 2009). Coggins and Walters (2009) assessed the status and trend of the humpback chub in the LCR (the LCR Inflow aggregation) utilizing the ASMR model. As of 2008, the adult (age 4+) population of humpback chub was estimated to be about 7,650 fish, with a range between 6,000 and 10,000 fish. The ASMR indicates that a decline in the abundance of adult humpback chub occurred throughout the late 1980s and early 1990s, reached a low in the early 2000s, and has since trended upwards. This recent upward trend represents about a 50 percent increase in adult abundance since 2001 (Coggins 2008a, Coggins and Walters 2009) with the population size continuing to increase. The 2006 estimate was 5,300-6,700, an increase of about 50 percent since 2001 (Coggins 2008a, Coggins and Walters 2009). The change in status was due to an increase in recruitment that began before many actions predicted to improve the humpback chub status (such as mechanical removal of non-native fishes or warming of mainstem water temperatures in the Colorado River). Mainstem warming and mechanical removal effects both started in 2003 and could have begun affecting the abundance of age-2 recruits in 2004 and later, (brood-years 2002 and later). Notably, the largest increase in adult abundance occurred in 2007, when the 2003 brood-year matured to age-4 (Coggins and Walters 2009). This was the first year of non-native fish control, which coincided with warmer water releases from Glen Canyon Dam. This reinforces the findings of the 2008 Opinion in which we predicted those brood years would likely benefit from these changes to the mainstem critical habitat in Reach 7. According to C. Walters (2011, pers. comm., Anderson 2009, Coggins et al. 2011) and other sources current data are insufficient to support piscivory of non-native fish on humpback chub as the causal mechanism in the period of decline in humpback chub (approximately 1990-2000) because of the complexity of numerous factors and because the upward trend in adult humpback chub numbers appears to have started before warmer water and removal efforts to control non-native fishes began.

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

In 2008, a large rainbow trout cohort spawned in Lees Ferry, apparently as a result of the 2008 HFE (Korman et al. 2010, 2011). Large downriver migration of this cohort, combined with local recruitment along downriver sections, likely led to a roughly 800 percent increase in rainbow trout densities in the vicinity of the Little Colorado River since 2006 (Makinster et al. 2010, Wright and Kennedy 2011. Preliminary estimates of the 2011 Natal Origins field work has estimated trout numbers at over 1 million age 0 fish in the Lees Ferry Reach, or 17 times higher than the previous estimate after the 2008 HFE (J. Korman, Ecometric, pers. comm. 2011). Although the fate of those age 0 fish cannot be reliably predicted, it is possible that a portion of this cohort will emigrate downstream and potentially interact with native fish. This increase in trout numbers may be due to high and steady dam releases in 2011 due to a wet water year and resulting equalization flows (from Lake Powell to Lake Mead) under the Interim Guidelines. Mainstem warming and mechanical removal effects both started in 2003 and could have begun affecting the abundance of age-2 humpback chub recruits in 2004 and later, (brood-years 2002 and later). But the increase in humpback chub recruitment appears to have begun in the mid-1990s before the population was exposed to warmer Colorado River water temperatures and reduced non-native fish abundance near the mouth of the LCR. However, Coggins and Walters (2009) state that the low summer steady flow conducted during the summer of 2000 (primarily a low flow of 8,000 cfs from June to September; see Ralston and Waring 2008), which warmed the mainstem river, may have resulted in increased recruitment of the 1999, 2000, and possibly 1998 brood-years. The increase in recruitment in the 1990s could also have been due to the implementation of the MLFF. Although the contribution of the mainstem aggregations, other than the LCR Inflow aggregation, to the overall Grand Canyon population is not known, and most of the population likely occurs in the LCR Inflow aggregation, the Grand Canyon population of humpback chub (i.e. the lower Colorado River basin recovery unit) is the largest of the humpback chub population range wide, and the only one with an increasing trend.

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

Most of Reclamation's conservation measures for humpback chub from the 2008 Opinion have either been implemented or are in the process of being implemented. The AMWG accepted the completed Humpback Chub Comprehensive Plan in August 2009, and Reclamation is currently implementing many aspects of the plan (Glen Canyon Dam Adaptive Management Program 2009). For example, translocations above Chute Falls were conducted every year between 2008 and 2011. Working with NPS, translocations have also occurred into Havasu and Shinumo Creeks. A genetics management plan for humpback chub was also completed in 2010.

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

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

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

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

Growth rates of translocated humpback chub are very high. Fish that are translocated at age 0-1 year have grown to maturity, over 200 mm TL (7.9 inches), within one year of being translocated. Typically a 200 mm TL (7.9 inches) fish in the Grand Canyon population is estimated to be 4 years old. Translocated fish may have spawned based on the presence of ripe fish and fry above Chute Falls, although only three fry have so far been captured, so spawning may be minimal (Van Haverbeke and Stone 2009). At least four humpback chub have been documented moving up Chute Falls on their own (Stone 2009, Van Haverbeke and Stone 2009), and in May of 2009 an adult female did so during base flow conditions, illustrating that even at base flow the falls are not a barrier to humpback chub movement (Stone 2009, D. Stone, FWS, pers. comm. 2009). Because PIT tagging was not initiated until the fourth translocation in 2008, there are not enough data to say with certainty what the contribution of translocated fish has been to the overall population. Given the high growth rate, the variable numbers between Atomizer and Chute falls, and the continued presence of humpback chub above Chute Falls, it seems reasonable that survivorship of translocated fish has been high. However, most humpback chub have moved below Chute Falls, calling any range extension from the translocation effort somewhat into question (Van Haverbeke and Stone 2009).

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

In another 2008 Opinion conservation measure over 900 non-native rainbow trout were removed from Shinumo Creek in May and June 2009, in preparation for the humpback chub release. Fisheries biologists also removed 394 rainbow trout from Shinumo Creek during the 2011 field season (Healy et al. 2011). Native bluehead sucker and speckled dace were also documented, measured, and returned to the creek. Following the 2009 humpback chub release, two monitoring trips, pre-and post-monsoon, were scheduled. The pre-monsoon monitoring trip was completed in July 2009. To help monitor potential downstream movement of translocated fish, two remote PIT tag antennas were installed in the lower end of the system above a waterfall near the mouth of Shinumo Creek. Monitoring indicated high retention of fish in the creek; 108 were captured in July, only six of which were below the falls, the rest in the two mile reach above the falls; the majority of these fish were in the same general location where they were released. Of the six humpback chub captured in the short reach below the falls, three (two young of year, and one 1-year old) were unmarked (Grand Canyon Wildlands Council 2009). The Shinumo aggregation is likely supporting a small mainstem spawning aggregation at Shinumo Creek, as captures of young fish indicates that successful spawning has occurred (Ackerman 2008, Grand Canyon Wildlands Council 2009).

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

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

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

Habitat Conditions

Water temperatures in the mainstem Colorado River below Glen Canyon Dam are an important factor of fishery habitat downstream. Glen Canyon Dam release temperature is a result of a combination of several factors: reservoir elevation (because warm water in the epilimnion, the warmest uppermost layer of a lake, is closer and more available to be released through the penstock intakes when lake elevation is low); temperature and volume of inflow (larger runoff volumes deepen the epilimnion, creating a larger, deeper body of warm water that is relatively closer to the penstocks at a given reservoir elevation, and therefore available to be released, than do smaller runoff volumes); and climate (solar insolation directly warms water). Releases from Glen Canyon Dam affect downstream temperature primarily as a function of release temperature and release volume. Wright et al. (2008a) found that mainstem temperatures at the LCR 124 km (77 miles) downstream of Glen Canyon Dam were influenced by both temperature and volume, but release temperature had the greater effect; generally, release temperature is more important closer to the dam, and volume more so further downstream. Release temperature peaked in 2005 when Lake Powell reached its lowest point since filling in the 1980s of 3,555.1 feet (1083.6 m) elevation on April 8. Since the 2008 Opinion, Lake Powell elevation has ranged from 3,588.26 feet (1093.70 m) on March 11, 2008 to 3,642.29 feet (1110.17 m) on July 12, 2009. Climate change is predicted to result in drier conditions in the Colorado River basin, thus lower Lake Powell reservoir elevations (and warmer release temperatures) may become the norm (Seager et al. 2007, U.S. Climate Change Science Program 2008a, 2008b).

Water temperatures in the mainstem Colorado River have generally been elevated over the last decade (Figure 4). These temperatures are not optimal for humpback chub spawning and growth, but may provide some temporary benefit and contribute to the improving status of the species. Release temperatures from Glen Canyon Dam have remained elevated relative to operations during the 1980s and 1990s due to continued drought-induced lower Lake Powell reservoir levels, and somewhat due to relatively high inflow in 2008, 2009, and 2011. Water temperature in the mainstem at Lees Ferry reached about 14 °C in 2008 (USGS 2009a), similar to temperatures in 2003 when drought effects from low Lake Powell levels began to raise Glen Canyon Dam release temperatures. The 2008 temperatures were warm enough to provide some benefit to humpback chub, though not as much as the high temperatures of 16° seen at Lees Ferry in 2005. Water temperatures peaked at 11° in 2010 and 13.5° in 2011 (Figure 4; USGS unpublished data).

Nearshore habitats are important nursery habitats for humpback chub (Valdez and Ryel 1995, Robinson et al. 1998, Stone and Gorman 2006). Temperature differences between mainchannel and nearshore habitats can be pronounced in backwaters and other low-velocity areas. The amount of warming that occurs in backwaters is affected by daily fluctuations, which cause mixing with cold mainchannel waters (AGFD 1996, Behn et al. 2010). Behn et al. (2010) found that the water in Grand Canyon backwaters completely exchanges with the mainstem an average of 6.5 times per day when discharge fluctuates but just 2.3 times per day when discharge is stable. Hoffnagle (1996) found that the mean, minimum, maximum, and daily range of water temperature in backwaters were higher under steady versus daily fluctuating flows, with mean daily temperatures (14.5 °C) under steady flows about 2.5 °C greater than those under fluctuating flows. Differences in the mainchannel temperatures during steady and fluctuating flows were also statistically significant, but mean temperatures differed by only 0.5 °C. Anderson and Wright (2007) also found that fluctuations have minimal effect on mainstem water temperatures but that fluctuations can have substantial effects to nearshore water temperatures. Similar results were documented by Trammell et al. (2002), who found backwater temperatures during the 2000 low steady summer flow experiment to be 2-4 °C above those during 1991-1994 under fluctuating flows. Korman et al. (2006) also found warmer backwater temperatures under steady flow conditions, concluding that backwaters were cooler during fluctuations because of the daily influx of cold main channel water. These effects were documented during the months of August and September, but not October, when cooler air temperatures caused backwaters to be about 1 °C cooler than the mainchannel. However, they also noted that the extent of the effect was variable and depended on the timing of daily minimum and maximum flows, the difference between air and water temperatures, and the topography and orientation of the backwater relative to solar insolation. Nevertheless, when mainstem temperatures are cold (i.e., <12 ° C) backwaters may provide a thermal refuge for juvenile and adult humpback chub, and the thermal conditions in backwaters are generally more favorable for native fish when discharge is stable relative to fluctuating. Use of thermal refuges (i.e., small, discrete locations that represent a more favorable thermal environment than the main river) by fish have been documented in a variety of systems (e.g., Ebersole et al. 2001, Torgerson et al. 1999).

The GCDAMP has been experimenting with high flow tests as a means to restore sand bars in Grand Canyon since 1996, most notably in 1996, 2004, and 2008. These tests have had varying results, and although a best case scenario of dam operations that permanently sustains existing sand bars appears feasible, this approach is still a research question (Wright et al. 2008b). HFEs do create sand bars and associated backwaters.

Although backwaters appear to be important habitat types of young humpback chub (AGFD 1996, Hoffnagle 1996), their overall importance relative to habitat suitability, availability, and humpback chub survival and recruitment are still in question, and additional research on this relationship has long been needed. A conservation measure of the 2008 Opinion aimed at meeting this need, the NSE, began in 2008. This study was designed to clarify the relationship between flows and mainstem habitat characteristics and habitat availability for young-of-year and juvenile humpback chub and other native and non-native fish species. The NSE has documented humpback use and available habitat in the small study area below the LCR between Heart Island and Lava Chuar rapid. Preliminary results suggest that backwater habitats in this reach were small and ephemeral with fluctuating flows because of the high shoreline gradients. When backwaters were present, these habitats were often submerged during higher water releases (>15,000). Additional preliminary NSE results suggest that during the NSE study period (July - October), humpback chub were most often found in talus slopes although positive selection for backwater habitats occurred when backwater habitats were available. However backwater habitats are clearly not required for humpback chub to persist in the NSE study reach because, while backwater habitats have been observed to be ephemeral in this study reach, juvenile humpback chub have been consistently collected and, as described below, exhibited juvenile survivorship between 12 NSE sampling trips (GCMRC unpublished data).

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

An important feature of the environmental baseline is climate change. Some studies predict continued drought in the southwestern United States, including the lower Colorado River basin due to climate change. Seager et al. (2007) analyzed 19 different computer models of differing variables to estimate the future climatology of the southwestern United States and northern Mexico in response to predictions of changing climatic patterns. All but one of the 19 models predicted a drying trend within the Southwest. A total of 49 projections were created using the 19 models and all but three predicted a shift to increasing aridity in the Southwest as early as 2021–2040 (Seager et al. 2007). Published projections of potential reductions in natural flow in the Colorado River Basin by the mid-21st century range from approximately 45 percent by Hoerling and Eischeid (2006) to approximately six percent by Christensen and Lettenmaier (2006). The U.S. Climate Change Science Program completed a report entitled “Abrupt Climate Change, A report by the U.S. Climate Change Science Program and the Subcommittee on Global Climate Change Research” (U.S. Climate Change Science Program 2008a) that concluded, if model results are correct, that the southwestern United States may be beginning an abrupt period of increased drought (U.S. Climate Change Science Program 2008b).

If predicted effects of climate change result in persistent drought conditions in the Colorado River basin similar to or worse than those seen in recent years, water resources will become increasingly taxed as supplies dwindle. Increased demand on surface and groundwater supplies throughout the Colorado River basin is also likely. The upper Colorado River basin states are not using their full allocations of Colorado River water and will likely look to implement projects to utilize additional water. For example, the Lake Powell Pipeline project is currently proposed to provide water from Lake Powell to communities in southwest Utah. The pipeline if it goes forward is anticipated to deliver approximately 100,000 acre-feet of water, likely resulting in lower Lake Powell reservoir elevations, and warmer Glen Canyon Dam release temperatures, on average, especially in the face of climate change (USFWS 2008).

Changes to climatic patterns may warm water temperatures, alter stream flow events, and increase demand for water storage and conveyance systems (Rahel and Olden 2008). Resulting warmer water temperatures across temperate regions are predicted to expand the distribution of existing warmer water aquatic non-native species by providing 31 percent more suitable habitat for aquatic non-native species, based upon studies that compared the thermal tolerances of 57 fish species with predictions made from climate change temperature models (Mohseni et al.

