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

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Preface

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

Introduction

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

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

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

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

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

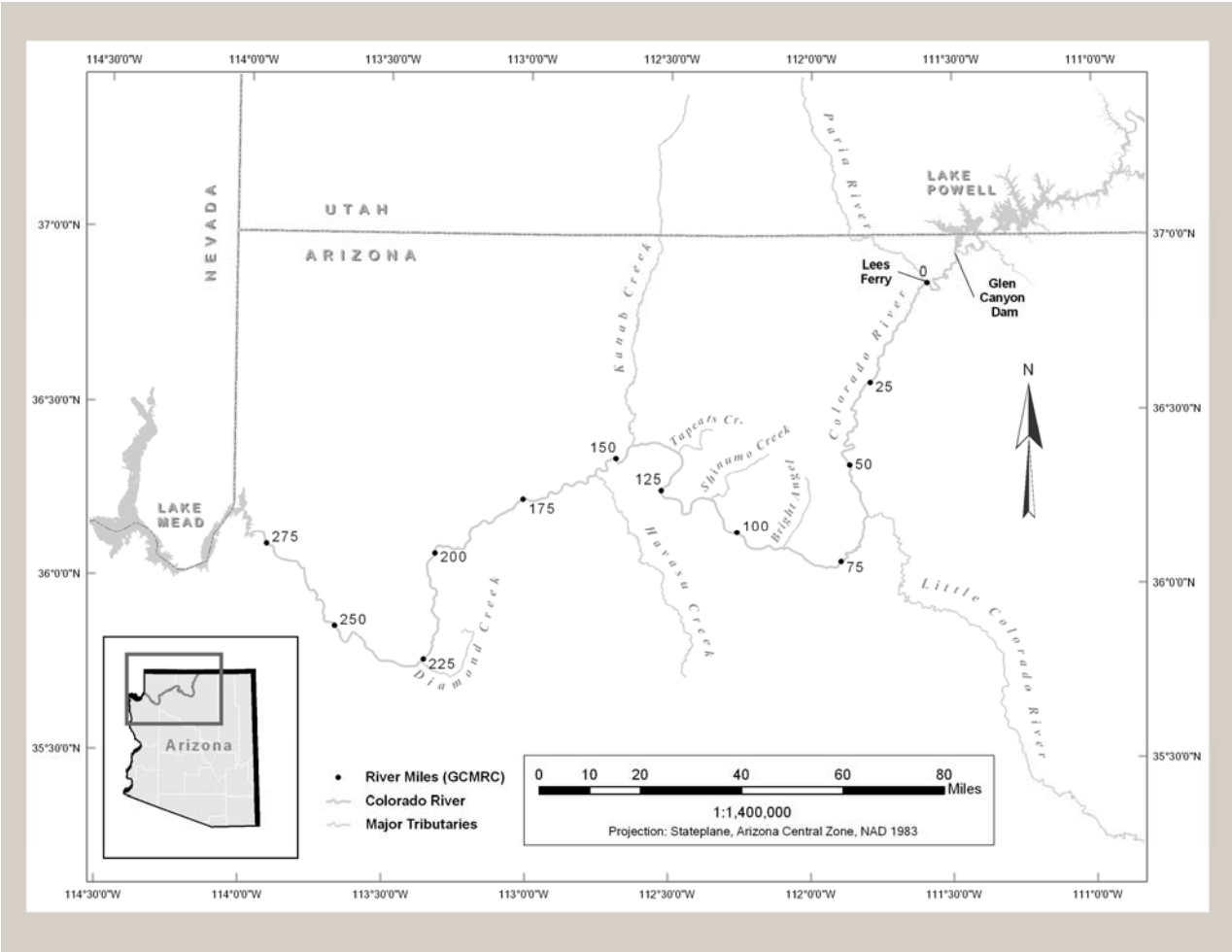

Figure 1. Map of the extent of the study area with river miles identified in 25 mile segments starting at Lees Ferry. The Little Colorado River (LCR) is identified and its confluence is at river mile 61. The Paria to Badger Rapid (PBR) Reach extends from river mile 1 to 8

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

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

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

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

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

To determine the effect of an experimental management action on humpback chub populations, the management action needs to be applied for a duration that approaches or exceeds the generation time of humpback chub—four to six years. Alternatively, inferences regarding the impact of a management action on humpback chub populations can be made using data on how a management action affects juvenile humpback chub growth or survival. Regardless of which approach is taken to reducing uncertainty (that is, designing management actions that are long enough in duration to elicit a population response, or designing shorter duration management experiments and monitoring vital rates for juvenile humpback chub), variation in environmental factors (for example, water temperature) can complicate interpretation

of results. Water temperature is a strong lever that affects native fish growth and predation/ competition interactions (Coggins, 2008a). Water temperature in the mainstem of the Colorado River near the confluence with the LCR is primarily affected by initial release temperatures from Glen Canyon Dam (Wright and others, 2008). Higher than average release temperatures from 2003-2006 while nonnative fish control at the LCR confluence was occurring confounded interpretation of humpback chub response to mechanical removal of rainbow trout (Coggins, 2008a). Therefore, as a contingency for this science plan for nonnative removal, if Glen Canyon release temperatures exceed the 2004-2005 average, then it is recommended that fish removal activities be discontinued. This would allow scientists to disentangle the effects of water temperature versus rainbow trout on humpback chub recruitment. Comparisons could then be made between humpback chub vital rates during elevated temperatures that had both high and low trout abundance.

