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Natural Resource Stewardship and Science

Humpback Chub Translocation to Havasu Creek, Grand Canyon National Park

Implementation and Monitoring Plan

Natural Resource Report NPS/GRCA/NRR—2012/586

ON THE COVER
Mini hoop netting in Havasu Creek, Grand Canyon National Park
Photograph by: Amy Martin, Grand Canyon National Park

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Executive Summary

Humpback chub is an endangered species endemic to the Colorado River.   Translocation of humpback chub into Grand Canyon tributaries has been identified as a tool for mitigating impacts of dam operations and providing population redundancy in the lower Colorado River basin. Havasu Creek is one of the larger tributaries to the Colorado River in Grand Canyon National Park, and the one most similar to the Little Colorado River in hydrology, habitat, and water chemistry. It is one of several tributaries evaluated by Valdez et al. (2000) for the potential to establish a second humpback chub (*Gila cypha*) population in Grand Canyon, to provide population redundancy in the case of catastrophic failure of the Little Colorado River aggregation. Havasu Creek's potential to support a second spawning aggregation of humpback chub was ranked highest of the tributaries evaluated (Valdez et al. 2000). Translocations of humpback chub were the recommended method for attempting to establish a second population of humpback chub in the Grand Canyon. This monitoring plan establishes a release schedule and monitoring methods to be used for the first three years of this study. Monitoring methods will be evaluated annually and refined as needed. Additional experimentation with passive integrated transponder (PIT) tag scanning techniques will be explored to improve remote sensing capabilities and maximize 'captures' of tagged fish. Carrying capacity estimations will be refined and translocation release numbers may be adjusted accordingly. Havasu Creek will be evaluated to determine the best use of this tributary as a translocation site. Potential outcomes include use as a grow-out area, augmentation of the local aggregation, a refuge, and ideally, a second spawning population in Havasu Creek. Criteria for success for this translocation effort will be established and evaluated in the final report. Criteria may include (a) retention of translocated humpback chub for a minimum of one year, (b) similar or increased survival of juveniles relative to mainstem, (c) similar or increased growth rates relative to the Little Colorado River and mainstem, (d) contributions to the mainstem aggregation, (e) evidence of successful reproduction, (f) measureable numbers of young, and (g) evidence of recruitment.

Introduction

Background

The humpback chub is a moderately large (450 mm) fish species in the minnow family (Cyprinidae) and is endemic to the Colorado River. Its current and historic distribution is limited to canyon bound reaches of the mainstem Colorado River and some of the larger tributaries. The humpback chub was first described in 1946 from a specimen captured in the Grand Canyon near Bright Angel Creek as well as other specimens (Miller 1946) and was included in the first list of endangered species in 1967. It is currently protected under the Endangered Species Act (ESA) of 1973 as amended (16 U.S.C. 1531 *et. seq*). There are six recognized populations of humpback chub, the largest of which is in Grand Canyon National Park. Alterations in the physical and biological characteristics of the Colorado River system by water development projects, introductions of nonnative fishes and other human activities are primarily responsible for the decline of the humpback chub. Other factors, including parasitism, hybridization, pesticides and pollutants are considered to have contributed to the decline as well (United States Fish and Wildlife Service (USFWS 2002). Translocation of humpback chub into Grand Canyon tributaries has been identified as a tool for mitigating impacts of dam operations and providing population redundancy in the lower Colorado River basin.

Havasu Creek is one of the larger tributaries to the Colorado River in Grand Canyon National Park, and the one most similar to the Little Colorado River in hydrology, habitat, and water chemistry. It is one of several tributaries evaluated by Valdez et al. (2000) for the potential to establish a second humpback chub (*Gila cypha*) population in Grand Canyon, to provide population redundancy in the case of catastrophic failure of the Little Colorado River aggregation. Havasu Creek's potential to support a spawning aggregation of humpback chub was ranked highest of the tributaries evaluated (Valdez et al. 2000). Translocations of humpback chub were the recommended method for attempting to establish a second population of humpback chub in the Grand Canyon. Humpback chub translocations were included as a Conservation Measure in the 2008 Biological Opinion on operation of Glen Canyon Dam (USFWS 2008), and as such are being funded by the Bureau of Reclamation (BOR) through the National Park Service (NPS; Healy 2009). The NPS is preparing a Native Fish Restoration Plan (draft) which considers translocations as part of proposed restoration efforts.

Tributary translocations can provide grow-out habitats for young humpback chub that can subsequently disperse to the mainstream and augment the existing aggregations of humpback chub (Valdez and Ryel 1995). Also, translocations contribute to restoration of native fish communities per the National Park Service mandate, potentially result in range expansion, and may provide additional fish for further translocation to other tributaries or to *ex situ* refuge populations or hatcheries.

Three tributaries were identified for potential initial translocations in Valdez et al. (2000), including Havasu Creek, Shinumo Creek, and Bright Angel Creek. Delays in permitting in Havasu Creek, and high densities of non-native predators in Bright Angel Creek resulted in Shinumo Creek being chosen for the initial translocation effort. In Shinumo Creek, rated second highest in Valdez et al. (2000), translocations began in 2009 (Healy et al. 2011). Humpback chub translocated into Shinumo Creek have remained in the creek for two and a half years to date, and have shown growth rates similar to or higher than those seen in the Little Colorado River and at

Dexter National Fish Hatchery and Technology Center (NPS/ University of Missouri unpublished data, Healy et al. 2011). Approximately 50% of the 902 humpback chub translocated in 2009, 2010, and 2011 were recorded by the remote antenna as having moved out of the creek into the mainstem Colorado River (NPS/ University of Missouri unpublished data). Translocated humpback chub that left the creek were recaptured in the Colorado River near the mouth of Shinumo Creek in 2010 and 2011 (Randy VanHaverbeke, USFWS, personal comm.) in the reach designated as the 'Shinumo Creek aggregation' by Valdez and Ryel (1995). No spawning of humpback chub in Shinumo Creek has been detected yet, although some of the translocated fish were just reaching maturity in 2011.

Although Havasu Creek was rated higher than Shinumo Creek in terms of habitat suitability and potential to support humpback chub, implementation was delayed due to jurisdictional concerns. The Havasupai, a Traditionally Associated Tribe and landowners of Havasu Creek above the NPS boundary at Beaver Falls (approximately 6 km above the confluence with the Colorado River), gave their consent for translocations of humpback chub into Havasu Creek on NPS lands in 2009. The first of three annual translocations began in June 2011.

Compliance

Section 106, National Historic Preservation Act (NHPA) – NPS received verbal correspondence from the Havasupai Tribe, via U.S. Fish and Wildlife Service (USFWS) tribal liaison on September 3, 2009, that the Tribal Council had decided the NPS and USFWS did not need to consult with the Tribe on translocations of humpback chub to Havasu Creek waters administered by the NPS because Beaver Falls would be considered a barrier to upstream movement (i.e. humpback chub could not move upstream onto Havasupai Tribal Lands).

Endangered Species Act (ESA) – This project is being implemented as a result of BOR's commitment under the 2008 Biological Opinion (USFWS 2008); thus, no additional ESA consultation is required. An ESA Section 10 (recovery) permit is held by Grand Canyon National Park permitting the project (Permit Number TE819473-2).

National Environmental Policy Act (NEPA)– The Grand Canyon National Park Office of Planning and Compliance (OPAC) has reviewed this project and completed its environmental review documentation. They determined that there:

1. Will not be any adverse effect on threatened, endangered, or rare species and/or their critical habitat;
2. Will not be any adverse effect on historical, cultural, or archaeological resources; and
3. Will not be serious or long-term undesirable environmental or visual effects.

The project was cleared for all NHPA, ESA, and NEPA compliance requirements as long as mitigation measures are followed (see NPS 2010, Bennett 2011).