2003). Eaton and Scheller (1996) reported that while several cold-water fish species in North America are expected to have reductions in their distribution due to the effects of climate change, several warm water fish species are expected to increase their distribution. In the southwestern United States, this may occur where water remains perennial but warms to a level suitable to non-native species that were previously physiologically precluded from these areas. Species that are known or suspected to prey on or compete with humpback chub populations such as black bullhead, fathead minnow, common carp, channel catfish, and largemouth bass are expected to increase their distribution by 5.9 percent, 6.0 percent, 25.2 percent, 25.4 percent, and 30.4 percent, respectively (Eaton and Scheller 1996). Rahel and Olden (2008) also predict that changing climatic conditions will benefit warm water non-native species such as red shiner, common carp, mosquitofish (*Gambusia affinis*), and largemouth bass. All of the above-mentioned species already occur in the Colorado River in Marble and Grand canyons, but climate change and warmer water temperatures could lead to their proliferation and range expansion within the river. The effect of water temperature (and flow volume and fluctuation, which affect water temperature) on the abundance and composition of non-native fish species, and the tradeoff this represents to natives that benefit from warmer water, is an important consideration that was apparently identified at the time of the 1995 Opinion and earlier; however, the severity of this threat appears to have been underestimated by biologists of the time, given newer information available on the effects of non-native species population increases and concomitant decreases in humpback chub populations in the Yampa and Green rivers, and how closely this now appears linked to temperature and hydrology (USFWS 1978, 1995a, Finney 2006, Fuller 2009, Johnson et al. 2008, R. Valdez, pers. comm., 2009).

Rahel et al. (2008) also noted that climate change could facilitate expansion of non-native parasites. This may be an important threat to humpback chub. Optimal Asian tapeworm (*Bothriocephalus acheilognathi*) development occurs at 25-30 °C (Granath and Esch 1983), and optimal anchorworm temperatures are 23-30 °C (Bulow et al. 1979). Cold water temperatures in the mainstem Colorado River in Marble and Grand Canyons have prevented these parasites from completing their life cycles and limited their distribution. Warmer climate trends could result in warmer overall water temperatures, increasing the prevalence of these parasites, which can weaken humpback chub and increase mortality rates.

Predation and Competition from Non-native Fish

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

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

3 (RM 69.1-109) have increased every year beginning in 2006 (Makinster 2010). Mainstem fish monitoring detected increases in rainbow trout in the LCR inflow reach of the Colorado River in 2008, prompting a removal trip in May of 2009. During the 2009 removal trip, AGFD removed 1,873 rainbow trout. The 2010 catch per unit effort in reach 2 (RM 56-69) was similar to 2009, but catch per unit effort in 2011 was nearly twice that of 2009 (B. Stewart, AGFD, written comm. 2011). These estimates may indicate that rainbow trout are likely increasing throughout Marble Canyon. Unlike the situation in 2003, however, the four native fish species occurring in Grand and Marble Canyons, flannelmouth sucker, bluehead sucker, speckled dace, and humpback chub, are still very abundant in the LCR inflow reach (Makinster et al. 2009b, Van Haverbeke et al. 2011).

The threat posed to humpback chub in Grand Canyon by non-native crayfish is unclear, although climate change could result in their spread in Marble and Grand Canyons due to warmer mainstem water temperatures (Valdez and Speas 2007, Rahel et al. 2008). Non-native crayfish have been found in Glen Canyon in the past, although they have not become established. At least two species of crayfish, the red swamp crayfish (*Procambaris clarki*) and the northern or virile crayfish (*Orconectes virilis*), have been introduced into the action area, which could affect native fish populations. The red swamp crayfish is well established downstream in Lake Mead, and northern crayfish is well established in Lake Powell (Johnson 1986). In 2007, northern crayfish were observed in Lees Ferry, although only three northern crayfish were observed, and none were captured in further intensive efforts to capture crayfish (A. Makinster, AGFD, pers. comm., 2009). Red swamp crayfish were also found as far upstream from Lake Mead as Spencer Canyon (RM 246) in 2003 (L. Stevens, Grand Canyon Wildlands Council, pers. comm., 2009). Presumably crayfish would have become established by now in Marble and Grand Canyons if conditions were suitable, given their close proximity in Lakes Powell and Mead, although precisely what conditions have prevented this are not known.

Crayfish appear to negatively impact native fishes and aquatic habitats through habitat alteration by burrowing into stream banks and removing aquatic vegetation, resulting in decreases in vegetative cover and increases in turbidity (Lodge et al. 1994, Fernandez and Rosen 1996). Crayfish also prey on fish eggs and larvae (Inman et al. 1998), and alter the abundance and structure of aquatic vegetation by grazing, which reduces food and cover for fish (Fernandez and Rosen 1996). Creed (1994) found that filamentous alga (*Cladophora glomerata*) was at least 10-fold greater in aquatic habitats absent crayfish. Filamentous alga is an important component of aquatic vegetation in Marble and Grand Canyons that is part of the food base for humpback chub (Valdez and Ryel 1995). Carpenter (2005) found that crayfish reduced growth rates of flannelmouth sucker, but Gila chub (*Gila intermedia*, a closely related species to humpback chub) were more affected by intraspecies competition than from competition with crayfish. Marks et al. (2009) found that, following eradication of non-native fishes and flow restoration in Fossil Creek, Arizona, crayfish abundance increased significantly, but this had no apparent effect on native roundtail chub (*Gila robusta*, another species closely related to humpback chub), which also increased in numbers significantly following removal of non-native fish. The threat posed to humpback chub in Grand Canyon by non-native crayfish is unclear, although climate change could result in their invasion in Marble and Grand Canyons due to warmer mainstem water temperatures (Valdez and Speas 2007, Rahel et al. 2008).

Humpback Chub Critical Habitat

Critical habitat for humpback chub in the action area consists of Critical Habitat Reach 6, the LCR, and Critical Habitat Reach 7, the Colorado River in Marble and Grand Canyons. Reach 6 consists of the lowermost 8 miles (13 km) of the LCR to its mouth with the Colorado River. Reach 7, consists of a 173-mile (278-km) reach of the Colorado River in Marble and Grand Canyons from Nautiloid Canyon (RM 34) to Granite Park (RM 208). The PCEs, as described in the Status of the Species section, are: Water of sufficient quality (W1) (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, turbidity, etc) that is delivered to a specific location in accordance with a hydrologic regime required for the particular life stage for each species (W2); Physical Habitat, areas for use in spawning (P1), nursery (P2), feeding (P3), and movement corridors (P4) between these areas; and Biological Environment, food supply (B1), predation (B2), and competition (B3) (Maddux et al. 1993a, 1993b, USFWS 1994).

Critical Habitat Reach 6 – Little Colorado River

The current condition of critical habitat in Reach 6, the LCR, is probably similar to historical conditions in many ways. As discussed in the Status of the Species section, all of the PCEs are provided for in this reach of humpback chub critical habitat, and this segment supports the majority of the Grand Canyon population, the largest of the humpback chub populations.

The PCE for water, water quality and quantity have likely been altered by land uses such as livestock grazing and development in the LCR basin, although little monitoring or research has been conducted on changes to this critical habitat segment from historical conditions. Water use in the basin has clearly diminished surface flows because much of the LCR is now intermittent while it was perennial historically (Valdez and Thomas 2009). But data for the USGS Cameron gauge (back to 1947) show that the LCR hydrograph has been highly variable with frequent floods as well as periods of low to no flow, with no discernable pattern. Flow in the reach of critical habitat is reduced annually to base flow from Blue Springs of about 225 cfs, although floods are common, and may even exceed historical floods in magnitude given that development results in greater peak runoff, and frequency and magnitude of flooding events (Hollis 1975, Neller 1988, Booth 1990, Clark and Wilcock 2000, Rose and Peters 2001, Wheeler et al. 2005). Livestock grazing, a land use throughout the LCR basin, similarly impacts aquatic and riparian habitats at a watershed level though soil compaction, altered soil chemistry, and reductions in upland vegetation cover, changes which lead to an increased severity of floods and sediment loading, lower water tables, and altered channel morphology (Rich and Reynolds 1963, Orodho et al. 1990, Schlesinger et al. 1990, Belsky et al. 1999).

Development can affect water quality in a number of ways. Urban runoff contains a variety of chemical pollutants including petroleum, metals, and nutrients from a variety of sources such as automobiles and building materials (Wheeler et al. 2005). Development also leads to increases in the number of dumps and landfills that leach contaminants into ground and surface water, reducing water quality and thereby degrading fish habitat, and there is evidence of this in the LCR, which contains surges of trash with each flooding event. Similarly, wastewater treatment plants that accompany development also can contaminate ground and surface water (Gallert and Winter 2005). Pharmaceuticals and personal care products also may contain hormones, which are present in wastewater, and can have significant adverse effects to fishes, particularly fish reproduction (Kime 1994, Rosen et al. 2007). The use of pesticides from agricultural and residential use may enter water sources which, can have lethal and sublethal effects to fish

(Ongley 1996). Despite the presence of much development in the LCR basin, we know of no significant water quality issues with W1 of critical habitat in Reach 6.

Whatever effect land and water use of the LCR basin has had on modification of the lower LCR and its hydrograph, it is not readily apparent from the physical habitats available to humpback chub. This could be because of the continued spring-fed base flow and the unique travertine geology of the system which forms a complex habitat matrix of pools, shallow runs, and races. Uncemented calcium carbonate particles form part of the stream bottom and contribute to the turbidity of the river (Kubly 1990), and flood flows are extremely turbid. This also could contribute to the lower levels of non-native predators in the LCR, which generally evolved and survive better in clear water. Perhaps also important, development of the LCR basin is widespread, but not dense, so effects of land uses are mediated by large expanses of open space and the sheer size of the basin. Regardless, all of the physical PCEs (P1-4) are provided for in the LCR, and the stream appears to fully support all life stages of the species, and all life stages appear to have been increasing in recent years (Coggins and Walters 2009, Stone 2008a, 2008b, Van Haverbeke et al. 2011).

Although the biological PCE for food supply (B1) is met in this reach (as described in the Status of the Species section), there appears to be greater food availability for adult humpback chub in the mainstem Colorado River based on body condition. Hoffnagle et al. (2000) reported that condition and abdominal fat were greater in the mainstem Colorado River than in the LCR during 1996, 1998, and 1999. Alternatively, this may have been due to the increased prevalence and abundance of parasites (especially *Lernaea cyprinacea* and Asian tapeworm) in the LCR fish as opposed to greater food availability in the Colorado River. The NSE study also documented higher growth rates of juvenile humpback chub in the mainstem relative to growth rates of juvenile fish in the LCR in 2009 and 2010 (GCMRC unpublished data), but it is uncertain whether these growth differences are a function of food availability, habitat, temperature, parasites, or a combination of these and other as of yet unidentified factors).

The biological PCEs of predation (B2) and competition (B3) from non-native species are also met. Non-native fish species that prey on and compete with humpback chub are present, but in very low numbers relative to native fishes including humpback chub. For example, although channel catfish captures increased between the spring and fall 2008 monitoring trips (from 1 fish in spring to 66 fish in the fall), even the increased number of channel catfish captured (n=66) was a small fraction of the total number of humpback chub captured (n=3,084) (Stone 2008a, 2008b). Although fish remains were found in non-native species in 2007 in the LCR, no direct evidence of humpback chub predation was documented, although predation on humpback chub by catfish and trout has been documented in the past (Marsh and Douglas 1997, Yard et al. 2008). However, for the LCR, the primary indication that the biological PCE, as well as the other PCEs, are met in the LCR is the increasing abundance of humpback chub and recruitment that has characterized the population in the LCR in recent years (Stone 2008a, Stone 2008b, Coggins and Walters 2009, Van Haverbeke et al. 2011).

The LCR reach of critical habitat plays an important role in the recovery of the species because this is the primary spawning and rearing area for the Grand Canyon population, which also constitutes (along with the mainstem Colorado River) the lower Colorado River Recovery Unit. As described in the Status of the Species section, demographic criteria must be met for this Recovery Unit, as well as for one or two core populations in the upper Colorado River basin, for downlisting and delisting, respectively, to occur (USFWS 2002a). As described earlier, in addition to the demographic criteria, the Recovery Goals also contain site-specific management actions and tasks and corresponding recovery factor criteria that must be met for downlisting and delisting to occur. In evaluating the effectiveness of the critical habitat unit in meeting recovery, the primary measure is the status of the population in relation to the demographic criteria, and the secondary measure is the state of the recovery factors and the implementation of their associated management actions and tasks, such as flow management and non-native fish control.

The 2008 abundance of humpback chub in the LCR was estimated to be 7,650 adults (between 6,000-10,000, age 4+; ≥ 200 mm (7.9 inches TL) which is nearing the 10,000-11,000 adults the ASMR estimates constituted the adult LCR population when marking began in 1989, and appears to have been in an upward increasing trend since 2001 (Coggins et al. 2006a, Coggins 2008a, Coggins and Walters 2009). The demographic criteria for the Grand Canyon population for downlisting is that the humpback chub population is maintained as a core population over a 5-year period, starting with the first point estimate acceptable to the FWS, such that the trend in adult (age 4+; ≥ 200 mm [7.9 inches]) point estimates does not decline significantly, the mean estimated recruitment of age-3 (150–199 mm [5.9-7.8 inches]) naturally produced fish equals or exceeds mean annual adult mortality, and the population point estimate exceeds 2,100 adults. The FWS Upper Basin (Region 6) has not yet determined that the demographic criteria for the Grand Canyon population have been met, but the best available science indicates that the demographic criteria are at least nearing being met. Given this, the PCEs in Critical Habitat Unit 6, the LCR, appear to be meeting the needs of recovery.

The recovery factor criteria and associated management actions and tasks that relate to this critical habitat unit are based on the five listing factors. Most of these are directed at improving and protecting humpback chub habitat including critical habitat and the PCEs of critical habitat. Those that relate to the LCR and Reach 6 are discussed below.

For Factor A, flows for the LCR that meet the needs necessary for all life stages of humpback chub to support a recovered Grand Canyon population appear to be met in recent years, given the status and trend of the LCR population (Stone 2008a, 2008b, Coggins and Walters 2009). However, a specific definition of the LCR flows that provides for these habitats, or a specific model that relates flow to habitat conditions, has not been developed and has been identified as a need by Valdez and Thomas (2009). They provide a comprehensive look at the LCR flow regime and the needs of the humpback chub in the LCR in a management plan for the LCR basin. This plan was developed in response to an element of the reasonable and prudent alternative of the 1995 Opinion (USFWS 1995b) which required that Reclamation be instrumental in developing a management plan for the LCR. LCR watershed planning was also a conservation measure of the 2008 Opinion and a project in the Humpback Chub Comprehensive Plan and will continue under this opinion (Glen Canyon Dam Adaptive Management Program 2009).

Valdez and Thomas (2009) discuss the effects of human land uses of the LCR watershed and how they affect ground and surface water and ultimately flow and humpback chub habitat in the lower LCR. Key water uses of the basin are associated with the communities of Flagstaff and Winslow and several regional power plants and associated withdrawals from the C-aquifer, the same aquifer that feeds Blue Spring. However, they also note that although these water uses clearly must have reduced inputs of surface flow causing the river to become intermittent, the change in the LCR hydrograph is not easy to detect. For example, for the period of record for the U.S. Geological Survey Cameron stream flow gauge (since 1947), there is no discernable pattern of no-flow days, although maximum daily flows have lowered since 1988, perhaps indicating an effect of drought and water use.

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

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

Asian tapeworm has been documented at infestation rates of 31.6–84.2 percent in the LCR, and has been hypothesized as a factor in poor condition factor of humpback chub in the LCR (Meretsky et al. 2000, Hoffnagle et al. 2006). Nevertheless, the status and trend of the LCR population indicates that the negative effect of Asian tapeworm is not significant. Research efforts have also noted that infestation rates are highly variable, and may be dependent on river flow, size class of fish, or other factors. More research is needed to determine the population-level effect of Asian tapeworm and the need and scope of a possible control program for the parasite. In the 2010 spring sampling trip, *Lernaea* was observed on 67 of 3,264 humpback chub (2.0%); individual fish were carrying between 1 to 4 parasites each. *Lernaea* was also seen on one bluehead sucker, one flannelmouth sucker, and 5 speckled dace. During the fall sampling effort of 2010, *Lernaea* was observed on 181 humpback chub (6.2% of total humpback chub captures). The infected humpback chub on both trips appeared to be distributed between the confluence and the top of Salt reach. One flannelmouth sucker and one speckled dace were also observed carrying *Lernaea* each during the fall survey effort (Van Haverbeke et al. 2011). The New Zealand mud snail, *Potamopyrgus antipodarum*, was also detected in the Grand Canyon in 1995 and may be expanding. The Humpback Chub Comprehensive Plan includes a project for the monitoring and control of humpback chub parasites and diseases (Glen Canyon Dam Adaptive Management Program 2009).