Objectives

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

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

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

Structured Decision Making (SDM) and Science Planning

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

among the "value weighted" control alternatives considered. Ranking was based on a variety of factors, including five fundamental objectives:

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

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

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

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

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

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

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

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

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

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

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Option 1–Postpone removal to accelerate learning about Objective 1

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

recommendations from the October 2010 ecosystem modeling workshop (Carl Walters, written communication, 2010).

Strengths of Option 1:

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

Weakness of Option 1:

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

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

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

Strengths of Option 2:

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

Weakness of Option 2:

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

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

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

Strength of Option 3 –

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

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

Weakness

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

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

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

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

1. Lees Ferry Age-0 Trout Marking Project

The Lees Ferry (juvenile fish) Age-0 trout marking (LFTM) project would determine what fraction of rainbow trout in the Marble Canyon/LCR area were spawned and reared in the Lees Ferry reach. Analysis of size-frequency data for rainbow trout captured in Marble Canyon indicate an absence of small-sized fish, which suggests these populations are supported by individuals that migrated from Lees Ferry. Alternatively, it is possible that scattered local reproduction in Marble Canyon, combined with relatively high growth and survival of juveniles rainbow trout in Marbel Canyon, may also contribute sufficient numbers of trout to support

observed adult densities (Korman, pers comm.). Resolving these competing hypotheses is important to determining the viability of removing rainbow trout from the PBR reach as a way to manage the trout population near the LCR. The LFTM project would determine the natal origin of downstream rainbow trout, and if emigration is due to Lees Ferry fishery trout production, then:

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

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

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

The PBR project is intended to:

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

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

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

Sampling Below Badger Rapid for Marked Rainbow Trout.

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

Linkages to Existing Monitoring and Research Projects

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

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

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

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

Annual Reporting

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

General budget

Under development

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Appendix A

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

1.2 *Purpose of and Need for Action*

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

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

2.3 *Proposed Action*

The proposed action alternative was the top performing alternative in the SDM Project. This alternative combines a strategy of removing rainbow trout in the LCR reach (RM 56 to 66) to reduce the extant threat of large numbers of rainbow trout in that reach, with removal of trout in the PBR reach (RM 1 to RM 8) to test a strategy of removing rainbow trout immediately downstream of Lees Ferry to reduce emigration of rainbow trout from Lees Ferry to the LCR reach. Up to 6 LCR reach removal trips and up to 10 PBR reach removal trips would be conducted in any one year for the ten-year period of 2011-2020. The 10-year period of the action is appropriate to coincide with the HFE Protocol EA, also a 10-year action, because there is evidence, discussed in other sections, that HFEs benefit rainbow trout, and is also necessary to ensure a long-term commitment to implementing the conservation measure, and provide a reasonable experimental timeframe to evaluate non-native fish control through research and monitoring in an adaptive management context. In the short term (one to several years), the focus would be to reduce trout at the LCR reach. If trout abundance at the LCR reach can be kept low through PBR reach-removal (which assumes both that PBR removal is effective at limiting emigration of rainbow trout from Glen Canyon, and Lees Ferry is the primary source of rainbow

trout in the LCR reach), effort can be shifted to the PBR reach to alleviate concerns of the tribes about removal in the LCR reach. Tribes are also concerned about the taking of life on a large scale with no beneficial use of the fish. The proposed action may result in thousands of fish being removed from the system per year. Prior efforts from 2003-2006 resulted in 23,266 non-native fish removed. To address the tribal concerns on the disposition of removed fish, it is anticipated that they would be frozen and stored for later beneficial use (used for human consumption, or for feeding eagles, other raptors, or other captive wildlife, particularly those animals kept and reared by tribes), or may be used for other purposes that may be identified through continued tribal consultation.

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

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

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

The taking of life in a sacred location such as the Grand Canyon and the LCR confluence and without beneficial use is a concern of tribes. If this alternative is selected, mitigating measures would likely consist of euthanizing non-native fish that are removed from both reaches and freezing them onsite using generators and electric freezers for storage and later beneficial use. Beneficial use would be for human consumption, or to feed eagles, other raptors, or other captive

wildlife, particularly those animals kept and reared by tribes. The advantage of the proposed action is that it conducts removal in two locations, the PBR and LCR reaches. If PBR reach removal proves effective, this would have two key advantages over removal in the LCR reach: the treatment would cost less to implement than removal in the LCR reach, and this treatment would alleviate the concerns expressed by some tribes about conducting removal at the LCR confluence, a place of particular cultural significance to several tribes. However, many tribes have also indicated that any removal in GCNP would be offensive because all of the Grand Canyon is considered a culturally important place, so PBR reach removal alone would not totally alleviate the tribal concerns.

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

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

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

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

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

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

control in the GCDAMP (U.S. Geological Survey 2008, Hilwig et al. 2010, see also Appendix B).

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

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

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

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

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

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