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Native Fish Sanctuary Project—Sanctuary Development Phase, 2007 Annual Report

By Gordon A. Mueller

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch	2.54	centimeter (cm)
inch	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	Kilometer (km)
mile, nautical (nmi)	1.852	Kilometer (km)
yard (yd)	0.9144	meter (m)
	Area	
Acre	4,047	square meter (m^2)
Acre	0.4047	hectare (ha)
Acre	0.4047	square hectometer (hm^2)
Acre	0.004047	square kilometer (km^2)
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09290	square meter (m^2)
square inch (in^2)	6.452	square centimeter (cm^2)
section (640 acres or 1 square mile)	259.0	square hectometer (hm^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)

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

$$°F=(1.8\times°C)+32$$

Agency or Program Abbreviations

Arizona Game and Fish Department	AGFD
Bureau of Land Management	BLM
Bureau of Reclamation	USBR
California Department of Fish and Game	CDFG
Lake Havasu Fisheries Improvement Program	LHFIP
Multi-Species Conservation Program	MSCP
National Park Service	NPS
Native Fish Work Group	NFWG
Nevada Department of Wildlife	NDOW
The Nature Conservancy	TNC
U.S. Fish and Wildlife Service	FWS
U.S. Geological Survey	USGS
Utah Division of Natural Resources	UDNR

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Abstract

Notable progress was made in 2007 toward the development of native fish facilities in the Lower Colorado River Basin. More than a dozen facilities are, or soon will be, online to benefit native fish. When this study began in 2005 no self-supporting communities of either bonytail or razorback sucker existed. Razorback suckers were removed from Rock Tank in 1997 and the communities at High Levee Pond had been compromised by largemouth bass in 2004. This project reversed that trend with the establishment of the Davis Cove native fish community in 2005. Bonytail and razorback sucker successfully produced young in Davis Cove in 2006. Bonytail successfully produced young in Parker Dam Pond in 2007, representing the first successful sanctuary established solely for bonytail. This past year, Three Fingers Lake received 135 large razorback suckers, and Federal and State agencies have agreed to develop a cooperative management approach dedicating a portion of that lake toward grow-out and (or) the establishment of another sanctuary. Two ponds at River's Edge Golf Course in Needles, California, were renovated in June and soon will be stocked with bonytail. Similar activities are taking place at Mohave Community College, Cerbat Cliffs Golf Course, Cibola High Levee Pond, Office Cove, Emerald Canyon Golf Course, and Bulkhead Cove. Recruitment can be expected as fish become sexually mature at these facilities. Flood-plain facilities have the potential to support 6,000 adult razorback suckers and nearly 20,000 bonytail if native fish management is aggressively pursued.

This sanctuary project has assisted agencies in developing 15 native fish communities by identifying specific resource objectives for those sites, listing and prioritizing research opportunities and needs, and strategizing on management approaches through the use of resource-management plans. Such documents have been developed for Davis Cove, Cibola High Levee Pond, Parker Dam Pond, and Three Fingers Lake. We anticipate similar documents will be developed in the near future for River's Edge Golf Course Ponds, Office Cove, Emerald Canyon Golf Course Ponds, Bulkhead Cove, Mohave Community College, and Cerbat Cliffs Golf Course ponds as these facilities come on line or are developed in the future.

The following report discusses the process that went into the development of these facilities. Sites were visited, assessed as to their suitability based on the control of nonnative predators, habitat suitability, conversion cost, logistics, geographical location, and willingness of landowners. They were then prioritized according to their suitability, cost, timely conversion, and willingness of landowners. Existing native fish facilities were included in this evaluation for their value in helping to determine physical and biological parameter ranges. This report describes the approaches that led to success, those leading to failure, and some of the biological, institutional, and management issues of implementing native fish sanctuary development.

Introduction

The bonytail (*Gila elegans*) and razorback sucker (*Xyrauchen texanus*) are endemic to the Colorado River and represent two of the four endangered, large-river fishes. A recovery program was started in 1987 for the purpose of recovering the bonytail, humpback chub (*Gila cypha*), and Colorado pikeminnow (*Ptychocheilus lucius*) and to prevent the listing of the razorback sucker. Unfortunately, human intervention has failed to recover these fish, nor slow their decline. Today, wild bonytail are extirpated from the main stem. The razorback sucker was listed in 1991, and today fewer than 1,000 wild razorback suckers remain. Juveniles are absent in any significant number in the main stem river and its reservoirs.

Native fish restoration projects have generally focused on reestablishing populations by stocking. A memorandum of understanding between U.S. Fish and Wildlife Service (FWS) and Arizona Game and Fish Department (AGFD) resulted in the FWS committing to the production and stocking of 100,000 razorback suckers per year for 10 years starting in 1981. Those stocking attempts were unsuccessful, primarily due to predation (Minckley and others, 1991; Marsh and Brooks, 1989). The Lake Mohave Native Fish Work Group (NFWG) took up the cause in 1989 with the goal of augmenting the Lake Mohave population (Mueller, 1995), and a few years later the Lake Havasu Fisheries Improvement Program (LHFIP) initiated a similar effort. The NFWG successfully developed techniques that captured the genetic diversity exhibited in the Lake Mohave razorback sucker by using wild larvae captured from wild and repatriated adults. The NFWG continues to augment the Lake Mohave population. Survival continues to be poor even for larger fish, and the group recently increased their targeted stocking size from 30 to 50 cm in 2006 to test whether survival could be increased. The LHFIP reached their goal of stocking 30,000 bonytail and razorback suckers and ended their program in 2005. Stocked suckers are surviving and contributing to the spawning populations; unfortunately, young suckers continue to be eaten shortly after they hatch. Predation is the primary factor restricting natural recruitment and main-stem recovery. Stocking is the only factor preventing the disappearance of bonytail and razorback sucker from the main-stem river (Mueller, 2006 and 2003).

The bonytail and razorback sucker are unique in their ability to spawn in both flowing and standing water. In recent years several cases of natural recruitment have been documented (Pacey and Marsh, 1998). Razorback suckers have produced multiple year classes in Cibola High Levee Pond and Rock Tank (LaBarbara, 1999; Marsh, 2000; Mueller, 2006). Recruitment has also occurred in Yuma and Davis Coves on Lake Mohave and grow-out ponds in Farmington, New Mexico (Mueller, 2006). Bonytail commonly produce volunteer spawn in hatchery or other types of holding ponds. In all cases, the common denominator was not physical habitat conditions; it was simply the absence of nonnative predators.

Possibly the most convincing cases have been Cibola High Levee Pond (CHLP) where natural recruitment of razorback sucker and bonytail occurred for nearly a decade (Mueller 2006) and at Rock Tank where three new year classes of fish were found, both communities established in the absence of nonnative predators (Mueller, 2006). However, once nonnative predators were introduced, Cibola High Levee Pond also illustrates how fast a native fish community can be eliminated from a previously highly successful sanctuary site. The native fish community that established, flourished, and eventually failed at Cibola High Levee Pond illustrates why management is and always will be necessary to maintain native fish communities that are now found in a landscape dominated by invasive species.

Besides stocking, predator removal and control in the main-stem river has been a major program component in the Upper Basin and San Juan Recovery programs for more than a decade. More than $5 million has been spent to remove more than 1.5 million nonnative fish. Removal efforts typically are ineffective and costly; and typically, treated areas are rapidly recolonized. Native populations are at an all-time low. Unfortunately, no evidence suggests these efforts have benefited native populations; and in the lower basin, removal efforts for nonnative fish have not been attempted due to conflicts with sport fishery interests (Clarkson and others, 2005; Mueller, 2005).

The discovery that these fish could produce young when left unmolested triggered an off-channel conservation strategy in the lower basin. Minckley and others (2003) published a plan (herein referred to as Minckley's Conservation Plan) that called for the creation of off-channel habitats dedicated to native fish communities. The sanctuary concept was based on the theory that if predators cannot be eliminated either biologically or politically in the river; they could be in small, constructed habitats.

Sanctuaries represent seminatural manmade habitats where native fish can complete their natural life cycle (that is, birth, survival, spawning, and sustainable recruitment of young into the population). Sanctuaries are not intended to achieve recovery, but they do advance the conservation and security of the species and provide the knowledge necessary to determine how best to approach recovery. The potential benefits of establishing sanctuaries are many. Sanctuaries provide habitats where not only stocking survival would be enhanced but the possibility of natural recruitment is substantially increased. Fish and their young (larvae) would be more accessible to researchers and managers compared to those stocked in the river, which would be more difficult to find, monitor, or recapture. They could also serve as intermediate rearing facilities, producing surplus large (that is, greater than 50 cm) fish that could be used for river stocking or research. Sanctuaries provide critical research opportunities where the complete life cycle of many native fish species actually can be found and studied. Finally, and most important sanctuaries provide a realistic scale to test whether conservation and recovery are feasible.

The sanctuary approach is scientifically sound and fiscally responsible and attempts to avoid conflicts with other resource uses. It proposes conservation genetics and population dynamic approaches that offer a realistic mechanism to ensure healthy populations. Extra populations would provide additional security for the species as stocking programs attempt to build up reservoir populations. This approach has been widely accepted in the lower basin and recently integrated in a Management Plan for the Big-River Fishes of the Lower Colorado River Basin that was agreed to by cooperating States (USFWS 2004). The U.S. Bureau of Reclamation (USBR) and FWS have been working to develop fish sanctuaries for the past 10 years. Unfortunately, predator proliferation coupled with water-quality problems limited progress in establishing native communities at large facilities built at Beal Lake and Duck Ponds (Brouder and Jann, 2004).

This study was based on three observations made in 2005: (1) Construction was going toward habitats larger than originally suggested (Minckley and others, 2003; Mueller, 2006), (2) Existing habitats and communities were not being used; and (3) there were opportunities to broaden involvement to include private landowners and State agencies. The goal was to test Minckley's Conservation Plan to determine if it is indeed "…scientifically sound, fiscally responsible and avoids conflicts with other resource uses" by using small (less than 5 acres), existing ponds. The results of this study indicate that smaller sanctuaries do support native fish recruitment but success depends upon the scale and agency commitment for their long-term management.

Objectives

As previously described, the goal was to test Minckley's Conservation Plan by using existing, small ponds and create multiagency partnerships in their development and long-term care. Through the formulation, development, and management of these communities, critical physical and biological parameters (that is, depth, size, food, cover, substrates, and so forth) could be identified, studied, and quantified. The study is composed of three elements: (1) formulation of a plan, (2) development of sites, and (3) the monitoring and analysis of those facilities. Herein, this report uses the term "site" to refer to undeveloped habitats and "facility" for those habitats that have been developed for native fish use. This report summarizes the formulation and developmental activities accomplished from the beginning (2005) through the summer of 2007 and presents a discussion pertaining to issues facing native fish sanctuary development in the Lower Colorado River Basin.

Methods

The study proposal was submitted in June 2005 to USBR, which funded the project. A request was posted on the Lower Colorado River list server asking for suggestions regarding sites that might be suitable for this project. Initial feedback included the following:

- Bureau of Reclamation (USBR, Yuma Project Office). The old diversion canal at Palo Verde Diversion Dam and Middle Pond near Senator Wash Reservoir.
- USBR (Boulder City). Office Cove, Three Fingers Lake, Long Pond, Davis Cove, several others.
- Fish and Wildlife Service (Arizona Fishery Resources Office [AZFRO—Flagstaff]). Stillman Lake.
- Bureau of Land Management (BLM). Bullhead City Nature Center.
- Arizona Game and Fish Department (AGFD—Kingman). Mohave Community College Pond, Bullhead City Nature Center.

In addition to these specific recommendations, BLM (Lake Havasu City); FWS (AZFRO, Parker/Bill Williams, Havasu and Cibola National Wildlife Refuges); National Park Service (NPS, Pipes Springs NM); Arizona Game and Fish Department (AGFD, Phoenix and Yuma); California Department of Fish and Game (CDFG, Blythe); The Nature Conservancy (TNC, Hassayampa and San Pedro Preserves); and the Cocopah and Chemehuevi Tribes were approached for other suggestions. These contacts led to the creation of a list of potential sanctuary sites that included existing grow-out ponds, sites used but abandoned in the past, those actively in the planning stage, and potential sites based on suggestions. I assessed each site regarding its suitability. The primary factors focused on whether nonnative fishes could be effectively removed and future contamination lessened by isolation, whether aquatic conditions supported fish life, and if the sites were considered manageable, in terms of nonnative fish control, habitat suitability, conversion cost, logistics, geographical location, and willingness of landowners. Then the sites were prioritized according to suitability, cost and timely conversion. Existing native fish facilities were included in the program for their value in broadening the monitoring program.

Once a suitable site was located, efforts were focused on pulling in necessary expertise, developing a management team and facility plans, and identifying available and needed resources. A member of that team would develop a draft Management Plan that would be modified and refined as needed. This document would be nonbinding but would describe and track objectives, needs and opportunities and be used to prioritize goals and help guide management and research. In some cases, the management plans contained a schedule and task assignments. These plans were updated annually or whenever necessary.

The team and other volunteers worked together to establish and manage these habitats. The sequence of events usually involved coordination of a management plan, an effort to salvage unwanted fish and a chemical or physical renovation followed by stocking and monitoring. Management issues that were identified in management plans were dealt with as resources were made available. The overall goal was to develop expertise and expand our knowledge of these fish through active management. This would be a learning process.

A range of successes was anticipated; not all facilities would support self-sustaining (natural reproduction) native fish communities. Preventing recolonization of nonnative predators would be the most daunting challenge. However, sites where predators could not be effectively removed or controlled could be used to benefit native fishes in other ways. Habitats that could be effectively renovated could be stocked with small native fish and used as grow-out facilities or sanctuaries.

Habitats where complete renovation was not practical were developed as repositories to hold large native fish where they could be recaptured at a later date for purposes of selective stocking or serve as brood stock, or be used for research purposes. Or these habitats could be used in the short term for grow-out of intermediate-sized natives. In these instances, survival of these fish was expected to be enhanced compared to survival rates expected if stocked immediately into mainstem habitats. Once native fish achieved adequate size, they could be stocked into mainstem habitats. For the purposes of this report, a sanctuary is defined as a habitat that supports natural recruitment, a grow-out facility is a habitat used to simply grow fish larger, and a repository is a location where large native fish are temporarily held.

Volunteer effort and direct costs incurred by this project were developed to measure resources used in developing native fish facilities. Volunteer effort is presented as "staff days" rather than estimated costs due to discrepancies in salary and administrative costs of different participating agencies. This provides the basic information needed for individual agencies to develop cost estimates germane to their own agencies. Material costs were costs directly funded by this project and may not represent what some may consider "real costs" or expenditures necessary to actually construct a similar site. This study was designed to use existing ponds and searched for "opportunities" where they could be converted toward native fish use. Previous construction costs are not included. In many instances, other agencies provided materials or loaned equipment that was described.

Carrying capacity estimates were developed for the purpose of providing a description of the potential contribution of these sites to conservation efforts. These estimates are not meant to imply management goals, optimal production, or recommendations; they simply represent "rough" predictions based on population estimates measured at Cibola High Levee Pond for native fish, or they may simulate numbers of nonnative fish removed.

Results

A list of potential sites was developed that included sites that had been abandoned and existing habitats that could be modified or converted (table 1, fig. 1). Those sites having the greatest likelihood of success were pursued first for development; if an obstacle blocked progress, we attempted to resolve the issues but then focused on the next project(s) in line.

Ten sites, which included 15 ponds, were either developed, their function broadened or included in this project's monitoring program (table 2). These facilities include Davis Cove, Mohave Community College Pond, Office Cove, Cibola High Levee Pond, Parker Dam Pond, Bulkhead Cove, Three Fingers Lake, River's Edge Golf Course, Emerald Canyon Golf Course, and Cerbat Cliffs Golf Course.

The following discussion describes the current status of the all sites and briefly summarizes our finding as to each site's suitability, status and management activities. A quantitative description of each site's physical and biological attributes will be presented in a separate monitoring report.

Sites that were Selected for Development, Reactivation, or Support by this Project

The following provides a brief description of the 10 facilities (table 2) that were developed, reactivated or partly supported by this study. A summary of management activities, the facility's current (2008) status, and general costs are provided.

Davis Cove. Davis Cove is located adjacent to the Arizona shoreline of Lake Mohave. The cove itself was initially blocked off with a barrier net in 1992, which failed. The facility was later blocked with an earthen berm in 1994. The berm had to be reinforced in 1996 due to beach erosion.