For Factor D, existing regulatory mechanisms, the Recovery Goals identify the need to determine and implement mechanisms for legal protection of adequate habitat in the Little Colorado River through instream-flow rights, contracts, agreements, or other means. The most thorough accounting of the mechanisms and stakeholders needed to accomplish this for the LCR are provided by Valdez and Thomas (2009). As mentioned above, it appears as if flow needs for all life stages are met for humpback chub in Reach 6, a required task of the Recovery Goals, although Valdez and Thomas (2009) recommend that a model be developed that defines the instream flow needs of humpback chub to ensure continued support for all life stages of the species and relate flow to habitat needs of all life stages (Valdez and Thomas 2009). The current status and upward trends in population abundance and recruitment (Stone 2008a, 2008b, Coggins and Walters 2009, Van Haverbeke et al. 2011) indicate that the current flow conditions in the LCR are adequate.

For Factor E, other natural or manmade factors, the primary element relative to the LCR is to identify and implement measures to minimize the risk of hazardous-materials spills from transport of materials along U.S. Highway 89 at and near the Cameron Bridge spanning the Little Colorado River. This is also a project of the Humpback Chub Comprehensive Plan (Glen Canyon Dam Adaptive Management Program 2009). A plan is needed to address this threat and efforts to develop one have not been initiated, though the need has been identified since at least 2002, and would likely require minimal expense. Reclamation has, as a conservation measure of the 2008 Opinion, agreed to assist in implementing the Humpback Chub Comprehensive Plan and Reclamation has agreed to continue to implement this as part of the proposed action.

Critical Habitat Reach 7 – Colorado River in Marble and Grand Canyons

Critical habitat in Reach 7, in Marble and Grand canyons, has been altered dramatically from historical conditions, primarily due to emplacement of Glen Canyon Dam. In the 2008 and 2009 Supplemental Opinions we stated that the importance of habitat in the mainstem to recovery is not known. However, we know that these "big river fish" use a variety of riverine habitats, with adults especially found in canyon areas with fast current, deep pools, and boulder habitat, and at least some of the PCEs are functional as demonstrated by the NSE study and the persistence of mainstem aggregations. Reach 7 provides an important role in support of the Grand Canyon population (the largest of the humpback chub populations) although the relationship with the LCR and the overall importance of habitats in the mainstem to recovery is not yet known. This is because most of the humpback chub population occurs in the largest aggregation, the LCR inflow aggregation, which utilizes the LCR to a large degree. To put this in perspective, the population estimate produced for the population, currently estimated at 7,650 adult fish, is essentially the LCR inflow aggregation (Coggins and Walters 2009) because there is little movement between the LCR inflow aggregation and the other mainstem aggregations (Paukert et al. 2006). All the other aggregations are much smaller than this, and the largest of these, the Middle Granite Gorge aggregation (RM 126.1-129.0) was estimated by Valdez and Ryel (1995) to be 98 adult fish. Preliminary data from mainstem aggregation monitoring (Figure 3) show the distribution of catch rates of humpback chub in Reach 7. Catch of fish is not adjusted for effort, such as hours of netting, seine hauls, etc. Therefore, the number of humpback chub caught during different time periods does not represent density or relative abundance because effort and gear types are different during different time periods. Distribution of catches across river miles may also be somewhat biased by gear types used; however, a relatively wide distribution of humpback chub catches between river mile 25 and 250 has been documented. Longitudinal distribution has not decreased in the last decade and the data suggest a broader distribution of chub since 2000 compared to the 1990s as well as local increases in abundance (W. Persons, USGS, written communication, 2011b).

Most spawning takes place in the LCR, and some adults may never leave the LCR. Marsh and Douglas (1997) thought that there was a contingent of resident adult fish that never leave the LCR, and another contingent that migrated into the LCR to spawn. Valdez and Ryel (1995) hypothesized that large adult humpback chub may only utilize the LCR to spawn, and Gorman and Stone (1999) found that smaller adults remain in the LCR, but once they reach a certain size, they leave after spawning to spend non-spawning periods in the mainstem. Thus it is possible that the demographic criteria for the Grand Canyon population could be met by providing for all of the PCEs of critical habitat in Reach 6, the LCR, and a set of PCEs in the mainstem focused on needs of non-spawning adult fish. However, this seems unlikely, and at the least, providing for all the PCEs in Reach 7 would add resiliency to the overall population by maintaining some recruitment from the mainstem aggregations.

The flow of the Colorado River in Marble and Grand canyons has been modified by Glen Canyon Dam since dam completion in 1964, and the dam is a primary factor in the function of PCEs in this reach. Flows since Reclamation's 1995 Environmental Impact Statement (EIS) and 1996 ROD have been limited to 5,000 to 25,000 cfs except during experimental flows such as in 1996, 2004, and 2008, when experimental high flows from 41,500 to 45,000 cfs were tested. Prior to the current MLFF period of flow releases, daily fluctuations were greater, from 1,000 to 31,500 with unrestricted ramping rates (Reclamation 1995). To put this in context, historically flood flows of over 120,000 cfs were relatively common, occurring about every six years, and low flows of 500-1,000 cfs were also common. Daily variation in flow was relatively small, with a median of about 542 cfs (Topping et al. 2003). Releases from Glen Canyon Dam are now varied on an annual and daily time scale to meet the demand for electricity. The post-dam median daily change in discharge (8,580 cfs) is now approximately 15 times greater than pre-dam (542 cfs) and actually exceeds the pre-dam median discharge (7,980 cfs) (Topping et al. 2003). Post-dam changes in discharge create dramatic changes in daily river stage, 6.6 ft or greater in some areas; pre-dam, diurnal stage change was seldom more than 1.0 ft (GCMRC unpublished data).

Since closure of the dam the river has usually been perennially cold because Glen Canyon Dam typically releases hypolimnetic water (the deepest, coldest layer of the reservoir) with a relatively constant temperature which ranges from 6-8 °C at high reservoir levels. Releases from 2003 to present have been warmer due to lower Lake Powell reservoir levels, and reached as high as 16 °C in the Lees Ferry reach in 2005, 13-14 °C in 2008, and about 13 °C in 2009 (Vernieu et al. 2005, USGS 2009a, c). A low summer steady flow experiment in 2000 also warmed river temperatures significantly, and may have been responsible for increased recruitment of the 1999-2001 brood years (Trammel et al. 2002, Coggins and Walters 2009). However, the warmer flows may also have provided an advantage to warm water predators of and competitors with humpback chub, which include fathead minnows, plains killifish (*Fundulus zebrinus*). Those two species and even rainbow trout appear to benefit from warmer water or reduced fluctuations, or both (Ralston 2011). Other warm water fish present in the Colorado River such as smallmouth bass, channel catfish, black bullhead, and common carp are also likely to benefit from warmer water. Climatologists predict that the southwest will experience extended drought, so lower Lake Powell Reservoir elevations and warmer release temperatures may become the norm (Seager et al. 2007, U.S. Climate Change Science Program 2008a, b).

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

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

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

As described above, mainstem water temperatures have been warmer in recent years due to climate conditions/drought and lower Lake Powell elevation (USGS 2009b). The temperature of dam release temperatures peaked in 2005 when they exceeded 16° C and Lake Powell elevation dropped to 3535 feet (1077 m) elevation, its lowest since filling in 1980. A low summer steady flow experiment in 2000 also warmed river temperatures significantly, and may have been responsible for increased recruitment of the 1999-2001 brood years (Trammel et al. 2002, Coggins and Walters 2009). Releases in that 2000 experiment and releases since 2003 during low Lake Powell reservoir levels have resulted in temperatures exceeding 12 °C at the mouth of the Little Colorado River (Figure 6), and this may in part explain why humpback chub status has been steadily increasing during this period (Coggins and Walters 2009).

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

Glen Canyon Dam operations also modify the hydrograph (the timing of water delivery in the river). The MLFF produces a hydrograph with the highest flow volumes in the winter and summer months to meet increased demand for electricity. Humpback chub evolved with a historically variable hydrograph in Grand and Marble canyons, but with consistently high flows in the spring following snow melt and low flows in the summer (Topping et al. 2003). The high spring flows of the natural hydrograph provided a number of benefits. Bankfull and overbank flows provide energy input to the system in the form of terrestrial organic matter and insects that are utilized as food. High spring flows clean spawning substrates of fine sediments and provide physical cues for spawning. High flows also form large recirculating eddies used by adult fish. High spring flows have been implicated in limiting the abundance and reproduction of some non-native fish species under certain conditions and have been correlated with increased recruitment of humpback chub (Chart and Lentsch 1997). Valdez and Ryel hypothesized that, in the post-dam era, the maximum release at powerplant capacity (31,500 cfs) is likely too low to provide many of the spring-flood benefits to native fishes (Valdez and Ryel 1995), although Schmidt et al. (2007) found that these flows can provide a moderate increase in sandbar area and total backwater habitat area. High flow tests that utilize the outlet works (such as the March 2008 high flow test of 41,500 cfs) provide more significant positive flood-flow benefits to humpback chub by building sandbars, rearranging sand deposits in recirculating eddies, and effectively reshaping reattachment bars and eddy return current channels (see discussion of high flow tests here and in the 2008 Opinion).

The daily hydrograph under MLFF is also adjusted to meet the changing demand for electricity throughout the day within the constraints of MLFF. This typically results in a unimodal hydrograph for warmer months of the year, with peak releases during the day, and low releases at night when demand for electricity is lowest. During the colder months, the daily hydrograph is typically more bimodal, because electricity demand wanes in the afternoon and resumes in the evening to meet heating needs of residences in the evening. Daily fluctuations can be highly variable, however, depending on electrical demand. Daily fluctuations have relatively little effect on warming mainstem temperatures, at least compared to release water temperatures or release volume (Wright et al. 2008a). As discussed earlier, daily fluctuations have a significant effect on the water temperatures of nearshore habitats such as backwaters that may be important nursery habitats for juvenile humpback chub (Hoffnagle 1996, Robinson et al. 1998, Trammel et al. 2002, Korman et al. 2005).

Despite the changes in Reach 7 of critical habitat caused by the dam, humpback chub successfully spawn in the LCR, and likely move into other aggregations, such as 30-mile where they may have spawned and successfully overwintered as documented by Andersen et al. (2010). The 30-mile aggregation is the furthest upstream and thus would be warmed the least by warmer Glen Canyon Dam release temperatures because the river gets warmer as it moves downstream from the dam. However, restricted flows and warmer water releases from Glen Canyon Dam along with reduced numbers of rainbow trout contributed to conditions that accommodated mainstem overwintering of y-o-y humpback chub.

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

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

The effect of Glen Canyon Dam release temperature on humpback chub and conservation has long been recognized (USFWS 1978), and Reclamation has made several attempts to investigate modifying the dam to release warmer water. In January 1999, Reclamation released a draft environmental assessment on a temperature control device (TCD) for Glen Canyon Dam (Reclamation 1999). The preferred alternative included a selective withdrawal structure, a single inlet, fixed elevation design with an estimated cost of $15,000,000. Sufficient concern was evidenced in the review of the EA (Mueller 1999) for the potential unintended negative effects, such as non-native fish proliferation in response to prolonged water warming, as a result of the operation of a TCD, as well as the lack of a detailed science plan to measure those effects, that the environmental assessment was withdrawn.

A risk assessment of the Glen Canyon Dam TCD proposal from the GCDAMP Science Advisors (Garrett et al. 2003) recommended the installation of a TCD for Glen Canyon Dam as soon as possible and the construction of a pilot TCD in the interim. However, Reclamation completed a risk assessment to help evaluate responses of aquatic resources in Grand Canyon to the construction and implementation of a TCD (Valdez and Speas 2007). The risk assessment utilized standard protocols and a mathematical model as a tool to quantify risks and benefits to fish, fish parasites, zooplankton, and macroinvertebrates from water temperature changes resulting from modification of two of the eight generation units on the dam. All taxa present or with known potential to access the area were inventoried for each of six regions, including lower Lake Powell, Glen Canyon Dam to Paria River, Paria River to LCR, LCR to Bridge Canyon, and Bridge Canyon to Pearce Ferry. Results suggested benefits to all native fishes, but correspondingly higher benefits to many non-native fish species that may compete with or prey upon native species. Fish species carrying the highest potential for benefiting from warmer water were rainbow trout, brown trout, common carp, fathead minnow, red shiner, channel catfish, and smallmouth bass (temperatures for all of these species in Grand Canyon are currently below their optimum temperature preferences). Preliminary results also showed more suitable conditions for warm water fish parasites, including anchor worm and Asian fish tapeworm. Results also predicted an increase in periphyton biomass and diversity with warmer water, which could lead to increased food and/or substrate for epiphytes, aquatic invertebrates, fish, and waterfowl. Warm water impacts to macroinvertebrates include minor shifts in relative abundance of existing taxa with the possibility of increased taxa richness, which could be beneficial if limited to insect taxa. However, increased potential for invasion by crayfish and other nuisance species which adversely affect native species is significant.

Reclamation concluded that a TCD designed to allow only warmer water to be released downstream is technically feasible, but that the risks in terms of increases in non-native species and their predatory and competitive effects to humpback chub are potentially significant. In light of these concerns and with the recommendation of an independent scientist panel convened in April 2007 (USGS 2008) to discuss long-term experimental planning, Reclamation also briefly investigated whether construction of a TCD with both warm- and cold-water release capability is possible and under what circumstances cold water would be available for release. Due to the high cost of design investigation, no specific design work or feasibility analysis was completed, thus feasibility of a TCD with both warm- and cold-water release capability remains a question and an information need. Specifically, if the operational feasibility of a warm- and cold-water TCD is considered, detailed aquatic modeling is needed that will examine and show predictive outcomes for young and adult age classes of rainbow and brown trout, smallmouth bass, green and other sunfish species, bullheads and catfish, striped bass, carp (including Asian carp if accidentally introduced), crayfish, other invertebrates, and parasites and diseases on humpback chub and other native fish populations.

Another aspect of the changes in water quality in Grand Canyon that may affect humpback chub is turbidity. Pre-dam, turbidity was very high much of the year except during base flows. The dam largely eliminated most of the sediment supply in the river, which greatly reduced turbidity in the mainstem. Most sediment in the mainstem now is derived from tributary inputs, and the mainstem is turbid now only at times of tributary flooding. With increases in non-native fishes over the last century in Grand Canyon, especially sight-feeding predators like rainbow trout, this loss of turbidity may cause humpback chub to be more susceptible to predation by non-native fishes (Ward and Bonar 2003, GCDAMP 2009). During the summer of 2000, high abundance of adult brown and rainbow trout in the mainstem and the high water clarity throughout the river corridor may have contributed to higher predation rates on native fish near the LCR (Ralston 2011). Reclamation completed a feasibility assessment for large-scale sediment augmentation in 2007. The project would collect sediment from Lake Powell and use a slurry pipeline to deposit it downstream of the dam. This would create a more turbid river and address the erosion of beaches and fine sediment-formed fish habitats by adding sediment directly to the river. The assessment concluded that such a project is feasible, though costs were estimated at $140 million for construction and $3.6 million annually for operation (Randle et al. 2007).