Goal and Tasks

The goal of this project is to conduct humpback chub translocations into Havasu Creek. NPS is considering the inclusion of translocations in its Native Fish Restoration Plan (draft), and the

BOR has a commitment under the 2008 Biological Opinion (USFWS 2008) to establish population redundancy of humpback chub in tributary refuges in Grand Canyon National Park:

> *In coordination with other Department of the Interior (DOI) AMP [Adaptive Management Work group] participants and through the AMP, Reclamation will assist NPS and the AMP in funding and implementation of translocation of humpback chub into tributaries of the Colorado River in Marble and Grand canyons. Nonnative control in these tributaries will be an essential precursor to translocation, so Reclamation will help fund control of both cold and warm-water nonnative fish in tributaries, as well as efforts to translocate humpback chub into these tributaries. Havasu, Shinumo, and Bright Angel creeks will initially be targeted for translocation, although other tributaries may be considered. Reclamation will work with FWS, NPS and other cooperators to develop translocation plans for each of these streams, utilizing existing information available such as SWCA and Grand Canyon Wildlands (2006) and Valdez et al. (2000a). These plans will consider and utilize genetic assessments (Douglas and Douglas 2007, Keeler-Foster in prep.), identify legal requirements and jurisdictional issues, methods, and assess needs for nonnative control, monitoring and other logistics, as well as an implementation schedule, funding sources, and permitting.*

Tasks

1. Conduct Baseline Surveys
    a. Determine fish community composition, distribution, and relative abundance
    b. Collect water quality, macroinvertebrate, and food web data to augment existing knowledge of baseline conditions.
2. Collect, hold, treat, and tag humpback chub for the purpose of translocations into Havasu Creek
    a. Capture humpback chub from the Little Colorado River to fulfill translocation and refuge needs (addressed in the Translocation Framework [USFWS and NPS, in prep.])
    b. Transport humpback chub from the Little Colorado River to holding facilities (e.g. Dexter National Fish Hatchery and Technology Center)
    c. Hold humpback chub in the refuge facility overwinter until large enough to mark with passive integrated transponder (PIT) tags
    d. Treat humpback chub for parasites and diseases
    e. Tag each fish with 134.2 kHz PIT tag

3. Translocate humpback chub into Havasu Creek
    a. Transfer humpback chub to stock truck, transport to Grand Canyon heli-base
    b. Transfer fish to aerated coolers and load into NPS helicopter
    c. Transport fish to the rim of Havasu Creek on NPS lands
    d. Transfer coolers to a ‘sling load’ and transport to base of Beaver Falls on NPS lands
    e. Temper fish to local water temperature and chemistry
    f. Release fish below Beaver Falls on NPS lands

4. Monitor translocated humpback chub and fish community in Havasu Creek and the nearby Colorado River mainstem
    a. Survey Havasu Creek twice annually (spring and fall)

b. Survey the mainstem Colorado River annually
c. Remove non-native fish captured during surveys

5. Determine the effectiveness of translocations
    a. Determine retention, growth, and survival rates of translocated humpback chub in Havasu Creek
    b. Determine if spawning occurs
    c. Determine if recruitment of spawned fish occurs
    d. Determine contribution of translocated fish to mainstem aggregation

6. Recommend further research and management actions
    a. Determine criteria for success for each potential outcome (e.g. grow out, refuge, second spawning aggregation)
    b. Determine best use of Havasu Creek as a translocation site

Study Area

Havasu Creek enters the Colorado River in Grand Canyon at River Mile 157, after originating at Havasu Spring approximately 16 miles upstream. The upper portion of the creek lies within the Havasupai Reservation and flows through the tribal village of Supai before flowing over several large waterfalls ending with Beaver Falls, the last significant barrier to fish movement until near the mouth of the creek. The lower 3.5 miles (5.6 km) below Beaver Falls lie within Grand Canyon National Park, and were identified by Valdez and others (2000) as being suitable for translocations of humpback chub (Figure 1). The lower 3.5 miles were divided into three study reaches, roughly equal in length. Reach length was based on the area a crew of 6 could sample in one day, and the distribution of pool habitat which was determined by visual observation. A series of smaller falls near the mouth of the creek have been considered to be barriers to fish movement; however, recent captures of non-translocated humpback chub in Havasu Creek below Beaver Falls suggests they are not complete barriers (Omana Smith et al. 2011).

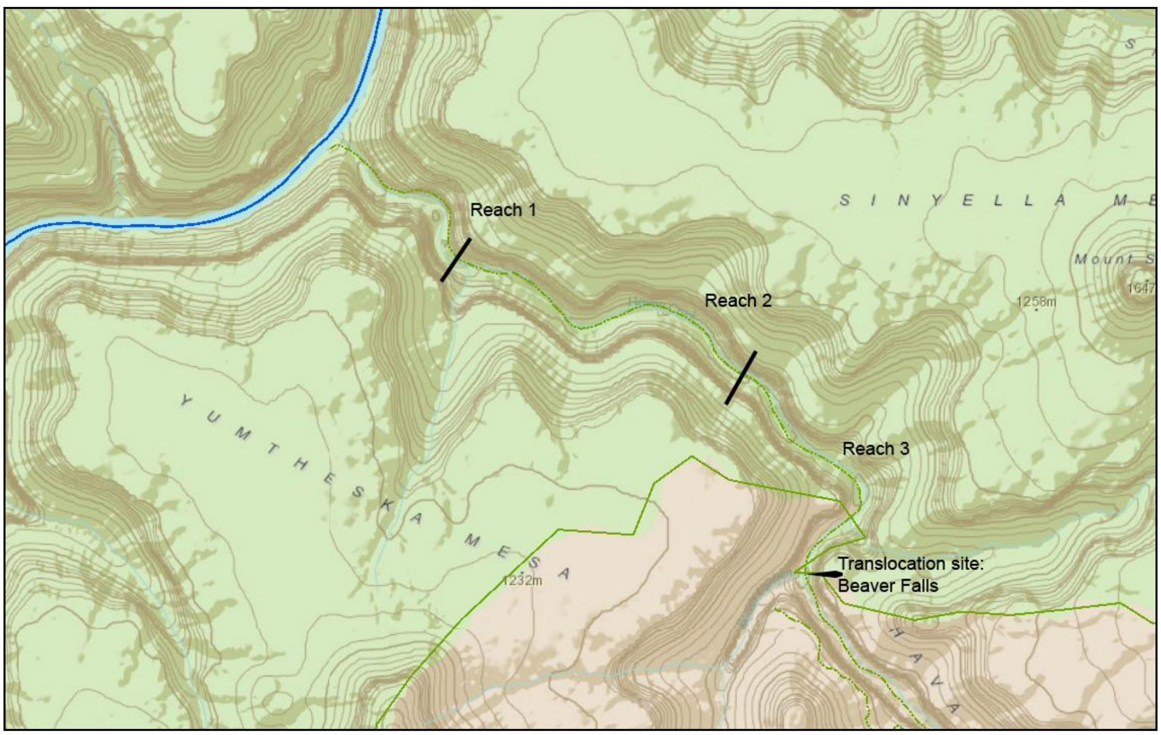

Figure 1. Map of study area in Havasu Creek, including reach delineations used for sampling. Reach locations are approximate. Areas in green represent Grand Canyon National Park.

Valdez and others (2000) identified Havasu Creek as the most favorable site for translocations among Grand Canyon tributaries evaluated, because it is most similar to the Little Colorado River in hydrology, geomorphology, and some water quality parameters, notably ionic composition (Gorman 1994, Kubly and Cole 1979). Havasu Creek has many deep pools, runs, and riffles. Water temperatures average 17.0°C, and range from 9.7 to 26.2°C (Voichick and Wright 2007). The preferred spawning, hatching, and growth temperatures of humpback chub are between 16-22°C (Hamman 1982). These temperatures occur in Havasu Creek at appropriate seasonal times; thus, Havasu Creek is ideal for spawning and growth of humpback chub. Average flows in Havasu Creek are very stable, between 59.3 - 74.5 cubic feet per second (cfs), with an average of 63.8 cubic feet per second, with the exception of monsoonal flooding which can produce flows as high as several thousand cubic feet per second. The Little Colorado River experiences similar monsoonal flooding, as well as spring snowmelt flooding. Base flows in Havasu Creek are greater than most Colorado River tributaries in Grand Canyon and are about 25-33% of those in the Little Colorado River. Water chemistry is also similar, with both tributaries being largely spring-driven and having significant calcium carbonate input and associated precipitates, along with sodium chloride, sulfates, and other constituents.