Table 1. An initial list of proposed, planned, existing, and abandoned native fish facilities in the Lower Colorado River Basin [Nat. Nature, DO, dissolved oxygen; ID, irrigation district; FWS, Fish and Wildlife Service; USBR, U.S. Bureau of Reclamation;, TNC, The Nature Conservancy; NPS, National Park Service; AGFD, Arizona Game and Fish Department; CRIT, Colorado River Indian Tribes].

Name	Abandoned-Existing Planned-Proposed	Status	Land Owner
Rock Tank	Abandoned	Sanctuary/Poor DO	FWS
Bulkhead Cove	Abandoned	Grow-Out Pond	USBR
Pittsburgh Point	Abandoned	Grow-Out/Poor Survival	BLM
Palm Lake	Abandoned	Sanctuary/Compromised	TNC
Boulder City Veteran's Park	Abandoned	Grow-Out	Boulder City
DU2 Ponds Imperial	Reconstructed	Grow-Out/Research	FWS
Yuma Cove	Existing	Grow-Out	NPS
Davis Cove	Existing	Grow-Out Pond	NPS
Office Cove	Existing	Grow-Out Pond	FWS
Cibola High Levee Pond	Existing	Sanctuary/Compromised	FWS
Mohave Community College Pond	Existing	Sanctuary	AGFD
Beal Lake	Existing	Compromised	FWS
Emerald Canyon Golf Course Ponds	Existing	Grow-Out	Lake Havasu City
Cerbat Golf Course	Planned	Sanctuary	AGFD
Cocopah Ponds	Planned	Backed out	Cocopah Tribe
Stillman Lake	Planned	Sanctuary/Repository	FWS/AGFD
Bullhead City Nat. Center	Planned	Sanctuary	AGFD
Pipe Springs	Proposed	Sanctuary	NPS
Three Fingers Lake	Proposed	Repository	FWS
River's Edge Golf Course Ponds	Proposed	Grow-Out Pond	Needles, California
Parker Dam Pond	Proposed	Sanctuary	USBR
Achii Hanyo	Proposed	Sanctuary	FWS
Chemehuevi	Suggested	Sanctuary	Chemehuevi Tribe
Palo Verde Abandoned Intake	Suggested	Sanctuary	Palo Verde ID
Dead Horse State Park	Suggested	Repository	AGFD
Long Lake	Suggested	Repository	CRIT

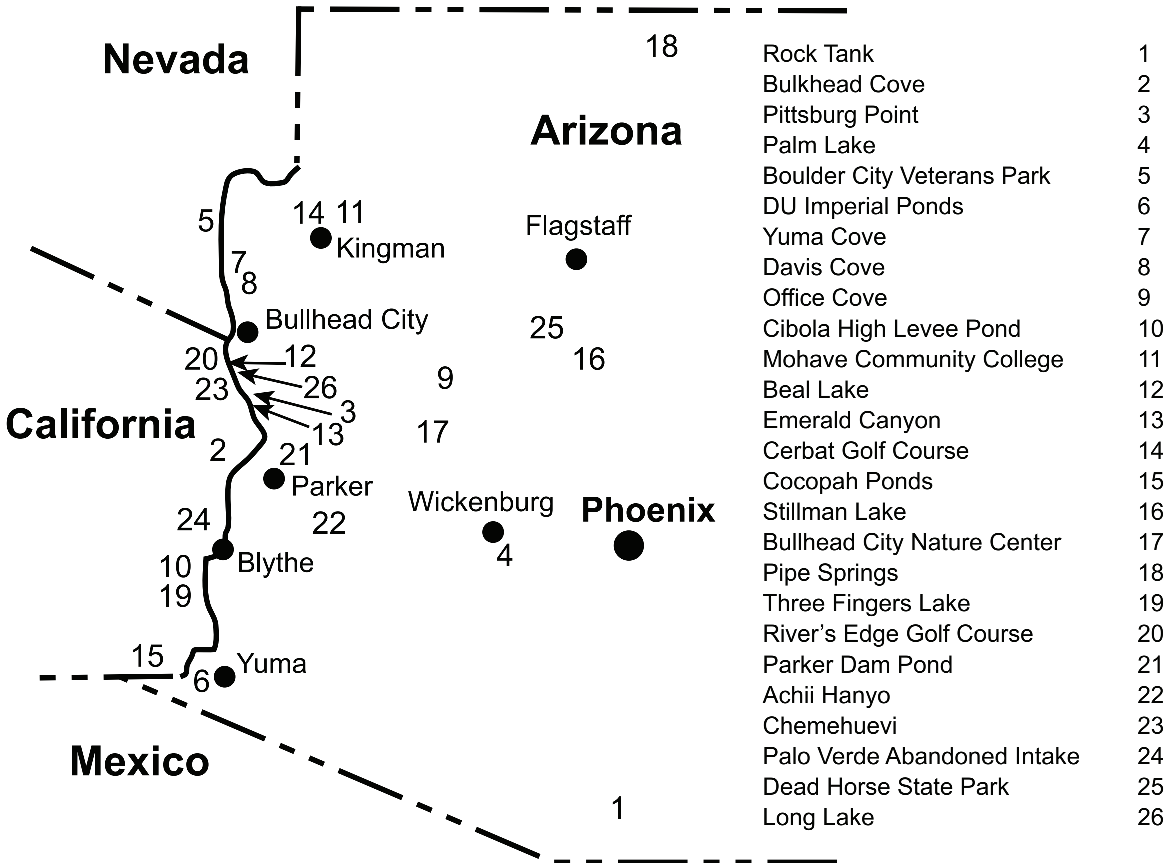

Figure 1. General map showing the locations of potential, existing, or abandoned native fish habitats examined by this project.

Table 2. Sites that are currently being developed or managed for native fishes under this project [Mang., management; No., number; BT, bonytail; RZB, razorback sucker; LMB, largemouth bass; NPS, National Park Service; AGFD, Arizona Game and Fish Department; FWS, Fish and Wildlife Service; CDFG, California Department of Fish and Game].

Location	Facility Type	No. of ponds	Status	Lead agency	Mang. Plan	Stocked/ Recruitment?
Davis Cove	Sanctuary BT-RZB	1	Complete (2005)	NPS	Yes	2005/Yes
Office Cove	Sanctuary and Grow-out RZB	1	Complete (2004)	FWS	Pending	2004/No
Cibola High Levee Pond	Sanctuary BT-RZB	1	Compromised LMB (2003)	FWS	Yes	1993/Yes
Mohave Community College Pond	Sanctuary RZB	1	Complete (2004)	AGFD	Pending	2006/?
Parker Dam Pond	Sanctuary BT	1	Completed (2007)	FWS-USBR	Yes	2007/Yes
Bulkhead Cove	Sanctuary BT	1	Pending (spring 08)	CFGD	Pending	Pending
Three Fingers Lake	Repository RZB	1	Stocked 2007	FWS	Yes	2007/?
River's Edge Golf Course	Sanctuary BT	2	Renovated	FWS	Pending	2007/No
Emerald Canyon Golf Course	Repository RZB	4	Existing	FWS	Pending	1994/No
Cerbat Cliffs Golf Course	Sanctuary Grow-out RZB-BT	2	Pending	AGFD	Pending	Pending

The pond was used as a grow-out facility by the Native Fish Work Group for bonytail and razorback suckers (fig. 2). The pond supported fish, but never achieved production levels seen at other Lake Mohave grow-out facilities. It suffered a fishkill in 2004 which was apparently triggered by storm runoff and suppressed dissolved oxygen. It was not restocked, and the suggestion came up to develop it into a native fish sanctuary. That suggestion triggered the development of the proposal for this study.

A research proposal was written and an oral presentation was given to the senior staff of the National Park Service (NPS) at Lake Mead National Recreation Area for the purpose of converting Davis Cove into a native fish sanctuary. The proposal was accepted as a research action by NPS and was initiated during the summer of 2005.

The pond was salvaged, renovated with rotenone, and stocked in September 2005 with 150 adult razorback suckers salvaged from Cibola High Levee Pond and with 1,500 bonytail provided by Dexter National Fish Hatchery. A draft management plan was sent to NPS for comment and distributed to other partner agencies (USBR, FWS, AGFD, NDOW) for their input in 2006 and again in 2007. Suggestions and comments were incorporated into the working draft (Appendix A).

Status Davis Cove has self-reproducing populations of bonytail and razorback sucker. The site serves as a native fish sanctuary for both species, and large surplus razorback suckers are intended to augment the Lake Mohave population. The razorback sucker community is being supplemented with large juveniles from Willow Beach National Fish Hatchery to maintain the genetic diversity of that population. The community remains at risk to storm-related fishkills although these storm events are not common.

Management Activities When Davis Cove was closed in 1994, the cove had a dense stand of submergent vegetation, dominated by pondweed (*Potamogeton* spp.) and spiny naiad (*Najas* spp.). These plants have been totally replaced by *Chara* sp., presumably due to increasing salinity. Salinity

Figure 2. Davis Cove is adjacent to Lake Mohave and is located on the Arizona shoreline. U.S. Geological Survey and National Park Service biologists are shown placing brush shelters for young fish.

had risen to 5,000+ microhms per centimeter (*u*mhos/cm), approximately 5+ times greater than the reservoir. An experimental pump test was done in November 2006 and was successful in reducing conductivity nearly 1,000 points when the lake was at its low cycle. We are currently examining the use of solar or wind pumps to draw water from the pond to increase ground-water intrusion.

Mechanical removal attempts in the early 1990s were unsuccessful in reducing the predation threat to small native fish. Chemical renovation was successful in removing fish during each of two events. On the first attempt, common carp and threadfin shad reappeared several years following renovation; however, a large population of crayfish established, which would feed on live fish captured in nets resulting in high fish mortality. Specially designed traps were used for a period, and crayfish numbers declined and have not been a problem in recent years.

In 2007, three hundred razorback suckers that originated from wild-caught larvae were stocked to augment and replace adult suckers brought in from Cibola High Levee Pond. In the future, larger (greater than 50 cm) adults that are captured during routine netting will be marked with a passive integrated transmitter (PIT) and released into Lake Mohave as part of the experiment to stock fish larger than 50 cm fish. Arizona Fish and Game Department has taken the lead in the facility's management. Input from the management team will be incorporated into the management plan.

Carrying Capacity Based on carrying capacity at Cibola High Levee Pond, it is anticipated that Davis Cove could support a minimum of 300 adult razorback suckers and approximately 5,000 adult bonytail.

Opportunities and Needs Recruitment for both species came remarkably easily. We are uncertain whether the elevated salinity is a problem or blessing. Dr. Horn (USBR, Denver) is currently (2007) experimenting to determine the lethal salinity limits for razorback sucker eggs and larvae. If native species exhibit a high tolerance to salinity, this may provide a useful tool to restrict colonization by unwanted fishes. This situation also provides an ideal location to test the effects that solar or wind generation may have on freshening saline habitats (Walker and others, 2007).

Activities and Expenditures (Thus Far)

- Salvage and renovation (September 2005): Participants included USGS, USBR, AGFD, NPS, FWS, ASU, NDOW volunteer effort = 22 staff days. Rotenone = $2,500.
- Stocking (November 2005). Two events. Participants included USGS, USBR, AGFD, NPS, FWS, ASU, NDOW volunteer effort = 14 staff days. No direct costs.
- Pump test to determine if the salinity could be reduced (November 2006). Participants included USGS and USBR, volunteer effort = 6 staff days. Gas and discharge hose = $2,000.

Total: Labor = 42 staff days; Material costs = $4,500.

Office Cove. This 1.1-ha pond is located along the Arizona shoreline of Lake Havasu near the Bill Williams River National Wildlife Refuge office complex and has been used as a grow-out facility for bonytail and razorback suckers (fig. 3). The facility initially was developed for the Lake Havasu Fishery Improvement Program as a grow-out area. The cove was blocked by using a net barrier in 1993 and stocked with 18,000 bonytail. Later that year, biologists noted that the net had been breached, allowing native fish to escape and nonnative fish to enter from the reservoir. A second net was installed

Figure 3. Office Cove is near the headquarters complex for the Bill Williams National Wildlife Refuge along the Arizona shoreline of Lake Havasu.

in 1994; the facility was again renovated and restocked. However, it soon became apparent the net was ineffective in isolating these fish and it was replaced with an earthen berm. The first berm failed and was reinforced, and that structure has maintained its integrity.

Fish production and growth are increased through the operation of a solar aeration system and supplemental feeding. When suckers reach a length greater than 30 cm they are typically stocked where needed.

We approached FWS with the idea to broaden its management goals at Office Cove to include both sanctuary and grow-out functions. In the fall of 2006, adult suckers were stocked into Office Cove to provide an opportunity for spawning and natural reproduction. The rationale of expanding the management objectives was based on the fact that the loss of the Cibola High Levee Pond native community left the refuge without a self-sustaining population either of bonytail or razorback suckers. Management options for ponds located in Arizona are more flexible than those in California due to State environmental compliance standards.

Status The earthen berm has maintained its integrity, and the pond appears to be free of nonnative predators. Natural reproduction has not been observed but it is expected as suckers become sexually mature. Unwanted fish species have not been detected. Small surplus razorback suckers from Willow Beach National Fish Hatchery recently were stocked. The pond has never been completely emptied and currently (2008) contains several year-classes of razorback sucker.

Management Activities The pond has a solar aerator and an automated fish feeder. Fish have been supplementally fed to optimize growth. In the past, fish reaching 30 cm in length were generally released into Lake Havasu. Rather than supplement the MSCP's stocking program for Lake Havasu, production from Office Cove will be moved to other locations as needs arise. The majority of large razorback suckers were recently removed and stocked in the Emerald Canyon Golf Course ponds where they can be recaptured and used elsewhere. This freed space for small surplus razorback suckers from Willow Beach National Fish Hatchery. Six mature razorback suckers salvaged from Cibola High Levee Pond and a number of sexually maturing juveniles still remain in the pond, which provides an opportunity to see if these fish successfully spawn.

This facility remains one of the few that have been successfully renovated. Today, it remains uncompromised by unwanted exotics. The loss of Cibola High Levee Pond in 2004 to largemouth bass has reinforced the importance of Office Cove as a sanctuary. However, predator-free habitats also provide a site for stocking small suckers for grow-out purposes. This type of management flexibility will help optimize the facility's value by meeting needs and opportunities.

Carrying Capacity According to discussions with Chuck Minckley (FWS—AZFRO), the ponds can support approximately 1,000 large juvenile razorback suckers with supplemental feeding. Based on carrying capacity at Cibola High Levee Pond, it is anticipated that Office Cove could naturally sustain a minimum of 500 adult razorback suckers and 2,500 bonytail.

Opportunities and Needs Office Cove is the most secure and manageable facility since it is located on refuge lands. Its location near the Bill Williams Office Complex provides security, public outreach, and educational opportunities due to its close proximity to the refuge's visitor center.

Activities and Expenditures (Thus Far) In 2006, FWS and USGS entered into an Interagency Agreement to work mutually toward the development of native fish sanctuaries in the Bill Williams, Cibola, and Lake Havasu National Wildlife Refuges. USGS provided FWS (AZFRO) supplemental funding ($20,000) to help compensate for their assistance in 2007 and 2008. This assistance will include work on Three Fingers Lake, Cibola High Levee Pond, Office Cove, and others.

Cibola High Levee Pond. Cibola High Levee Pond is a 2.2 ha pond located along the Arizona-California border of the Colorado River in Cibola National Wildlife Refuge. It was initially developed in 1993 as a grow-out facility for bonytail and razorback sucker (fig. 4) (La Barbara, 1999). In 1998, biologists discovered thousands of young from both species, indicating both had successfully spawned and produced young. Followup studies determined the pond supported more than 1,000 adult razorback suckers, an unknown number of their young, and more than 10,000 bonytail (Mueller, 2006).

Status The pond supported natural recruitment for both species from 1994 to 2003; however, largemouth bass illegally introduced in 2003 produced thousands of young, and natives rapidly disappeared (Mueller, 2006). Native recruitment ceased in 2004, and efforts began to salvage native adults. Biologists were unable to capture any bonytail in 2006, and only a few adult razorback suckers remained. The pond remains inhabited by largemouth bass, but plans are being made to renovate the lake in late 2007.

Management Activities A draft management plan was developed and provided to FWS (Appendix B). FWS has taken the lead in acquiring the necessary permits to renovate the pond; renovation is scheduled for fall of 2008. The goal is to conduct a final salvage, renovate the pond, and restock it with razorback suckers and bonytail.