The physical PCEs (physical habitat for spawning [P1], nursery habitat [P2], feeding areas [P3], and movement corridors [P4]) of humpback chub critical habitat are also affected by dam releases and may benefit or be negatively affected by HFEs. In general, the deep low-velocity habitats that adult humpback chub prefer are provided by the large deep pools and eddy complexes available in Marble and Grand canyons, and are sufficiently available to provide adequate habitat for adult humpback chub in the mainstem (Valdez and Ryel 1995). In fact, the condition factor of adult fish of the mainstem has been documented to be better than adult fish in the LCR (Hoffnagle et al. 2006), suggesting that food availability (PCEs P3 and B1) may be better for adults in the mainstem. However, as stated earlier, the humpback chub condition in the LCR may have been limited by parasites (Hoffnagle et al. 2006). Studies completed by GCMRC and the University of Wyoming found a high degree of dietary overlap between humpback chub and rainbow trout (Donner et al. 2011). Both species rely on black flies and midges which are in short supply, so the degree of resource overlap is very high. In fact, consumption of invertebrate prey by the fish assemblage at all sites that were studied overlaps with independent estimates of invertebrate production. In other words, the fish assemblage appears to be consuming close to, or all of, the available midge and black fly production that occurs annually. This indicates the fish assemblage may be food-limited. The spatial overlap between humpback chub and rainbow trout is the highest at the LCR confluence.

Juvenile humpback chub also prefer lower velocity habitats in the mainstem, but in shallow nearshore areas (Valdez and Ryel 1995). Fluctuating flows cause these nearshore habitats to be in constant change. Korman et al. (2006) found that nearshore areas affected by fluctuating flows warmed substantially for brief periods each day, which posits an ecological trade-off for fish utilizing these areas (also discussed in Reclamation 2007). On the one hand, fish may choose to exploit the warmer temperatures of the fluctuating zone on a daily basis and simply sustain any bioenergetic disadvantages of acclimating to rapidly changing discharge; or they may choose to remain in the permanently wetted zone, which is colder than the immediate near-shore margin. In a separate study, Korman et al. (2005) observed that slightly more than half of observed young-of-year rainbow trout in the Lees Ferry reach maintained their position as flows fluctuated rather than follow the stream margin up slope. Thus, for trout, it appears that the bioenergetic cost of changing stream position with fluctuations in discharge perhaps outweighs the benefits of exploiting the slightly warmer stream margins. Additionally, Korman and Campana (2009) found that juvenile rainbow trout in Lees Ferry did increase use of shallow nearshore habitats during periods of stable flow, and that growth of juvenile trout increased as a result.

Backwaters are thought to be important rearing habitat for native fish due to low water velocity, warm water, and high levels of biological productivity. They are formed as water velocity in eddy return channels declines to near zero with falling river discharge, leaving an area of partially to completely non-flowing water surrounded on three sides by sand deposits and open to the mainchannel environment on the fourth side. Reattachment sandbars are the primary geomorphic features which function to isolate nearshore habitats from the cold, high velocity mainchannel environment (Reclamation 2007). Approximately 84-94 percent of the fine sediment input is now trapped behind the dam, and the post-dam median discharge of 12,600 cfs causes remaining fine sediment, and associated habitat types, to be lost continually (Topping et al. 2004, Topping et al. 2003, Wright et al. 2005). Beaches and associated habitats such as backwaters can be recreated with high flow tests as in March of 2008, but the long-term efficacy of this approach is unknown (Wright et al. 2008b). As discussed previously and in the Effects of the Proposed Action section below, the effects of high flows on the physical PCEs of critical habitat are quite variable.

The physical PCE for spawning (P1) does not appear to be met in most of the mainstem. All of the mainstem aggregations are small, although small fish have been captured (Johnston and Lauretta 2007), and overwintering of y-o-y have been documented at the 30-mile aggregation (Andersen et al. 2010) and the LCR Reach (GCMRC unpublished data). Nursery habitat (P2) for juvenile humpback chub may be limited by fluctuating flows that alternately flood and dewater mainstem near shore habitats important to early life stages of humpback chub (AGFD 1996), and by the loss of sediment-formed habitats. Feeding areas are available to all life stages, especially for adult fish as indicated by condition factor of adult fish in the mainstem compared to those in the LCR (Hoffnagle et al. 2006), although feeding areas may be limiting for juvenile humpback chub due to the effect of fluctuations on nearshore habitats (AGFD 1996). Movement corridors (P4) appear to be adequate based on movements of humpback chub throughout the system (Valdez and Ryel 1995, Paukert et al. 2006).

The biological environment PCEs in Reach 7 of humpback chub critical habitat have also responded to the post-dam changes to the ecosystem. Productivity is much higher in terms of algal and invertebrate biomass, thus food availability for fishes (PCE B1), especially adult fishes, is likely greater than pre-dam (Blinn and Cole 1991), although the previously discussed effects of cold water temperatures and fluctuations on the nearshore environment may inhibit the optimal suitability of nursery habitats (P2) and feeding areas (P3) for juvenile warm water fishes like humpback chub in most years. Grand et al. (2006) found that the most important biological effect of fluctuating flows on backwaters is reduced availability of invertebrate prey caused by dewatered substrates (see also Blinn et al. 1995), exchange of water (and invertebrates) between the mainchannel and backwaters, and (to a lesser extent) reduced temperature. As the magnitude of within-day fluctuations increases, so does the proportion of backwater water volume influx, which results in a net reduction in as much as 30 percent of daily invertebrate production (Blinn et al. 1995, Grand et al. 2006). However, recent investigations into the use of nearshore habitats in the mainstem just downstream of the LCR by 0-3 year old humpback chub (40-199 mm [1.6-7.8 inches] TL) indicate that the PCEs of critical habitat in the area immediately downstream of the LCR confluence appears to be functioning properly and may support recovery. Juvenile humpback chub used a variety of mainstem nearshore habitats, and survivorship and growth of fish in these habitats was documented (GCMRC unpublished data). Humpback chub in other aggregations in Marble and Grand canyons also appear to have persisted and possibly increased in size in recent years (W. Persons, USGS, written communication, 2011a); other native fish including flannelmouth sucker that have similar habitat needs have also increased in abundance in western Grand Canyon (Makinster et al. 2010). Thus, there are several lines of evidence indicating that the biological environment PCEs of critical habitat in Reach 7, although limited, may have improved in recent years which is important for recovery.

Non-native fish species that prey on and compete with humpback chub affect the PCEs (B2 and B3) of the biological environment aspect of critical habitat. Catfishes (channel catfish and black bullhead), trouts (rainbow and brown trout), and common carp are well established in the action area and will continue to function as predators or competitors of humpback chub. Minckley (1991) hypothesized that non-native fish predation and competition may be the single most important threat to native fishes in Grand Canyon (Valdez and Ryel 1995, Marsh and Douglas 1996, Coggins 2008b, Yard et al. 2008). Valdez and Ryel (1995) estimated that 250,000 humpback chub are consumed by channel catfish and, rainbow and brown trout annually. Small-bodied species such as fathead minnow, red shiner, plains killifish, and mosquitofish are also found in nearshore areas of Marble and Grand canyons and may be important predators and/or competitors of juvenile humpback chub in nearshore habitats. Marsh and Douglas (1997) suggested that entire year classes of humpback chub may be lost to predation by non-native fish species, and Yard et al. (2008) estimated that, although predation rate of rainbow trout on humpback chub is likely low, at high densities, trout predation can result in significant losses of juvenile humpback chub. Yard et al. (2011) also concluded that even though predation levels were high (humpback chub comprised approximately 30% of the identifiable fish in trout stomachs), it is not evidence that there was a population-level effect on humpback chub.

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

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

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

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

Climate change is predicted to result in greater aridity in the southwest (Seager et al. 2007, U.S. Climate Change Science Program 2008a, b). Greater aridity is likely to reduce inflows to Lake Powell (Seager et al. 2007), and implementation of the Interim Guidelines, will result in lower Lake Powell reservoir elevations, and increase Glen Canyon Dam release temperatures. Warming downstream temperatures will benefit native fishes, and likely already has (Andersen

2009, Coggins and Walters 2009). But warmer Colorado River temperatures are just as likely to benefit some warm water non-native species that may function as competitors or predators to humpback chub and other native fish (Valdez and Speas 2007, Rahel and Olden 2008, Rahel et al. 2008). Recent changes in the fishery of the Yampa River illustrate how these changes could occur. Drought significantly reduced stream flows in the Yampa River in 2002, which elevated river temperatures, resulting in a rapid spread of smallmouth bass (Fuller 2009). Prior to 2002, smallmouth bass were very rare in the system, and humpback chub were common, with a small but stable population of several hundred adults. This rapid expansion of smallmouth bass essentially eliminated the humpback chub population in the Yampa in a matter of a few years (Finney 2006, T. Jones, FWS, pers. comm. 2009). The shift in the fish community in the Yampa River due to water temperature and hydrologic changes is now the greatest threat to the native fishery, and non-native fish control efforts are so far not effective (Fuller 2009). The Yampa example illustrates what could happen if efforts by the GCDAMP to warm mainstem water temperatures (e.g. through the use of a TCD or seasonal steady flows) result in the unintended consequence of an invasion or expansion of non-native fish species. Indeed, given climate change predictions, an increased capacity to deliver cold water for sustained periods seems more pressing. The relationship between warmer water temperatures and non-native fishes was recognized at the time of the 1995 Opinion, but was apparently not considered as severe a threat as it is today, especially given the newest information on climate change and its potential effect on the expansion of non-native fishes.

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

PCEs B2 (competition) and B3 (predation) continue to threaten the conservation of humpback chub, particularly in Reach 7. However, there appears to be an important relationship between the effects of dam operations on the water and physical PCEs of critical habitat and the biological PCEs of non-native fish competition and predation that needs more careful consideration before additional efforts to manipulate water temperature are attempted. Reclamation has committed to evaluating flow and non-flow non-native suppression experiments focused on the Lees Ferry reach to lower emigration of trout, which may be particularly informative in years like fiscal year 2012 when trout numbers are very high. Also, Reclamation will continue to support research on juvenile humpback chub use of Grand Canyon, which will help to better understand the degree to which predation and competition may be limiting recruitment.

Most of the Grand Canyon population relies on the LCR for spawning and a proportion of the population may never leave the LCR. Nevertheless the recent improvement in status of the Grand Canyon population, which also constitutes the lower Colorado River Recovery Unit, has coincided with improvements in the PCEs in this mainstem reach of critical habitat, with no obvious changes in the PCEs of the LCR (Reach 6). As described earlier, the PCEs for water improved largely due to warmer water temperatures between 2004 and 2011 from low Lake Powell reservoir levels and/or warm water releases. The physical PCEs improved temporarily through high flow tests that have improved nearshore habitats, and the biological environment PCEs of predation and competition improved by removal of non-native fishes between 2003 and 2009. Considering the improvement in the status of humpback chub over this period, obtaining and maintaining high quality PCEs for humpback chub in this reach of critical habitat is likely essential to recovery of the species. As noted in the 2008 Opinion and 2009 Supplemental Opinion, conservation measures are an important aspect of Reclamation's proposed action. In collaboration with the GCDAMP and associated research efforts, literature and peer reviewed reports are regular products of the program providing updated information about native fishes throughout Grand Canyon.

As described in the Status of the Species section, demographic criteria must be met for this Recovery Unit as well as for one or two core populations in the upper Colorado River basin for downlisting and delisting, respectively, to occur (USFWS 2009). As described earlier, in addition to the demographic criteria, the Recovery Goals also contain site-specific management actions and tasks and corresponding recovery criteria that must be met for downlisting and delisting to occur.

As described earlier, the abundance of humpback chub in the LCR is estimated to be 7,650 adults (between 6,000-10,000, age 4+; ≥ 200 mm [7.9 inches] TL); this is nearing the 10,000-11,000 adults the ASMR estimates constituted the adult LCR population when marking began in 1989, and appears to have been in an upward increasing trend since 2001 (Coggins et al. 2006a, Coggins and Walters 2009). FWS monitoring efforts in the LCR in 2008 and 2009 also indicate increasing recruitment and abundance. Van Haverbeke and Stone (2009) note that the 2007 and 2008 closed estimates of humpback chub abundance in the LCR do not differ statistically from the 1992 spring abundance estimates obtained by Douglas and Marsh (1996). This is significant because the Recovery Goals require an increasing trend relative to prior abundance estimates (USFWS 2009), and Douglas and Marsh (1996) provided one of the earliest robust estimates of humpback chub abundance in the LCR. Thus it now appears that humpback chub have returned to levels of abundance first documented in the early 1990s.

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

Nevertheless, questions remain about the role of the mainstem in recovery, and how best to improve the PCEs in this reach to best promote recovery. These questions are outlined in the Recovery Goals recovery factor criteria and management actions and tasks, and are currently the focus of a number of monitoring and research efforts of the GCDAMP. The recovery factor criteria and associated management actions and tasks that relate to this critical habitat unit are based on the five listing threat factors. These management actions and tasks are directed at research to determine the role of the mainstem Colorado River in providing for recovery of humpback chub. Those that relate to the Colorado River in Marble and Grand Canyons and Reach 7 of critical habitat are summarized here:

Factor A: Adequate habitat and range for recovered populations provided; investigate the role of the mainstem Colorado River in maintaining the Grand Canyon humpback chub population and provide appropriate habitats in the mainstem as necessary for recovery, including operating Glen Canyon Dam water releases under adaptive management to benefit humpback chub in the mainstem Colorado River through Grand Canyon as necessary and feasible, and investigate the anticipated effects of and options for providing suitable water conditions in the mainstem Colorado River through Grand Canyon (steady flows and flows that suppress non-native fish) that would allow for range expansion of the Grand Canyon humpback chub population and provide appropriate water temperatures if determined feasible and necessary for recovery.

Factor B: Adequate protection from overutilization; protect humpback chub populations from overutilization for commercial, recreational, scientific, or educational purposes through implementation of identified actions to ensure adequate protection for humpback chub populations from overutilization.

Factor C: Adequate protection from diseases and predation; identify and implement levels of control of non-native fish (from Lees Ferry, Bright Angel, and other areas), as necessary for recovery, and develop and implement procedures for stocking sport fish to minimize escapement of non-native fish species into the Colorado River and its tributaries through Grand Canyon.

Factor D: Adequate existing regulatory mechanisms; determine and implement mechanisms for legal protection of adequate habitat in the Colorado River in Marble and Grand Canyons through instream-flow rights, contracts, agreements, or other means.

Factor E: Other natural or manmade factors; minimize the risk of hazardous-materials spills in critical habitat by reviewing and implementing modifications to State and Federal hazardous-materials spills emergency-response plans to ensure adequate protection for humpback chub populations from hazardous-materials spills, including prevention and quick response to hazardous-materials spills.

The Recovery Goal recovery factor criteria for Factor A in the mainstem require that life stages and habitats of humpback chub be identified and the relationship between individuals in the mainstem and the LCR are determined. The Colorado River through Grand Canyon must provide for adequate spawning, nursery, juvenile and adult habitat. Although a TCD will not be pursued at this time, other flow options could be developed through the GCDAMP to take advantage of years when above normal water temperatures are released from Glen Canyon Dam to provide suitable water temperatures in the mainstem Colorado River through Grand Canyon that would allow for range expansion of humpback chub (see earlier discussion on the history and current state of TCD investigations).

The PCEs W1 and W2 in Reach 7 appear to be achieving recovery, with the caveat that the needs necessary for all life stages of humpback chub in the mainstem to support a recovered Grand Canyon population are still under investigation. The GCDAMP continues to provide information and address the recovery goal of determining the importance of the mainstem in recovery and defining a Glen Canyon Dam release flow that meets all the habitat needs of a recovered Grand Canyon population. Ongoing research, such as the Natal Origins study should serve to provide much valuable information on the needs of the species in this reach of critical habitat in terms of Glen Canyon Dam flows and water temperature of releases, and how the PCEs function in meeting the recovery needs of the species.