Valdez and others (2000) estimated carrying capacity of Havasu Creek and Shinumo Creek on the basis of existing densities of fish in the Little Colorado River and a comparison of stream flow and linear distance. The density of humpback chub in the Little Colorado River in 2000 was estimated to be 303 adults per kilometer. Since that time, estimates of adult humpback chub in the Little Colorado River have increased (Coggins and Walters 2009, USGS 2007), thus carrying capacity of the Little Colorado River may be larger than assumed in Valdez et al. (2000). The authors assumed that average streamflow is directly proportional to habitat availability; thus, based upon the 2000 estimate, they estimated Havasu Creek (approximately 25.5% of Little Colorado River base flow) could support about 77 adults per kilometer (Valdez et al. 2000). Using this estimate, the total estimated carrying capacity below Beaver Falls in Havasu Creek would be 462 adult humpback chub. In comparison, the numbers of fish that Shinumo Creek (approximately 3.6% of Little Colorado River base flow) could be expected to support would be about 11 adults per kilometer, or 110 adults in the 10 kilometer reach above Shinumo Falls (near the mouth). These numbers fall below the recommended establishment of 1000 adult fish in the translocation sites to maintain genetic integrity (Keeler-Foster and Wilson 2010). However, in addition to being a potentially low estimate based on Little Colorado River densities, their carrying capacity estimate did not take into account the removal of non-native fish in the translocation tributaries which could open additional capacity for humpback chub. Furthermore, differences in the existing food base (Table 1) and fish community composition in each tributary compared to the Little Colorado River (Table 2) were not considered. Analyses of Surber samples taken in Havasu and Shinumo creeks in February 2011 and Bright Angel Creek in January 2011 show that Shinumo has about 10 times, and Bright Angel Creek has about 26 times the density of aquatic macroinvertebrates of Havasu Creek (Table 1, NPS/ University of Missouri unpublished data). In a comparison of annual and monthly macroinvertebrate biomass among ten tributaries in Grand Canyon, Oberlin et al. (1999) characterized the Little Colorado River and Havasu Creek as similar, and among those with the lowest macroinvertebrate biomass while Bright Angel Creek had the highest biomass. They did not sample Shinumo Creek. Given the differences in macroinvertebrate biomass and the nonnative removal efforts, both Havasu and Shinumo Creeks might be able to support more fish per linear habitat area than originally estimated by Valdez and others (2000). Additional evaluations of stream carrying capacity are needed for both Havasu and Shinumo creeks, and potentially Bright Angel Creek as well.

Table 1. Total aquatic macro-invertebrate counts in Shinumo, Havasu and Bright Angel creeks, December 2009, February 2010, and January 2011 (NPS/University of Missouri, unpublished data). EPT includes major taxa of Ephemeroptera, Plecoptera, and Trichoptera.

	Shinumo	**Havasu**	**Bright Angel**
	Dec-09	**Feb-10**	**Jan-11**
Total Ind./m2	3977	366	9729
Total EPT (Ind./m2)	1668	280	3440
% EPT	42	76	35
Richness	17	11	26

Table 2. Number of each species captured and species composition during tributary sampling (Little Colorado River- hoop nets, Shinumo Creek - multi-gear, Havasu Creek- hoop nets, Bright Angel Creek- backpack electrofishing) and Colorado River mainstem sampling (boat electrofishing) on recent representative trips. Little Colorado River data adapted from Ward and Persons (2007); Shinumo Creek data adapted from Healy et al. (2011); Havasu Creek data adapted from Sponholtz et al. (2011); Bright Angel Creek data adapted from Omana Smith et al. (2012), Colorado Mainstem data adapted from Makinster et al. (2011).

Species - Number of Fish Captured

	Native				**Nonnative**							
Tributary Data	**BHS**	**FMS**	**HBC**	**SPD**	**BBH**	**BNT**	**CCF**	**CRP**	**FHM**	**PKF**	**RBT**	**RSH**
LCR - lower 1200 m (AGFD Spring 2006)	395	483	587	3,173	12	0	13	19	1,286	9	1	44
Shinumo (NPS SEP 2011)	217	1*	234	6,529	0	1*	0	0	0	0	364	0
Havasu (NPS OCT 2011)	106	0	109	236	0	0	0	0	0	0	28	0
Bright Angel (NPS 2012)	87	0	0	3,199	0	120	0	0	0	0	87	0
Colorado mainstem (AGFD Summer 2009)	112	1,062	11	720	1	177	4	88	108	0	1,737	240

Species - Percent Composition

	Native				**Nonnative**							
Tributary Data	**BHS**	**FMS**	**HBC**	**SPD**	**BBH**	**BNT**	**CCF**	**CRP**	**FHM**	**PKF**	**RBT**	**RSH**
LCR - lower 1200 m (AGFD Spring 2006)	6.6	8.0	9.8	52.7	0.2	0.0	0.2	0.3	21.4	0.2	0.0	0.7
Shinumo (NPS SEP 2011)	3.0	0.01*	3.2	88.9	0	0.01*	0	0	0	0	5.0	0
Havasu (NPS OCT 2011)	22.1	0	22.8	49.3	0	0	0	0	0	0	5.8	0
Bright Angel (NPS 2012)	2.5	0	0	91.6	0	3.4	0	0	0	0	2.5	0
Colorado mainstem (AGFD Summer 2009)	2.6	24.9	0.3	16.9	0.0	4.2	0.1	2.1	2.5	0.0	40.8	5.6

Species Codes: BHS- bluehead sucker, FMS – flannelmouth sucker, HBC- humpback chub, SPD- speckled dace, BBH – black bullhead, BNT – brown trout, CCF – channel catfish, CRP – common carp, FHM – fathead minnow, PKF – plains killifish, RBT- rainbow trout, RSH – red shiner

* captured below falls

Baseline Surveys

Methods

Prior to the first translocation of humpback chub, two baseline fish surveys (Sponholtz et al. 2010, Healy et al. 2011, Omana Smith et al. 2011) were conducted in Havasu Creek. Approximately four miles of Havasu Creek on NPS land was divided into three reaches (Figure 1) and surveyed, beginning below Beaver Falls and ending at the confluence with the Colorado River. During both trips, each reach was surveyed with baited mini-hoop nets (50 x 100 cm, 10 cm throat, 6 mm nylon mesh) and baited minnow traps (0.46 x 0.3 m, 2 mm mesh). Each mini-hoop net was baited near its cod end by attaching a nylon mesh bag (30 x 30 cm, 6 mm mesh) containing approximately 160 grams of AquaMax Grower 600 for Carnivorous Species (Purina Mills, Inc.). Mini-hoop nets and minnow traps were set in pools, eddies, and other relatively low velocity habitats. Trammel nets (23 m x 2 m, 25 mm inside mesh) were also set in the pool below Beaver Falls.

During baseline surveys, all captured fishes were identified to species, and examined for the presence of external anchorworms (*Lernaea cyprinacea)* and other visible parasites. All captured fishes were measured to total length (TL, millimeters) and weighed (WT, grams) and adults were inspected for sex, spawning condition (e.g., ripe, spent) and spawning characteristics (e.g., spawning tuberculation and coloration). Humpback chub, bluehead suckers (*Catostomus discobolus*), and flannelmouth suckers (*Catostomus latipinnis*) were also measured for fork lengths (FL, millimeters) and examined for passive integrated transponder (PIT) tags (Biomark and Allflex, Inc.). Untagged humpback chub, bluehead suckers, and flannelmouth suckers that were at least 150 millimeters in total length were tagged using 134.2 kHz PIT tags. All native fishes were released back into Havasu Creek alive. Non-native fish (rainbow trout, *Oncorhynchus mykiss*) were examined for PIT or Floy tags and/ or fin clips, sacrificed, and their stomach contents examined for the presence or absence of fish prey items.

