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In Reply Refer to:

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Memorandum

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

From: Field Supervisor, Phoenix, AZ HEATHER WHITLAW
Digitally signed by HEATHER WHITLAW
Date: 2022.08.02 13:05:29 -07'00'

Subject: Report on the 2016 Biological Opinion for Glen Canyon Dam Long-Term Experimental and Management Plan: Compliance Summary and Conservation Measures Progress, Fiscal Year (FY) 2021

Thank you for the Bureau of Reclamation's (Reclamation) annual summary of progress of the implementation of the Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP) and progress towards the associated Biological Opinion (BO). This responds to your memorandum requesting review by the U.S. Fish and Wildlife Service (Service) of the summary of LTEMP activities related to listed species under the care of the program. In your summary you included the report entitled "LTEMP Biological Opinion – Progress Report on Compliance & Conservation Measures Fiscal Year 2021", and associated reports for that year. This report helps inform LTEMP management for the following year and ensures that impacts to listed species, and their habitats are within the reasonable bounds outlined in the BO.

We have reviewed the materials provided and conclude that the actions of Reclamation meet the requirements of the LTEMP BO and acknowledge the program made sufficient progress in FY 2021. All covered actions and implementation of the conservation measures are suitably described and documented. Reclamation is a strong partner for conservation in the Lower Colorado River Basin, and we commend the program's contribution.

Thank you for your continued coordination and commitment to conservation of threatened and endangered species. In all future correspondence on this project, please refer to the consultation number 2022-0063848. Should you require further assistance or if you have any questions, please contact Dan Leavitt, daniel_leavitt@fws.gov, of my office staff.

cc: Project Leader, Arizona Fish and Wildlife Conservation Office (jess_newton@fws.gov)
Program Coordinator, San Juan River Recovery Implementation Program (melissa_mata@fws.gov)



— BUREAU OF —
RECLAMATION

LTEMP Biological Opinion – Progress Report on Compliance & Conservation Measures



Fiscal Year 2021

LTEMP Compliance Summary

This report serves to summarize the Bureau of Reclamation's (Reclamation) evaluation of progress regarding implementation of the U.S. Fish and Wildlife Service's (FWS) 2016 Biological Opinion for the Glen Canyon Dam Long-Term Experimental and Management Plan (2016 LTEMP BO) for fiscal year 2021. Reclamation has reviewed the reporting requirements of the 2016 LTEMP BO and offers this summary report, which reviews the status of listed species in the action area, describes progress on implementation of conservation measures, and assesses levels of incidental take. The humpback chub was reclassified from endangered to threatened on November 17, 2021, the razorback sucker was proposed for reclassification from endangered to threatened on July 7, 2021, and the kanab ambersnail was officially removed from the federal list of endangered and threatened species on July 26, 2021. These reclassifications have not affected the work reported here. As supporting documentation to the summary report, we have also attached the reports and publications that support implementation of the 2016 LTEMP BO conservation measures.

Incidental Take Summary for Fiscal Years (FY) 2019 – 2021

The measures described in the Incidental Take Statement of the 2016 LTEMP BO are non-discretionary and must be undertaken by Reclamation when triggered. To monitor the impact of incidental take, Reclamation must report the progress of the action and its impact on the species to the FWS as specified in the incidental take statement.

Humpback Chub

The tables below summarize data from the past three years to determine whether Tier 1 (early intervention) or Tier 2 (threat reduction) actions required by the 2016 LTEMP BO have been, or may be, triggered to prevent exceeding incidental take. Under Tier 1 parameters, early intervention action is required if the combined point estimate for adult humpback chub (HBC; adults defined as ≥ 200 mm total length) in the Colorado River mainstem and Little Colorado River (LCR aggregation) falls below 9,000. Similarly, early intervention action is required if recruitment of sub-adult HBC does not equal or exceed adult mortality. Early intervention consists of conservation actions such as expanded translocation efforts. As shown in Table 1, the point estimate for the number of adults and the three-year average population and recruitment estimates for the sub-adult spring estimate of the LCR population are above levels that would require Tier 1 action. However, the three-year average of the sub-adult fall estimate was below the 810 required for the period from 2018-2020, as reported in 2021, and again for period from 2019-2021, as reported here (2022), thus triggering Tier 1 early intervention actions (see FWS Mark-Recapture & Fish Monitoring Activities in the LCR in Grand Canyon 2000-2021). In response to the trigger, 535 HBC were moved above Chute Falls in the LCR in 2021. HBC moved above Chute Falls generally grow faster and have higher survival rates (Yackulic et al. 2021). Although this action is expected to improve HBC survival in the long-term, an immediate impact on the trigger was not expected. A response to exceeding the sub-adult trigger in 2021 will be planned once larval estimates are available in spring 2022.

Under Tier 2 parameters, threat reduction actions are required if the combined point estimate for adult HBC in the Colorado River mainstem and Little Colorado River (LCR aggregation) falls

below 7,000. Threat reduction actions consist of mechanical removal of nonnative predators from the LCR aggregation reach and immediate vicinity. Table 2 summarizes the conditions under which Tier 2 actions would be terminated, either by reducing the predator index or by increasing HBC population and recruitment levels.