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

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

The Recovery Goals also identify the need to develop and implement levels of control for rainbow trout, brown trout, and warm water non-native fish species (USFWS 2002a). Non-native fish control has been a focus of the GCDAMP for some time. The degree to which these removal efforts have improved the PCEs B2 and B3 is still a research question, although Yard et al. (2008) estimated that the 2003-2006 removal of rainbow and brown trout contributed significantly to reduce predation losses of juvenile humpback chub. Andersen (2009) and Coggins and Walters (2009) noted the potential role these removal efforts may have had in improving the status of the humpback chub in Marble and Grand Canyons, but the available information is insufficient to evaluate the effects of removal alone. The GCDAMP and GCMRC have been testing various methods to monitor and remove warm water non-native fish species, so far with little success. Information on which non-native species should be removed during which times of the year continues to be a research question.

For Factor D, adequate existing regulatory mechanisms, the Recovery Goals identify the need to determine and implement the mechanisms for legal protection of habitat in the mainstem Colorado River, through instream-flow rights, contracts, agreements, or other means. The Law of the River (which determines water delivery), coupled with the protection afforded by Grand Canyon National Park, may or may not be sufficient to meet this need in reach 7 of critical habitat, but such an analysis has not been completed.

For Factor E, the Recovery Goals identify the need to review and recommend modifications to State and Federal hazardous-materials spills emergency-response plans to ensure adequate protection for humpback chub populations from hazardous-materials spills, including prevention and quick response to hazardous-materials spills. This applies mostly to the Highway 89 bridge at Cameron. Other bridges could be an issue, such as Navajo Bridge in Marble Canyon, although it carries much less traffic. A comprehensive evaluation of State and Federal hazardous-materials spills emergency-response plans to ensure adequate protection for humpback chub populations from hazardous-materials spills has not been completed for the Colorado River.

In summary, the Recovery Goals provide specific criteria for Reach 7 of critical habitat and its PCEs, and the most important of these are to identify Glen Canyon Dam releases that maintain adequate humpback chub habitat to support recovery and to implement levels of non-native fish control as necessary to support recovery. Reclamation's proposed action includes an active adaptive management program that is progressively testing different flow regimes. Reclamation has also included in its proposed action several projects to monitor and evaluate the effect of these experimental flows on the PCEs of critical habitat in this reach, including the Natal Origins Study, and various monitoring and research projects of the GCDAMP annual work plans (as discussed earlier in the Proposed Action). Reclamation has also included non-native fish control as a conservation measure. The benchmark for success of these efforts is the Recovery Goals demographic criteria for humpback chub in the lower Colorado River basin Recovery Unit. Although FWS has not yet determined that the demographic criteria have been met, recent monitoring has documented an increase in humpback chub numbers and the native fish community.

Razorback sucker

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

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

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

Razorback Sucker Critical Habitat

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

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

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

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

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

Kanab ambersnail

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

B. FACTORS AFFECTING SPECIES' ENVIRONMENT WITHIN THE ACTION AREA

Humpback chub

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

The Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Mead and Lake Powell will govern releases from Glen Canyon Dam through September 2026. Flows were developed in the 1996 Record of Decision on the Operations of Glen Canyon Dam, and currently follow the MLFF 5-Year Plan. A full description of the operation strategies is discussed in the 2007 Shortage Opinion (USFWS 2007). Reclamation conducted a high flow test initiated on March 5, 2008, and completed on March 9, 2008. During the high flow experiment, Reclamation released water through Glen Canyon Dam's powerplant and bypass tubes to a maximum amount of 41,500 cfs for 60 hours. As a result of the high flow test, the elevation of Lake Powell dropped by approximately 2.3 feet (0.7 m). The annual volume of water released from Lake Powell for water year 2008 was not modified as a result of the high flow experiment. Although 2008 was originally projected to be an 8.23 maf release year, the April 24-month study projected the September 30, 2008, Lake Powell elevation to be above 3,636 feet (1,108 m) (the equalization level for water year 2008), based on the April 1st final inflow forecast.

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

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

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

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

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

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

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

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

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

Razorback sucker

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

Kanab Ambersnail

There has likely been some loss of snails and habitat from the highest MLFF flows, although this has been undetectable in surveys conducted since the 2008 Opinion. Kanab ambersnail habitat only begins to be affected by flows at about 17,000 cfs (Sorensen 2009), and flows only exceeded this level in 2011. Meretsky and Wegner (2000) noted that even at flows from 20,000 to 25,000 cfs (MLFF allows flows up to 25,000 cfs), only one patch of snail habitat is significantly affected (Patch 12), and a second patch is impacted to a lesser extent at flows above 23,000 cfs (Patch 11). Very few Kanab ambersnail have been found in patches 11 and 12 historically, and habitat in these patches is of low quality (Sorensen 2009). Surveys in 2008 and 2009 indicated that overall, habitat at Vasey's Paradise is in good condition, and the species is in numbers that are comparable to recent years, although their numbers are lower than levels during the late 1990s and early 2000s. The abundance of Kanab ambersnail has not returned to levels seen before the 2002-2003 drought that severely reduced the amount of available habitat and likely cropped the population in that year (J. Sorensen, AGFD, pers. comm., 2009).

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

The translocated population at Elves Chasm is not affected by dam operations and appears to have recovered from drought conditions, and surveys in 2009 found more snails than in previous years. The habitat also now has more wet habitat than in prior years (J. Sorensen, AGFD, pers. comm. 2009). Critical habitat for Kanab ambersnail has not been designated, thus none will be affected. The habitat at Vasey's Paradise remains somewhat stable from year to year but is easily scoured by high floods and likely is affected by microclimatic conditions such as higher humidity and lower air temperatures. The surrounding environments and high vegetative cover may be important habitat features related to Kanab ambersnail survival (Sorenson and Nelson 2002).

EFFECTS OF THE ACTION

Effects of the action refer to the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated and interdependent with that action that will be added to the environmental baseline. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration. Indirect effects are those that are caused by the proposed action and are later in time, but are still reasonably certain to occur.

Humpback chub

As discussed in the 2008 Opinion and 2009 Supplemental Opinion, the operation of Glen Canyon Dam has adverse affects to humpback chub (USFWS 1995b, 2008, and 2009 Supplement). The 2008 Opinion and 2009 Supplemental Opinions provide thorough analyses of these effects and the parts of those opinions that were not challenged are incorporated here by reference. The MLFF will continue as described in the 1995 EIS and 1996 ROD. The MLFF as defined in the 1995 EIS (Reclamation 1995) was implemented following the 1995 EIS and 1996 ROD as part of an action that included formation of the GCDAMP, and with the intention of modifying the action over time based on the principles of adaptive management. This approach utilizes science, monitoring, and stakeholder and public involvement to improve management decisions on implementing changes in management (Williams et al. 2007), in this case Glen Canyon Dam releases. Many of the effects documented during the first years of MLFF are expected to be seen during this 10-year project as discussed in detail in the 2008 and 2009 Supplemental Opinion; those discussions are incorporated by reference.

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

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

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

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

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

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

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

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

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

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

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

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

Under the proposed action, we anticipate that the majority of humpback chub will spend most if not all of their life in a very small portion of the action area. This is because the largest aggregation of humpback chub in the Grand Canyon (the LCR aggregation), occupies only a few miles of river in Grand Canyon. Many subadult and adult humpback chub (approximately 200 mm and larger) leave the LCR once they reach a certain size to spend non-spawning periods in the mainstem (Gorman and Stone 1999). These larger size classes are more likely to withstand cold water temperatures and avoid most predators. While this movement is part of their life history, some scientists believe that these fish move into mainstem habitats because of density dependent factors in the LCR. That is, food resources in the LCR are limited and competition is high so the larger individuals move into the mainstem in search of food. Thus, as stated in our 2008 Opinion, it is possible that the recovery goal for the Grand Canyon population could be met by providing for all of the PCEs of critical habitat in Reach 6, the LCR, and a set of PCEs in the mainstem focused on needs of non-spawning adult fish. We conclude that prospects for recovery would improve by providing for all the PCEs in Reach 7, which would add resiliency to the overall population by maintaining some recruitment from the mainstem aggregations.

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

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

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

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

Impacts to food resources are expected to occur during the life of this project. As stated in the 2008 and 2009 Supplemental Opinions, fluctuations and seasonal variation in flow volume to meet electricity demand also affects the food base available for fishes. As flow volume increases, Valdez and Ryel (1995) documented increasing densities of chironomids and simuliids in the drift (water current) on the descending limb of the diurnal hydrograph, and McKinney et al. (1999) documented a similar response for *G. lacustris*. Chironomids and simuliids are important food items for adult humpback chub (Valdez and Ryel 1995), thus flow fluctuations may make these prey items more available in the drift. Flow fluctuations may have a negative effect on food availability in nearshore habitats, reducing the food base of juvenile humpback chub. In a study conducted in the upper Colorado River basin (middle Green River, Utah), Grand et al. (2006) found that the most important biological effect of fluctuating flows in backwaters is reduced availability of invertebrate prey caused by dewatered substrates (see also Blinn et al. 1995), exchange of water (and invertebrates) between the mainchannel and backwaters, and (to a lesser extent) reduced temperature. As the magnitude of within-day fluctuations increases, so does the proportion of backwater water volume influx, which results in a net reduction in as much as 30 percent of daily invertebrate production (Grand et al. 2006).

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

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

Non-Native Fish Control

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

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

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

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

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

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

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

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

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

OR

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Effects to Humpback Chub Critical Habitat

In our analysis of the effects of the action on critical habitat, we consider whether or not the proposed action will result in the destruction or adverse modification of critical habitat. In doing so, we must determine if the proposed action will result in effects that appreciably diminish the value of critical habitat for the recovery of a listed species (see p. 4-34, USFWS and National Marine Fisheries Service 1998). To determine this, we analyze whether the proposed action will adversely modify any of those physical or biological features that were the basis for determining the habitat to be critical PCEs. To determine if an action results in an adverse modification of critical habitat, we must also evaluate the current condition of all designated critical habitat units, and the physical and biological features of those units, to determine the overall ability of all designated critical habitat to support recovery. Further, the functional role of each of the affected critical habitat units in recovery must also be defined.

The water and physical habitat PCEs of critical habitat of the LCR reach (Reach 6) will be little affected by MLFF because dam operations affect the mainstem Colorado River primarily, and would only affect the lower-most portion of the LCR via mainstem effects on the configuration of the mouth of the LCR, which is less than a quarter of a mile of the eight mile reach, (about three percent of critical habitat in Reach 6). Protiva (Protiva, in Ralston and Waring 2008) found that optimal habitat conditions for juvenile humpback chub at the LCR inflow, in terms of temperature and flow, are achieved at about 13,000 cfs in the mainstem. Because daily fluctuations are constantly changing conditions at the mouth in a manner that differs from pre-dam conditions, this theoretically results in less-than-optimal habitat conditions for juvenile humpback chub much of the time (Protiva, in Ralston and Waring 2008). At high flows, ponding can also occur (Protiva, in Ralston and Waring 2008), which may provide a benefit by slowing current velocity in the LCR and reducing passive or active emigration from the LCR, thereby increasing the residence time of juvenile humpback chub in the LCR where they have higher survival rates. Ponding only occurs at flows of more than 40,000 cfs however (Protiva, in Ralston and Waring 2008). But the effect of dam operations on the mouth of the LCR is likely a minimal effect overall to humpback chub, and only occurs in a very small portion of Reach 6.

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

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

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

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

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

The LCR reach of critical habitat plays an important role in the recovery of the species because this is the primary spawning and rearing area for the Grand Canyon population, which constitutes the lower Colorado River Recovery Unit. As described in the Status of the Species section, demographic criteria must be met for this Recovery Unit as well as for one or two core populations in the upper Colorado River basin for downlisting and delisting, respectively, to occur (USFWS 2002a). The demographic criteria constitute the best scientific information with which to analyze the performance of critical habitat reaches in meeting the recovery needs of the species. As described earlier, in addition to the demographic criteria, the Recovery Goals also contain site-specific management actions and tasks and corresponding recovery factor criteria that must be met for downlisting and delisting to occur. So in evaluating the effectiveness of the critical habitat unit in meeting recovery, the primary measure is the status of the population in relation to the demographic criteria, and the secondary measures are the state of the recovery factors and implementation of their associated management actions and tasks.

As stated in the 2008 an 2009 Supplemental Opinions, the current abundance of humpback chub in the LCR is estimated to be 7,650 adults (between 6,000-10,000, age 4+; ≥ 200 mm [7.8 inches] TL) which is nearing the 10,000-11,000 adults the ASMR estimates constituted the adult LCR population when marking began in 1989, and appears to have been in an upward increasing trend since 2001 (Coggins et al. 2006a, Coggins and Walters 2009). The net effect of implementation of MLFF in recent years does not appear to be restricting the ability of critical habitat in Reach 6 to meet the demographic criteria of recovery.

The recovery criteria and associated management actions and tasks that relate to this critical habitat unit are based on the five listing factors. Most of these are directed at improving and protecting humpback chub habitat including critical habitat and the PCEs. For Factor A, an adequate flow for the LCR that meets the needs necessary for all life stages of humpback chub to support a recovered Grand Canyon population appears to be met in recent years, given the status and trend of the LCR population (Stone 2008a, 2008b, Coggins and Walters 2009). However, a specific definition of the LCR flow that provides for these habitats, or a specific model that relates flow to habitat conditions, has not been developed (Valdez and Thomas 2009). MLFF will have minor effects to the flow in the LCR, limited to the effects on habitat suitability related to flow conditions in the immediate vicinity of the mouth of the LCR. This is a very small percentage of habitat in the LCR that is impacted by MLFF or HFEs, thus these effects are likely negligible in terms of a population-level response.

Valdez and Thomas (2009) have a completed a draft management plan for the LCR basin that focuses on the needs of humpback chub, which was developed in response to an element of the reasonable and prudent alternative of the FWS 1994 jeopardy biological opinion (USFWS 1994). That reasonable and prudent alternative required that Reclamation be instrumental in developing a management plan for the LCR (USFWS 1995). The LCR watershed planning is also a conservation measure of the 2008 Opinion and thus part of Reclamation's proposed action, and is also a project in the Humpback Chub Comprehensive Plan (Glen Canyon Dam Adaptive Management Program 2009). Reclamation's assistance in this regard will help protect critical habitat in the LCR to the extent consistent with Reclamation's legal authority.

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

For Factor C, the focus of the Recovery Goals is on controlling the proliferation and spread of non-native fish species that prey on, compete with, and parasitize humpback chub. For the non-native fish species, current levels of control appear adequate. Non-native fish in Reach 6 of critical habitat continue to be at low levels (see Tables 6 and 7). Clearly such low levels should be maintained, but a specific target level as alluded to in the Recovery Goals has not been identified. Better regulation of sport fish stocking through development and implementation of stocking goals with the relevant basin states has not occurred, is still needed, and is a project of the Humpback Chub Comprehensive Plan (Glen Canyon Dam Adaptive Management Program 2009). As a conservation measure of the 2008 biological opinion, Reclamation will continue to support the implementation of the Humpback Chub Comprehensive Plan, which will assist with this aspect of recovery.

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

Asian tapeworm has been documented at infestation rates of 31.6–84.2 percent in the LCR, and has been hypothesized as a factor in the poor condition factor of humpback chub in the LCR (Hoffnagle et al. 2006, Meretsky et al. 2000). Nevertheless, the status and trend of the LCR population indicates that the negative effect of Asian tapeworm is not significant. Because MLFF results in net cooling effect to the mainstem and nearshore habitats of the mainstem, MLFF contributes to the suppression of both non-native fish species and Asian tapeworm.