February 2010 Survey

In February 2010, baseline water quality, fish abundance and distribution, macroinvertebrate, and food web data were collected to augment the existing knowledge base of the biotic and physical community in Havasu Creek (Sponholtz et al. 2010, Healy et al. 2011). Each reach (Figure 1) was sampled consecutively for one evening (approximately 18 to 24 hours) using 20 baited mini-hoop nets and 20 baited minnow traps. Several seine hauls were also attempted in shallow, sandy habitats and in riffle areas along Havasu Creek but yielded poor catches. Trammel nets were deployed during the daytime hours in deepwater habitat below Beaver Falls and checked every two hours for a total of six hours. Native bluehead sucker were the most commonly captured fish, followed by native speckled dace (*Rhinichthys osculus*) and non-native rainbow trout (Table 3). No previously captured fish were found during the survey (i.e., those already PIT-tagged).

Table 3. Fish captures in Havasu Creek and below in February 2010, by method.

Species Code*	Hoop Nets	Minnow Traps	Trammel Nets	*Totals by Species*
BHS	114	3	0	*117*
SPD	98	15	0	*113*
RBT**	8	0	2	*10*
Totals by Method	*220*	*18*	*2*	*240*

*Species Codes: BHS- bluehead sucker, SPD- speckled dace, RBT- rainbow trout

** Rainbow trout (non-native) were removed from the creek.

June 2011 Survey

A second baseline survey (Omana Smith et al. 2011) was conducted in June 2011 to collect data including fish abundance and distribution, water quality, and trophic samples for food web analysis. As in 2010, each reach (Figure 1) was sampled for one evening (approximately 15 hours) using 20 baited mini-hoop nets and 20 baited minnow traps. One mini-hoop net and 1 minnow trap were set in the mouth of Havasu Creek near where its confluence with the Colorado River. Two trammel nets were set in the pool below Beaver Falls for 2 hours, but discontinued due to captured fish response. The native fishes captured in Havasu Creek (Table 4) included humpback chub, bluehead sucker, and speckled dace. Non-native rainbow trout were also present (Table 4). Flannelmouth suckers were captured in the mouth of Havasu Creek, below the lowermost cascade. Eight individual untagged humpback chub were captured in mini-hoop nets and trammel nets prior to translocation in Havasu Creek; one humpback chub was caught twice. Seven of the chub were caught in the pool below Beaver Falls and one was approximately 1.75 miles above the confluence of Havasu Creek with the Colorado River. None of the humpback chub captured possessed a PIT tag; seven of the eight were given one upon capture.

Table 4. Fish captures in Havasu Creek and below in June 2011, by method.

Species Code*	Hoop Nets	Minnow Traps	Trammel Nets	Totals by Species
HBC	7	0	2	*9*
BHS	36	14	0	*50*
SPD	289	228	0	*517*
NFC	2	9	0	*11*
FMS	18	0	0	*18*
RBT**	22	0	0	*22*
Totals by Method	*374*	*251*	*2*	*627*

*Species Codes: HBC- humpback chub, BHS- bluehead sucker, SPD- speckled dace, NFC- no fish captured, FMS- flannelmouth sucker, RBT- rainbow trout

** Rainbow trout (non-native) were removed from the creek.

Translocation Planning

Humpback Chub Collection

Juvenile humpback chub are collected from the Little Colorado River for several purposes, including Chute Falls translocation, tributary translocations (Havasu Creek, Shinumo Creek, others to be determined), and hatchery refuges (Dexter National Fish Hatchery and Technology Center, other to be determined). Currently, fish are collected in July; age-1 fish are captured for Chute Falls translocations and young-of-year (YOY) fish are captured for hatchery refuge development and tributary translocations. If fewer than the target number of fish is captured in July, crews return in October or November to capture additional fish. The USFWS and NPS are jointly developing a translocation framework which will further refine collection guidelines.

Participants representing the NPS, BOR, USFWS, Grand Canyon Monitoring and Research Center (GCMRC), and Arizona Game and Fish department (AGFD) attended a workshop led by R. Valdez (SWCA Environmental Consultants) and B. Pine (University of Florida) in July 2011 to develop a model to help inform decisions on future humpback chub collections and release strategies. The model is currently being finalized. One preliminary model result suggested that future collections target larval or early juvenile forms of humpback chub to reduce the potential effects of collections on the Little Colorado River population; however, higher expected survival rates of individuals stocked at larger sizes may outweigh the risks of cropping. Preliminary model simulations suggest that the numbers of young humpback chub collected from the Little Colorado River for translocations to date pose little risk to the source population. The guidelines developed by Keeler-Foster and Wilson (2010) for managing translocated humpback chub in the lower Colorado River Basin will be followed if long-term management of humpback chub is proposed for Havasu Creek.

Minimum Requirement Analysis

Humpback chub translocation into Havasu Creek will follow NPS guidelines developed by fisheries biologists, wilderness and recreation staff, and compliance office staff to minimize impacts to wilderness qualities as well as minimize time spent in transit. National Park Service Minimum Requirement Analysis (2011) determined that helicopter support combined with hiking or river access for staff would result in the least disturbance to wilderness characteristics of the area, while minimizing fish transport time. Humpback chub will be flown to the translocation site in one sling load. Two sling loads of fisheries gear and camping equipment will be dropped and picked up at the base camp for each sampling occasion. As much gear as possible will be stored at a remote field camp, out of sight of recreationists, to minimize the number of helicopter flights on future monitoring or translocation-related trips.

Release Schedule

The proposed release schedule and completed NEPA compliance (NPS 2010, Bennett 2011) for Havasu Creek calls for 300 young-of-year humpback chub to be translocated for each of three years beginning in 2011, for a total of 900 fish (Table 5). The genetics management plan developed for managing translocated humpback chub in the lower Colorado River recommended a minimum of 200 chub be translocated into any site for five years, for a total of 1000 fish (Keeler-Foster and Wilson 2010). This schedule was developed to maximize the genetic variability of the founding stock; however, according to Dr. Wade Wilson, a geneticist with Dexter National Fish Hatchery and Technology Center and co-author on the genetics management plan, 300 per year for three years is acceptable to begin to establish the population (personal communication, July 2011). Depending on the initial monitoring results of Havasu Creek translocations, future translocations may consider alternative release schedules, fish numbers, and/or fish ages.

Table 5. Activity Schedule for Havasu Creek humpback chub translocation-related activities. Monitoring methods include hoop nets (HN), minnow traps (MT), trammel nets (TN), and mobile PIT tag surveys (MPS).

	LCR Collection	Translocation	Monitoring
2010			
Spring	--	--	HN, MT, TN
Summer	X	--	--
Fall	X	--	--
2011			
Spring	--	--	--
Summer	--	243 HBC	HN, MT, TN
Fall	X	--	HN, MT, MPS
2012			
Spring	--	300 HBC*	HN, MT, MPS*
Summer	X*	--	--
Fall	X*	--	HN, MT, MPS*
2013			
Spring	--	300 HBC*	HN, MT, MPS*
Summer	X*	--	--
Fall	X*	--	HN, MT, MPS*

* planned

2011 Translocation

Little Colorado River Collection

In summer and fall of 2010, 800 humpback chub were collected from the Little Colorado River for translocation into Shinumo and Havasu creeks, as well as for a genetic refuge population at Dexter National Fish Hatchery (NFH) and Technology Center (USFWS). Havasu Creek was scheduled to receive 300 fish in June 2011; however, only 243 were released in Havasu, after Shinumo Creek and the refuge received their full allotments (300 and 200 fish respectively). The remainder was lost to treatments and tagging-related mortality. The initial collection of humpback chub intended for Havasu Creek was held at Bubbling Ponds Hatchery (AGFD); hereafter, they will be held at Dexter NFH where the refuge fish are also held.