The pond was electrofished by FWS, USBR and CFGD on May 31, 2006. Workers collected 60 razorback suckers and 24 largemouth bass. No bonytail or small natives were collected or observed. These fish were removed; the razorback suckers were released into the river. On a following trip, six mature razorback suckers were collected and transferred to Office Cove.

Carrying Capacity Based on previous carrying capacity measurements it is anticipated Cibola High Levee Pond community could once again contain 1,000 adult razorback suckers and 7,500 bonytail.

Opportunities and Needs The problems encountered since the unfortunate largemouth bass introduction suggest more flexibility, planning, and preparation may be necessary to reduce renovation delays and other anticipated and unanticipated problems. Updating and use of a management plan could help reduce this type of problem just by anticipating these common needs and doing the appropriate

Figure 4. Cibola High Levee Pond was a channel of the Colorado River that was isolated by levee during the 1960s. The pond is located in Cibola National Wildlife Refuge, CA-AZ.

planning. This situation is complicated by the jurisdictional issues associated with Cibola High Levee Pond.

Activities and Expenditures (Thus Far)

- Salvage (September 2005): Participants included USGS, USBR, FWS, CDFG volunteer effort = 44 staff days. No direct costs other than the USGS–FWS Interagency Agreement.
- Drafting environmental compliance analysis under National Environmental Policy Act to renovate Cibola High Levee Pond (USGS–FWS).
- Renovation (2007). $2,500 has been obligated for chemicals in anticipation of the pond's renovation.

Mohave Community College Pond. This concrete-lined 0.1 ha pond located on the campus of Mohave Community College in Kingman, Arizona was constructed in 2004 and stocked with longfin dace (*Agosia chrysogaster*) (fig. 5). Andy Clark (AGFD) inquired regarding our involvement in this project, and as a result it has been incorporated into our monitoring and assessment program. In addition to the longfin dace, six razorback suckers were stocked in the spring of 2006 to complement the community. The suckers came from a shipment of fish from Willow Beach National Fish Hatchery destined for the Hualapai Reservation.

Status The longfin dace are reproducing naturally. Due to the small size of the pond, only six razorback suckers were introduced, and no recruitment has been observed for those fish, which is probably good due to the small founder population. No unwanted fish species have been observed. The facility was being modified in 2007 with the construction of an amphibian pond.

Figure 5. Mohave Community College Pond is located on the Mohave Community College grounds in Kingman, Arizona.

Management Activities The USGS is currently (2008) working with Andy Clark and Greg Cummings (AGFD) to determine the need to develop a management plan and opportunities to more closely interact with the college on a number of issues. Monitoring has detected very high pH levels (10+) that need to be addressed. Possible remedies include the repair of the aeration system and partial and periodic replacement of water. A new aeration pump and timer were ordered and installed by AGFD. A timer was added to the system to reduce power costs and pump wear, and to improve the system's effectiveness.

Carrying Capacity No recent information is available; however, it is suspected the pond supports several hundred longfin dace and a small (less than 6) number of razorback suckers.

Opportunities and Needs The pond is small, but it is located on the campus of Mohave Community College. That location provides excellent opportunities for student projects. However, to realize the pond's potential, it will be necessary to develop a better working relationship with college instructors and administration. We have had difficulty contacting their representatives.

Activities and Expenditures (Thus Far)

- Aerator pump replacement was bought and installed by AGFD, cost = $300.

Parker Dam Pond. Parker Dam Pond is a small (10 x 20 m) seep pool located on the highway approach to Davis Dam (Arizona) (fig. 6). The pond has been a popular swimming hole for locals and is locally known as "Hippy Hole." Because several areas along the Lower Colorado River have this same name, in order to reduce confusion, this pond was renamed Parker Dam Pond for this project. This pool was brought to our attention by Mitch Thorson (FWS). It contained small numbers of sunfish, bullhead, and bass. USBR has provided access and support in the project. FWS took the lead to develop this facility into a native fish sanctuary. Initially, pupfish were going to be stocked, but FWS later changed this to bonytail.

Status The pond was stocked with bonytail in April 2007. Recruitment was documented 3 months later (July 2007) by Mitch Thorson, who observed thousands of small bonytail while snorkeling the pond. Young were dispersed throughout the pond, and a large concentration was located near the gaging station. Adult fish commonly were seen swimming along shore.

Management Activities The pond was chemically renovated in January 2007. The pond received two treatments; the first treatment was with rotenone, which was followed by a treatment of antimycin. The pond was deemed safe for fish after the successful survival of test fish in a cage in mid-March. The pond was stocked with approximately 100 bonytails in April, 2007. "Keep out" signage is planned to be installed. A draft management plan (Appendix C) was written and distributed for comment to AGFD, FWS, and USBR in January 2007. The plan will be refined and comments and suggestions incorporated and updated as needed. FWS has taken the lead in the facility's management.

Carrying Capacity Parker Dam Pond could support a minimum of 250 adult bonytail and 1,250 juvenile bonytail. Bonytail can become sexually mature at 10 cm, and the dense mats of bank vegetation would afford cover and habitats for hundreds of small fish.

Opportunities and Needs Parker Dam Pond represents the first successful bonytail sanctuary that currently supports natural recruitment. The facility provides research and management opportunities to learn more about these unique fish. No additional resources are needed at this time.

Activities and Expenditures (Thus Far)

- Salvage, renovation, and stocking (January, April-2007): Participants included USGS, USBR, NPS, FWS volunteer effort = 15 staff days.

Figure 6. Parker Dam Pond is adjacent to the highway approach to Parker Dam in Arizona.

- FWS monitoring = 5 staff days.
- FWS supplied the ichthyocide. No direct costs to this program.

Total expenditure = 20 staff days.

Bulkhead Cove Bulkhead Cove is a small (1/8 ha), isolated backwater on Lake Havasu (fig. 7). It is near Parker Dam on the California shoreline. The pond was isolated by the construction of an earthen berm that is used to support a frontage road that runs along the California shoreline. Approximately 50 m of the terminal tip of the backwater was blocked. BLM, FWS and USBR

Figure 7. Bulkhead Cove is located adjacent to Lake Havasu on the California shoreline. It was successfully used to grow-out bonytail and razorback suckers in the 1990s by the Bureau of Land Management, Fish and Wildlife Service and Bureau of Reclamation.

developed the facility in 1994 for use as a grow-out facility for bonytail and razorback sucker (Doelker 1995). Development included the placement of artificial cover and an aerator. The pond was renovated and initially stocked with 650 bonytail in 1994. It was operated as a grow-out facility for a number of years to help meet the Lake Havasu Fishery Improvement Program's stocking goal of 30,000 bonytail and razorback suckers. A sucker that originated from this facility was captured recently near Needles, California. No native recruitment was ever suspected, and renovation efforts either were not effective or the pond was rapidly reinvaded by nonnative fishes. The facility was abandoned in late 1990s.

Status The facility was successfully used as a grow-out facility for bonytail and razorback sucker. Natural recruitment had not been reported from previous activities. The pond has not been used in recent years and has been recolonized by sunfish (*Lepomis* spp.) and bullhead.

Management Activities Brush was cut from the trail to allow boat access. Physical water-quality parameters were measured, and the pond has been repeatedly netted and fish removed. Plans are currently (2008) being made to examine natural methods (for example, suspending sediments) of renovating it for bonytail. CDFG has taken the lead in the facility's development and management and is being supported by USBR, FWS and USGS. The goal is to prepare the facility for bonytail with renovation followed by stocking. A management plan will be developed at that time.

Carrying Capacity Based on carrying capacity at Cibola High Levee Pond and the recent removal of several hundred small sunfish, it is anticipated that Bulkhead Cove could support a minimum of 250 adult bonytail and approximately 1,250 juvenile bonytail.

Opportunities and Needs The primary need is to find an effective way to renovate the pond without the need to use rotenone or antimycin due to state environmental restrictions. Possible approaches include mimicking storm conditions (that is, sediment upheaval/mixing) to depress dissolved-oxygen levels, which would trigger a "natural" fishkill. Other approaches may also be explored on this very small (less than 1,000 m^2) body of water.

Activities and Expenditures (Thus Far)

None at this time.

Three Fingers Lake Three Fingers Lake is located along the California shoreline of the Colorado River at the southern end of Cibola National Wildlife Refuge, Arizona - California. Historically, this portion of the river bottom included a natural wetland complex and meanders of the Colorado River. Mechanical dredging of the river channel in the 1960s isolated this habitat from the river and partly drained it as ground-water levels receded due to dredging. Although the initial suggestion to develop Three Fingers Lake into a native fish repository was rejected, the idea was further developed and presented at a joint meeting of CNWR, AZFRO—Parker, and AZFRO—Pinetop for their consideration. The proposal was accepted onsite and the group planned how best to use the lake as a repository to hold and grow-out larger razorback suckers. Initial and followup sampling by ASU, FWS, USBR and CFGD revealed the absence of large-bodied fish in the lake. Only mosquitofish were found, suggesting the lake had summer or winterkilled. Suspecting dissolved oxygen was a problem, biologists took steps to initiate a monitoring program and implement actions that might reduce the chances of a depletion of oxygen from occurring. Monitoring through the summer, fall, and winter failed to find any problems with low dissolved-oxygen concentrations. The lake was stocked with 135 large razorback suckers left over from experiments at Achii Hanyo in December 2006. Two solar aerators were installed (January 2007) and a chemical herbicide program was started to reduce bioaccumulation of aquatic vegetation. Road access was closed due to law-enforcement issues and to reduce the chances of theft or vandalism of the solar aeration systems. CFGD expressed concerns regarding prior management commitments made by FWS, and further native fish management actions ceased. Followup meetings resulted in a compromise that balances native fish and angling interests. The project is once again moving forward.

Status The lake currently contains a maximum of 135 razorbacks suckers. A Draft Management Plan was written by FWS and distributed to other agencies for comment. It contains objectives for isolating areas of the lake solely for native fish grow-out and (or) for the establishment of sanctuaries (Appendix D).

Management Activities The lake is heavily infested with coontail (*Ceratophyllum demersum*), and the large biomass of decaying plant material poses a potential dissolved oxygen problem. To combat the buildup of plant biomass, a herbicide treatment program was initiated by the refuge in 2007. This combined with the installation of two solar aerators, should help remediate dissolved-oxygen concerns. The solar aerators were installed in January, and a herbicide was applied later that spring that successfully retarded growth in approximately ½ km of submergent vegetation where the aerators were installed. Appropriate water monitoring was conducted prior to and following treatment. FWS purchased additional herbicide in case a second treatment is needed. Conditions will be closely monitored; however, during the past 12 months dissolved-oxygen concentrations have remained within reasonable levels.

Carrying Capacity An accurate surface area is unknown but believed to be between 20 and 40 ha. Based on carrying capacity at Cibola High Levee Pond, it is anticipated that Three Fingers Lake could support a minimum of 5,000 adult razorback suckers if the entire lake were used. However, if a smaller portion of the lake were used, carrying capacity would be expected to be about 500–600 adult razorback suckers per hectare. Bonytail densities could reach 2,500 to 3,500 fish per hectare if nonnative predators were absent.

Opportunities and Needs This repository provides managers a place to hold or grow-out large native fish. The use of blocking trammel nets and electrofishing provides an effective method of harvesting large fish. However, it is likely that only small sections of the lake will be used for grow-out to provide a balance between the needs of the natives and that of the sportfish community.

USBR has expressed interest in helping to further develop and maintain the facilities. Opportunities exist to benefit not only native fish but also to improve recreational fisheries. The separation and isolation of channel extensions could provide isolated areas were native fish could be reared, or these areas could be designated as sanctuaries for natural reproduction. Prior to this proposal, I am not aware of any active management for either the native or recreational fishery. This initiative is a positive move toward cooperative management of the resource.

Activities and Expenditures (Thus Far)

- Two solar aerators and installation materials = $20,000.
- Herbicide and required water-quality testing = $2,000.
- Installation of solar aerators by FWS, USGS, USBR and setting up the herbicide program = 45 staff days.

Total: = 45 staff days and $22,000.

River's Edge Golf Course. The golf course lies adjacent to the Colorado River on the north side of Needles, California, just south of the Highway 95 bridge. The facility has two interconnected (underground culvert) ponds that collectively measure approximately 1 ha (fig. 8). The ponds are a landscape feature; they are maintained by well water and not used for irrigation which is a normal practice at similar facilities. They both have aeration systems that run all day, every day. The ponds were never stocked but they were found to contain small numbers of catfish, largemouth bass, and sunfish, possibly resulting from bait bucket introduction. I inquired about the possible use of these ponds for native fish, and the facility manager and City Manager expressed interest. This information was passed along to FWS, who developed a joint plan with City officials. FWS took the lead and coordinated with the golf course to drain both ponds, allowing them to dry to ensure total removal of unwanted fishes.

Status An agreement was reached between the City of Needles and the FWS to manage these two ponds for native fishes. At the time of this writing, the City assisted the FWS, USBR, and USGS in the complete drainage of both ponds to remove unwanted fish and to remove unwanted cattails along the pond's shore. This work was accomplished in July 2007, but filling was delayed due to mechanical problems with the aeration systems. Beavers persistently eat through the aeration lines. By late fall 2007 the aeration lines were repaired and the ponds were refilled and stocked with bonytail for mosquito abatement purposes. A management plan is being drafted by AZFRO and will be completed in winter 2007.

Carrying Capacity The ponds have an estimated surface area of approximately 1 ha. Based on carrying capacity at Cibola High Levee Pond, it is anticipated that the River's Edge Golf Course ponds could support approximately 500 adult razorback suckers or 1,500 juvenile suckers. The ponds would be expected to support a bonytail community roughly 7 to 10 times greater.

Figure 8. Photograph of one of the River's Edge Golf Course ponds taken during its drainage in June 2007. The second pond lies adjacent to the right, connected by the culvert shown on this pond's right bank (photograph courtesy Fish and Wildlife Service).

Opportunities and Needs The location of these ponds provides a unique opportunity for promoting public awareness and education while providing additional grow-out facilities. The ponds are located adjacent to the section of river that currently (2008) supports the largest population of river-spawning razorback suckers in the basin. Public awareness of this resource could be furthered by inviting local high school students and other interested volunteers to participate in the annual harvest event. During this event, surplus fish or those reaching appropriate lengths may be captured and transported 500 m to the river.

Activities and Expenditures (Thus Far)

- Pond renovation
    - 20 staff days (FWS–USBR).
    - Pump and equipment rental costs (FWS) = $2,000.
- Ongoing maintenance (FWS) = 10 staff days.

  Total: = 30 staff days and $2,000.

Emerald Canyon Golf Course Ponds. The golf course is operated by La Paz County, Arizona and is located 5 miles south of Parker Dam. In the late 1980s, a management agreement was reached among county, golf course management, BLM and FWS to manage its four ponds for native fish (fig. 9). The ponds were chemically renovated in 1994 and initially stocked with bonytail. The ponds were fed with unfiltered river water making predator-free maintenance impossible. The ponds were quickly invaded by threadfin shad, red shiners, largemouth bass, crappie, channel catfish, and various sunfish. As a result, the ponds were periodically used as repositories to hold large native fish and were stocked with larger individuals for further grow-out.

In 2007, FWS and USBR redesigned the ponds; deepening and installing screening devices to prevent nonnative fishes from entering with river water. The ponds were stocked with native fish in the fall of 2007. FWS is managing the facility and USGS is providing monitoring assistance and will use the information in this study's final analyses. Information pertaining to associated costs can be obtained from FWS.

Figure 9. One of four ponds on Emerald Canyon Golf Course that are being used to hold and grow-out native fish.

Cerbat Cliffs Golf Course Ponds. This golf course is in Kingman, Arizona, and contains two ponds, each approximately 1 ha in size. Both ponds currently (2008) contain nonnative fish, and the goal of the project is to convert these facilities specifically to native fish. This project is being led by AGFD and includes participation by the golf course, FWS, and USGS. Plans are in the preliminary stage, but it appears that the two ponds may be developed for native fishes. FWS Partners for Fish and Wildlife funds have been applied for to help offset renovation costs. It is anticipated this work may be accomplished in 2008.