Table 1. Tier 1 thresholds that trigger additional conservation actions for humpback chub (HBC)

TIER 1 Early Intervention	# of HBC that triggers an action	ESTIMATED # of HBC			
		2019	2020	2021	3-year average
1. Combined adult (≥ 200 mm) HBC in the Colorado River mainstem aggregation ($\geq 2,000$) and in Little Colorado River ($\geq 7,000$)	$\leq 9,000$	13,000*	13,000*	11,000	
OR					
2. Recruitment of sub-adult (150-199 mm) HBC does not equal or exceed estimated adult mortality					
A. Sub-adult population estimate in LCR in spring	$\leq 1,250$ for 3 years	2,592	990	696	1,426
OR					
B. Sub-adult population estimates in mainstem in JCM Reach* in fall	≤ 810 for 3 years	400	100	800	433

*These numbers provided for reference only. The point estimate for 2021 must be $>9,000$ to avoid triggering action.

**Juvenile Chub Monitoring Reach is RM 63.45-65.2 of the mainstem.

Table 2. * Tier 2 triggers that terminate mechanical removal of non-native fish to protect humpback chub

TIER 2 Mechanical Removal	Action Termination Trigger	Observed	
		2020	2021
Nonnative Aquatic Predator index	< 60 rainbow trout / km	--	--
Immigration rate	Low (to be determined)	--	--
HBC population estimates	$> 7,500$	--	--
Survival rates of sub-adult chub	Exceeds adult mortality for at least 2 years	--	--

*This table remains blank unless the number of adult humpback chub $< 7,000$, which indicates mechanical removal is required. This table outlines the conditions necessary to terminate the action.

Razorback sucker

The incidental take of razorback suckers is considered to be exceeded if actions associated with LTEMP base operations and experimental flows result in a statistically significant decline (95% confidence intervals) in mean catch per unit effort (CPUE) of adult flannelmouth suckers for a consecutive 3-year period following the occurrence of experimental flows. Because razorback suckers are extremely rare in the project area and it is impossible to distinguish larval razorback suckers from flannelmouth suckers in the field, flannelmouth suckers are identified as a surrogate for incidental take of razorback suckers in the 2016 Biological Opinion. The most recent experimental flows that occurred were a fall High Flow Experiment (HFE) in November 2018, macroinvertebrate production flows (bug flows) in 2018, 2019, and 2020 and a spring disturbance flow in 2021.

CPUE data is collected by Arizona Game & Fish Department (AGFD) in lower Grand Canyon in spring and fall where flannelmouth suckers overlap with known locations of larval razorback suckers (approximately from RM 179.1 to RM 284).

Table 3. Catch per unit effort (CPUE) with 95% confidence intervals of adult flannelmouth suckers (>325 mm total length) in lower Grand Canyon (RM>179) by capture method. Incidental take is considered exceeded if a statistically significant decline is observed in CPUE of adult flannelmouth suckers for a consecutive 3-year period following the occurrence of experimental flow actions.

Method	2019	2020	2021
Electrofishing (fish/hr)	3.73 (2.59-4.88)	3.88 (1.68-6.09)	0.82 (0-1.73)
Hoop net (fish/net)	1.57 (0.85 – 2.30)	0.922 (0.46 – 1.38)	0.23 (0.09 – 0.37)

Conservation Measure Progress, FY 2021

HUMPBACK CHUB

Ongoing Actions:

- 1) Reclamation would continue to support the NPS, FWS, U.S. Geological Survey’s (Survey) Grand Canyon Monitoring and Research Center (GCMRC), and GCDAMP in funding and implementing translocations of humpback chub into tributaries of the Colorado River in Marble and Grand Canyons, and in monitoring the results of these translocations, consistent with agencies’ plans and guidance (e.g., NPS Comprehensive Fisheries Management Plan [CFMP], FWS Humpback Chub Genetics Management Plan and Translocation Framework, and GCMRC Triennial Work Plan). Specifically, the following would occur:

- i. Humpback chub would be translocated from the lower reaches of the Little Colorado River (LCR) to areas upstream of Chute Falls to increase growth rates and survivorship.

Efforts to translocate HBC upstream of Chute Falls in the LCR have been ongoing since 2003 with 4,676 juvenile (~80-130 mm TL) HBC translocated to date. Of these, 535 were released above Chute Falls (at river kilometer [RKM] 16.2) on May 28, 2021. The number of HBC released in 2021 was higher than the 300 juveniles typically translocated each year to respond to triggering Tier 1 Early Intervention management actions (see 2021 GCMRC Annual Report for Project Element G.7, Chute Falls Translocations).

FWS conducts an annual trip to monitor the abundance of HBC translocated upstream of Chute Falls (RKM 13.6) and in the “Atomizer reach,” (RKM 13.6 - 14.1). This effort typically occurs in May or June, when there is no danger of flooding, and it is safe to conduct activities in this stretch of river. The abundance estimates obtained in May 2021 are listed in Table 4 (see 2021 GCMRC Annual Report for Project Element G.7, Chute Falls Translocations).

Table 4. The number of humpback chub (HBC) estimated by size with standard error (SE) for two sample reaches in the Little Colorado River (LCR) in May 2021.