Transport and Tempering

On June 28, 2011, 243 fish (Table 5) with a mean total length of 86 millimeters were transported from Bubbling Ponds Hatchery by AGFD personnel in an aerated cooler to Grand Canyon National Park's south rim heli-base and flown to the rim of Havasu Creek in the interior of the NPS helicopter. Due to a lack of safe landing areas near the release site, the fish were transferred to a sling-load and delivered to a dry wash (Beaver Canyon Springs) just downstream of Beaver Falls. A fisheries crew tempered the fish to stream temperature and chemistry, transferred the fish to aerated buckets, and released them into Havasu Creek (Omana Smith et al. 2011). No mortality and minimal stress was observed in the humpback chub during the tempering and release process, and fish actively swam away and headed to areas of cover upon release.

Dissolved carbon dioxide (CO_2) levels were of particular concern during the tempering process and were closely monitored in Havasu Creek and in the transport cooler. Carbon dioxide measurements were made using phenolphthalein as an indicator for color change. The titrant was introduced to creek water a few drops at a time until a color change persisted for 30 seconds. Titrator readings were then multiplied by 0.2 to obtain dissolved CO_2 levels.

To temper the humpback chub before translocation, five gallons of water was removed from the transport cooler and replaced with 5 gallons of water from Havasu Creek every 15 minutes. Fish were monitored for signs of stress (gulping at the surface, dorsal color change) after each water change. Once CO_2 concentrations in the cooler were within 15-25 milligrams per liter of levels in Havasu Creek, fish were tempered for an additional 15 minutes and released. Water temperature during these activities changed by less than 1 degree (from 21.2°C to 21.9°C) and was within one degree of local Havasu Creek water temperature (21.6° C). This tempering protocol will be followed for future translocations. During future translocations, mortalities, if any, will be preserved in ethanol for later examination.

Monitoring

Initial translocations of humpback chub to Havasu Creek are considered experimental. Therefore, post-translocation monitoring at Havasu Creek is designed to answer several key questions related to the success of the initial translocations and assess the potential for translocations as a long-term management activity to conserve humpback chub in Grand Canyon (Table 6):

1. Will humpback chub remain in Havasu Creek, and how many will be retained?
2. How does juvenile growth compare to that of the source population in the Little Colorado and mainstem Colorado rivers?
3. How does survival compare between the source population and in Havasu Creek?
4. Does reproduction and recruitment by translocated humpback chub occur?
5. Will translocated humpback chub augment the mainstem Colorado River aggregation?

Answers to these questions are critical for the long-term planning and management of translocated humpback chub in not only Havasu Creek, but in other translocation projects as well. Table 6 shows a matrix of management questions and sampling and analysis methods to be used to address each of the questions. In addition, changes in the fish community as a response to the translocations and nonnative fish removal will be monitored. Temperature and discharge will be continuously monitored and the effects of these environmental parameters on growth and retention will be evaluated. Post-translocation monitoring of the fish community in Havasu Creek, including humpback chub, will be conducted twice per year, in spring (April/May) and fall (September/October).

Physico-chemical

National Park Service installed a thermograph and a pressure transducer in near the mouth of Havasu Creek to measure stage changes in June 2011. Temperature and flow measurements will be used to evaluate the response of the translocated humpback chub to these parameters. Stage changes will be correlated with in-situ discharge measurements to develop a stage-discharge curve. Turbidity will be measured at the beginning of each day during monitoring trips, as high turbidity has been shown to decrease capture success of humpback chub and other native fishes in Grand Canyon (Stone 2010).

Table 6. Monitoring metric and analysis matrix.

Monitoring Metric	Sampling Method	Sampling Frequency	Analysis Method
Retention/ Abundance	Mark-recapture sampling (2-pass): HN*, MT**; MPS***	Annual: spring; MPS***	Population estimate via closed population models.
Growth (mm/30-day)	HN, MT	Biannual: spring & fall	Absolute growth calculation: increase in length/time (days) x 30
Survival/ Abundance	Mark-recapture sampling: HN, MT	Triannual: spring, fall, spring	Annual estimate: Cormack-Jolly-Seber open population models
Reproduction	Larval or YOY sampling	Spring and/or fall	Presence/absence of larvae/YOY
Aggregation augmentation	GCMRC aggregation sampling: HN, TN****	Annual: fall	Presence

*HN= baited mini hoop-nets
**MT= baited collapsible minnow traps
*** MPS= mobile PIT tag scanners; may be used for additional sampling if mobile scanners prove useful.
****TN= trammel nets

Fish Community Monitoring

Fish community monitoring in Havasu Creek will follow the methods described in the baseline surveys. All nonnative fish will be removed. Additional sampling designed specifically for monitoring translocated humpback chub and answering the key management questions are described below. Electrofishing will not be used because conductivity is too high in Havasu Creek for this method to be effective. Also, if non-translocated humpback chub are captured that are too small to PIT tag (< 100 mm), visual implant elastomer (VIE) tags will be used following standard protocols developed through GCMRC (Persons et al. 2011). Color schemes and locations of tags will be coordinated between NPS, USFWS, GCMRC, AGFD, and other cooperators working in Grand Canyon so that unique marks can be used for each project and/or geographical location.

Retention, Abundance, Growth, and Survival

Retention/Emigration

Mark-recapture abundance estimation will be used to estimate population size, which can be extrapolated to provide information about the retention of translocated humpback chub in Havasu Creek. In Shinumo Creek, a remote solar-powered PIT tag antenna was installed near the mouth to estimate emigration, and thus retention. A similar system was proposed for near the mouth of Havasu Creek. However, installation of the system was determined to be logistically infeasible at Havasu Creek because the narrow canyon walls preclude sufficient winter sunlight to power a solar panel. Other power options were also evaluated and ultimately determined to be infeasible (Peter McKinnon, Utah State University Fish Detection Specialist, personal communication, September 2010). Instead of a fixed antenna system, mobile PIT tag scanners may also be used to evaluate the retention of translocated humpback chub in Havasu Creek (see *Mobile PIT Tag Surveys*).

Based on data collected using a fixed PIT tag antenna system in Shinumo Creek, translocated humpback chub are most likely to emigrate during the first several nights following translocation (Healy et al. 2011). Because no antenna will be installed to assess emigration in Havasu Creek, the main channel of the Colorado River will also be sampled near the mouth of Havasu as part of ongoing 'aggregation' sampling trips conducted by GCMRC (see *Contribution to Mainstem Aggregations*).

Abundance

Annual mark-recapture sampling will occur during spring monitoring trips, prior to each translocation. Two-passes of mini hoop-netting and minnow trapping will be conducted on a single trip, with each pass completed over 3 nights (1 night per reach, Figure 1, Table 7), similar to pre-translocation monitoring. The second pass will also be completed over 3 nights, beginning on the 4th night of the monitoring trip (Table 7). For abundance estimation, the population will assumed to be "closed" (no immigration or emigration) between passes, and therefore an appropriate closed population model will be used during analysis. A similar sampling regime was established for monitoring translocated humpback chub in Shinumo Creek, and it was found that a potential behavioral effect may occur between the mark and the recapture pass (Healy et al. 2011). This potential difference in mark capture probability (*p*) versus re-capture probability (*c*), as well as other potential sources of bias, can be accounted for in Program MARK (White and Burnham 1999). In addition, data can be pooled from multiple samples to estimate capture probability, which may become important if low sample fish detections are encountered through the course of this study (Cooch and White 2011).

Table 7. Annual mark-recapture sampling sequence for Havasu Creek for the spring sampling trip.

	Reach 3	Reach 2	Reach 1
Day 1	Set nets	--	--
Day 2	Mark	Set nets	--
Day 3	--	Mark	Set nets
Day 4	Set nets	--	Mark
Day 5	Recapture	Set nets	--
Day 6	--	Recapture	Set nets
Day 7	--	--	Recapture

In Havasu Creek sampling intervals will include data collected during the spring, fall, and the following spring trips. Additional sampling occasions may be added to augment the encounter histories of individual humpback chub for survival estimates if the experimental mobile PIT tag scanners prove to be useful in detecting humpback chub. Assuming improvements in the technology are achieved, future mobile PIT tag surveys will consist of at least two passes to allow for estimation of humpback chub abundance and retention in Havasu Creek (see *Mobile PIT Tag Surveys*). Captures of translocated humpback chub found in the mainstem during aggregation trips will be incorporated into survival estimate models, to the extent possible.

Mobile PIT Tag Surveys
Abundance and survival estimates may be improved by additional captures from mobile PIT tag surveys. O'Donnell and others (2010) successfully used mobile PIT tag scanners to survey stream reaches for known numbers of tagged salmonids in closed experiments with high detection rates, and to conduct population estimates on open populations with similar results to electrofishing surveys. However, they found a negative relationship between detection probability and increasing stream discharge (O'Donnell et al. 2010). Havasu Creek is larger than the streams surveyed by O'Donnell and others (2010) and has numerous deep pools and high velocity segments. Nonetheless, efforts are underway to further refine mobile PIT tag scanner technology to more thoroughly assess the number of fish remaining in the stream and learn about habitat use in Havasu Creek by translocated humpback chub.

Mobile PIT tag scanners developed by Utah State University were tested in October 2011 between Beaver Falls and the mouth of Havasu Creek. Two mobile PIT tag scanners, operated in a similar fashion to backpack electrofishing units (Figure 2), were used in various types of habitat (i.e., pools, riffles, backwaters, runs) moving downstream to scan for PIT tagged humpback chub and other fish (i.e. bluehead sucker). Approximately two-thirds of reach 3, all of reach 2, and three-quarters of reach 1 were surveyed. The units were equipped with GPS to record the location of all detected PIT tags. In addition, the rings of the two units were baited with AquaMax and left in a large pool immediately below Beaver Falls for approximately 2 hours. Sixteen PIT-tagged humpback chub, seven of which were not captured in mini hoop-net sampling, were detected by the mobile PIT tag scanners. This is a relatively small number compared to the 101 translocated humpback chub that were captured with mini hoop-nets during the same trip. The majority of the tags were detected using the stationary baited rings in the release pool below Beaver Falls. As O'Donnell and others found (2010), the read-range of the mobile PIT tag scanners may be too small relative to the volume of Havasu Creek, which may explain the low rate of detection. In contrast, the same system was used effectively at Shinumo Creek, a much smaller volume creek.

Figure 2. Mobile PIT tag scanner operated by Emily Omana Smith in Havasu Creek October 2011.

Future PIT tag surveys, if implemented, will consist of at least two passes. Because discharge in Havasu Creek is too high to allow the use of block nets (approximately 65 cfs), 50 to 100 meter creek sections with natural hydrological controls at the beginning and end will be sampled. In each section two operators will cover as much of the stream as possible, crossing back and forth to ensure good coverage. Each unit will record any PIT tag found and its GPS location. Operators can also record comments directly into the data logger when a PIT tag is detected, such as general location and approximate habitat type (i.e. pool, run, riffle). For the mark-recapture population estimates, PIT tags recorded on the first pass will be counted as 'marked' fish and PIT tags recorded on the second pass will be counted as 'recaptured' fish. This system could also be used to augment the capture history for individual fish to estimate survival.

Tag retention in humpback chub has been shown to be high (NPS unpublished data); however, 'ghost tags' could potentially accumulate in the creek due to tag loss, mortalities, and predation. Of all translocated humpback chub in Shinumo Creek that have been recaptured, none have lost a tag to date (NPS unpublished data). Nonetheless, to avoid incorrectly categorizing 'ghost tags' as live fish during mobile PIT tag surveys in Havasu Creek, operators will re-sample each detection area until the status of the tag (i.e, 'ghost tag' or live fish) can be determined. For example, if upon repeat scanning of the area the tag is not detected, it can be assumed that the tag is inside a live fish that has vacated the area. If the operator suspects a 'ghost' tag, efforts will be made to remove it from the creek to avoid sampling errors.

Growth
In addition to the spring mark-recapture sampling, a fall monitoring trip will be conducted to assess growth of translocated fish. Sampling will follow the protocol for baseline fish inventories, where a single night of netting is implemented in each of the three established creek reaches. Absolute growth rates (rate per unit time) will be calculated using fish total length and weight, which will be compared to growth data from other populations of humpback chub including the Little Colorado River and Colorado River (see Robinson and Childs 2001, Coggins and Pine 2010).

Survival
Annual survival will be estimated for each cohort of translocated humpback chub using open population capture-recapture models (e.g., Cormack-Jolly-Seber models, see Lebreton et al. 1992). These types of models generate estimates of capture probability and "apparent" survival, meaning the estimate does not separate individuals that had simply emigrated from the sampling area from those that did not survive between sampling intervals. A minimum of three sampling intervals are necessary to generate an annual apparent survival estimate.

Reproduction
Documenting reproduction is an important step in assessing the objective of establishing a reproducing population of humpback chub in Havasu Creek. In the Little Colorado River, humpback chub spawn in May/June when temperatures reach 16-20°C (Valdez and Ryel 1995). McAda and others (2003) summarized several studies in the Upper Colorado River Basin and found that spawning occurred in various locations at river temperatures ranging from 11 to 24°C. Spawning dates varied because of large differences in spring runoff, with spawning occurring earlier in years with low runoff and early warming, and later in years with high runoff. Chart and Lentsch (1999) reported that river temperatures were consistently between 19 and 21°C when spawning activity peaked. Humpback chub translocated into Havasu Creek in 2011 are likely to be mature by 2013 or 2014. Thermal conditions are adequate in Havasu Creek for

humpback chub to ripen and spawn by May or early June (Figure 3, unpublished USGS data), similarly to the Little Colorado River. Evidence of reproduction may include detection of larvae or of young-of-year in the fall.

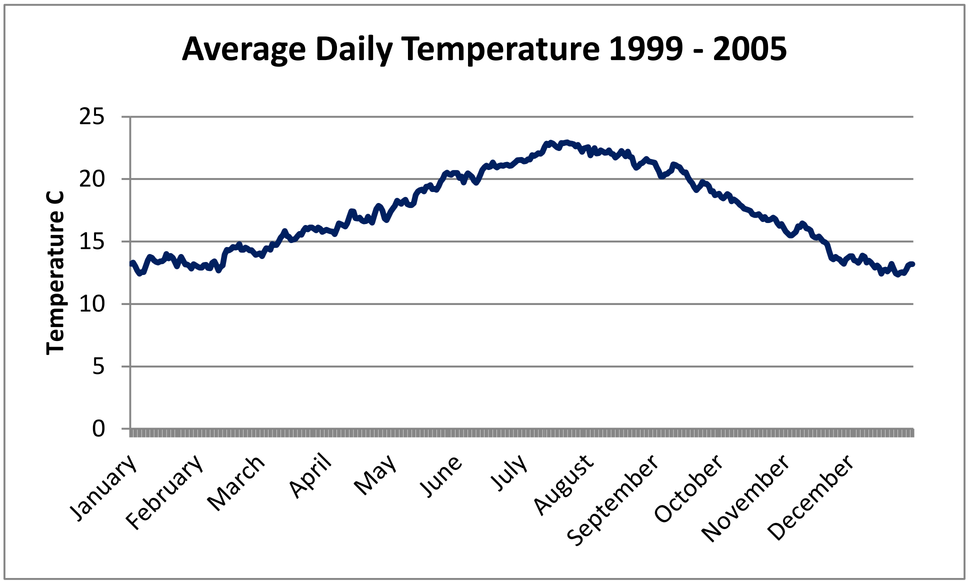

Figure 3. Average daily water temperature in Havasu Creek from 1999 to 2005. USGS unpublished data.

Detection of Reproduction/ Larval Fish Sampling and Identification

Little sampling for larval humpback chub has occurred in either the Grand Canyon or Upper Colorado River Basin populations to date; instead, sampling generally focuses on early juveniles (YOY, aged 2-8 months). However, several methods have been used to capture larval fish of sympatric endangered species such as Colorado pikeminnow and razorback sucker in the Upper Basin, including larval light traps, drift nets, and egg collectors. Light traps are bulky and delicate and must be set in zero or very low velocity habitats, and need at least 0.3 m depth; these habitats are uncommon in Havasu Creek. Drift nets and egg collectors result in lethal sampling. Based upon these considerations, these methods were rejected as inappropriate in Havasu Creek.

Small mesh seines (1 m x 1 m x 0.8 mm) and dip nets are also used effectively to collect larval Colorado pikeminnow and razorback sucker in the San Juan Basin (Brandenburg et al. 2010). Multiple seine hauls (between 3 and 12) are made through each individual collecting site depending on the size of the habitat. Habitats are located opportunistically as investigators travel downstream (Brandenburg et al. 2010). Habitats in Havasu Creek are much smaller than those sampled in the San Juan Basin; therefore, small dip nets may also be used to sample there. Opportunistic sampling with small mesh seines and dip nets allows broader coverage in habitat type and stream length, and allows immediate identification and release of fish collected. These methods are appropriate for sampling in Havasu Creek.

During spring surveys, low velocity areas will be visually examined for presence of small/larval fish. Small mesh seine and/or small dip nets will be used to capture larval fish. Shoreline margins with dense vegetation will be sampled by running seines and/or dip nets over and through the vegetation to capture fish not immediately visible. Samples will be taken near each mini-hoop net site, and opportunistically in areas between mini-hoop nets. Attempts to identify and release fish alive will be made (see *Larval Fish Identification*). All mortalities in will be preserved in properly labeled whirl-paks. Large samples that cannot be identified immediately will be preserved for later processing. If humpback chub larvae are identified or suspected, at least 10 specimens will be preserved for confirmation by a species expert. Up to 100 humpback chub larvae may be preserved. Based upon Hamman (1982) estimation of 2,523 eggs per female (350-450 mm TL), this is approximately equivalent to 10% of the progeny of 4 female humpback chub.

Naturally reproduced humpback chub would be expected to be 30-50 millimeters in total length by the fall monitoring trips in Havasu Creek. The minnow traps used in monitoring translocated fish during this time may also capture these young-of-year humpback chub if present, although mini hoop-nets would be unlikely to do so.

All fish will be identified, measured, and released if possible. During baseline surveys and translocation-related monitoring in Havasu Creek, only four fish species have been captured above the Colorado River: native humpback chub, bluehead sucker and speckled dace and non-native rainbow trout; native flannelmouth sucker were also captured below the falls near the confluence (Sponholtz et al. 2010, Healy et al. 2011, Omana Smith et al. 2011, Sponholtz et al. 2011). Distinguishing characteristics will be used to identify the larvae of each fish species as follows (Table 8). Rainbow trout emerge early in the year and are large enough to easily identify by late spring, and are not likely to be confused with humpback chub. Bluehead sucker and speckled dace spawn in late spring/early summer, similarly to humpback chub, and their larvae have been observed in low velocity habitats in Havasu Creek in May and June (personal observation). Bluehead sucker larvae can be distinguished from humpback chub or speckled dace by the location of the anal vent at approximately 75% of body length, compared to about 50% on HBC and SPD, a feature easily seen through the near-transparent bodies. An additional identifying characteristic is the pelvic fin origin. In bluehead sucker the pelvic fin originates behind the dorsal fin whereas in humpback chub and speckled dace pelvic fin origin is in-line or slightly ahead of the dorsal fin origin.

Humpback chub and speckled dace superficially resemble each other at the larval stage. Humpback chub hatch slightly larger than speckled dace (7 mm vs. 5 mm) and transform (i.e. develop full fin complement) at a larger size (18 mm vs. 14 mm). They also appear to be nearly pigmentless, while speckled dace develop a lateral ‘stripe’ near the head and tail by the time they reach 15 millimeters (TL). By the time both species are 20 millimeters (TL), they can be easily distinguished (Table 8).

Table 8. Identifying characteristics of larval humpback chub, speckled dace, and bluehead sucker (Snyder 1981, Snyder and Muth 2004).

	Humpback chub	Speckled dace	Bluehead sucker
Length at hatch	6-7 mm	5-6 mm	9-10 mm
Length at transformation	18 mm	14 mm	20 mm
Pigment	Little to none	Faint lateral stripe at 15 mm, including on upper lip resembling a 'mustache'	Little to none, dark peritoneum visible
Position of anal vent	50% of body length	50% of body length	75% of body length
Position of Dorsal/ Pelvic fins	Pelvic origin directly under Dorsal Origin	Pelvic slightly before Dorsal	Pelvic distinctly behind Dorsal

Fin Origin = leading edge of fin

Augmentation of Mainstem Aggregations

Grand Canyon Monitoring and Research Center conducted 'aggregation' monitoring trips in the fall of 2010 and 2011 to monitor the relative abundance and catch rates of humpback chub and other fishes at the nine known Colorado River humpback chub aggregations in Grand Canyon, which include the outflows of Shinumo and Havasu creeks (Valdez and Ryel 1995). Humpback chub that had been translocated into Shinumo Creek and Havasu Creek were captured during the trips (VanHaverbeke, personal communication). Data collected on translocated humpback chub during these and future mainstem aggregation trips will be used to study emigration from the creeks.

Reporting and Interpretation

All data collected will be entered and QA/QC checked by NPS fisheries personnel into the standard GCMRC database format. Trip reports will be prepared following each field trip. Havasu Creek translocation and monitoring results will be published annually along with Shinumo Creek results as NPS Natural Resource Technical Reports (spring 2012, 2013, and 2014- Havasu Creek only). A project synthesis will be prepared as a final report in fiscal year 2014, also as a NPS Natural Resource Technical Report.

This monitoring plan establishes a release schedule and monitoring methods to be used for the first three years of this study. Monitoring methods will be evaluated annually and refined as needed. Additional experimentation with PIT tag scanning techniques will be explored to improve remote sensing capabilities and maximize 'captures' of tagged fish. Carrying capacity estimations will be refined and translocation release numbers may be adjusted accordingly.

Havasu Creek will be evaluated to determine the best use of this tributary as a translocation site. Potential outcomes include the use of Havasu Creek as a grow-out area to augment the local aggregation, as a refuge, or ideally, as a second spawning population. Criteria for success for this translocation effort for each of three potential outcomes will be established and evaluated in the final project synthesis report. Criteria may include (a) retention of translocated humpback chub for a minimum of one year, (b) similar or increased survival of juveniles relative to mainstem, (c) similar or increased growth rates relative to the Little Colorado River and mainstem, (d) contributions to the mainstem aggregation, (e) evidence of successful reproduction, (f) measureable numbers of young, and (g) evidence of recruitment.

Literature Cited

Bennett, Rachael. 2011. NPS Letter of Authorization for NEPA and NHPA Clearance: Havasu Creek Humpback Chub Translocation and Monitoring (34414).

Brandenburg, W.H., and M.A. Farrington. 2010. Colorado pikeminnow and razorback sucker larval fish surveys in the San Juan River during 2009. San Juan River Basin Recovery Implementation Program. U.S. Fish and Wildlife Service, Albuquerque, NM.

Coggins, L. G., Jr., and W. E. Pine, III. 2010. Development of a temperature-dependent growth model for the endangered humpback chub using capture-recapture data. The Open Fish Science Journal 2010 (3): 122-131.

Coggins, L.G., Jr., and C.J. Walters. 2009. Abundance trends and status of the Little Colorado River population of humpback chub; an update considering data from 1989-2008. U.S. Geological Survey Open-File Report 2009-1075, 18 p.