For Factor D, existing regulatory mechanisms, the Recovery Goals identify the need to determine and implement mechanisms for legal protection of adequate habitat in the Little Colorado River through instream-flow rights, contracts, agreements, or other means. The most thorough accounting of the mechanisms and stakeholders needed to accomplish this for the LCR are provided in Valdez and Thomas (2009). As mentioned above, a primary need is to develop a model to define the instream flow needs of humpback chub to provide for all life stages of the species and relate flow to habitat needs of all life stages (Valdez and Thomas 2009). The current status and upward trends in population abundance and recruitment (Stone 2008a, 2008b, Coggins and Walters 2009) indicate that the current hydrograph of the LCR is adequate to achieve recovery. Reclamation will also continue to support watershed management efforts as a conservation measure of the proposed action, such as creation of the Valdez and Thomas' (2009) management plan, which will also help achieve this aspect of recovery for Reach 6.

For Factor E of the Recovery Goals, other natural or manmade factors, the primary element relative to the LCR is to identify and implement measures to minimize the risk of hazardous-materials spills from transport of materials along U.S. Highway 89 at and near the Cameron Bridge spanning the Little Colorado River. This is also a project of the Humpback Chub Comprehensive Plan (Glen Canyon Dam Adaptive Management Program 2009). A plan is needed to address this threat and efforts to develop one have not been initiated, though the need has been identified since at least 2002, and would likely require minimal expense. The Humpback Chub Comprehensive Plan includes a project to create this plan (Glen Canyon Dam Adaptive Management Program 2009). Reclamation will continue to support development and implementation of the Humpback Chub Comprehensive Plan as a conservation measure of the 2008 Opinion, which will serve to address this recovery need in Reach 6.

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

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

The MLFF will continue to affect the PCEs of humpback chub critical habitat in Reach 7 by manipulating flow releases on an hourly, daily, and monthly basis, affecting the timing and volume of delivery of water, water quality (W1, W2), the formation and quality of nearshore habitats (P2, P3), the composition of the food base, and the abundance and distribution of native and non-native fishes (B1, B2, and B3). The Recovery Goals relevant to Reach 7 are the demographic criteria and the mainstem recovery factor criteria. The mainstem recovery factor criteria focus on determining the role of mainstem habitats in humpback chub recovery and the relationship of mainstem flow to habitat, providing the appropriate Glen Canyon Dam releases, and reducing other threats in the mainstem, in particular, the threat of predation and competition from non-native fish species, as necessary to meet the demographic criteria for the Grand Canyon population. Although not explicitly mentioned in the Recovery Goals, all of the critical habitat PCEs in reach 7, water quality and quantity (W1 and W2), physical habitat for spawning, nursery areas, feeding and movement (P1-4), and the food supply, predation and competition components of the biological environment (B1-3), must be addressed in determining the needs of the species in the mainstem.

As described in the Status of the Species section, demographic criteria must be met for this Recovery Unit as well as for one or two core populations in the upper Colorado River basin for downlisting and delisting, respectively, to occur (USFWS 2002a). The current abundance of humpback chub in the LCR is estimated to be 7,650 adults (between 6,000-10,000, age 4+; ≥ 200 mm [7.8 inches] TL) which is nearing the 10,000-11,000 adults the ASMR estimates constituted the adult LCR population when marking began in 1989, and appears to have been in an upward increasing trend since 2001 (Coggins et al. 2006a, Coggins and Walters 2009). Van Haverbeke and Stone (2009) also note that closed estimates of abundance of humpback chub in the LCR in 2008 are now equivalent to closed estimates utilizing very similar methods conducted in the early 1990s (Douglas and Marsh 1996). The demographic criteria for the Grand Canyon population for downlisting includes the humpback chub population maintained as a core over a 5-year period, starting with the first point estimate acceptable to the FWS, such that the trend in adult (age 4+; ≥ 200 mm [7.8 inches] TL) point estimates does not decline significantly, the mean estimated recruitment of age-3 (150–199 mm [5.9- 7.8 inches] TL) naturally produced fish equals or exceeds mean annual adult mortality, and the population point estimate exceeds 2,100 adults.

As discussed earlier, the FWS has not yet determined that the demographic criteria for the Grand Canyon population has been met, but the best available science indicates that the PCEs in Critical Habitat Unit 7 are contributing to recovery because the demographic criteria are near to being met and the status of the species continues to improve in portions of the mainstem Colorado River. The Recovery Goals identify the need to determine the role of habitats in the mainstem in meeting the demographic criteria for humpback chub in Grand Canyon, and to determine and implement Glen Canyon Dam releases that will meet these needs in the mainstem. Reclamation is in the process of determining what flows are necessary in the mainstem to meet humpback chub habitat needs, which consist of all of the PCEs of critical habitat. The current focus of the GCDAMP is to complete the research needed to address the first criterion of Factor A in the Recovery Goals for Grand Canyon, to determine the relationship between humpback chub and its habitat in the mainstem and humpback chub and its habitat in the LCR, and determine what Glen Canyon Dam releases are required to meet and maintain the demographic criteria for the species. The steady flow experiment in September and October from 2008 - 2012, the 2008 high flow test, the NSE, and other research, monitoring, and management actions, tested how the MLFF affects the PCEs of critical habitat, in comparison to how steady flows affect the PCEs of critical habitat. A key component of this research, the NSE, will be continued by Reclamation as part of the Natal Origins Study, and evaluate the response of fish and other variables in nearshore habitats such as backwaters under different flows to help clarify the relationship between flows and mainstem habitat characteristics, and the availability of nursery habitat for y-o-y and juvenile humpback chub, and the degree to which humpback chub are effected by competition and predation in these nearshore habitats.

Ongoing research efforts of the proposed action will better define how the PCEs in Reach 7 function in recovery, and will help meet the recovery criteria of determine the relationship of habitats in the mainstem and the LCR, thus defining appropriate operations of Glen Canyon Dam to achieve humpback chub recovery, as required by the Recovery Goals. The Recovery Goals require that procedures for stocking sport fish be updated to minimize escapement of non-native fish species into the Colorado River and its tributaries through Grand Canyon to minimize negative interactions between non-native fishes and humpback chub. Information provided in the FWS Sport Fish Opinion has provided updated information on the threat of sport fish stocking and AGFD has committed to implement the Conservation and Mitigation Program (CAMP) which uses a suite of tools to provide on-the-ground conservation benefits to the native aquatic species and, where appropriate, to riparian or terrestrial species indirectly affected by anglers. Reclamation has also included as a conservation measure in the 2008 and 2009 Supplemental Opinions continued support for the implementation of the Humpback Chub Comprehensive Plan; the plan included a project to develop sport fish stocking procedures with the relevant basin states to minimize escapement of sport fish into humpback chub critical habitat (Glen Canyon Dam Adaptive Management Program 2009).

The Recovery Goals also identify the need to develop and implement levels of control of non-native fish species. As a conservation measure of the proposed action, Reclamation has also committed to continue implementation of non-native fish control efforts. As discussed above, the GCDAMP has demonstrated that successful removal of non-native trout is possible, and may benefit humpback chub (Coggins 2008b, Yard et al. 2008). The degree to which these removal efforts have improved the PCEs B2 and B3 is still a research question, although Yard et al. (2011) found that the 2003-2006 removal of rainbow and brown trout contributed significantly to reduce predation losses of juvenile humpback chub. Non-native removal has been identified by several authors as a possible cause of improved status of humpback chub (Andersen 2009, Coggins and Walters 2009, Van Haverbeke and Stone 2009). Reclamation's proposed action also includes evaluation of various non-native fish control techniques which will continue to refine methods of controlling non-native fish species. Reclamation's effort to control non-native fish species directly addresses this recovery need for the B2 and B3 PCEs of Reach 7.

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

In summary, the Recovery Goals provide specific criteria for Reach 7 of critical habitat and its PCEs, and the most important of these are to identify Glen Canyon Dam releases that maintain adequate humpback chub habitat to support recovery and to implement levels of non-native fish control as necessary to support recovery. Reclamation's action includes an active adaptive management program that is progressively testing different flow regimes to benefit native fishes, and taking corrective actions based on the status of the humpback chub and its habitat. Reclamation has also included in its proposed action several projects to continue to monitor and evaluate the effect of flows and other actions on the PCEs of critical habitat in this reach. During the life of the proposed action, Reclamation will implement Non-native Fish Control when necessary, and is actively working to refine methods to remove and control the spread of non-native fishes. The benchmark for success of these efforts is the Recovery Goals demographic criteria for humpback chub in the lower Colorado River basin Recovery Unit. Although FWS has not yet determined that the demographic criteria have been met, as stated in the 2009 Supplemental Opinion, recent monitoring and modeling suggests that it has (Coggins and Walters 2009, Van Haverbeke and Stone 2009).

Razorback Sucker and its Critical Habitat

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

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

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

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

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

Kanab ambersnail

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

Total habitat available in July 1998 (minus two patches that were not included in the total measurement) was 276.82 m^2 (2,979.7 ft^2). Thus, the patches expected to be affected by MLFF (patches 11 and 12), even in a good year, constitute less than 10 percent of total habitat available. Also, very few Kanab ambersnail have been found in patches 11 and 12 historically, and these patches are of low habitat quality for Kanab ambersnail (Sorensen 2009). The amount of habitat loss at the 25,000 cfs flow level due to scour would be low, and is estimated to be about 300-350 ft^2 (27.9-32.5 m^2) or less (Meretsky and Wegner 2000). Thus the scouring effect of MLFF is predicted to have limited effect on the overall population of Kanab ambersnail at Vasey's Paradise and scouring would occur in habitat low quality.

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

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

The proposed action will have no effect on the water flow from the side canyon spring that maintains wetland and aquatic habitat at Vasey's Paradise. Kanab ambersnail at Elves Chasm would also be unaffected by MLFF because the snails and their habitat are located up the chasm well above the Colorado River and the influence of dam operations on flow. No critical habitat has been designated for Kanab ambersnail, thus none would be affected.

Climate Considerations for Effects to Humpback Chub

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

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

CUMULATIVE EFFECTS

Cumulative effects include the effects of future State, tribal, local or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Cumulative effects to the humpback chub and its critical habitat stem from Native American actions, and State, local, or private actions in tributary watersheds upstream of the action area. Native American use of the Colorado River in Grand Canyon includes cultural, religious, and recreational purposes, as well as land management of tribal lands (e.g. recreational use including rafting, hunting, and fishing). These uses affect humpback chub and its critical habitat in similar ways to uses permitted by NPS, although on a much smaller scale thus far, and thus are projected to have minimal effects to humpback chub and its critical habitat.

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

Non-Federal actions on the Paria River and Kanab Creek are limited to small developments, private water diversions, and recreation, and are expected to continue to have little effect on humpback chub and its critical habitat. Non-Federal actions in the LCR drainage are extensive, but as discussed in the Environmental Baseline section, these effects have thus far not had a detectable adverse effect on humpback chub and its critical habitat in the LCR, perhaps because these effects are diffuse over a wide area, and are distant from humpback chub and its critical habitat. The draft management plan for the LCR watershed (Valdez and Thomas 2009) provides recommendations to conserve humpback chub in light of these potential effects.

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

Kanab ambersnail occurrence in the action area is entirely on Federal lands managed by Grand Canyon National Park, and thus would not be subject to these effects, although their habitat is created by springs, and it is conceivable that some distant non-Federal action could affect the ground water that supplies these springs. We are currently unaware of any possible future non-Federal actions that affect the aquifers that create Kanab ambersnail habitat.

Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA. Since a significant portion of the action area is on Federal lands, any legal actions occurring in the future would likely be considered Federal actions, and would be subject to additional section 7 consultation. All activities will occur with the uncertainty surrounding the effects of climate change. The potential for alteration of flows in the basin as a result of climate change could have large impacts on the basin's aquatic ecosystem, including changes in the timing of peak flows from an earlier snowmelt; lower runoff peaks because of reduced snow packs; and higher water temperatures from increased air temperature. Not only would climate change affect the ecology of the species, it also could greatly affect the management of the programs through changes in politics and economics, such as a greater evaporation losses in the larger reservoirs that may reduce flexibility of operations; and drier conditions in the basin that may cause irrigators to call on their water rights more often or request more water rights.

CONCLUSION

This biological opinion does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02. Instead, we have relied upon the statutory provisions of the ESA to complete the following analysis with respect to critical habitat. We have also relied upon the U.S. Fish and Wildlife Service and National Marine Fisheries Service Consultation handbook (Consultation Handbook) (U.S. Fish and Wildlife Service and National Marine Fisheries Service 1998), which provides guidance on determining adverse modification of critical habitat, including the following (p. 4-34): "Adverse effects on individuals of a species or constituent elements or segments of critical habitat generally do not result in jeopardy or adverse modification determinations unless that loss, when added to the environmental baseline, is likely to result in significant adverse effects throughout the species' range, or appreciably diminish the capability of the critical habitat to satisfy essential requirements of the species."

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

Humpback chub

As stated in the 2008 and 2009 Supplemental Opinions and re-affirmed in 2011, the Grand Canyon population appears to have improved to approximately 7,650 adult fish (age 4+) (an increase of 1,650 since the 2008 Opinion). This estimate is similar to the number of adult fish thought to be present in Grand Canyon in 1995, and is nearing or has met the demographic criteria for this population (USFWS 2002). The status of the species overall is reduced from what it was in 1995 because of declines in populations of the upper basin as of September 2009, most notably in Yampa, Desolation, and Gray canyons, due primarily to the proliferation of non-native fishes that prey on and compete with humpback chub. The most recent and best available estimates for the Grand Canyon humpback chub population trend (Coggins and Walters 2009) indicate that there has been increased recruitment into the population from some year classes starting in the mid- to late-1990s, during the period of MLFF operations, causing the decline in humpback chub to stabilize and begin to reverse in 2001. And the Grand Canyon population of humpback chub has increased in number during implementation of MLFF. This improvement in the population status and trend has been attributed in part to actions taken pursuant to MLFF, such as non-native fish mechanical removal, and the 2000 low steady summer flow experiment and other experimental flows and actions, as well as a serendipitous warming of Glen Canyon Dam releases due to lower reservoir elevations and inflow events (Andersen 2009). However, population modeling indicates the improvement in humpback chub status and trend was due to increased recruitment in the mid to late 1990s (Coggins and Walters 2009), prior to implementation of non-native fish control, incidence of warmer water temperatures, the 2000 low steady summer flow experiment, and the 2004 high flow test. The exact causes of the increase in recruitment, and whether it is attributable to conditions in the mainstem or in the Little Colorado River are unclear. The increase in recruitment may have been due to the implementation of MLFF. Reclamation's proposed conservation measures and ongoing research will likely be beneficial to humpback chub and its critical habitat.

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

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

Reclamation is committed to implementing a suite of conservation measures, through the GCDAMP, that will benefit humpback chub and its critical habitat. We are confident that Reclamation will implement these measures because of their continued demonstration of effectiveness in implementing past and ongoing conservation measures. These conservation measures further increase our confidence in our opinion that any and all adverse affects of the proposed action are reduced to the point that the action will not jeopardize the species or result in the destruction or adverse modification of critical habitat by precluding or compromising humpback chub recovery. The proposed action includes a number of actions to benefit the species. Conservation measures and ongoing research that will likely be beneficial to both the humpback chub and its critical habitat. The following is a summary of past efforts that demonstrate Reclamation's commitment to implementing these conservation measures to benefit humpback chub, and future conservation measures that will be implemented as part of the proposed action.