LCR Reach	# of HBC ≥ 100 mm (SE)	# of HBC ≥ 200 mm (SE)
Atomizer (RKM 13.6)	234 (10)	157 (7)
Chute Falls (RKM 13.6-14.1)	228 (29)	160 (20)

- ii. Monitoring would be conducted annually, or as needed, depending on the data required, to determine survivability, population status, or genetic integrity of the Havasu Creek humpback chub population. Intermittent translocations of additional humpback chub in Havasu Creek would be conducted if the FWS and NPS determine it is necessary to maintain genetic integrity of the population.

NPS conducted monitoring trips to Havasu Creek in October 2020 and May 2021. In October 2020, 121 HBC were captured during single-pass netting including juveniles and adults. Of these, 26 were translocated and 95 were non-translocated fish. In May 2021, 256 humpback chub were captured including juveniles and adults, with 45 previously translocated and 211 non-translocated fish. The abundance estimate was 215

individuals (95% CI: 200-264), with 182 of these non-translocated fish (95% CI: 170-211). The 2021 Havasu Creek population consists of 85% non-translocated fish, or wild fish. Population growth estimates in Havasu Creek are indicative of a stable or increasing population (2021 NPS Monitoring Humpback Chub Translocated to Grand Canyon Tributaries Annual Report).

No HBC were translocated to Havasu Creek in 2021. Annual monitoring continued in Havasu Creek to better understand the population dynamics.

- 2) Reclamation would continue to fund a spring and fall population estimate annually, using a mark-recapture based model for the Little Colorado River or the most appropriate model developed for the current collecting techniques and data.

In 2021, FWS and volunteers conducted monitoring trips in April and May and in September and October to monitor the population status and trends of humpback chub in the LCR. See Table 5 for the estimates of HBC by sampling period (see FWS Mark-Recapture & Fish Monitoring Activities in the LCR in Grand Canyon 2000-2020).

Table 5. The estimates of humpback chub (HBC) in the Little Colorado River by size (total length (TL)) with standard errors (SE) for each sampling period.

Sampling Period	# of HBC TL >150 mm ± SE	# of HBC TL ≥200 mm ± SE
Spring 2021	4,805 (530)	4,070 (527)
Fall 2021	3,813 (282)	1,925 (208)

- 3) Reclamation would continue to fund control or removal of nonnative fish in tributaries prior to chub translocations depending on the existing fish community in each tributary. Reclamation, NPS, and FWS would lead any investigation into the possibility of using a chemical piscicide, or other tools, as appropriate. Tributaries and the appropriate control methods would be identified by the FWS, NPS, Reclamation, and GCMRC, in consultation with AGFD. Depending on the removal methods identified, additional planning and compliance may be necessary.

In 2021, NPS operated a weir at the confluence of Bright Angel Creek from October 2020 through March 2021; 8 brown trout and 18 rainbow trout were removed. Electrofishing was also conducted in Bright Angel Creek and other tributaries from October through January yielding removal of 8,301 brown trout and 5,632 rainbow trout (see 2020-2021 NPS Bright Angel Creek Brown Trout Control Season Report).

- 4) Reclamation would continue to fund the FWS in maintenance of a humpback chub refuge population at a federal hatchery (Reclamation has assisted the FWS in creating a humpback chub refuge at the Southwestern Native Aquatic Resources and Recovery Center [SNARRC]) or other appropriate facility by providing funding to assist in annual maintenance (including the collection of additional humpback chub from the Little Colorado River for this purpose). In the unlikely event of a catastrophic loss of the Grand Canyon population of humpback chub, the refuge would provide a permanent source of sufficient numbers of genetically representative stock for repatriating the species.

Collection of larval humpback chub to support the refuge was planned, but due to poor recruitment no larval fish were transferred to the refuge in 2021.

- 5) Reclamation would continue to assist the FWS, GCMRC and the GCDAMP to ensure that a stable or upward trend of humpback chub mainstem aggregations can be achieved by:
- i. Continuing to conduct annual monitoring of the LCR humpback chub aggregation (e.g., juvenile chub monitoring parameters). Periodically, an open or multistate model should be run to estimate abundance of the entire LCR aggregation inclusive of mainstem fish.

In 2021, GCMRC conducted monitoring trips in April, July & October in the JCM-East reach. Slow-shock electrofishing and hoop nets were used to capture fish, and 8 submersible antennas were deployed to supplement electrofishing and hoop netting efforts. During those efforts 2,049 HBC > 79mm TL and 341 HBC 40-79 mm TL were captured.

A multi-state model was run to estimate abundance. For 2021, the estimate of abundance of the LCR aggregation was 11,000 adults.

- ii. Supporting annual monitoring in the mainstem Colorado River to determine status and trends of humpback chub and continuing to investigate sampling and analytical methods to estimate abundance of chub in the mainstem.

FWS conducted the annual HBC aggregation trip from September 1-17, 2020, between Lees Ferry and Pearce Ferry with the objective of continuing long-term relative abundance (CPUE) index of HBC in known historical aggregation sites (2021 GCMRC Annual Report for Project Element G.5 & FWS Monitoring HBC in the CO River Grand Canyon 2020). During this trip 13 sites were sampled in Marble & Grand Canyon.

The highest CPUE for adult HBC > 200 mm were in the JCM and Ghost camp reaches.

FWS also conducted 3 additional river trips in late 2020 to develop closed mark-recapture abundance estimates for HBC and further understand the expansion of HBC in far western Grand Canyon. Results are summarized in Table 6.

Table 6. Abundance estimates with 95% confidence intervals (CI) for adult humpback chub (total length \geq 200 mm) based on trips conducted in September and October 2020 except for the Columbine site which was monitored in June & July 2021.

Site	River Mile	Abundance estimate of adult HBC per mile (95% CI)
JCM-west near Pumpkin Springs	210.2-213.8	752 (303-1,201)
Downstream of Diamond Creek	227.2-229.2	544 (462-626)
Below Separation Canyon	239.9-241.9	567 (328-806)
Island Reach	265-267	403 (251-555)
Columbine	273.9-275.9	253 (216-289)

- iii. Conducting periodic surveys to identify additional aggregations and individual humpback chub.

HBC specific surveys outside of recognized aggregations is performed every 3rd year. The next survey is scheduled for 2022.

- iv. Evaluating existing aggregations and determining drivers of these aggregations, for example, recruitment, natal origins, spawning locations, and spawning habitat (e.g., consider new and innovative methods such as telemetry or the Judas-fish approach; Kegerries et al. 2015).

Estimates of vital rates and recruitment of HBC in the Little Colorado (JCM-East) and Pumpkin Springs/Fall Canyon (JCM-West) aggregations have been developed. A mark-recapture model is currently being developed for fish in JCM-West. Preliminary results suggest that numbers of large adults (>250mm TL) have remained relatively stable since 2018. Adult survival is estimated to be lower than for adult humpback chub in JCM-East, but survival rates are highly uncertain. Growth of HBC in JCM-West is faster than in JCM-East (Table 7). Thus, the relatively high growth and low adult survival in JCM-West likely indicates faster rates of population turnover. Movement into and out of the JCM-West sampling reach is high and this complicates estimation of survival.

Sampling near JCM-west (Fall Canyon) consisted of six passes of hoop net captures and three passes of night-time electrofishing. In the JCM-West reach monitoring trips occurred in April/May, July, and October. During these trips 642 HBC >79 mm TL and 80 HBC 40-79 mm TL were captured in JCM-West (2021 GCMRC Annual Report for Projects G.3 & G.6).

Table 7. The number of juvenile humpback chub of each size identified during mainstem monitoring trips conducted in April, July, and October 2021. The table only includes unique fish.

Location	April/May		July		October		TOTAL	
	40-79 mm	>79 mm	40-79 mm	>79 mm	40-79 mm	>79 mm	40-79 mm	>79 mm
JCM-East	178	847	134	882	29	320	341	2,049
JCM-West	19	264	33	263	28	115	80	642

In 2021 NPS used an open-population model to assess the effect of Shinumo Creek translocations on the Shinumo Creek Inflow humpback chub aggregation. Translocated fish comprised a large proportion of the aggregation relative to non-translocated fish through 2015; however, both group’s abundance declined after 2016 (2021 NPS Monitoring Humpback Chub Translocated to Grand Canyon Tributaries Annual Report). Translocations have not occurred in Shinumo Creek since 2013.

- v. Exploring means of expanding humpback chub populations outside of the Little Colorado River Inflow aggregation. Evaluate the feasibility of mainstem augmentation of humpback chub that would include larval collection, rearing, and release into the mainstem at suitable areas outside of or within existing aggregations.

The initial intent of this measure was to explore the potential for expansion in mainstem areas with suitable thermal characteristics (warm) below Havasu Creek. HBC have expanded unaided into the Western Grand Canyon mainstem since 2014 and established multi-aged recruiting populations by 2017 (Van Haverbeke et al. 2017). Research to better understand the drivers behind this autonomous expansion is ongoing (Measure 5.iv.; JCM-West). Low abundances of non-natives and warm water temperatures are believed to be dominant drivers.

Based on conversations with FWS, work on this measure is not warranted at this time, but evaluation may be considered in the future.

- 6) Reclamation would, through the GCDAMP, conduct disease and parasite monitoring in humpback chub and other fishes in the mainstem Colorado. The GCMRC is currently

conducting parasite monitoring in the Little Colorado River. However, in order to better understand how/if disease and parasites (primarily Asian tapeworm) are affecting chub and how temperature differences may affect parasite occurrence, this work would be expanded to include investigations of parasites in humpback chub (and surrogate fish if necessary) in the mainstem.

In 2021, monitoring for Asian fish tapeworm did not occur because there were so few humpback chub available for collection that priority was placed on minimizing handling of fish. Infestation rates from 2015-2019 indicated relatively low incidence of infestation (average = 20% infestation) with typically only a single worm found per fish, whereas assessments conducted from 2005-2007 averaged 40% infestation, with up to 182 tapeworms found in a single fish. The reason for this apparent recent decline in Asian tapeworm infestation is unknown (see 2021 GCMRC Annual Report Project I). Standardized monitoring protocols for HBC in the LCR and the mainstem require tracking of external parasites and are reported annually (FWS Mark-Recapture & Fish Monitoring Activities in the LCR in Grand Canyon 2000-2020; FWS Monitoring HBC in the CO River Grand Canyon 2020)

Table 8. The number of Asian fish tapeworms detected in humpback chub from 2018-2021 at 2 locations in the Grand Canyon.

Year	Boulder’s Camp (LCR)		Bridge City (below Diamond Creek)	
	# of HBC sampled	# of HBC with Asian tapeworm	# of HBC sampled	# of HBC with Asian tapeworm
2018	36	6	43	0
2019	43	12	0	0
2020*	0	N/A	0	N/A
2021**	0	N/A	0	N/A

*No sampling conducted due to COVID-19.

**No sampling conducted to minimize handling stress on fish.

New Actions:

- 7) Reclamation would collaborate with the FWS, GCMRC, NPS, and the Havasupai Tribe to conduct preliminary surveys and a feasibility study for translocation of humpback chub into Upper Havasu Creek (above Beaver Falls). The implementation of surveys

and translocations, following the feasibility study, would be dependent on interagency discussions, planning and compliance, and resulting outcomes of tribal consultation.

FWS is leading initial discussions about the feasibility of translocating humpback chub into Upper Havasu Creek. FWS initiated coordination with the Havasupai Tribe in 2019 with the objective of an initial field survey. No additional coordination or progress has been possible since the pandemic began due to continued closure of Havasupai Tribal lands. FWS will report back when progress has been made.

- 8) Reclamation would, in cooperation with the FWS, NPS, GCMRC, and AGFD, explore and evaluate other tributaries for potential translocations.

NPS conducted two monitoring trips to Shinumo Creek-Colorado River Inflow and captured 14 humpback chub total. Shinumo Creek continues to be monitored to evaluate its potential for future humpback chub translocations. Data reflecting trends in stream habitat (e.g., substrate composition, channel dimensions, etc.), temperature, macroinvertebrates (food base), and native and nonnative fish distribution and abundance pre- and post-flood are in the process of being evaluated and summarized for discussion. NPS also conducted inflow monitoring in 2021 near Bright Angel and Havasu creeks and at river mile 168.6, yielding 34 additional humpback chub captures (2021 NPS Monitoring Humpback Chub Translocated to Grand Canyon Tributaries Annual Report).

RAZORBACK SUCKER

Ongoing Actions:

- 1) Reclamation would continue to assist the NPS, FWS, and the GCDAMP in funding larval and small-bodied fish monitoring in order to:
 - i. Determine the extent of hybridization in flannelmouth and razorback sucker collected in the western Grand Canyon.

A study to determine genetic hybridization between flannelmouth suckers and razorback suckers is ongoing. Larval fish are collected during river sampling and preserved in alcohol to allow for genetic testing. Samples have been collected and preserved in alcohol since 2019; however, the number of larval razorback suckers that have been collected each year has

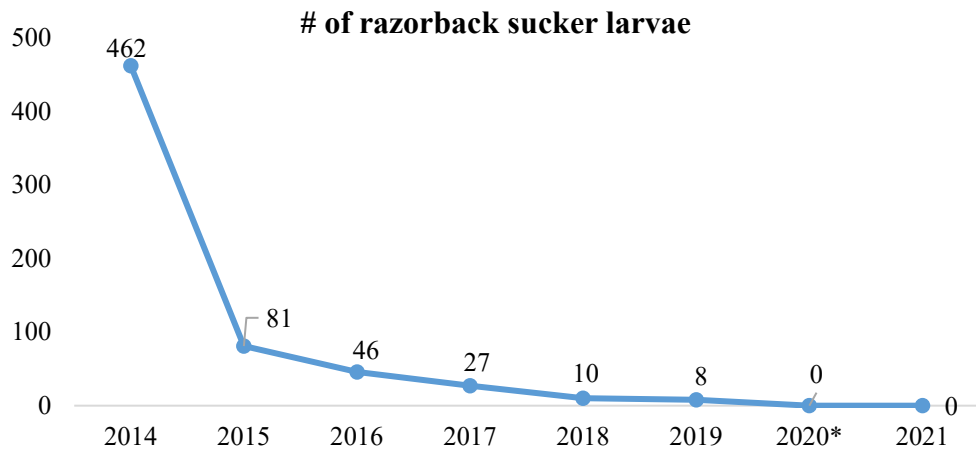
dropped significantly since the first collections of larvae in 2014 (samples collected from 2014-2018 were preserved in formalin which is not conducive to genetic testing). No larval razorback suckers were collected upstream of the Pearce Ferry Rapid in 2020 or 2021.

- ii. Determine habitat use and distribution of different life stages of razorback sucker to assist in future management of flows that may help conserve the species. Sensitive habitats to flow fluctuations could be identified and prioritized for monitoring.

Bio-West continued monitoring of razorback suckers and other fish in 2021 on the Colorado River within Grand Canyon National Park. No larval razorback suckers were identified in 2021 (2021 Biowest Razorback Sucker Research & Monitoring Annual Report). The number of larval razorback sucker taken per sampling year has continued to decline since this monitoring was initiated in 2014 (Figure 1).

Other native and non-native larval and small-bodied fish are identified during collections throughout the Grand Canyon. Since samples are collected over several months and multiple years, the data will help to identify patterns in distribution and abundance of various native and nonnative fish species. The long-term data set might also be useful for making inferences regarding effects of flows and water temperature on various fish species.

Figure 1. The number of razorback sucker larvae identified in the Grand Canyon from 2014-2021.



* No trips occurred in April or May due to COVID-19 restrictions. These are the months when larval razorback suckers have been identified in previous years.

- iii. Assess the effects of Trout Management Flows (TMF) and other dam operations on razorback sucker.

No TMFs have occurred since implementing the 2016 LTEMP, nor have they been scheduled to be tested. On November 5-8, 2018, the Department of the Interior conducted the most recent HFE release from Glen Canyon Dam. The HFE release included a peak flow of approximately 38,100 cubic feet per second for 60 hours (four days including ramping from baseflows to peak release) to move accumulated sediment downstream to help rebuild beaches and sandbars.

Macroinvertebrate production flows were conducted during weekends from May through August from 2018-2020. During the experimental period regular fluctuating flows occurred on weekdays while steady low flows were maintained on weekends with the objective of providing a time period for insects to emerge over the weekends while minimizing impact to hydropower.

In spring 2021, a spring disturbance flow was designed to evaluate whether resources in the Colorado River Ecosystem would be improved. The flow took advantage of an apron repair that was necessary to drop to a low flow and then bring it back up to a high flow.

Baseline data collected during Bio-West monitoring for razorback suckers from March through September was used to evaluate the effect of the HFE. Native catch rates were significantly lower in 2015, 2016, 2019, 2020, and 2021 compared to 2014, 2017, and 2018 (reported in 2021 Bio-West Razorback Sucker Research & Monitoring Annual Report, page 41). Due to the low numbers of razorback suckers in the Grand Canyon, the impact specifically on this fish species could not be evaluated. However, the impact is expected to be similar to that of other native fish species. Additional data will be collected during and after future flow experiments to assess the effects on razorback suckers and other native fish species.

ACTIONS TO BENEFIT ALL NATIVE SPECIES

Ongoing Actions:

- 1) Reclamation, in collaboration with the NPS and FWS, and in consultation with the AZGFD, would investigate the possibility of renovating Bright Angel and Shinumo Creeks with a chemical piscicide, or other tools, as appropriate. Additional planning and compliance, and tribal consultation under Section 106 of the NHPA, would be required.

This feasibility study is outlined in the NPS CFMP (2013; see “Feasibility Study for Use of Chemical Fish Control Methods”).

NPS continues to monitor the recovery of Shinumo Creek to evaluate its potential for future humpback chub translocations and/or chemical piscicide treatment. Following completion of the NPS Expanded Nonnative Aquatic Species EA and FONSI in 2019, and in cooperation with the AGFD, the NPS began to plan for a future rotenone treatment in the upper reaches of Bright Angel Creek and in Shinumo Creek. The treatment is being planned to remove invasive trout in both areas and to prepare to reinitiate translocations of humpback chub to Shinumo Creek. As stipulated in the programmatic agreement between NPS, Arizona State Historic Preservation Office, and Tribes, additional consultation will be completed during planning for piscicide use.

- 2) Reclamation would continue to fund efforts of the GCMRC and NPS to remove brown trout (and other nonnative species) from Bright Angel Creek and the Bright Angel Creek Inflow reach of the Colorado River, and from other areas where new or expanded spawning populations develop, consistent with the NPS CFMP. After 5 years of removal efforts are completed (in 2017), an analysis of success would be conducted. Piscicides may be considered for removal of nonnative species if determined to be appropriate and following completion of the necessary planning and compliance actions.

From October 1, 2020, through March 1, 2021, a modified resistance board weir with a downstream-orientated fish trap was operated in Bright Angel Creek near its confluence with the Colorado River. Trout captures in the weir increased slightly with 8 brown trout and 18 rainbow trout captured at Bright Angel Creek.

Electrofishing was conducted in Bright Angel Creek and other tributaries from October 22, 2020 – January 31, 2021 with 8,301 brown trout and 5,632 rainbow trout removed (2020-2021 NPS Bright Angel Creek Brown Trout Control Season Report).

The NPS is considering alternative non-native fish control mechanisms in the upper reaches of Bright Angel and Shinumo creeks to restore stream function and limit non-native fish populations in those areas. Further coordination and consultation with tribal partners, the AGFD, and federal collaborators will determine if a restoration effort will be implemented in the future.

New Actions:

- 3) Reclamation would explore the efficacy of a temperature control device at the dam to respond to potential extremes in hydrological conditions due to climate conditions that could result in nonnative fish establishment. Evaluations would be ongoing for all current and evolving technological advances that could provide for warming and cooling the river in both high- and low-flow discharge scenarios, and high and low reservoir levels. These studies should include evaluating and pursuing new technologies, an analysis of the feasibility, and a risk assessment and cost analysis for any potential solutions.

Reclamation’s Research and Development Office (based in Denver) completed a report reviewing the temperature control options for reservoir releases in January 2020. A technology search was recommended as a next step to seek industry cross-cutting ideas. In March 2020, Reclamation contracted with the company yet2 to complete a Technology Search to explore innovative water temperature control devices. Reclamation received and reviewed the report 2021, but none of the options were applicable to Glen Canyon Dam. The bypass cooling capacity of Glen Canyon Dam was reviewed and discussed during the June 2021 Technical Work Group and the August 2021 Adaptive Management Work Group meetings. Reclamation is also pursuing a value planning study for infrastructure alternatives, including bypass generation, that may also support temperature management.

- 4) Reclamation would pursue means of preventing the passage of deleterious invasive nonnative fish through Glen Canyon Dam. Because Glen Canyon Dam release temperatures are expected to be warmer under low reservoir elevations that may occur through the LTEMP period, options to hinder expansion of warmwater nonnative fishes into Glen and Grand Canyons would be evaluated. Potential options to minimize or eliminate passage through the turbine or bypass intakes or minimize survival of nonnative fish that pass through the dam would be assessed (flows, provide cold water, other). While feasible options may not currently exist, technology may be developed during the LTEMP period that could help achieve this goal.

Reclamation initiated a new project in 2021 to better understand the potential for passage of non-native fish through the dam. The purpose of the project is to characterize the fish community in the forebay area. Hydroacoustic monitoring and fish netting across various depths will be used to better understand when fish are in the forebay and what species are found at different depths. The engineering group at the Technical Services Center is also reviewing potential options for reducing entrainment at Glen Canyon Dam and will identify a top 3 list of physical and non-physical barriers using past reports, prize competitions, and technology searches.

- 5) Reclamation would, in consultation with the FWS and AGFD, fund the NPS and GCMRC on the completion of planning and compliance to alter the backwater slough at River Mile (RM) -12 (commonly referred to as “Upper Slough”), making it unsuitable or inaccessible to warmwater nonnative species. Depending on the outcome of NPS planning and compliance, Reclamation would implement the plan in coordination with the FWS, AGFD, NPS and GCMRC. Additional coordination would be conducted to determine and access any habitats that may support warmwater nonnatives.

Reclamation produced a report of possible engineering options for modifying the slough in 2018. Using this report, NPS developed a set of tiered actions for addressing green sunfish and other priority nonnative fish species infestations in the slough that were included in the 2019 Expanded Non-Native Aquatic Species EA. This included pump-down and removal of green sunfish, possible chemical treatments, and limited dredging and placement of a water control weir at the outlet thereby facilitating dewatering/refilling and removal of any unwanted fish species including green sunfish.

In September 2020 NPS sent approximately 60 fish to an AGFD laboratory to be examined for parasites and disease. In October 2020, NPS removed 3,250 green sunfish from the Upper Slough by pumping water out of the slough and then using a backpack shocker. The fish were quarantined for 2 weeks to ensure that no New Zealand mudsnails were removed and 350 were relocated into Lake Powell near the Wahweap Marina. Although green sunfish were observed in the slough in 2021, removal has been delayed until spring 2022. Since a fall HFE did not occur, NPS considered removal less urgent and green sunfish removal is now planned for spring.

- 6) Reclamation would support the GCMRC and NPS in consultation with the FWS and AGFD on the completion of planning and compliance of a plan for implementing rapid response control efforts for newly establishing or existing deleterious invasive nonnative species within and contiguous to the action area. Control efforts may include chemical, mechanical, or physical methods. While feasible options may not currently exist, new technology or innovative methods may be developed in the LTEMP period that could help achieve this goal. Rapid response to new warmwater fish invasions may become a more frequent need in the future with lower reservoir elevations and warmer dam releases.

The NPS Non-Native Aquatic Species Environmental Assessment was completed in 2019 and includes options for rapid response to warmwater fish invasions.

- 7) Reclamation, will consider, in consultation with the GCDAMP, the experimental use of TMFs to inhibit brown trout spawning and recruitment in Glen Canyon, or other mainstem locations. Inhibiting brown trout spawning and recruitment will benefit chub by reducing the potential for brown trout to predate upon humpback chub.

GCMRC recently conducted a literature review related to TMFs to determine characteristics of flow regimes that lead to higher levels of fish stranding. Key factors identified in the literature that influence the extent of stranding include: fish size class and life history stage, flow factors (down-ramp rate, magnitude of stage change, duration of high and low flows, and frequency of flow fluctuations), diel cycle, and channel morphology factors (lateral slope, substrate composition, habitat complexity). Stranding studies included in this review were found to be site-specific and key factors influencing stranding are highly interdependent. General findings suggest that faster down-ramp rates during the daytime between May and July (February-April if targeting brown trout) at lower flow elevations could optimize young-of-year stranding. Repeated cycles of TMFs could decrease the compensatory survival response. TMFs remain experimental to determine exact metrics for each factor required to optimize stranding specific to the Colorado River below Glen Canyon Dam.

GCMRC analyzed bathymetry and predictions from a 2-dimensional flow model from Glen Canyon to predict relative changes in young-of-year stranding risk under different TMF scenarios. Given current limitations in water availability, results suggest a steady TMF high flow of 12,000-16,000 ft³/s, combined with a minimum flow of 3,000- or 5,000 ft³/s may effectively strand age-0 fish while also minimizing risk to other resources.