Cooch, E., and G. White, Editors. 2011. Program MARK: A gentle introduction. 9th Edition, Software Manual. 894 pages with appendices.

Douglas, M. R. and M. E. Douglas. 2007. Genetic structure of humpback chub *Gila cypha* and roundtail chub *G. robusta* in the Colorado River Ecosystem: Final Report -- May 2007. Department of Fish, Wildlife and Conservation Biology, Colorado State University, Fort Collins, Colorado.

Grand Canyon Wildlands Council and SWCA Environmental Consultants. 2006. Humpback chub translocation in Grand Canyon: Feasibility and experimental design, Final Report submitted to Grand Canyon National Park. 33pp.

Gorman, O.T. 1994. Habitat use by the humpback chub, *Gila cypha*, in the Little Colorado River and other tributaries of the Colorado River. Final report for Glen Canyon Environmental Studies Phase II. U.S. Fish and Wildlife Service, Flagstaff, Arizona.

Hamman, R.L. 1982. Spawning and culture of humpback chub. *Progressive Fish-Culturist* 44:213–216.

Healy, B. 2009. Scope of Work submitted to Bureau of Reclamation in support of humpback chub translocations in Grand Canyon National Park.

Healy, B.D., E. Omana Smith, J.J. Spurgeon, C. Paukert, J. Whittier, P. Sponholtz, and W. C. Leibfried. 2011. Translocation of humpback chub to Grand Canyon tributaries and related nonnative fish control activities: 2010 Annual Report. Final report Prepared for the Upper Colorado Region, Bureau of Reclamation, Interagency Agreement: 09-AA-40-2890. Grand Canyon National Park, National Park Service. May 4, 2011.

Healy, B., and E.Omana Smith. 2011. Shinumo Creek humpback chub monitoring and translocation, September 5-18, 2011 Trip Report. Report Prepared for the Upper Colorado

Region, Bureau of Reclamation, Interagency Agreement: 09-AA-40-2890. Grand Canyon National Park, National Park Service. October 18, 2011.

Hunt, T.A. 2009. The effects of capture by trammel nets on native Arizona fishes. Master's thesis submitted to Northern Arizona University. 57pp.

Keeler-Foster, C. and W. Wilson. 2010. A genetic management plan for captive and translocated humpback chub in the lower Colorado River Basin. Dexter National Fish Hatchery and Technology Center, New Mexico.

Kubly, D.M., and G.A. Cole. 1979. The chemistry of the Colorado River and its tributaries in Marble and Grand Canyons. Pages 565-572 *In* Proceedings of the First Conference on Scientific Research in National Parks. U.S. Department of the Interior, Washington, D.C.

Lebreton, J-D., K. P. Burnham, J. Clobert, and D. R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecological Monographs 62(1): 67-118.

Makinster, A.S., Persons, W.R., Avery, L.A., and Bunch, A.J., 2010, Colorado River fish monitoring in Grand Canyon, Arizona—2000 to 2009 summary: U.S. Geological Survey Open-File Report 2010–1246, 26 p.

McAda, C.W. 2003. Flow recommendations to benefit endangered fishes in the Colorado and Gunnison Rivers. Recovery Program Project Number 54, Final Report. Grand Junction CO.

Miller, R. R. 1946. *Gila cypha*, a remarkable new species of cyprinid fish from the Colorado River in Grand Canyon, Arizona. Journal of the Washington Academy of Sciences 36(12):409-415.

National Park Service. 2011a. Categorical Exclusion for Havasu Creek humpback chub translocation and monitoring. CE 34414.

National Park Service. 2011b. Minimum Requirement Analysis for translocation of humpback chub into Havasu Creek.

Oberlin, GE., Shannon, JP., and Blinn, WD. 1999. Watershed influences on the macroinvertebrate fauna of ten major tributaries of the Colorado River Through Grand Canyon, Arizona. *The Southwestern Naturalist* 44:17-30.

Omana Smith, E., P. Sponholtz, and B. Healy. 2011. Havasu Creek humpback chub baseline monitoring and translocation: June 23-29, 2011 Trip Report. Report Prepared for the Upper Colorado Region, Bureau of Reclamation, Interagency Agreement: 09-AA-40-2890. Grand Canyon National Park, National Park Service. August 5, 2011.

Propst, D.L., S.P. Platania, D.W. Ryden, and R.L. Bliesner. 2000. San Juan River monitoring plan and protocols. San Juan River Basin Recovery Implementation Program. U.S. Fish and Wildlife Service, Albuquerque, NM.

Robinson, A. T. and M. R. Childs. 2001. Juvenile growth of native fishes in the Little Colorado River and in a thermally modified portion of the Colorado River. North American Journal of Fisheries Management 21: 809-15.

Snyder, D. E. 1981. Contributions to a guide to the cypriniform fish larvae of the Upper Colorado River system in Colorado. U.S. Bureau of Land Management, Biological Sciences Series 3, Denver, CO. 81 pp.

Snyder, D. E. and R. T. Muth. 2004. Catostomid fish larvae and early juveniles of the upper Colorado River Basin- morphological descriptions, comparisons, and computerinteractive key. *Colorado Division of Wildlife Technical Publication* No. 42.

Sponholtz, P., B. Healy, and M. Trammell. 2010. Havasu Creek baseline survey: February 2010 Trip Report. Report Prepared for the Upper Colorado Region, Bureau of Reclamation, Interagency Agreement: 09-AA-40-2890. Grand Canyon National Park, National Park Service.

Sponholtz, P., B. Healy, and E. Omana Smith. 2011. Havasu Creek humpback chub monitoring. October 7-13, 2011 Trip Report. Report Prepared for the Upper Colorado Region, Bureau of Reclamation, Interagency Agreement: 09-AA-40-2890. Grand Canyon National Park, National Park Service. November 11, 2011.

Stone, Dennis M. 2005. Effect of baiting on catch rates of endangered humpback chub. North American Journal of Fisheries Management, 25:640-645.

Trammell, M., R. Valdez, S. Carothers, and R. Ryel. 2002. Effects of a low steady summer flow experiment on native fishes of the Colorado River in Grand Canyon, Arizona. Final Report for Contract #99-FC-40-2260 to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. SWCA Environmental Consultants, Flagstaff, Arizona.

Valdez, R.A, and R. J. Ryel. 1995. Life history and ecology of the humpback chub (*Gila cypha*) in the Colorado River, Grand Canyon, Arizona. Bio/West Final Report to the Bureau of Reclamation. Glen Canyon Environmental Studies, Flagstaff, AZ.

Voichick, N., and Wright, S.A. 2007. Water-temperature data for the Colorado River and tributaries between Glen Canyon Dam and Spencer Canyon, northern Arizona, 1988–2005: U.S. Geological Survey Data Series 251, 24 p.

U.S. Fish and Wildlife Service and National Park Service. In preparation. Framework for translocations of humpback chub in Grand Canyon National Park.

U.S. Fish and Wildlife Service. 2002. Humpback chub recovery goals: amendment and supplement to the humpback chub recovery plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

U.S. Fish and Wildlife Service 2008. Biological Opinion on the Operations of Glen Canyon Dam. February 27, 2008.

U.S. Geological Survey. 2007. Grand Canyon humpback chub population improving. U.S. Geological Survey Fact Sheet 2007-3113.

Valdez, R.A., S.W. Carothers, M.E. Douglas, M. Douglas, R.J. Ryel, K.Bestgen, and D.L. Wegner. 2000. Final research and implementation plan for establishing a second population of humpback chub in Grand Canyon. Grand Canyon Monitoring and Research Center, U.S. Department of the Interior, Flagstaff. 56 pp.

Ward, David, and W. Persons. 2007. Little Colorado River Fish Monitoring Report 2006 annual report. Arizona Game and Fish Department, Research Branch. Report completed for Grand Canyon Monitoring and Research Center, Flagstaff, Arizona 86002. Cooperative Agreement 04WRAG0016 Mod 2

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