Fish Research and Monitoring

- As discussed in the 2008 and 2009 Supplemental Opinions, Reclamation has been a primary contributor to the development of the GCDAMP's Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon. Reclamation plans to utilize this plan in cooperation with the USFWS and other GCDAMP members to determine what actions remain to be accomplished, and find additional funding sources that will be provided by other willing partners to help achieve recovery of the humpback chub.

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

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

Non-native Fish Control

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

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

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

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

Humpback Chub Translocation and Refuge

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

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

-

Re-Evaluation Points

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

Parasite Monitoring

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

Sediment Research

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

Little Colorado River Watershed Planning

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

Humpback Chub Critical Habitat

- We believe humpback chub critical habitat in Reach 6, the LCR, will remain functional and continue to serve the intended conservation and recovery role for the humpback chub. MLFF should have minimal effect on PCEs of this unit, and some PCEs of critical habitat will be protected by the proposed action.

- The W1 and W2 PCEs of critical habitat in Reach 6 will benefit from Reclamation's efforts to address watershed planning for the LCR, and projects in the Humpback Chub Comprehensive Plan provide protective measures for PCEs in Reach 6, such as watershed planning to protect flows, and spill prevention planning for the U.S. Highway 89 Cameron Bridge spanning the Little Colorado River. PCEs B2 and B3 of Reach 6 will benefit from efforts to control non-native species, and perhaps from the cooling effect that MLFF has on the mainstem, which may suppress warm water non-native species.

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

Razorback sucker and Critical Habitat

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

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

Razorback Sucker Habitat Assessment and Potential Augmentation

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

Kanab ambersnail

- As stated in the 2008 and 2009 Supplemental Opinions, although the MLFF will result in some loss of Kanab ambersnails and their habitat at Vasey's Paradise, we anticipate this loss will be small and not impair the long-term stability of the population because MLFF will only scour habitat at the highest flows during median and wet years, thus scouring would occur infrequently, and scouring would affect only a small proportion of overall habitat available; the habitat lost would be of low quality, and is expected to contain few snails. Kanab ambersnails have been subjected to such flows in the past under MLFF since 1991 and this occasional scouring effect of high MLFF releases appears to have had a negligible effect on the status and trend of the Vasey's Paradise population and is not expected to preclude the species' conservation. HFEs likely will result in the loss of some habitat, and Reclamation will monitor how this effects the population status.

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

INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is further defined (50 CFR 17.3) to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. "Harass" is defined (50 CFR 17.3) as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding or sheltering. "Incidental take" is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

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

AMOUNT OR EXTENT OF TAKE

<u>Humpback Chub</u>

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

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

OR

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

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

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

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

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

Razorback Sucker

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

Kanab Ambersnail

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

EFFECT OF THE TAKE

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

REASONABLE AND PRUDENT MEASURES AND TERMS AND CONDITIONS

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

Humpback chub

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

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

> A. Within two years, Reclamation should include an assessment of the feasibility to disadvantage reproduction of rainbow trout as described in Treatment #3 and Treatment #4 in Valdez et al. 2010, and repeated here.
>
> ***Treatment 3: Increase Daily Down-Ramp to Strand or Displace Age-0 Trout***
> This treatment would use dam releases during June through August to strand or displace age-0 trout and reduce rainbow trout survival. Increased down-ramp rates could reduce survival of age-0 trout by stranding them in exposed dewatered areas or by displacing them into less favorable habitats where they are subject to increased predation. Increased fluctuations would be most effective if they occurred daily from June through August

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

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

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

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

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

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

Kanab Ambersnail

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

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

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

Review requirement: The reasonable and prudent measures, with their implementing terms and conditions, are designed to minimize incidental take that might otherwise result from the proposed action. If, during the course of the action, the level of incidental take is exceeded, such incidental take would represent new information requiring review of the reasonable and prudent measures provided. Reclamation must immediately provide an explanation of the causes of the taking and review with the AESO the need for possible modification of the reasonable and prudent measures.

Disposition of Dead or Injured Listed Species

Upon locating a dead, injured, or sick listed species initial notification must be made to the FWS's Law Enforcement Office, 2450 W. Broadway Rd, Suite 113, Mesa, Arizona, 85202, telephone: 480/967-7900) within three working days of its finding. Written notification must be made within five calendar days and include the date, time, and location of the animal, a photograph if possible, and any other pertinent information. The notification shall be sent to the Law Enforcement Office with a copy to this office. Care must be taken in handling sick or injured animals to ensure effective treatment and care, and in handling dead specimens to preserve the biological material in the best possible state.

CONSERVATION RECOMMENDATIONS

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

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

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

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

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

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

In order for the FWS to be kept informed of actions minimizing or avoiding adverse effects or benefiting listed species or their habitats, the FWS requests notification of the implementation of any conservation recommendations.

REINITIATION NOTICE

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

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

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

/s/ Steven L. Spangle

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

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

Glen Canyon Natural Recreation Area, Page, AZ
Chief, Habitat Branch, Arizona Game and Fish Department, Phoenix, AZ (B. Stewart)
Director, Environmental Programs, Bureau of Indian Affairs, Phoenix, AZ
Havasupai Tribe, Supai, AZ
Hopi Tribe, Kykotsmovi, AZ
Hualapai Tribe, Peach Springs, AZ
Kaibab Band of Paiute Indians, Pipe Springs, AZ
Navajo Nation, Window Rock, AZ
Pueblo of Zuni, Zuni, NM
San Juan Southern Paiute Tribe, Tuba City, AZ
Southern Paiute Consortium, Fredonia, AZ

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APPENDIX A AND LITERATURE CITED ON THE FOLLOWING PAGES

APPENDIX A

SOUTHWESTERN WILLOW FLYCATCHER

Status in the Action Area

The southwestern willow flycatcher was listed as endangered without critical habitat on February 27, 1995 (60 FR 10694; USFWS 1995b). Critical habitat was later designated on July 22, 1997 (62 FR 39129; U.S. Fish and Wildlife Service 1997). On October 19, 2005, the FWS re-designated critical habitat for the southwestern willow flycatcher (70 FR 60886; USFWS 2005b). Critical habitat was voluntarily remanded by the FWS in 2009 and revised proposal was published August 15, 2011(76 FR 50542) but does not include the Colorado River through Grand Canyon. The 2005 critical habitat designation remains in effect until the current proposal is finalized. Proposed critical habitat on the Lower Colorado River begins at RM 243. A final recovery plan for the southwestern willow flycatcher was completed in 2002 (USFWS 2002c).

Flycatchers have nested along the Colorado River in Grand Canyon over the last 30 years, with territories typically located in tamarisk-dominated riparian vegetation along the river corridor (James 2005). Suitable nesting habitat is extremely disjunct from approximately RM 28 to RM 274 (Holmes et al. 2005, James 2005). Surveys conducted between 1992 and 2007 documented a very small breeding population in upper Grand Canyon, mostly at RM 50-51 and the area around RM 28-29, although only 1 to 5 territories have been detected in any one year (Holmes et al. 2005, James 2005). Another area of importance in the mid-1990s was RM 71-71.5. However, that area does not appear to have been occupied for the last 10 years (Holmes et al. 2005, James 2005). A total of 16 breeding sites have been detected through 2007, with a high of 16 territories detected in 1998 (Sogge and Durst 2008), but that declined to an estimated 4 territories in 2007 (Durst et al. 2008). The lack of flycatchers recently in Grand Canyon is likely more a function of decreasing numbers in more important areas nearby, like Lake Mead, than from changes in habitats in Grand Canyon.

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

Analysis of Effects

The southwestern willow flycatcher can be adversely affected by high flows through scouring and destruction of willow-tamarisk shrub nesting habitat or wetland foraging habitat, or conversely, through a reduction in flows that desiccate riparian and marsh vegetation. However, willow flycatcher nests in Grand Canyon are typically above the 45,000 cfs stage, and thus would not be affected by the highest Glen Canyon Dam releases (Holmes et al. 2005). Flycatchers nest primarily in tamarisk shrub in the lower Grand Canyon (Sogge et al.1997), which is quite common, and can tolerate very dry and saline soil conditions, and thus is capable of surviving lowered water levels (Glenn and Nagler 2005). Therefore, maximum flows of the MLFF of 25,000 cfs and minimum flows of 5,000 cfs are neither expected to scour or dewater habitats enough to kill or remove tamarisk, and no loss of southwestern willow flycatcher nesting habitat from flooding or desiccation is anticipated. HFEs may create flows of up to 45,000 cfs for up to 96 hours; similar flows have been tested in past HFEs and have not affected southwestern willow flycatcher habitat.

An important element of flycatcher nesting habitat is the presence of moist surface soil conditions (USFWS 2002c). Moist surface soil conditions are maintained by overbank flow or high groundwater elevations supported by river stage, and provide nesting habitat of riparian trees, and habitat for insects that contribute to the food base for flycatchers. The HFEs may result in the distribution of fine sediments extending farther laterally across the floodplain and deeper underneath the surface providing for the retention of subsurface water, which may provide for the development of the vegetation that provides flycatcher habitat and microhabitat conditions. The MLFF flows have been implemented since 1991, and given the typical range of daily fluctuations, groundwater elevations adjacent to the channel are not expected to modify nesting habitat. Thus the proposed action will likely have little effect on the abundance or distribution of southwestern willow flycatcher in the action area.

Conclusions

After reviewing the status of the southwestern willow flycatcher including the environmental baseline for the action area, and the effects of the proposed action, we concur that the proposed action may affect, but is not likely to adversely affect the southwestern willow flycatcher. No southwestern willow flycatcher critical habitat occurs in the action area, thus none will be affected. The downstream proposed critical habitat will not be affected.

We base our concurrence on the following:

- Flycatcher habitat in the action area consists of tamarisk, which is not likely to be affected by flows within the limits of the MLFF or HFEs.
- The flow limits of the MLFF are not expected to desiccate flycatcher habitat to the point that food base for willow flycatcher is affected.
- HFEs may result in the distribution of fine sediments extending farther laterally across the floodplain and deepening the soils surface providing for the retention of subsurface water, which may provide for the development of the vegetation that provides flycatcher habitat and microhabitat conditions.

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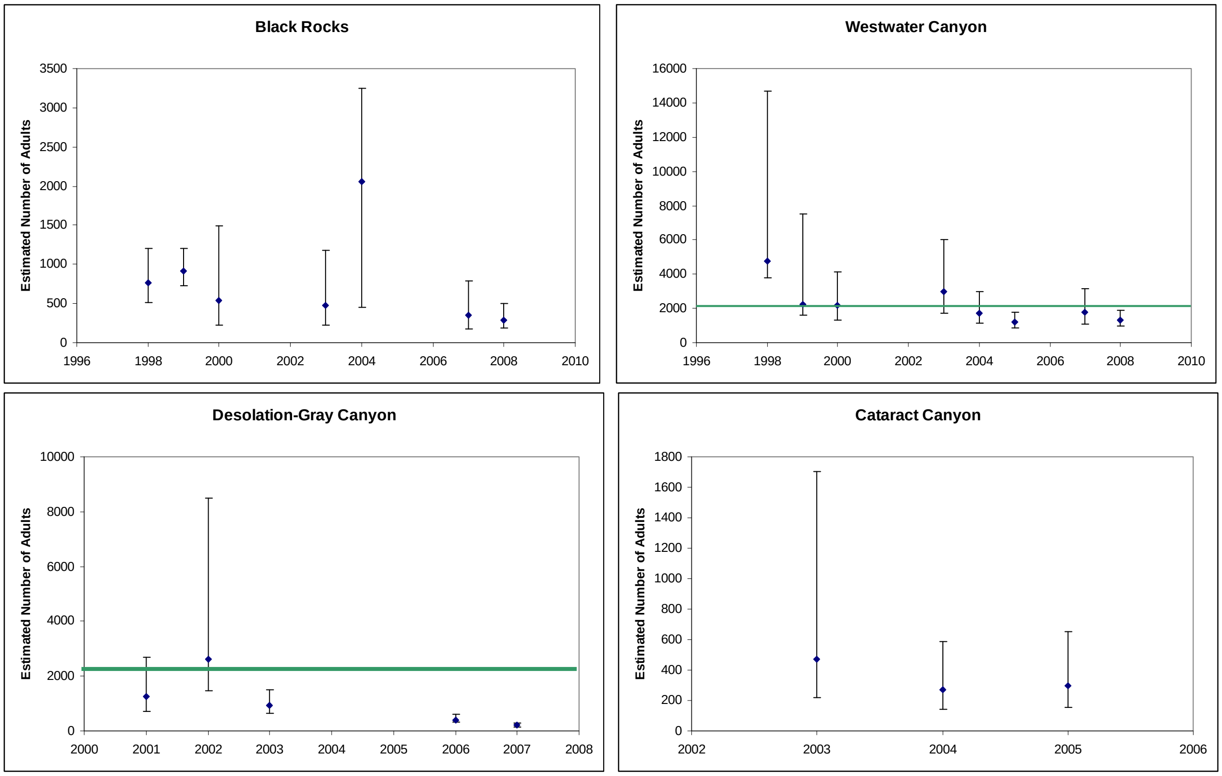
FIGURES –

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

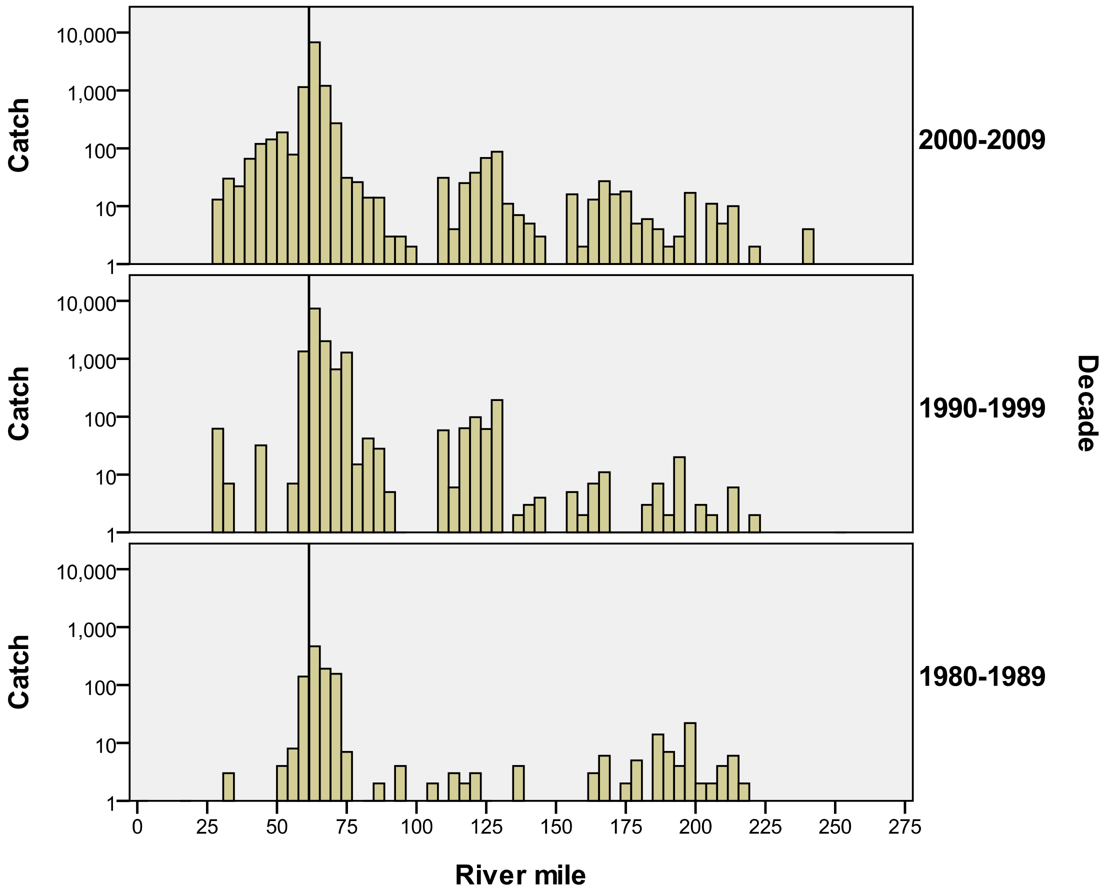
Figure 1. Distribution of humpback chub in the Colorado River System