SOUTHWESTERN WILLOW FLYCATCHER

- 8) Reclamation would partially assist in funding NPS to conduct Southwestern Willow flycatcher (SWFL) surveys once every other year for the life of the LTEMP.

Surveys were conducted in May, June & July for southwestern willow flycatchers in 2021 per the revised 2021-2023 workplan schedule. Willow flycatchers were identified during the May trip but no southwestern willow flycatchers were identified (Biannual Surveys for Southwestern Willow Flycatcher (*Empidonax traillii extimus*) along the Colorado River in Grand Canyon National Park 2021 Annual Report). The next surveys are planned for 2023.

YUMA RIDGWAY’S RAIL

- 9) Reclamation would partially assist in funding NPS to conduct Yuma Ridgway’s rail surveys once every three years for the life of the LTEMP.

No Yuma Ridgway’s rail surveys were conducted in 2021 per the revised 2021-2023 workplan schedule. The next surveys are planned for 2022.

CONSERVATION MEASURES SUMMARY

The table below shows, for each conservation measure, the project that addresses it and the agency responsible for implementing the work.

Table 8. Summary of Conservation Measures as identified in the 2016 Biological Opinion

RESOURCE PROTECTED	CONSERVATION MEASURE	DETAILS	TWP PROJECT or OTHER FUNDING	AGENCY CONDUCTING WORK
Humpback Chub	Support translocations of humpback chub into tributaries and monitoring the translocations	Translocation above Chute falls	GCMRC G7	FWS
		Annual monitoring to determine survivability, population status in Havasu Creek	Reclamation	NPS
	Conduct spring & fall population estimates annually using a mark-recapture based model for the LCR	GCMRC G2	FWS/GCMRC	
	Control or removal of non-native fishes in tributaries prior to translocations	Reclamation	NPS	
	Support FWS maintenance of humpback chub population at federal refuge (SNARRC)	Reclamation	FWS	
	Ensure a stable or upward trend of HBC mainstem aggregations	Annual monitoring of the LCR aggregation	GCMRC G1, G2, G3	GCMRC/FWS
		Annual monitoring of mainstem CO River	GCMRC G5	FWS/GCMRC
		Conduct periodic surveys to identify additional aggregations & individual HBC	GCMRC G5	FWS/GCMRC
		Evaluate existing aggregations & determine drivers of aggregations	GCMRC G1	GCMRC
		Explore means of expanding population outside of LCR (mainstem augmentation)		
	Conduct disease & parasite monitoring in mainstem & LCR	GCMRC G2, Project I	FWS/GCMRC	

RESOURCE PROTECTED	CONSERVATION MEASURE	DETAILS	TWP PROJECT or OTHER FUNDING	AGENCY CONDUCTING WORK
	Conduct preliminary surveys for translocation into Upper Havasu		Reclamation	NPS/FWS
	Explore other tributaries for potential translocation			
Razorback Sucker	Determine extent of hybridization with flannelmouth suckers		Reclamation	AGFD
	Determine habitat use & distribution of different life stages of RBS		Reclamation	Bio-West
	Assess effects of TMFs & other dam operations			
Benefit Native Aquatic Species	Evaluate use of piscicide or other tools to renovate Bright Angel and Shinumo			
	Remove brown trout from Bright Angel, inflow & and other new areas		Reclamation	GCMRC/NPS
	Explore efficacy of a temperature control device		Reclamation C10	Reclamation
	Pursue means of preventing passage of non-native fish through dam		Reclamation C9	Reclamation
	Complete planning and compliance to alter the backwater slough		Reclamation Technical Report #SRH 2018-17 completed in 2018	NPS/Reclamation
	Complete planning and compliance of a plan for implementing rapid response control efforts		GCMRC I1, I2, I3	AGFD/GCMRC/NPS
	Consider the experimental use of TMFs to inhibit brown trout spawning & recruitment		GCMRC H2	GCMRC
Yuma Ridgway's Rail	Partially assist in funding surveys every 3 years		Reclamation C11	NPS
Southwestern Willow Flycatcher	Partially assist in funding surveys every 2 years		Reclamation C11	NPS

SUPPORTING DOCUMENTATION

Work on the 2016 LTEMP BO conservation measures is ongoing. Reclamation has received several final reports detailing activities supporting conservation measures in the 2016 BO. These reports are attached with the transmittal of this document and are identified below.

Attached reports

2020-2021 NPS Bright Angel Creek Brown Trout Control Season Report

2021 NPS Monitoring Humpback Chub Translocated to Grand Canyon Tributaries Annual Report

2021 Bio-West Razorback Sucker Research & Monitoring Annual Report

2021 GCMRC Annual Report

Biannual Surveys for Southwestern Willow Flycatcher (*Empidonax traillii extimus*) along the Colorado River in Grand Canyon National Park 2021 Annual Report.

FWS Mark-Recapture & Fish Monitoring Activities in the LCR in Grand Canyon 2000-2021

FWS Monitoring Humpback Chub Aggregations in the Colorado River, Grand Canyon 2020

Van Haverbeke DR, Stone DM, Dodrill MJ, Young KL, Pillow MJ. 2017. Population expansion of humpback chub in Western Grand Canyon and hypothesized mechanisms. *Southwestern Naturalist* 62:285-292.