Status of Other Potential Facilities

There are six other facilities that are either in the final stages of planning, proposed for construction by other programs, or existing facilities where data may be collected for the analysis phase of this study (table 3). None of the facilities has been previously used for native fish, and all require some management action (renovation, modification, cooperative agreement) to ready them for use. I have included Iceberg Canyon, which is outside the geographic area of this study but we were asked to assist in the development of the NPS proposal. The following provides a brief description of the facility and progress status.

Table 3. Facilities under consideration for development as native fish sanctuaries or existing facilities where data may be collected for the analysis phase of this study [BHC, Bullhead City; BT, bonytail, RZB, razorback sucker; AGFD, Arizona Game and Fish Department; NPS, National Park Service; FWS, Fish and Wildlife Service; UDNR, Utah Department of Natural Resources; MSCP, Multi-Species Conservation Program].

Location	Facility Type	Status	Agency
BHC Nature Center	Sanctuary BT-RZB	Planning Stage	AGFD
Stillman Lake	Repository	Planning Stage	FWS & AGFD
Pipe Springs National Monument	Sanctuary	Pending (?)	NPS
Achii Hanyo	Sanctuary	Pending (?)	FWS
Iceberg Canyon	Sanctuary	Pending (?)	NPS/UDNR
DU2 Ponds Imperial	Test facility	Existing	MSCP

Bullhead City Nature Center Arizona Game and Fish Department is developing a nature center adjacent to the Colorado River near Bullhead City, Arizona. Partners in this endeavor include BLM and Bullhead City. The facility was scheduled for construction in late summer 2006; however, the project has experienced delays. Plans include the development of 30 ha of aquatic habitat which includes 10 ha of deep pool habitat and 20 ha of shallow habitat.

Presently, the project is still undergoing environmental compliance procedures, and construction has not yet started. At this time it is uncertain if the project will move forward, and if it does, when construction would be completed. AGFD was assisted in developing and submitting a stocking request to FWS for razorback sucker and bonytail.

Stillman Lake. The project is intended to restore and enhance the native fish community in the headwaters of the Verde River by eradicating nonnative fish from Stillman Lake (8 ha) in Yavapai County, Arizona, and restocking the area with native fish (fig. 10). The action would be undertaken cooperatively by the Arizona Ecological Services and Fishery Resources Offices of the FWS and AGFD, in coordination with other partners. An environmental assessment was written and distributed for review. Final aspects of the environmental compliance are currently (2008) being finalized.

Pipe Springs National Monument. The monument is near the Arizona/Utah border, near the town of Fredonia, Arizona. The monument is a former Mormon cattle ranch that is centered on a large spring complex. The facility is operated by the National Park Service. The spring has two cisterns that are surrounded by large mature trees (fig. 11). The ponds are stone lined, approximately 15 m in diameter and 1 m deep, and are connected by a culvert. They represent one of the center attractions of the facility. The ponds are drained every 4–5 years for maintenance purposes. Historically the ponds

Figure 10. Photograph taken of Stillman Lake, Yavapai County, Arizona.

Figure 11. One of the two connected ponds (drained) at Pipe Springs National Monument in Arizona.

have supported a number of fish, which included common carp to rainbow trout. Today, the ponds are fish free; however, they do support tiger salamander newts (*Ambystoma tigrinum*). NPS is interested in possibly introducing fish, which might help reduce insect and algae problems.

NPS contacted FWS regarding the possibility of getting their help to stock fish in these ponds, but somehow the matter was forgotten. After consulting with FWS, monument staff were contacted to determine if they would consider stocking bonytail. Bonytail are omnivorous; they eat both algae and insects. Hatcheries experience volunteer spawn with bonytail in which case young are often destroyed. I proposed bonytail could be used as a surrogate to determine if they would survive and prove suitable. If bonytail did work to the satisfaction of both NPS and FWS, they could be replaced by another imperiled species when the ponds were drained for maintenance.

A meeting occurred with their Chief of Natural Resources who was considering the proposal. A decision to stock the ponds has been delayed due to an unexpected problem with the ponds' developing a severe leak. As soon as the seepage problem is fixed, the Chief assured me she would make a decision whether to move forward with native fish.

Achii Hanyo. The Fish and Wildlife Service's fish facility at Achii Hanyo is a substation of Willow Beach National Fish Hatchery. Achii Hanyo was initially a commercial aquaculture farm that was leased from the Colorado River Indian Tribes. It contained more than 50 ponds during production peak; all were abandoned for several years. The FWS began leasing the facility in the early 1990s to produce native fish. Seven ponds had been returned to production as of 2007, and they currently produce more than 15,000 bonytail annually. FWS has plans to rebuild several others as funding and time permit (fig. 12). One of their needs is to create a deeper pond that would support fish year-round. There are no plans to return all 50 ponds or even the majority into production.

Figure 12. The Achii Hanyo Native Fish Facility is operated by the U.S. Fish and Wildlife Service on land leased from the Colorado River Indian Tribes. The facility is approximately 10 miles east of Parker, Arizona.

Iceberg Canyon. Plans are pending in the development of a native fish sanctuary on Lake Powell. NPS has taken the lead and is currently completing necessary environmental compliance. A grant request, which is currently under consideration, was made by NPS to fund the project. We have assisted in the proposal request and informally consulted with FWS Ecological Services (Salt Lake City) regarding necessary permits and the availability of bonytail for this project. The FWS informed us they do support the effort.

DU2 Ponds Imperial. DU2 Ponds represented a series of six shallow ponds located in Imperial National Wildlife Refuge. The ponds were constructed initially for waterfowl use through a partnership among FWS, USBR and Ducks Unlimited. Attempts were made during the early 2000s to use these ponds for native fish; unfortunately, several thousand razorback suckers were initially lost due to inadequate water quality and the inability to effectively remove unwanted nonnative fishes. These problems were finally mitigated through the use of ground water.

The facility is currently (2008) being enlarged and designed specifically for native fish by the MSCP. Prior to construction, the initial pond successfully produced 1,200 razorback suckers that were salvaged in 2006 and released into the Colorado River. Management, monitoring, and research aspects of this facility are being covered by other studies and are not included in this study.

Sites Dropped from This Study's Consideration. There were nine sites dropped from further consideration of this study: Rock Tank, Pittsburgh Point, Palm Lake, the Boulder City's Veteran's Park, Cocopah Ponds, No Entry Cove, Twin Cove South, Twin Cove North, and Dead Horse State Park. The reasons for their exclusion are discussed here in detail.

Rock Tank. Rock Tank is a small 1.0-ha earthen tank located on Buenos Aires National Wildlife Refuge in Arizona (fig. 13). Razorback suckers were stocked by FWS in Rock Tank and two other ponds located in the refuge during the late 1980s (Marsh, 1990). Attempts to recapture these fish in 1997 revealed four year-classes in Rock Tank indicating razorback suckers had successfully recruited young multiple times in one tank, simply survived in one of the ponds, and perished in the other pond. However, the fish were observed gulping on the surface at Rock Tank and were suspected of suffering from depressed dissolved-oxygen concentrations. They were removed and stocked elsewhere. Natural recruitment was attributed to sufficient water quality, lack of competing fishes and a gravel bottom (Bonar and others, 2002).

Figure 13. Rock Tank is located on the Buenos Aires National Wildlife Refuge in southern Arizona.

FWS was approached with a proposal to restock Rock Tank and the other ponds with razorback suckers following the installation of solar aerators to address the dissolved-oxygen issues. However, since the removal of razorback suckers in 1997, the ponds were drained and the refuge has been attempting to reestablish the Chiricahua leopard frog (*Rana chiricahuensis*) at this site. Because of concerns that introduction of razorback suckers could compromise the amphibian reintroduction program, this facility is no longer available as a potential sanctuary.

Pittsburgh Point. Pittsburgh Point is also a small backwater located on Lake Havasu on the California shoreline which for awhile was used in the Lake Havasu Fishery Improvement Program rearing effort. The area sees heavy recreational use during the summer. Bonytail and razorback suckers were stocked beginning in 1993 (Doelker, 1995). Fish were stocked a number of times; however, survival was extremely poor due to inadequate water quality. Aquatic vegetation combined with the shallowness of the pond resulted in high water temperatures and low dissolved-oxygen levels. The facility was abandoned in the late 1990s.

More recently, the Bureau of Land Management suggested the pond would require major renovation to deepen it. When previously used, the pond had poor water quality due to the high biomass of aquatic vegetation and the shallow, warm nature of the pond. While these issues might be addressed in a more remote facility, Pittsburgh Point is a popular recreational site that supports heavy recreational use during the summer. This makes it an unlikely candidate for chemical treatment or the installation of solar aerators that could be vandalized. It was deemed unsuitable for this project.

Palm Lake. Palm Lake is in the Hassayampa River Preserve, which is owned and operated by The Nature Conservancy (TNC) (fig.14). The preserve is just outside of Wickenburg, Arizona. A great deal of effort went into developing Palm Lake into a native fish sanctuary starting in the late 1980s and continued until mid-1990. It began with the signing of a cooperative agreement among TNC, FWS, and AGFD. The pond was drained, chemically renovated and stocked with bonytail, razorback sucker, and Colorado pikeminnow. Subsequently, TNC received a Presidential Award for this project.

However, the renovation ultimately proved unsuccessful in removing mosquitofish (*Gambusia spp*.) and bullheads (*Ictalurus spp*.). A combination of factors including cool spring water temperatures, high loads of terrestrial and aquatic vegetative biomass, total canopy cover, and shallow depths contributed to high oxygen demand and anaerobic conditions. A water circulation system was installed but failed to prevent summer fishkills. Surviving fish were salvaged and the effort abandoned. The pond is fed by a large spring, which makes it impossible to completely drain or chemically renovate. This, combined with the chronic dissolved oxygen problem, makes this site unsuitable for our purposes. TNC was notified that the site was unsuitable for this project.

Boulder City Veteran's Park. Five small (1/2 ha) ponds located in Boulder City's Veteran's Park and municipal golf course were used periodically from 1995 to 2005 to raise razorback suckers. Three ponds at the golf course were used by the Lake Mohave NFWG from 1995 to 2000. Five ponds in the Boulder City Veteran's Park were used from 1997 through 2003, and another pond was used by NDOW in 2004 and 2005 (fig. 15). The project was a cooperative agreement through the city, USBR and the Nevada Department of Wildlife. City managers withdrew from the agreement because of West Nile Virus concerns.

Cocopah Ponds. We approached the National Wildlife Foundation, which was developing a resource management plan for the Cocopah Tribe, to determine if they would be interested in having native fish communities occupy one or both of the ponds scheduled for construction in their riverside cultural park. The tribe was consulted and declined the offer due to concerns of potential endangered fish and management conflicts.

Figure 14. Palm Lake is in the Hassayampa River Preserve near Wickenburg, Arizona. The preserve is owned and operated by The Nature Conservancy.

Figure 15. Boulder City Veteran's Park is located on the west side of Boulder City, Nevada, and was used by the Bureau of Reclamation to raise razorback suckers for Lake Mohave.

Other Sites. BLM and FWS developed other grow-out and rearing facilities along the shoreline of the Lake Havasu by using barrier nets (Doelker, 1995). These facilities were used to support native fish production for the Lake Havasu Fishery Improvement Program. These included No Entry Cove, Twin Cove South, and Twin Cove North. Barrier nets were installed at all three sites in 1994. The sites were renovated and stocked with around 80,000 bonytail in 1994 alone. Barrier net enclosures were plagued from problems with net tears and over-the-top breaching. The vast majority of bonytail, either escaped or were eaten by invading predators, and the facilities were abandoned. These facilities were not considered due to the cost and problems associated with construction of permanent barriers.

Dead Horse State Park, Arizona is located on the Verde River and contains a small reservoir that is sustained by diverted river water. This site was dropped from consideration due to the need to screen inflow waters and the associated costs.

Sites Deserving Further Consideration and Evaluation

Several sites were encountered that might be suitable if adequate resources were available for development. They are identified in the following section in case other agencies wish to pursue their development.

Yuma Cove. Yuma Cove is located on Lake Mohave on the Arizona shoreline and was the site where natural recruitment for razorback suckers was first documented. The cove had a natural sand berm that isolated a 2-ha impoundment from the reservoir during low elevations (fig. 16). Biologists placed adult razorback suckers in the cove during the spawning season in 1986. That fall, young suckers were found. This discovery led to the formation of the Native Fish Work Group in 1989 (Mueller, 1995). The sand berm was heightened in 1990 to permanently isolate it from the reservoir. Natural recruitment was intermittent, the next occurring in 1992 when 296 young suckers were harvested in the fall. The facility was then converted into a grow-out facility where the facility was stocked with fertilized eggs, larval suckers, and other life stages. Fish had to be removed in the fall when drawdown operations typically dewatered the impoundment.

Figure 16. Yuma Cove is adjacent to Lake Mohave and situated on the Arizona shoreline.

The pond has been and continues to be actively used for grow-out by the Native Fish Work Group (NFWG). Higher than usual water elevations allowed suckers to survive through the annual drawdown in 2005 and 2007, which resulted in surviving fish spawning and natural recruitment both years.

Proposal The concept of converting Yuma Cove into a sanctuary by deepening it to sustain fish year-round was raised at the NFWG's annual meeting at Laughlin, Nevada, in 2007. This could be accomplished using land-based equipment. The group acknowledged that deepening would also improve the facility for grow-out; however, they chose to address this at a later date. Currently (2008), they want to maintain its use for grow-out. Bank erosion makes it necessary periodically to rebuild the earthen berm. Ground access is not available and heavy equipment has to be brought in by barge or walked across barren ground. Tom Burke (USBR) offered that berm repair will be necessary in the next 5 years and the proposal will be revisited. When berm repair does occur, the NFWG will entertain bringing in a large backhoe to deepen a portion of the pond. This spoil could be used to reinforce the berm. If deepened and maintained predator free, it is highly likely the facility would serve as a sanctuary.

Palo Verde Dam Abandoned Intake. Following the initial request for potential sites, USBR's Yuma Project office notified us about an old abandoned canal turnout located just upstream from Palo Verde Dam, California. That office was looking for potential mitigation features for another project. This portion of the canal remains connected to the river and consists of a control structure (boarded check structure) and approximately 200 m of canal (fig. 17). The site appears ideal in terms of size and location but would require structural repairs to the check structure to ensure it holds water. Each year the diversion dam is opened to drain the upstream pool for maintenance, which dries the canal turnout. Some method of maintaining a pool in the canal would be necessary if this site were used. This annual draining could also be used to harvest and renovate the backwater. It may be feasible to repair the old water control structure not only to isolate this section of canal but also to impound water during operational draw downs (fig. 18). Such modifications exceed the resources of this study; however, we encourage the MSCP to explore these possibilities.

Figure 17. A blocked-off portion of the old diversion canal still remains just upstream from the current diversion canal at Palo Verde Dam in California.

Figure 18. Remains of the diversion control structure of the old Palo Verde Canal Diversion located near the Colorado River.

Long Lake. Long Lake is on the Fort Mohave Indian Reservation, south of Bullhead City, Arizona. The lake is currently being used as a recreational fee area but appears to have marginal recreational value (fig. 19). There is a $5 per day charge to fish the lake. I was told by the tribal warden that the lake has been stocked with largemouth bass and catfish, and when water is added from the river, fish also pass through the pumps. The lake has become quite shallow, and bank vegetation has encroached the channel, making access difficult. Anglers have to walk nearly a mile to get to the main portion of the lake. One of the tribal rangers said the tribe was trying to promote more angler usage. They acknowledged the problem of access and that the most prominent complaint is that the lake is too shallow. They are interested in having it deepened.

The lake apparently receives no agricultural drainage, and the tribe appeared receptive to dedicating a portion of the lake to native fishes in return for having the rest deepened for recreational species. The lake is entirely fenced, and the terminal end is isolated. There may be an opportunity to build a permeable berm across the terminal end of the lake that would allow renovation and the

Figure 19. Long Lake is on the Fort Mohave Indian Reservation and was initially built to store irrigation water.

establishment of a native fishery. This would require tribal council approval and substantial construction and dredging capital.

Beal Lake. Beal Lake has been an ambitious project of the USBR and FWS and is located on the Havasu National Wildlife Refuge (Fitzpatrick, 1997). It represents a portion of a large marsh complex that was deepened by mechanical dredge for the purpose of surviving as a native fish sanctuary for razorback sucker. The facility is approximately 80 ha in size and consists of a complex of dredged channels and flooded shallow flats. Water quality and elevation are maintained through the use of an inflow channel, a permeable barrier, and water-filtering device. These were designed and constructed to prevent nonnative fishes from entering.

The facility has been renovated and stocked twice, and nonnative fishes have been observed shortly after each event. Following the failed renovation in 2001 and the loss of 10,000 razorback suckers, the inflow system was redesigned. A permeable levee or barrier and water-filtering channel were installed. These were designed and constructed to prevent nonnative fishes from entering. The lake was chemically renovated again in April 2006; 3 months later, bonytail and a few dozen razorback suckers were stocked. Shortly following that introduction, common carp, largemouth bass and other fish species were detected in the lake. Monitoring ceased once again. It is not known whether the chemical renovations were simply incomplete or if fish had breached the permeable barrier or filters. It is quite possible both occurred. Many unanswered questions remain as to why stocked native fishes disappeared and nonnative fishes reappeared so quickly. FWS is working on a summary report that may shed some light on the challenges associated with managing such a large facility, and USBR has expressed its commitment to see the lake become a native fish sanctuary. FWS continues to work with AGFD and USBR to refine the goals and objectives of managing Beal Lake.

Discussion

The challenges of this project were not the fish; they thrived and produced young when provided predator-free habitats and adequate water quality. Our dilemma centered on finding suitable habitats, finding partners willing to work together, overcoming personal biases, circumventing institutional barriers, and convincing people of the potential benefit these facilities could provide. The following discussion summarizes those attempts to provide insight on the difficulties and provides useful information in the additional development of native fish sanctuaries in the Lower Colorado River Basin and elsewhere.

Availability of Suitable Habitats

Finding existing habitats that were both suitable and available to native fish use proved difficult. Obstacles involved the scarcity of these types of habitats, competing uses, conflicting management goals within and between agencies, and philosophical differences of opinion with regard to who should develop native fish sanctuaries and where.

First of all, aquatic resources are extremely scarce in the desert southwest. There are small aquatic habitats scattered along the Colorado River corridor; however, the vast majority would require extensive modifications that go beyond the resources of this project. The greatest opportunities were found on public lands, most notably the national wildlife refuges and national parks. However, the national wildlife refuges contain the remnants of wetland complexes that are typically interconnected, making nonnative predator control difficult if not impossible. Unfortunately, it is virtually impossible to find habitats that are naturally isolated and also suitable for fish.

Physical isolation generates its own unique set of water-quality problems, which usually come in the form of increased salinity and anoxic conditions that are aggravated by thermal and chemical stratification. For example, since the closure of Davis Cove 13 years ago, salinity levels have risen 5 times initial concentrations due to evaporation and poor water exchange. Butler and McAllister Lakes illustrate how increasing salinity can make them unsuitable for most forms of aquatic life (Walker and others, 2007). Past fishkills at Pittsburgh Point, DU2 Ponds Imperial, and Palm Lake illustrate the chronic problems associated with plant growth, high temperatures, and depressed dissolved oxygen. In some cases, these problems can be mitigated through the use of mechanical circulators or aeration systems depending upon the problem's severity or the ability to prevent vandalism. There are many factors to be considered in site selection.

Not all flood-plain ponds are created equal, especially in desert climates. Unfortunately, the inter-relationships of oxbow ecology, geomorphology, and ground-water hydrology are poorly understood. Researchers report that productivity can be greatly enhanced and perpetuated by ground-water influx (Amoros and Bornette, 2002; Kingsford, 2006). In some arid ecosystems these sustainable habitats are critically important in maintaining "seed" populations necessary to repopulate river communities during the rainy season. However, many oxbows that are hydraulically isolated from ground water become death traps as water warms and evaporates; dissolved solids concentrate and biological oxygen demands turn the environment anoxic. We have to realize that simply making a depression and filling it with water will not always support a fish community. A better understanding of the influence and importance of ground-water exchange is needed, especially in view of recent setbacks in the construction of sanctuary habitats (Brouder and Jann, 2004).

Unfortunately, the spread and dominance of nonnative predator fishes have become the primary factors restricting native populations. All the successful native fish facilities have been modified or excavated to ensure their physical isolation from the main-stem river. Several of the facilities were either used for, or specifically developed for, native-fish grow-out by other programs. Examples include Davis Cove, Office Cove, Cibola High Levee Pond, Bulkhead Cove, and Three Fingers Lake.

The availability of abandoned facilities for use as sanctuaries (for example, Davis Cove and Bulkhead Cove) benefited this program but it became apparent that stocking and grow-out represents the prevailing management philosophy in the lower basin. Minckley's Conservation Plan has received wide verbal support, but it is noteworthy that no existing grow-out ponds were proposed to be used solely as a sanctuary instead. Resource management and regulatory agencies continue to pursue stocking as a major conservation effort even though these types of programs have generally failed for decades (Minckley and others, 1991; Marsh and others, 2005). At best, these programs can only attempt to maintain a presence of these species, which can be accomplished with fewer resources. One possible explanation is that production and stocking quotas are more tangible than actual survival, something that is harder to measure.

The two primary factors required in the selection of a potential site are the ability to restrict predators and relative ease of management. Even when a habitat supports fish, the real challenge comes in totally eliminating and then preventing unwanted fishes from reinvading these habitats. There is the saying among biologists "Fish can walk." That seems to be the case as bait bucket introductions are commonplace despite laws at State and Federal levels to prohibit this activity. The compromise and loss of Cibola High Levee Pond is being attributed to such a stocking. Draining is the ideal solution, and is a feature we were able to use only once in this project (River's Edge Golf Course). Draining makes chemical renovation unnecessary, generally reduces environmental compliance and public concerns, and reduces labor and chemical costs. However, mechanical draining (pumping) is costly in terms of equipment and time and often is difficult to implement due to water-discharge restrictions.

There have been some attempts in the past to partly pump down ponds during renovation. Theoretically, it would reduce the amount of ichthyocide needed and avoids the problems associated with treating densely vegetated areas. However, reduced head can increase seepage or ground water upwelling. Fish can sense and avoid rotenone by seeking and remaining in these infiltration areas where they can survive leading to incomplete fishkills (which is what may have happened at Beal Lake).

Effective renovation is as important as prevention. Construction costs (per hectare) usually decline as size increases; however, the cost associated with predator removal is much more untenable for large facilities. Unfortunately, operation and maintenance costs generally are not estimated prior to construction. These issues need to be considered in the future design and management of facilities.

Personal, Institutional, or Perceived Hurdles

There is a lot of truth to the old saying: "We've met the enemy and he is us!" Problems arise from personal biases, poor communication, perceived problems, overlapping management jurisdictions, conflicting management goals, environmental compliance procedures, and simply different interpretations of the same policies. As always, these problems are most apparent in the beginning of a program. Native-fish conservation efforts should become more effective with time, refinement, and gradual acceptance.

Some problems undoubtedly center on personal priorities and the availability of time and resources. It is much easier to find reasons why something can not be done than to actually push forward and add to an already overburdened workload. Fortunately, persistence generally wins out. Nothing is more gratifying than finding a colleague(s) wanting to do something good for the resource and willing to work with others to make those goals a reality.

There also are institutional challenges. Agencies, whether State or Federal, have different priorities and simply do things differently. Being flexible and creative helped. For instance, Davis Cove had to be designated a "research project" to move forward. It was accepted by NPS as a research project; NPS covered their environmental compliance needs, and the "experiment" went forward. Six agencies participated and provided volunteers and (or) material. Once the Davis Cove project proved successful, AGFD offered to take the lead to actively manage the facility. This approach worked well; however, some may find it unusual that a state would offer to manage a resource within a national park. This collaboration is perfectly normal as NPS and the States generally have joint agreements to do simply that, to share management responsibilities.

Other State and Federal agencies have differences in management priorities that often cause conflicts. For example, a conflict developed between CDFG and FWS pertaining to prior environmental commitments on a Federal refuge. CDFG supports construction of new native fish sanctuaries but not at the cost of converting and losing existing sport fishery habitats. CDFG objected to not being consulted prior to the stocking of razorback sucker in Three Fingers Lake and the closure of road access. Follow up negotiations resulted in the addition of recreational fishing features into the lake's management plan and discussion about increasing law-enforcement activities. Resulting accommodations balanced native and recreational fishing interests. Generally, these types of conflicts are more common within State agencies which often have to balance native and recreational fish management objectives (Clarkson and others, 2005). This is especially problematic when the major funding source for State agencies is the sale of recreational fishing licenses.

While FWS does consult with State agencies on management activities, they have the sole management authority on national wildlife refuges. Projects on Federal refuges generally were adopted into their specific management plan by amendment. That was the case for Cibola High Levee Pond, Beal Lake, Office Cove, and others. Proposals to develop Three Fingers Lake into a native fish repository and Office Cove into a sanctuary and grow-out facility were initially rejected but later were supported by AZFRO and the refuges. Through negotiations, both projects went forward with remarkable speed.

There also were problems with geographical boundaries; in one case State boundaries intersected a native fish facility. Environmental compliance and permitting procedures are different for each State. Often one State's regulations are more stringent than another's in the use of chemicals for renovation. Whether this is a real or perceived problem is unclear; regardless, it has delayed renovation at Cibola High Levee Pond for nearly 4 years. In the meantime, the native community has been totally replaced by largemouth bass. Quite possibly, the MSCP could help broker interagency agreements between member agencies to help resolve these types of management problems.

The perception of bureaucratic quagmire also can scare away potential partners when dealing with endangered species. Some believe they may become drawn into an unwanted and long-term commitment when dealing with these fish. These concerns were raised by one of the Indian tribes and by the NPS.

Finally, having only 2 years to find and develop these facilities, opportunities were pursued at any level where support was found. Through this process, two important factors became apparent. First, team building is critically important if these facilities are to work. The old days of "hobby projects" are essentially over; native communities require a long-term commitment by agencies rather than by individuals. Second, the establishment of a scientific steering committee or clearinghouse might be useful to help resolve some of the problems encountered in studies (Fish and Wildlife Service 2004).

"Success"—An Assumption?

Our understanding and skill of how to manage these habitats are in their infancy. A good deal of what has been learned has come about either by accident or informal design. Natural recruitment was discovered from "lets try this" events and later in grow-out ponds (Pacey and Marsh, 1998; Bonar and others, 2002). These were critically important discoveries that became the basis for Minckley's Conservation Plan (2003). Regrettably, there has been little coordinated effort to integrate these habitats into existing management programs (until this study), and as result, these "pioneer" communities were lost along with what could have been learned through their active management. While scientists understand that nonnative fishes must be controlled to allow a sanctuary to establish, there is very little information available concerning the level of management necessary to make these habitats function. That expertise may exist with the FWS's Hatchery Division. For instance, a hatchery's most importance asset is its water source; it must not be biologically contaminated. It is also noteworthy that hatchery ponds typically are small due to the need for manageable flexibility and cost effectiveness. In contrast, recent sanctuary development appears to be based on construction economics; larger acreages are more cost effective. However, the potential cost of operation, maintenance, and management are seldom or ever included in these types of analyses (U.S. Bureau of Reclamation, 2005).

Sanctuaries—Their Role and Potential Use

A major benefit of these sanctuaries is the knowledge and management experience that will be learned through their operation. One option is to use these habitats as tools toward achieving larger management goals. For example, Minckley's Conservation Plan (2003) pointed out that sanctuaries could be used to augment river populations or supply fish for research purposes. There also are the goals set by the Management Plan for the Big River Fishes of the Lower Colorado River (U.S. Fish and Wildlife Service, 2004) in terms of flood-plain communities of native fish. How many acres does it take to establish a stable population of 5,800 adult razorback suckers? Would that be the same for bonytail? The answers to these and other critical questions will only come through the experience gained by actively managing these facilities. In essence, we need to learn as we go, build upon our successes, and have robust monitoring programs to accurately measure progress and help answer questions.

These facilities could also be used to achieve larger management goals. A concerted effort was made to develop native fish management goals for the Lower Colorado River Basin, a program led by FWS. The Management Plan for the Big River Fishes of the Lower Colorado River (U.S. Fish and Wildlife Service, 2004) provides a description of the management goals for native fish populations in the lower basin. The document has been signed by all the land-management and State wildlife agencies. However, the specifics of how to achieve those goals seem to be missing. Some type of guidance document or process linking the goals outlined in the management plan (2004) and the resources being provided by the MSCP is lacking. These sanctuaries could be pivotal in optimizing those resources for the benefit of the species.

A key element in this study was the use of management plans that were developed specifically for each facility. The plans provide a description and prioritize management goals and provide resources and a "road map" of how we expected to accomplish them. This mimics the successful process used by the Native Fish Work Group on Lake Mohave. There flood-plain ponds and other tools are used to optimize fish survival and growth. Management plans are basically planning and tracking documents that should be used and updated by field personnel to provide managers better information regarding realistic goals and accomplishments and the necessary resources. This type of documentation is essential to bring new replacements up to date and for developing and justifying budget requests.

In the same light, resource managers need to consider how best to use sanctuaries to advance management goals for native fishes. Sanctuaries can be used to maintain genetic stocks, and allow populations to recruit naturally, which in turn would provide additional management flexibility. For instance, with the facilities currently or soon to be in operation, it is anticipated that they have the capability of supporting nearly 6,000 adult razorback suckers and 20,000+ bonytail. That represents a doubling of the populations of razorback sucker currently found in Lake Havasu and Lake Mohave. The addition of this many bonytail would be an unprecedented advancement for the species.

Finally, a topic that is receiving more attention in the literature pertains to the suitability of hatchery-reared fish for introduction. Robert Miller (1954) reported more than five decades ago that hatchery-reared cutthroat trout exhibited inferior survival skills compared to their wild counterparts. The issue of the suitability of hatchery-reared fish to augment wild stocks has received substantial attention this past decade, especially for salmonid introductions in the Pacific Northwest (Brown and Smith, 1998; Olla and Davis, 1989; Mirza and Chivers, 2000). Poor stocking survival worldwide has prompted researchers to question whether hatchery-reared fish possess the skills necessary to survive in the wild (Philippart, 1995; Brown and Day, 2002). The answer generally has been no.

Recent studies conducted on bonytail and razorback sucker indicate hatchery-reared individuals are not only predator naïve but are actually attracted to large predators due to their curiosity (Mueller and others, 2007). Those studies showed that predator exposure and flow conditioning significantly increased their survival when compared to their control hatchery counterparts. The collective challenge of adapting to flow and natural foods, developing effective foraging skills, and successfully avoiding a matrix of fish and avian predators may simply overwhelm hatchery-produced fish. Research suggests translocation of wild individuals provides the greatest chance for survival. However, if wild fish are not available, the second best choice is to use fish that have already acquired some survival skills (Olla and others, 1998; Brown and Day, 2002).

Sanctuary habitats provide that choice. Sanctuary fish have successfully adapted to local water conditions, natural foods, and feeding behavior. While predatory fish are absent, native fish still have to contend with a list of avian, amphibian, reptilian, and mammalian predators. These less hostile environments result in higher survival as fish develop predator avoidance skills and adapt to more natural conditions. There is little question these fish would outperform fish stocked directly from a hatchery environment (Olla and others, 1998) and this approach represents a management strategy suggested in Minckley and others (2003) conservation plan.

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Appendix A. Davis Cove Management Plan

NATIVE FISH SANCTUARY MANAGEMENT PLAN

Location: Davis Cove, Lake Mohave, Lake Mead National Recreational Area
Managing Agency: National Park Service

Goal: To provide habitat conditions that promote native fish recruitment at levels that sustains a natural community while providing management and research opportunities to promote advances in conservation and recovery.

Purpose of this document: This Management Plan is intended to be a working document intended to identify management purposes, goals and resources needed to manage native fishes. Through the active management of these species in small sanctuary habitats, scientists and resource managers will gain the knowledge and experience that will be critical if these species recovered on a larger scale. This document describes those steps.

Management Agencies: Arizona Game and Fish Department and National Park Service.

Last Modified: January 19, 2007

INTRODUCTION

In 1989, the National Park Service entered into a cooperative, multiagency program call the Native Fish Work Group. A group of state, federal agencies and academia pooled resources and expertise in a joint effort to save razorback suckers in Lake Mohave (Mueller 1995). The program evolved into a strategy of collecting wild USBRn sucker larvae and growing them in isolated ponds until fish reached a sized deemed sufficient to avoid predation. They were then stocked into the reservoir to augment the dwindling population of old adults.

In 1992, Davis Cove was selected as a grow-out site for these fish. A net barrier was built and installed at the coves entrance; isolating approximately 1.3 ha of water. The coves depth (7 m) maintained a permanent pool of water during operational drawdowns of the reservoir. An attempt was made to remove non-native fish in 1992 and the cove was stocked with 10,000, small razorback suckers.

A year later, survival of these suckers was deemed extremely poor (0.1%) and sand buildup combined with reservoir fluctuations, caused the barrier net to be compromised several times. In 1995 the net was replaced with an earthen berm that permanently blocked movement of fishes between the cove and reservoir. The cove was chemically renovated that year and stocked with razorback suckers. During the past decade it has been managed as a grow-out facility for bonytail and razorback sucker.

USGS approached Bureau of Reclamation and the National Park Service (NPS) regarding the possibility of testing Minckley's Native Fish Conservation Plan (Minckley et al. 2003). The goal is to utilize the resources and expertise of the Lower Colorado River Native Fish Work Group in the development of a small scale, native fish sanctuary system. Reclamation agreed to help fund the endeavor while Lake Mead National Recreation Area volunteers to convert Davis Cove into a native fish sanctuary. This document is the first step in identifying goals and the necessary resources to accomplish those objectives.

The Native Fish Sanctuary Management Plan is a working document designed to flexible and adaptive for the purpose of optimizing

MANAGEMENT PLAN ISSUES

Habitat Quality:

The closure of Davis Cove from Lake Mohave has had several physical and chemical repercussions to the cove's aquatic community. These may or may not effect the productivity, let alone the suitability of the cove to support native fish spawning and their necessary food webs. For instance, conductivity (salinity) has increased nearly 5 fold during the past decade, reaching 5,000 u/cm. The cove mimics reservoir fluctuations indicating the two bodies of water remain hydraulically connected but the pond's high salinity suggests there is actually limited exchange of cove and reservoir waters. Apparently the subterranean volume under the berm provides sufficient area where saline water simply moves between the pond and berm with minimal dilution with reservoir waters.

There have been obvious shifts in the aquatic vegetation community. Initially after closure the pond experienced a dramatic increase in pondweed (*Potamogeton* sp.) and spiny naiad (*Naiad* sp.). Those species have been replaced by sparse stands of stonewart (*Chara* spp.). The shift in plant composition could be expected to have a dramatic impact on the food web which may have implications for bonytail and razorback sucker.

Available Resources:

The purpose of this project is to determine if the native fish sanctuary approach is practical on a small and possibly larger scale. Currently, no one single agency has the expertise or the resources to implement such a program. However, by pooling various resources from several sources we feel such a test would be more economic and practical and results could be better controlled and measured. Even then, uncertainty pertaining to available resources, staff and funding makes it necessary to prioritize needs. This plan presents and prioritizes those management, monitoring and research needs. Available resources will be directed at the highest priority items. The priority order, addition or deletion of these lists will be an ongoing process as information is collected, processed and analyzed.

Management Objectives In Order of Priority (1 highest):

1. Natural Recruitment
   a. Establish, improve or maintain habitat conditions that support natural recruitment for both introduced native fishes at rates that sustain their population and produce surplus fish.
   b. Establish, improve or maintain habitat conditions that support natural recruitment for one introduced native fish at rates that sustain their population.
   c. Establish, improve or maintain habitat conditions that support limited natural recruitment for both introduced native fishes. Supplemental stocking is necessary to sustain one or both population.
2. Grow-Out Facility
   a. Establish conditions that allow for grow-out of native fishes.
3. Abandon Project

Possible Management Actions (1 highest):

1. Biological Actions
   a. Remove large surplus (>50 cm) razorback suckers and (>30 cm bonytail).
      i. Stock surplus fish in (order of preference): Lake Mohave, other sanctuaries, Lake Havasu.
   b. Suppliment stocks with fish from other genetic sources every few years.
   c. Stock natives to augment or replace losses due to natural causes (predators/habitat conditions).
2. Water Quality Improvements
   a. During high water level, use portable pumps to lower salinity in the cove. Water should be pumped from the cove to the reservoir to reduce pond salinity and increasing groundwater circulation. Pumping from the pond will reduce the likelihood of contamination by unwanted organisms (predators and zebra mussel).
   b. Install an aerator to improve dissolved oxygen concentrations.

3. Physical Habitat Improvements
    a. Create a sediment catch/barrier at inflow.
        i. Using hay bails or similar structures create 'dry' sediment dams in the wash.
        ii. Use rock gabion or similar framing structures in the inflow delta to create hummock platforms for aquatic emergent plans. These structures would be placed in a manner to intercept, slow, and filter wash waters entering the pond.
4. Interpretive Actions
    a. Install signs on site that informs the public of the cove's use and the plight of these fish.
    b. Develop a public brochure informs the public of the cove's use and the plight of these fish.
    c. Develop a portable display for use at visitor centers.

Management Triggering Actions

Davis Cove will require management activities necessary to sustain the native fish community. This community is temporary, being subject to common or unique threats. These include invasion by nonnative fishes, storm events that result in fish kills, and existing habitats conditions that may not support spawning, natural recruitment or optimal productivity. In anticipation of these, the following 'triggering' conditions are specifically set in order to trigger appropriate management actions to mitigate or remedy the problem. All actions would require appropriate environmental compliance by NPS.

Problem	Management Action
>5% nonnative fish	Add to renovation list, initiate salvage
Spawning or recruitment failure	Add spawning substrate
Salinity proves a limiting factor	Add fresh water by pumping
Natural fish die-off (storm related)	Restock
Poor body condition (stunting)	Harvest and remove >20%

PROPOSED MONITORING

The conceptual plan for developing fish sanctuaries in the Colorado River (Minckley et al. 2003; BioScience 53:219-234) suggests that stabilizing native fish populations requires developing and/or creating habitats of sufficient physical, chemical, and biological quality. Thus the purpose of our monitoring plan is to evaluate these factors with regards to enhancing survival of all life stages of native fish. Our goal is to provide land managers with essential information for maintaining and improving the quality of Davis Cove as a fish sanctuary. Our methods are designed to address the following questions:

1) Are the water chemistry and physical characteristics of Davis Cove sufficient to allow long-term survival of razorback and bonytail populations?
2) Is the spawning and nursery habitat sufficient within Davis Cove, or do they need to be altered or actively managed to increase success of spawning and recruitment?
3) Is there an appropriate food base for fish available in Davis Cove?
4) Is the aquatic vegetation healthy and stable?
5) Is the native fish population stable in numbers, and free of disease and non-natives? What is the growth rate of native species?
6) Is the native fish population spawning successfully?
7) Is recruitment of native fish occurring?
8) If there are non-native species in Davis Cove, what is their relative abundance? Are the non-natives reproducing?

We outline specific methods below to answer these questions.

Physical Quality

Methods:

1): Depth. Davis Cove has a bathymetric map developed before the berm was constructed. Depths will be ground-truthed with multiple transects, and an electronic sounder or sounding cables.

2): Substrate. To assess baseline conditions, substrates of the entire backwater will be mapped when water levels are lowest or when water clarity allows a complete snorkeling survey. Our initial survey in October 2005 suggests substrates at Davis Cove may not be adequate for bonytail or razorback sucker spawning. If recruitment is unsuccessful in 2006 we recommend augmenting spawning substrate by gathering cobble from the reservoir side of the berm.

3): Cover. Our initial survey of Davis Cove indicated a lack of submerged cover for fish. We will be installing brush piles in January 2006 at a variety of depths. Natural (e.g., aquatic vegetation) and installed sources of cover will be quantified and monitored to determine their use by fish (see Fish Monitoring section).

Water Quality

Methods:

1): Instantaneous in-situ measurements. In October 2005, we used a Hydrolab to measure DO, temperature, pH, conductivity, and salinity measured at 0.5-m intervals at 3 stations in the deepest areas of the cove. We will continue to take these measurements on all sample trips; if possible, this will be quarterly for the first year of monitoring. We will also take Secchi disk measurements.

2): Water quality sampling. In 2006 we will collect initial samples for major ion analysis by USBR; chlorophyll, total suspended solids; and elemental and contaminant analysis (Hg, Se, As, ClO_4). Future sampling frequency will depend on initial levels of elements of concern.

3): 24-hr sampling of DO and water temperature. We expect DO to be lowest and temperatures highest in July and August. During this time we will use three MiniSondes (at bottom, middle, and upper sections of the water column along an installed post) to continually measure these variables over a 24-hr period. Our goal is to determine if DO or temperature may limit the success of the sanctuary and if other methods to improve water quality need to be considered (e.g, installing a solar aerator, or methods to improve permeation of water through the berm).

4): Long-term temperature data. We will install two water temperature recorders (e.g., Hobos) in Davis Cove, to record hourly temperatures over a 1-yr period.

Zooplankton and Macroinvertebrates

Methods:

1): Zooplankton. Three vertical tows will be taken in the deepest portion of the cove in February and/or March, and mid-summer. The February-March sample should provide an estimate of maximum zooplankton productivity, so it will most likely capture high diversity as well. The mid-summer sample (June-July) is when zooplankton are important for recruitment. Biomass will be measured by filtering through a plastic graduated cylinder. All samples will be preserved for later analysis. Phytoplankton and chlorophyll will be sampled in April.

2): Macroinvertebrates: Concurrent with zooplankton samples, we will collect aquatic insects caught in the larval light traps. In addition, we will collect macroinvertebrates using a variety of sample techniques at 6 locations at varying depths in March, June, and October to determine average number of organisms/m^2. Our purpose is to measure the abundance of invertebrates, not to provide a detailed description of aquatic insect diversity in Davis Cove.

Aquatic Vegetation

Methods:

1): Estimate plant abundance and composition. Once or twice per year, we will identify plant species present and estimate areal vegetation coverage. When visibility is good, transects north-south and west-east across the cove will be snorkeled, as well as a transect around the entire perimeter. We will use these transects to create a map showing extent of coverage by each plant species. If water clarity is reasonable, we will take water surface and/or underwater photographs to serve as permanent records of plant abundance.

2): Evaluate the general health of the aquatic plants within the cove. On each sampling trip we will record water level of the cove and note if it is higher or lower than normal (i.e., are plants exposed or growing at deeper depths?). Once or twice a year we will examine plants for general health; evidence of stress; or damage by animals or disease. We will note all invasive plants; and note whether installed salt cedar bundles have sprouted (notifying NPS as necessary).

3): Monitor trace element or contaminant bioaccumulation within the vegetation. We will determine levels of elements that may pose a threat to the health of the fish or ecosystem. We will collect three specimens of each existing plant species for analysis that may include, but is not limited to, selenium, mercury, arsenic, and perchlorate. Other elements or contaminants can be added to this list if there is a cause for concern, such as pesticides, pharmaceuticals, viruses, etc.

Fish Populations

Method: At the beginning of this monitoring plan, we listed questions specific to the fish population that are necessary to understand how well Davis Cove is working as a sanctuary. We list these questions again, in order of importance:

1): Are the stocked razorback and bonytail surviving or have they disappeared? Are they free of disease? Are non-natives present? We will collect population data via a snorkel survey in summer and electrofishing and/or trammel-netting in October. Each fish will be measured, weighed, and spawning condition evaluated. Crayfish presence and abundance will be estimated with minnow traps baited with canned food, set overnight in February/March.

2) If there are non-native fish in Davis Cove, what is their relative abundance? Are the non-natives reproducing? This question can be answered from data collected above.

3): Are razorbacks and bonytail growing? This question can be answered by comparing data between October samples.

4): Are the razorback and bonytail spawning? We will set four larval light traps for 2-hr periods in February, March, and June, beginning in 2007, to determine presence of fish larvae. Larvae collected will be preserved to identify species.

5): Is there evidence of recruitment? We will look for young-of year fish during June snorkeling surveys; and by setting minnow traps and ½ -inch trammel nets in October.

6): Are razorback and bonytail using the available cover and substrate? We will snorkel and/or use underwater videography in the vicinity of the brush piles and installed substrates to determine use. To determine if the installed substrate is producing larvae, larval light traps will be set directly above in February and June.

Data Handling and Reporting

Jeanette Carpenter will maintain and keep all datasets. Annual reports will be written and provided to all interested persons and agencies.

Special Situations:

The monitoring program will be reviewed on an annual basis to determine if changes to the protocol need to be made. If a significant event occurs, such as an unusual climatological, hydrological, or biological event, we may need to revise our methods and consider additional or alternative monitoring techniques or sampling dates.

PROPOSED SCHEDULE AND ACTIVITIES

Timing	Action	Crew#	Lead Agency	Contact
September 2005	Renovation	15	USGS/NPS	Mueller/Haley
October 2005	Stocking	12	USGS/NPS/FWS	Mueller
January 2006	Cover	6	USGS/NPS	Carpenter/Haley
February 2006	Monitoring	3	USGS/NPS	Carpenter/Haley
April 2006	Monitoring	3	USGS/NPS	Carpenter/Haley
August 2006	Monitoring	3	USGS/NPS	Carpenter/Haley
October 2006	Monitoring	3	USGS/NPS	Carpenter/Haley
April 2007	Monitoring	3	AGFD/USGS	Cummings/Carpenter
August 2007	Monitoring	3	AGFD/USGS	Cummings/Carpenter
October 2007	Monitoring	3	AGFD/USGS/BR	Cummings/Carpenter

IDENTIFIED RESEARCH NEEDS:

1. Identify the most efficient means of maintaining water quality (temp, salinity, DO) without enhancing recolonization of exotic species.
2. Develop natural ‘recharge’ techniques to maintain water quality.
3. Identify spawning requirements of targeted species.
4. Identify cover requirements.
5. Identify salinity tolerances of all life stages of bonytail and razorback sucker.
6. Identify salinity tolerances of food web organisms critically needed by native fishes.

Appendix B. Cibola High Levee Pond Management Plan

Draft

NATIVE FISH SANCTUARY MANAGEMENT PLAN

Location: Cibola High Levee Pond, Cibola National Wildlife Refuge, Cibola, Arizona
Managing Agency: Fish and Wildlife Service

Project Principles:

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Goal: To provide habitat conditions that promote native fish recruitment at levels that sustains a natural community while providing management and research opportunities to promote advances in conservation and recovery.

Purpose of this document: This Management Plan is a working document intended to identify and describe management goals, resources and methods required to effectively manage native fishes at this site and research opportunities. Through the active management of these species in small sanctuary habitats, scientists and resource managers will gain the knowledge and experience that will be critical for the species to be recovered on a larger scale. This document describes those steps, resources and opportunities.

Last Modified: January 22, 2006

INTRODUCTION

In 1989, the Fish and Wildlife entered into a cooperative, multiagency program call the Native Fish Work Group. The group of state, federal agencies and academia pooled resources and expertise in a joint effort to save razorback suckers in Lake Mohave (Mueller 1995). The program evolved into a strategy of collecting wild USBRn sucker larvae and growing them in isolated ponds until fish reached a sized deemed sufficient to avoid predation. They were then stocked into the reservoir to augment the dwindling population of old adults.

The approach was adopted for other portions of the river basin. In 1993, FWS converted Cibola High Levee Pond into a rearing facility for razorback suckers and bonytail. Nearly 58,400 small bonytail and 14,000 razorback sucker were stocked between 1993 and 1996. Fish growth was monitored and as fish reached 30 cm in length they were removed, PIT tagged and stocked elsewhere.

In December 1998, biologists discovered that both species had successfully produced young. Fish stocking and removal were both suspended in order to study this phenomena. USGS and FWS biologist studied this community and found that both species were successfully recruiting young at levels necessary to support the community. The community consists of roughly 6,000 bonytail (>15 cm) and 1,100 razorback suckers. In 2002 the pond's carrying capacity was measured at 4,350 fish/ha with a biomass of 635 kg/ha.

In 2004, largemouth bass were discovered. Attempts to remove these fish failed and they were able to spawn in 2005, resulting in the production of thousands of young bass. By the end of 2005, largemouth bass numerically dominated the fish community. Sampling in that fall indicated the absence of native young and that largemouth bass represented more than 80% of the fish community.

As a result, steps are being taken for the salvage, chemical renovation and restocking of the pond with native fishes. The pond's fish community was unique in that it represented the only sustainable natural recruitment of these species in the world. W.L. Minckley's (et al. 2003) Conservation Plan For Native Fishes was based on this phenomena as are key components of C.O. Minckley's Lower River Management Plan. As outlined in the BioScience paper, these communities are temporary and require long-term management. This management plan outlines the goals, resources and steps necessary for the maintenance of Cibola High Levee Pond.

MANAGEMENT PLAN ISSUES

Habitat Quality:

The conditions at Cibola High Levee Pond are unique in terms of habitat and water quality. The pond represents a historical portion of the river channel which contains a wide variety of substrate types. Groundwater hydraulics is unique in terms of water circulation and flow gradient. Both the river and flood levee are permeable, allowing river/ground water to flow between the river and Pretty Water. This combination maintains optimal water quality, especially temperature and dissolved oxygen which are critical parameters for desert aquatic habitats.

The pond does have support lush growth of aquatic vegetation (*Potamogeton* sp.; *Naiad* sp.). During peak summer heat, fish congregate in the deepest portion of the pond where its suspected that substantial quantities of ground water enter. Evidence of this includes lower water conductivity and lush growth of aquatic vegetation at depths exceeding 3 meters. We suspect this growth is stimulated by incoming nutrients. During peak summer heat, fish take advantage of the cooler temperatures afforded by depth and from shade provided by floating mats of vegetation.

Available Resources:

The purpose of this project is to determine if the native fish sanctuary approach is practical on a small and possibly larger scale. Currently, no one single agency has the expertise or the resources to implement such a program. However, by pooling various resources from several sources we feel such a test would be more economic and practical and results could be better controlled and measured. Even then, uncertainty pertaining to available resources, staff and funding makes it necessary to prioritize needs. This plan presents and prioritizes those management, monitoring and research needs. Available resources will be directed at the highest priority items. The priority order, addition or deletion of these lists will be an ongoing process as information is collected, processed and analyzed.

Environmental Compliance

The Arizona Fisheries Resources Office will work with refuge staff to meet appropriate compliance of federal and state environmental laws and regulations.

Management Options In Order of Priority (1 highest):

4. Natural Recruitment
   a. Establish, improve or maintain habitat conditions that support natural recruitment for both introduced native fishes at rates that sustain their population and produce surplus fish.
   b. Establish, improve or maintain habitat conditions that support natural recruitment for one introduced native fish at rates that sustain their population.
   c. Establish, improve or maintain habitat conditions that support limited natural recruitment for both introduced native fishes. Supplemental stocking is necessary to sustain one or both population.
5. Repository for adult razorback suckers
   a. Maintain a population of adult razorback suckers that were produced from wild-USBRn larvae captured in Lake Mohave.
6. Grow-Out Facility
   a. Establish conditions that allow for grow-out of native fishes.
7. Abandon Project

Management Actions:

5. Physical Habitat Improvements
   a. Reduce the spread of cattails,
   b. Construct a floating island to provide structure and shade,
   c. Experiment with floating hummock designs.
6. Biological Actions
   a. Remove large surplus fish and stock in appropriate places.
   b. Stock natives to augment or replace losses due to natural causes (predators/habitat conditions).
   c. Maintain nonnative crayfish reduction efforts.
7. Interpretive Actions
   a. Develop a portable display for use at visitor centers,
   b. Develop a interpretative field talk.

Management Triggering Actions

Cibola High Levee Pond will require management activities necessary to sustain the native fish community. This community is temporary, being subject to common or unique threats. These include invasion by nonnative fishes, storm events that result in fish kills, and existing habitats conditions that may not support spawning, natural recruitment or optimal productivity. In anticipation of these, the following 'triggering' conditions are specifically set in order to trigger appropriate management actions to mitigate or remedy the problem in a timely manner. All actions would require appropriate environmental compliance by FWS.

Problem	Management Action
>5% nonnative fish	Add to renovation list, initiate salvage
Poor recruitment	Initiate bullfrog, tadpole and crayfish control
Natural fish die-off	Restock w/multiple year classes
Poor body condition (stunting) (Need to set those standards, i.e., (K-0.8?)	Harvest and remove >20%

PROPOSED MONITORING

The conceptual plan for developing fish sanctuaries in the Colorado River (Minckley et al. 2003; BioScience 53:219-234) suggests that stabilizing native fish populations requires developing and/or creating habitats of sufficient physical, chemical, and biological quality. Thus the purpose of our monitoring plan is to evaluate these factors with regards to enhancing survival of all life stages of native fish. Our goal is to provide land managers with essential information for maintaining and improving the quality of High Levee as a fish sanctuary. The majority of this work has been accomplished during the past 5 years through the measurement of physical parameters. We propose a maintenance and refinement of that data set through routine monitoring and additional research.

Physical Habitat Monitoring.

1): Instantaneous in-situ measurements will be taken using a Hydrolab to measure DO, temperature, pH, conductivity, and salinity measured at 0.5-m intervals at the deepest areas of the cove. We will continue to take these measurements on all semi-annual sampling trips.

2): Water quality sampling. We will collect initial samples for major ion analysis by USBR; chlorophyll, total suspended solids; and elemental and contaminant analysis (Hg, Se, As, ClO_4). Future sampling frequency will depend on initial levels of elements of concern.

3): 24-hr sampling of DO and water temperature. We expect DO to be lowest and temperatures highest in July and August. During this time we will use three MiniSondes (at bottom, middle, and upper sections of the water column along an installed post) to continually measure these variables over a 24-hr period.

4): Long-term temperature data. We will install a water temperature recorder (e.g., Hobos) to record hourly temperatures over a 1-yr period.

Zooplankton and Macroinvertebrates

1): Zooplankton. Three vertical tows will be taken in the deepest portion of the cove of the pond each trip. Biomass will be measured by filtering through a plastic graduated cylinder. All samples will be preserved for later analysis. Phytoplankton and chlorophyll will be sampled both trips.

2): Macroinvertebrates: Concurrent with zooplankton samples, we will collect aquatic insects caught in the larval light traps. In addition, we will collect macroinvertebrates using a variety of sample techniques at 6 locations at varying depths to determine average number of organisms/m^2. Our purpose is to measure the abundance of invertebrates, not to provide a detailed description of aquatic insect diversity.

Aquatic Vegetation

1): Estimate plant abundance and composition. During the fall survey, we will identify plant species present and estimate aerial vegetation coverage. When visibility is good, transects north-south and west-east across the cove will be snorkeled, as well as a transect around the entire perimeter. We will use these transects to create a map showing extent of coverage by each plant species. If water clarity is reasonable, we will take water surface and/or underwater photographs to serve as permanent records of plant abundance.

2): Evaluate the general health of the aquatic plants within the cove. On each sampling trip we will record water level of the cove and note if it is higher or lower than normal (i.e., are plants exposed or growing at deeper depths?). Once a year we will examine plants for general health; evidence of stress; or damage by animals or disease. We will note all invasive plants; and note whether installed salt cedar bundles have sprouted (notifying NPS as necessary).

3): Monitor trace element or contaminant bioaccumulation within the vegetation. We will determine levels of elements that may pose a threat to the health of the fish or ecosystem. We will collect three specimens of each existing plant species for analysis that may include, but is not limited to, selenium, mercury, arsenic, and perchlorate. Other elements or contaminants can be added to this list if there is a cause for concern, such as pesticides, pharmaceuticals, viruses, etc.

Fish Populations

1): Are the stocked razorback and bonytail surviving or have they disappeared? Are they free of disease? Are non-natives present? We will collect population data via a snorkel survey in spring and electrofishing and/or trammel-netting in the fall. Each fish will be measured, weighed, and spawning condition evaluated. Crayfish and bullfrog presence and abundance will be estimated with minnow traps baited with canned food, set overnight.

2) If there are non-native fish, what is their relative abundance? Are the non-natives reproducing? This question can be answered from data collected above.

3): Are razorbacks and bonytail growing? This question can be answered by comparing data between samples by subsampling fish using PIT tags.

4): Are the razorback and bonytail spawning? We will set four larval light traps for 2-hr periods to determine presence of fish larvae. Larvae collected will be preserved to identify species.

5): Is there evidence of recruitment? We will look for young-of year fish during spring snorkeling surveys; and by setting minnow traps and ½ -inch trammel nets in the fall.

6): Are razorback and bonytail using the available cover and substrate? We will snorkel and/or use underwater videography in the vicinity of the brush piles and installed substrates to determine use. To determine if the installed substrate is producing larvae, larval light traps will be set directly above in the spring.

Data Handling and Reporting

Jeanette Carpenter will maintain and keep all datasets. Annual reports will be written and provided to all interested persons and agencies. The monitoring program will be reviewed on an annual basis to determine if changes to the protocol need to be made. If a significant event occurs, such as an unusual climatological, hydrological, or biological event, we may need to revise our methods and consider additional or alternative monitoring techniques or sampling dates.

IDENTIFIED RESEARCH NEEDS:

High Levee pond presents unique research opportunities that would advance the refinement of native fish sanctuaries. While out side the resources of this study, these research needs should be identified and promoted.

7. Examine the use of new PIT tag technology (134.2 kHZ) to monitor populations.
8. Identify the most efficient means of salvaging native fish. Can broadcast feeders and pop nets make salvage efforts more effective and less stressful on fish?
9. Measure the hydraulic exchange that is occurring and develop natural 'recharge' techniques to maintain water quality at other sites.
10. Examine rearing and growth parameters for bonytail.
11. Develop and test 'floating island' technology that would enhance aeration and provide solar shade.

PROPOSED SCHEDULE AND ACTIVITIES

Timing	Action	Crew#	Lead Agency	Contact
September 2005	Salvage	10	FWS/USGS	Minckley/Mueller
Spring 2006	Salvage	10	FWS/USGS	Minckley/Mueller
Spring 2006	Renovation	10	FWS/USGS	Minckley/Mueller
Summer 2006	Stocking	12	FWS	Minckley
Fall 2006	Monitoring	3	USGS/FWS	Carpenter/Minckley
Spring 2007	Monitoring	3	USGS/FWS	Carpenter/Minckley
Fall 2007	Monitoring	3	USGS/FWS	Carpenter/Minckley
Spring 2008	Monitoring	3	USGS/FWS	Carpenter/Minckley
Fall 2008	Monitoring	3	USGS/FWS	Carpenter/Minckley

Appendix C. Parker Dam Pond Management Plan

Parker Dam Pond
Draft Native Fish Management Plan

Last Modified: December 8, 2006

Prepared by:

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I. History/Background

USGS approached Bureau of Reclamation regarding the possibility of testing Minckley's Native Fish Conservation Plan (Minckley et al. 2003). The goal is to utilize the resources and expertise of the Lower Colorado River Native Fish Work Group in the development of a small scale, native fish sanctuary system. This document represents the attempt to establish a native fish community at Parker Dam Pond which lies within the land management jurisdiction of the Bureau of Reclamation.

The Native Fish Sanctuary Management Plan is a working document designed to flexible and adaptive for the sole purpose of management. This process is intended to optimize available resources and expertise, identify resource problems and needs, prioritize research needs and opportunities and how this facility may best be used to accomplish goals and objectives established in the Management Plan for the Big-River Fishes of the Lower Colorado River Basin (FWS 2004).

The existence of Parker Dam Pond was pointed out by Mitch Thorsen (FWS). The pond lies off Highway 95's approach to Parker Dam and is situated approximately 200 m southeast of the Dam. Located on the east slope of the road it sets in a small wash that has been damned by the highway.

The pond is approximately 50 m long, 15 m wide and 5 m deep. It can only be accessed by the highway by walking down a steep rock abutment a distance of 50 m. The terrain is mostly fractured granite and vegetation is limited to cattail, catclaw, mesquite and a couple of palm trees that boarder the pond shoreline. The pond is deep with relatively steep slopes. A gauging station is located on a sheer rock bluff on the northern end where to pond extends down to what appears to be a drilling hole or mine shaft. Waters have been crystal clear (>3 m visibility) and we suspect it is hydraulically connected (seepage) to Lake Havasu which only lies 300 m way. Based on relatively mild temperatures, there may be a source of geothermal water and with relative low conductivity, there must be some seepage toward the Colorado River. We have been unable to detect any flow.

Water quality appears to be excellent. The pond does support a small non-native fish community which has no recreational angling value. Largemouth bass, bluegill and possibly green sunfish have been observed in small numbers along the pond's parameter.

The site has the local name "Hippie Hole." The site is secluded and not easily seen but is apparently used by some locals as a swimming hole. Trespass is prohibited; however guards at the dam occasionally see people sneaking into the site to presumably swim. For the purposes of management its designation was changed to "Parker Dam Pond" to avoid confusion with other locations named "Hippie Hole".

II. Introduction

Native fish management at Parker Dam Pond only becomes reality when goals, objectives, and actions are identified and then translated into on-the-ground action by allocating resources. In addition, successful completion of the actions needed to achieve the goals and objectives of this Native Fish Management Plan (NFMP) will require full cooperation among AZFRO, AGFD, USBR, USGS, and others, to help identify and allocate all available resources, and complete several of the on-the-ground actions. In some cases, objectives may require refinement and evaluation from cooperating partners before specific management actions can be applied. Within this context, the following are the primary goals that if achieved, would constitute successful completion of this NFMP:

Goals: (In order of priority)

1. Develop and manage Parker Dam Pond in a manner in which the site functions as a native fish sanctuary that supports natural recruitment for one or more species.
2. Better understand the physico-chemical-biological make up of Parker Dam Pond, as it relates to the potential for long-term management as a native fish sanctuary through an active monitoring and research components.
3. Promote research and public educational opportunities.

III. Habitat Development/Native Fish Establishment

The primary purpose of this section of the NFMP is to outline the objectives and actions necessary to promote the practical and effective establishment of habitat and razorback sucker at Parker Dam Pond. The ultimate goal is to create semi-natural conditions where native fish communities could thrive and that would include natural recruitment. Those objectives can not be realized in the short-term but will be developed through time as additional action plans are developed and resources become available. This document is the instrument for advancing this goal. The primary partners for completing specific actions under each objective are identified; the logical lead for a given action is identified in **bold**.

Goal 1. Develop Parker Dam Pond into a native fish sanctuary

Objective 1. Completely remove nonnative fish to allow survival and natural recruitment for the purpose of developing a self-sustaining native fish community. Necessary actions include:

Action(s):

1.1. Provide access for research and management activities. **USBR**

1.2. Chemically renovate the pond removing unwanted fishes.

- 1.2.1. Use two separate chemical treatments to renovate the pond, first using rotenone followed by an application of antymicin a few weeks later. **AZFRO**, AGFD, USGS, USBR.

1.3. Following an appropriate period for detoxification; stock the pond with 100 adult (>12-cm) bonytail.

- 1.3.1. If available; stock some fish prior to March 1 to allow for possible spawning in 2007.

1.4. Acquire and maintain the necessary chemical permits (piscicide) for future treatment as needed **AZFRO,** AGFD

Goal 2: Promote research and public educational opportunities.

Objective 1. Promote research or special projects opportunities with locate high schools, colleges, universities and special interest groups (i.e., Boy Scouts).

Action(s):

1.1. Identify the site as a refuge research station**. AZFRO,** AGFD, USBR, USGS

1.2. Share research needs with outside agencies and institutions. **AZFRO, AGFD, USBR, USGS**

1.3. Develop an outreach program with local high schools and colleges for volunteer help. **AZFRO**, AGFD, USBR, USGS

Objective 2. Promote public education and awareness of the plight of native fishes and programs that are designed for their recovery.

Action(s):

2.1. Develop refuge interpretive signing. **AZFRO, AGFD, USBR, USGS**

2.2. Develop sanctuary brochures. **AZFRO**, **AGFD, USBR, USGS**

2.3. Develop refuge interpretive programs and walks. **AZFRO, AGFD**, USBR, USGS

2.4. Develop local school interpretive programs and projects. **AZFRO, AGFD,** USBR, USGS

IV. Monitoring and Assessment Program

The conceptual plan for developing fish sanctuaries in the Colorado River (Minckley et al. 2003; BioScience 53:219-234) suggests that stabilizing native fish populations requires developing and/or creating habitats of sufficient physical, chemical, and biological quality. Thus the purpose of our monitoring plan is to evaluate these factors with regards to enhancing survival of all life stages of native fish. Our goal is to provide essential information for maintaining and improving the quality of Parker Dam Pond as a fish sanctuary. Team members need to examine if these activities could be covered under existing state and federal resource agency collecting and handling permits to reduce paperwork.

Goal 1:

Objective 1: Monitor physical and water quality conditions.

Actions(s):

1.1. Monitor standard water quality parameters at one or more locations in the habitat. Information will be taken at a minimum of 1 m depths from the ponds surface to its bottom. Data will include but not be limited to: dissolved oxygen, pH, conductivity and temperature. Vertical collections of plankton will quantify zoo- and phyto plankton in terms of species and densities. An general census of the macrophyte community will be conducted at the beginning of the project and repeated when necessary. **USGS, AZFRO,** AGFD,

1.2. If conditions are detected that restricts or limits water quality goals; then it may be necessary to expand monitoring effort and the parameters being examined. That determination will be made as problems arise. **AZFRO USGS,** AGFD.

1.3. Develop recommendations or options to mitigate those problems. **AZFRO,** USGS AGFD.

Objective 2. Monitor the fishery community.

Action(s):

2.1. Sample fish community utilizing sampling techniques that collect all life stages. These techniques will include but not be limited to: seines, minnow traps, hoop nets, trammel nets, and electrofishing. **AZFRO,** AGFD, USBR, USGS

2.1.1. At minimum, collect data pertaining to individual fish species, length (TL-mm), weight (g-1.), sex (if possible) and general health. **AZFRO,** AGFD, USBR, USGS

2.2. PIT tag fish >15-cm for growth analysis. **AZFRO,** AGFD, USBR, USGS

2.3. Calculate CPUE, mean length, mean weight, relative conditions (*Kn*), and length frequency histograms**. - AZFRO**

2.4. Bonytail >30-cm will be considered "surplus" and can be used to establish new sanctuaries or be stocked into Lake Havasu or other waters as needed. Fish stocked outside the sanctuary will be PIT tagged and the appropriate information provided to ASU and FWS for their respective data bases. **AZFRO,** AGFD, USBR, USGS

Objective 3. Reporting and Maintenance of Data Bases.

Action(s):

1.1 Annual reports will be developed as deemed important or necessary and circulated to participating agencies and parties and provided to others upon request. Maintain all dataset and records. **USGS** (2007, 2008) **AZFRO, (**there after).

2.2 Maintains data sets and provides information to other agencies upon request. **USGS** (2007, 2008) **AZFRO, (**there after).

V. Research Opportunities

The primary purpose of this section of the NFMP is to outline the objectives and actions necessary to promote practical and effective short-term (1-3 years) research into the physico-chemical components of Parker Dam Pond to allow for a better understanding of why survival, growth, and possible reproduction of bonytail is possible, or why not. The primary partners for completing specific actions under each objective are identified; the logical lead for a given action is identified in **bold**.

Objective 1: Utilize and promote research opportunities to advance our understanding of the ecology of these fish and test and refine management approaches to best utilize funding, wildlife and human resources.

Action(s):

1.1: Develop proposals/studies to examine methods of more effective fish harvest by reducing costs and minimizing actions associated with fish stress and trauma. (Proposal to be developed.)

1.2: Develop studies to determine the range of materials (i.e., substrates) and conditions used by bonytail to spawn. (Designs and proposals to be developed).

1.3 Develop other research proposal as management needs or research opportunities arise.

VI. Management And Linkages

The goal is to develop a successful native fish community and have it incorporated into the FWS's management program. The development of multiple native fish facilities will provide managers the necessary flexibility to acquire brood stock, provide locations for salvaged or surplus fish and be used to expand our management expertise on these unique species. Management approaches will be influenced by fish supply, their body size and genetic origin, the success of the facility, stocking demands and of course; surpluses. The ultimate goal is to develop Parker Dam Pond into a native fish sanctuary that supports natural recruitment and sustains native fish communities. Secondary goals would include the grow-out of brood stock or produce fish for research or other habitats.

Objective 1. Develop an analysis to determine the carrying capacity of the habitat in terms of species, numbers and biomass.

Actions:

1.1. Document the number and biomass of all fishes recovered during renovation efforts. This would include the actual collection, enumeration, and weighing off all fish and snorkel surveys and associated estimates of fish not collected. **AZFRO,** AGFD, USBR, USGS.

Objective 2. Develop a native fish community to be used as a repository for salvaged fish, a source of fish for other sanctuaries or for release in the mainstem river.

Actions:

2.1 Parker Dam Pond can be used as a repository for bonytail salvaged from other facilities as long as the number and duration does not exceed the carrying capacity of the system. **AZFRO,** AGFD, USBR, USGS

2.2 Surplus fish will be used for the following purpose, listed in order of priority: 1. to stock new habitats, 2. recently renovated habitats, 3. for research purposes and 4. to be released in adjacent waters (i.e., river, drain outfall). Definition of a surplus bonytail is a fish >30-cm or a fish of any size if over population and stunting is detected. **AZFRO,** AGFD, USBR, USGS

Objective 3. Develop and refine as needed a genetics management protocol that best diversifies the genetics of each species.

Action:

3.1 Populations exhibiting natural recruitment will have 10% of their population (up to 100 individuals >15-cm) replaced with fish from another source every five years. The source of these fish can include any source, including natural recruitment from holding facilities at hatcheries. **AZFRO**.

VII. Tentative Schedule For 2007 and 2008.

2007

January Renovate Parker Dam Pond with one treatment of rotenone followed by a treatment of antimycin. **AZFRO**, USGS. (Chuck and Gordon)

February Stock with a few dozen bonytail prior to spawning. **AZFRO**, USGS (Chuck and Gordon)

May Stock with 100 bonytail. **AZFRO**, USGS (Chuck and Gordon)

November Annual monitoring trip **USGS, AZFRO, AGFD**, USBR (Jeanette-lead)

2008

November Annual monitoring trip **USGS, AZFRO, AGFD**, USBR (Jeanette-lead)

VIII. Projected Needs

LaUSBR: All volunteer USGS, USBR, AGFD, AZFRO. No additional needs anticipated.

Permits: Renovation covered by AZFRO, no others needed.

Equipment: All equipment and chemicals already available**.**

Fish: Surplus bonytail are available from Achii Hanyo, stocking will be done by AZFRO and USGS.

Remarks: No outside or special funding needs are anticipated. Everything necessary to establish native fish sanctuary is being donated by partner agencies.

IX. Literature Cited

Minckley, W.L., P.C. Marsh, J.E. Deacon, T.E. Dowling, P.W. Hedrick, W.J. Matthews, and G. Mueller. 2003. A conservation Plan for native fishes of the lower Colorado River. BioScience 53(3): 219-234.

U.S. Fish and Wildlife Service. 2004. Management Plan for the Big-River Fishes of the Lower Colorado River Basin: amendment and supplement to the Bonytail, Humpback chub, Colorado pikeminnow, and Razorback sucker Recovery Plans. Southwest Region (2), Albuquerque, New Mexico. 52 p.

Appendix D. Three Fingers Lake Management Plan

Cibola National Wildlife Refuge
Three Fingers Lake
Fish Management Plan
2007-2010

Purpose:
The purpose of this project is to work cooperatively with the Cibola National Wildlife Refuge, California Department of Fish and Game, U.S. Fish and Wildlife Service, the Bureau of Reclamation, U.S. Geological Survey and others to develop Three Fingers Lake into a balanced recreational and native fishery. We hope that Three Fingers Lake can become a model where traditional recreational fishing interests are congruent with native fish needs. This document is intended to be a supplement to the existing 1994 Environmental Assessment.

Background
Three Fingers Lake is an historic oxbow of the lower Colorado River located on the Cibola National Wildlife Refuge (CNWR), on the California side, just north of Walter's Camp. Three-Fingers Lake is a naturally occurring water body in the floodplain of the Colorado River downstream from its confluence with Milpitas Wash. When the Bureau of Reclamation dredged and channelized the Colorado River, Cibola Division, in the1960s the water surface in Three-Fingers Lake dropped, functionally dewatering the lake. Three-Fingers Lake now lies at the lower end of a cutoff section of the main Colorado River channel and water backs up into the area. As such the water surface elevation is controlled from the downstream end rather than from upstream, as had been the case before the construction of the Cibola Drycut as part of the dredging and channelization.

In the early 1980s Tom Grahl of USFWS AESFO reviewed the records and produced the "Cibola Followup Report," a review of the mitigation for the original channelization project and outstanding needs. Restoration of Three-Fingers Lake was included as a recommendation in that report. In response to this report, the Bureau of Reclamation asked interested parties to participate in a committee of the Lower Colorado River Management Program Workgroup to make recommendations for the restoration of Three-Fingers Lake. The Committee was chaired by Wes Martin, Refuge Manager Cibola NWR. The Workgroup includes all interested agencies along the lower Colorado River and was originally established as a working body of the Lower Colorado River Coordinating Committee, which was heads of agencies affected by river management activities (an outgrowth of tension during the dredging and channelization period.)

Planning for restoration of Three-Fingers Lake was slow to start. Eventually the Bureau asked the Backwater Committee of the Workgroup, chaired by Bill Werner, to take over the task of planning restoration. Subsequently the Cibola Refuge developed plans which included dredging to deepen the lake, a water control structure and pump to enable increasing the water surface elevation to create marsh and riparian woodland zones, and an isolated section of channel to be managed for native fish. Reclamation completed an Environmental Assessment (Department of the Interior, 1994) on the plan. The dredge was launched at Walter's Camp and worked inland from the Old River Channel. Since worker and supply access to the dredge is by boat, a boatable waterway was maintained during the construction period. There was a delay in construction of the sheet pile and rock barrier blocking off the dredged access channel from the Old River Channel. It was necessary to block of the recently dredged channel in order to control the water surface at an elevation higher than the Old River Channel (otherwise the water would just run out).

The rock and sheet pile barrier was installed and a pump installed. Again there was a delay, this time because of negotiations for electrical power at the report site. Once power was established pumping began. In general there was not great success in increasing the water surface elevation, apparently because of leakage through the barrier at the dredged channel.

During the course of construction anglers had boat access into Three-Fingers Lake from the Old River Channel, which is itself open to the main Colorado Rover channel at Walter's Camp. During this time, the lake became a popular destination for bass anglers. Angler interests probably include both those who remember Three-Fingers Lake as it was prior to channelization of the Colorado River and believe there is a debt owed. The Palo Verde Rod and Gun Club, based in Palo Verde California, have been concerned about the condition of the river over the years. Another group is the younger anglers who took advantage of access during the construction period.

In 2003, biologists from Arizona State University surveyed Three Fingers Lake and reported that it contained a typical representation on nonnative fishes, and that no native fishes were found. A similar sampling trip conducted by ASU in 2005 resulted in no fish being captured, although mosquitofish were observed, suggesting that Three Fingers Lake may have experienced a fish kill. Three Fingers Lake was sampled via electrofishing during the summer of 2006 by AZFRO, the California Department of Fish and Game (CDFG), and USBR and no fish were collected further suggesting this. Site visits at Three Fingers Lake by the U.S. Geological Survey (USGS) in September 2005 and January 2006 were also conducted, at which time cursory physical and chemical measurements were taken. Mid-channel depths of Three Fingers Lake averaged 5 to 10 feet, water conductivity ranged around 1200 Uohm/cm, and the channel was heavily infested with coontail (*Ceratophyllum demersum)*. Based on these initial findings, it is suspected that the high biomass of coontail and its seasonal respiration and decomposition, and high ambient temperatures resulted in anoxic conditions that limit fish survival.

On 20 March 2006 biologists from USGS, CNWR, and AZFRO met to discuss potential native fish management options for Three Fingers Lake. The two primary management options identified during this meeting were Management Option 1) a repository for large ($\geq$30 cm TL) razorback suckers, allowing for continued survival and growth ("grow out") before being returned to the wild at a larger size ($\geq$ 45 cm TL) or used for establishing future "populations" in other native fish habitats. Management Option 2) was to develop Three Fingers Lake into a series of native fish sanctuary habitats allowing for the possible development of a multi-species (bonytail and razorback sucker) populations and their management. During this meeting, it was decided that in the short-term (1-3 years), efforts should be focused on meeting Management Option 1 and develop Three Fingers Lake into a grow-out habitat for large razorback suckers, striving for continued survival, growth, and possible reproduction/recruitment. However, it was also decided that planning for the implementation of the longer-term ($\geq$ 3 years) Management Option 2, a native fish sanctuary allowing for the development of a recruiting population would also begin and continue simultaneously with efforts to accomplish Management Option 1. A Management Plan for developing Three Fingers Lake into a native fish sanctuary will follow in a separate document. Lastly, the need for research into the quantification of the physico-chemical features of Three Fingers Lake that allow for, or don't allow for, successful implementation of either management options was also identified.

While the March 2006 meeting was effective in determining goals and objectives for Three Fingers Lake, it unfortunately failed to recognize some of the other important uses of Three Fingers Lake such as its historical value as a recreational fishery. In response to concern over managing Three Fingers Lake solely as a native fishery, agency representatives from U.S. Fish and Wildlife Service, California Fish and Game, Cibola National Wildlife Refuge and the Bureau of Reclamation met in June 2007 to discuss compromise and how, using a collaUSBRative approach, we might develop more all inclusive goals for Three Fingers Lake.

Goals and Objectives

Native and nonnative fish management at Three Fingers Lake only becomes reality when goals, objectives, and actions are identified and then translated into on-the-ground action by allocating resources. In addition, successful completion of the actions needed to achieve the goals and objectives of this Fish Management Plan (NFMP) will require full cooperation among CNWR, CDFG, USFWS, USBR, USGS, and others, to help identify and allocate available resources, and complete the on-the-ground actions. In some cases, objectives may require refinement and evaluation from cooperating partners before specific management actions can be applied. Within this context, the following are the primary goals that if achieved, would constitute successful completion of this fish management plan.

Goals:

1. Address access and law enforcement issues
2. Develop a timeline for long-term maintenance and implementation

Goal 1: Develop small (less than 10 acres) areas of Three Fingers Lake into a grow-out areas for large ($\geq$ 30 cm TL) razorback sucker

Objective 1: By the end of May 2007, reduce the amount of coontail in Three Fingers Lake by at least 0.5 miles

1. Acquire Pesticide Use Permit (PUP) for the use of the Sonar
2. Calculate area of coontail to be treated and treat the north and south ends of Three Fingers Lake (0.25mi/location)
3. Monitor water quality in each location before application, 5 days and 10 days post application
4. Analyze samples

Objective 2: Implement a water quality Program in Three Fingers Lake

1. Record water quality parameters (pH, dissolved, oxygen, temperature hourly
2. Acquire at least 2 datasondes and deploy 1 in each location near the bottom

Objective 3: Using one of the semi-isolated "arms" in Three Fingers Lake, develop into a native fish growout area

1.
2. Ensure water quality is still supportive of fish
3. Complete necessary compliance paperwork, pesticide use proposal
4. Following salvage operations, use rotenone/antimycin to remove nonnative fishes
5. Stock approximately 500 (250-300mm) subadult razorback suckers per acre

Objective 4: Implement a monitoring program that tracks abundance, survival, growth, relative condition within native fish habitats in Three Fingers Lake

1. Conduct fishery surveys using hoop, trammel
2. nets, and electrofishing
3. Calculate CPUE, mean lengths and weights, relative condition (*Kn*)
4. Generate length frequency histogram to determine if recruitment is occurring
5. Produce summary reports containing finds and recommendations
6. Harvest fish greater than 400mm for stocking into the river

Goal 2. Develop open water areas of Three Fingers Lake for recreational fishing

Objective 1: Re-open the North access berm for recreational fishing access

1. Using existing hydrologic studies to determine how much of the berm and where it should be removed to facilitate water movement through Three Fingers Lake
2. Monitor water quality pre and post berm removal in conjunction with Goal #1
3. Install stop log structure when necessary to keep larger boats out of Three Fingers Lake

Objective 2: Create public access points near southwest corner to encourage fishing

Objective 3: Implement a monitoring program that tracks abundance, survival, growth, relative condition of sportfish within Three Fingers Lake.

1. Conduct fishery surveys using hoop, gill nets, and electrofishing
2. Calculate CPUE, mean lengths and weights, relative condition (*Kn*)
3. Generate length frequency histogram to determine if recruitment is occurring

4. Produce summary reports containing finds and recommendations
5. Implement creel surveys to gage angler satisfaction

Goal 3. Address access issues and improve law enforcement

Objective 1: Address access issues

1. Catalog existing wildcat roads around Three Fingers Lake
2. Determine which roads should remain and which should be closed
3. Reclaim wildcat roads and install barriers to re-establishment

Objective 2: Improve Law Enforcement

1. Develop a needs assessment of when and where law enforcement is needed for Three Fingers Lake and on the Cibola National Wildlife Refuge
2. Develop a region-wide cooperative law enforcement exchange to take advantage of officer time from other agencies

Goal 4. Develop a timeline for long-term maintenance and implementation

***Need to add here or elsewhere monitoring for Giant *Salvinia* and how to prevent invasion