Figure 2



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

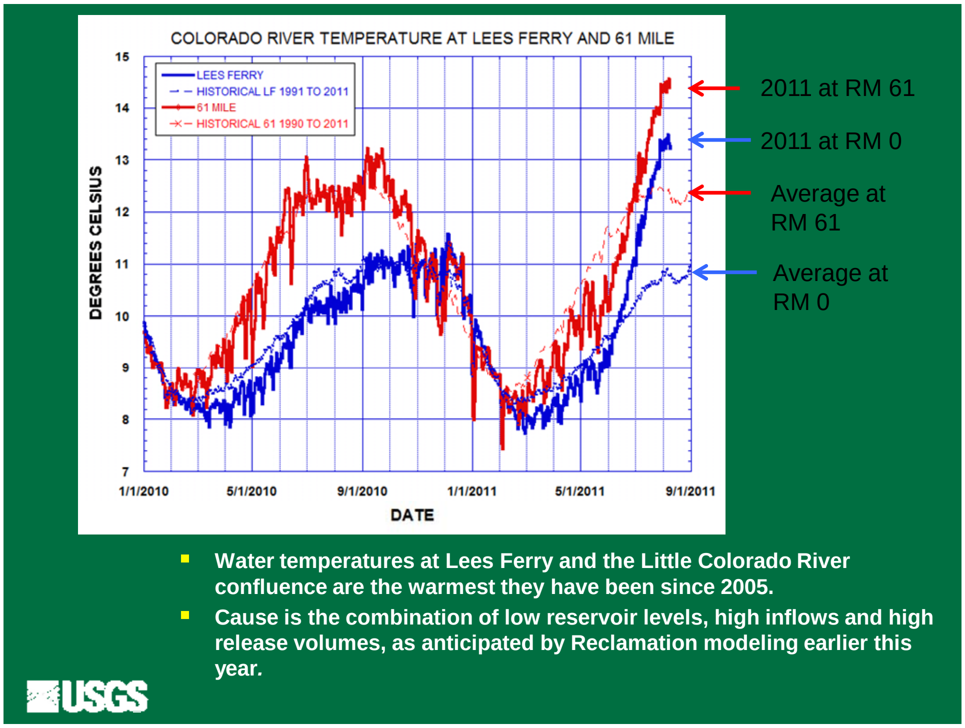
Figure 3



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

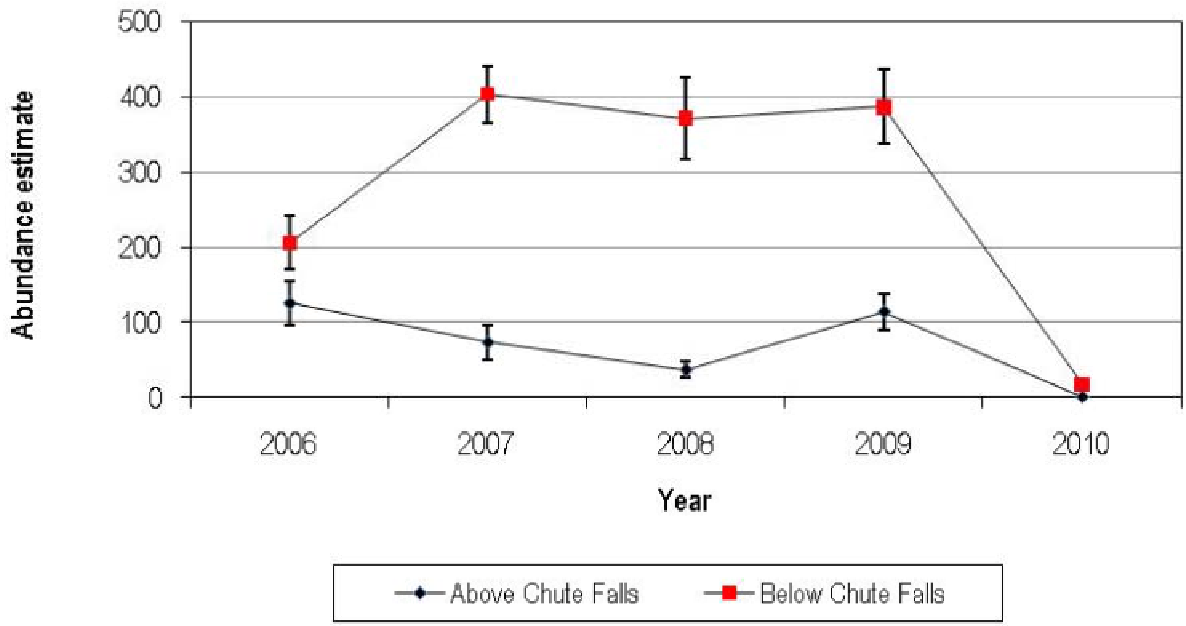
1977-1989 n = 1,081
1990-1999 n = 13,447
1999-2009 n = 10,958

Figure 4



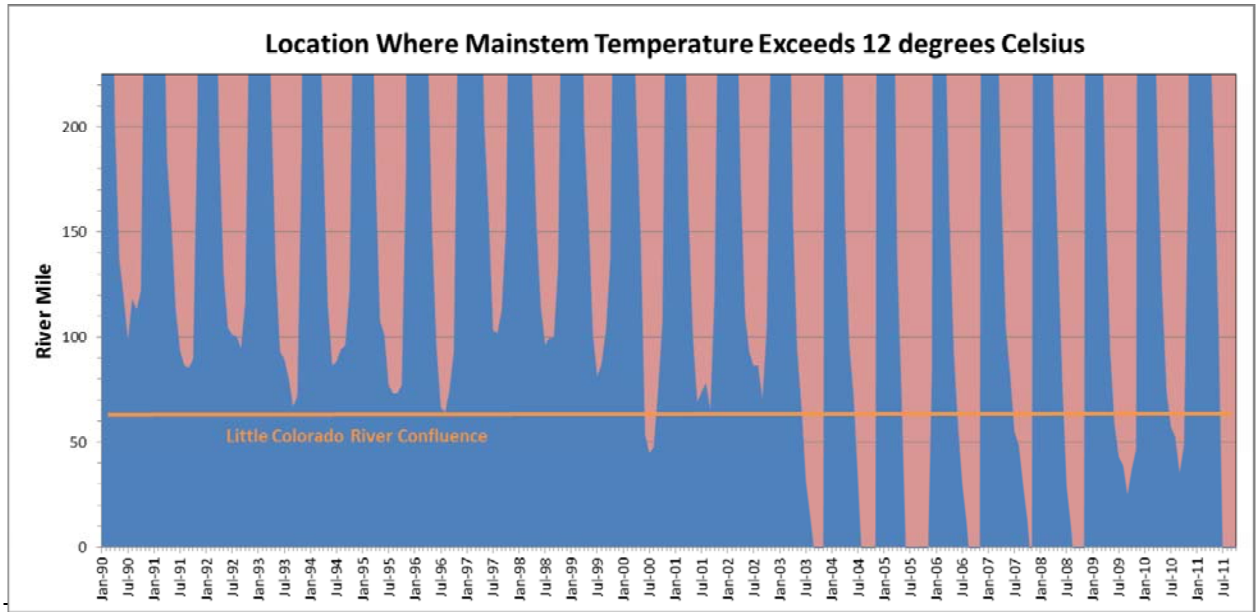
Colorado River water temperatures at Lees Ferry and the LCR confluence from January 2010 to September 1, 2011; upublished data from USGS.

Figure 5



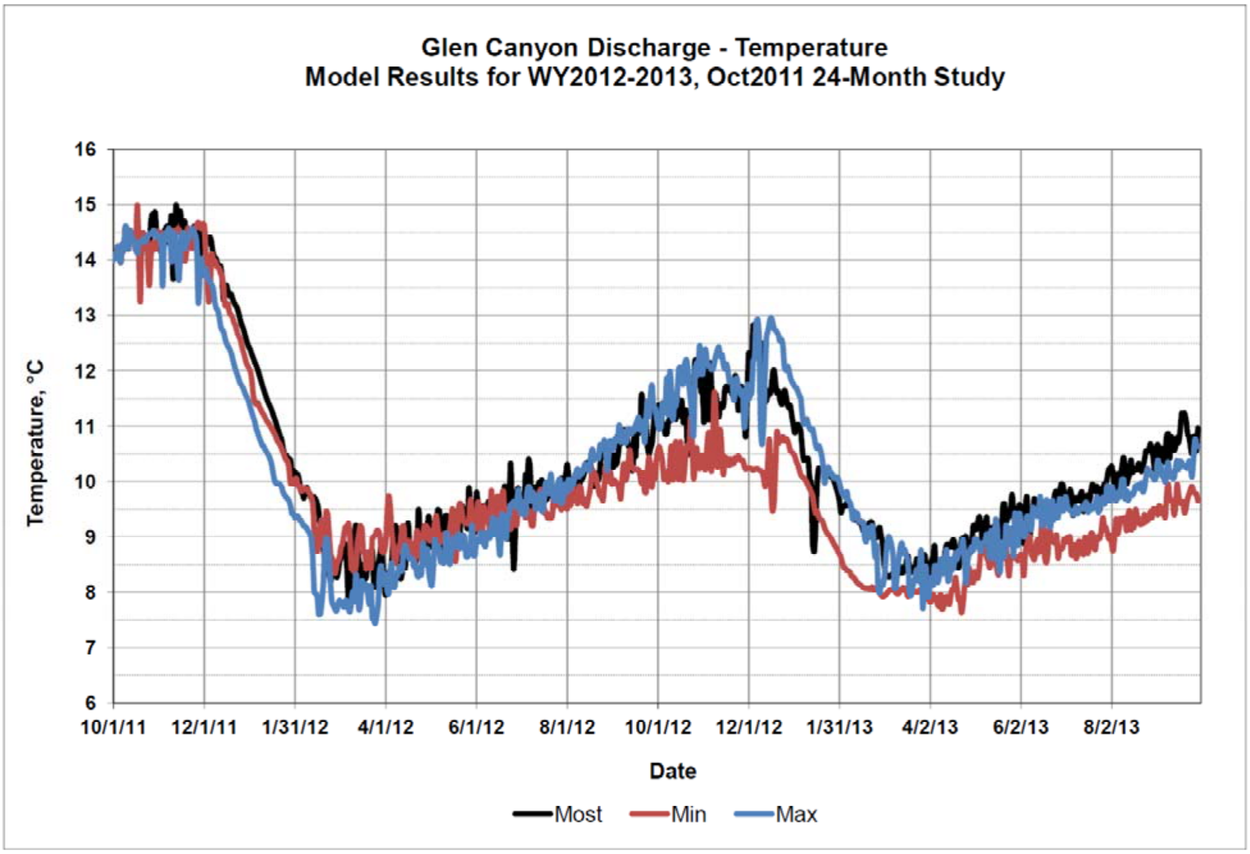
Abundances of adult humpback chub (≥ 200 mm) from lower reach below Chute Falls (13.6 to 14.1 km) and from upper reach above Chute (14.1 to 18 km) since summer 2006 (from Van Haverbeke et al. 2011).

Figure 6



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

Figure 7



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

Appendix F: Letter to State Historic Preservation Office with Concurrence Stamp

SHPO-2011-0843(92770)DOE

United States Department of the Interior

BUREAU OF RECLAMATION
Upper Colorado Regional Office
125 South State Street, Room 6107
Salt Lake City, UT 84138-1102

IN REPLY REFER TO:
ENV-3.00
UC-720

JUN 2 7 2011

JUL 0 1 2011
AH

Mr. James Garrison
State Historic Preservation Officer
Arizona State Parks
1300 West Washington
Phoenix, AZ 85007

Subject: Determination of Eligibility and Effect on Historic Properties Regarding Non-native Fish Control Downstream from Glen Canyon Dam, Coconino County, AZ

Dear Mr. Garrison:

As agency official for purposes of compliance with Section 106 of the National Historic Preservation Act of 1966, I wish to consult your office regarding the Bureau of Reclamation, Upper Colorado Region's proposed undertaking, which is the control of non-native fish downstream from Glen Canyon Dam (Dam) within Grand Canyon National Park (GCNP). While a programmatic agreement for operations of the Dam has been in effect since 1994, concerns of the Pueblo of Zuni and other Indian tribes regarding the proposed undertaking are such that I have elected to follow the 36 CFR 800 process.

The undertaking would 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 (river mile or RM 0) from the Paria River to Badger Creek Rapid (RM 8) and up to 6 removal trips would be conducted in the Colorado River near the Little Colorado River from Kwagunt Rapid (RM 56) to Lava Chuar Rapid (RM 65.5) in each year of the proposed action. Removal in the vicinity of the Little Colorado River (RM 61.5) 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.

For this undertaking, the area of potential effects (APE) is the Colorado River between Lees Ferry and Lava Chuar Rapid (RM 65.5). This 65 mile section of river lies entirely within GCNP.

In compliance with 36 CFR 800.2 and 800.4, Reclamation has reviewed existing information on historic properties within this APE; has sought new information from consulting parties, including the National Park Service, the federal agency that administers Glen Canyon National Recreation Area (GCNRA) and GCNP.

In addition, Reclamation has been consulting with Indian tribes that may attach traditional religious or cultural significance to the Colorado River and adjacent properties below the Dam.

While these identification efforts are not yet complete, as documented in the enclosed site forms and reports, I find that the National Register Criteria for Evaluation are met as follows:

Site	Criteria for Evaluation	Eligibility
Hopi traditional cultural property	a,b,c,d	Eligible
Hualapai traditional cultural property	a,b,c,d	Eligible
Kaibab Paiute traditional cultural property	a,b,c,d	Eligible
Navajo traditional cultural property	a,b,c,d	Eligible
Zuni traditional cultural property	a,b,c,d	Eligible

In consultation with the Hopi Tribe and the Pueblo of Zuni, in particular, fish in the Colorado River contribute to eligibility under Criterion c. The fish lack individual distinction, but they add to the overall traditional value of the properties for these tribes. If fish are killed and removed from the properties, it would diminish the integrity of feeling and association, constituting an adverse effect.

As indicated above, Reclamation has coordinated with the National Park Service in determining eligibility and effects information for this undertaking, and we are continuing to consult with them. I understand that they will correspond with your office directly in the next few days.

I am seeking your concurrence with these determinations of eligibility and effect for Reclamation's section 106 compliance purposes. If I do not hear from you within 30 days, I will assume your concurrence and proceed to the next step in the section 106 process which is resolution of effects pursuant to 36 CFR 800.6. If you have any questions, please contact Beverley Heffernan, at 801-524-3712, or email bheffernan@usbr.gov.

CONCUR

for Ann V. Howard

ARIZONA STATE HISTORIC PRESERVATION OFFICER
ARIZONA STATE PARKS BOARD

7-28-11

Sincerely,

Larry Walkoviak

Larry Walkoviak
Regional Director

Enclosure - (CD containing 5 files)

cc: Dr. Alan Downer
Navajo Tribal Historic Preservation Officer
P.O. Box 4950
Window Rock, AZ 86515

Mr. Ronald Maldonado
Cultural Resource Compliance Section
Navajo Nation
P.O. Box 4960
Window Rock, AZ 86515

Continued on next page: