Native and non-native fishes of the Grand Canyon: Ecology and management strategies

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Fish of the Grand Canyon

Native fish within the Colorado River, numerous rivers in the American west, and worldwide have been declining for many years due to a variety of natural and anthropogenic factors. The species at greatest risk are those specialized for life in large rivers and endemic species with small ranges (Moyle and Leidy 1992). As the Grand Canyon has the lowest diversity of native fish species and highest levels of endemism of any North American River, its native fish were highly adapted to the natural high variability of the flows and temperatures within the river (National Park Service, 2018). The Colorado River within the Grand Canyon was previously home to eight species of native fish, six of them endemic to the Colorado River Basin. The population of native fish in the Grand Canyon has declined since the Glen Canyon Dam was Constructed in 1963. Instead, there are now numerous non-native species that thrive under the new flow and thermal regimes below the dam. The future of native fish in the Grand Canyon is now largely dependent on management actions to control non-native species, boost native fish populations, and manage flows and habitat to support native fish needs.

The native fish that are still found within the Grand Canyon are the humpback chub, razorback sucker, bluehead sucker, flannelmouth sucker and speckled dace. The humpback chub was listed as endangered in 1967 followed by the razorback sucker in 1991. As endangered species, management actions to improve their population status are required. Three species, the Colorado pikeminnow, roundtail chub, and bonytail have already been extirpated from Grand Canyon (National Park Service). The Glen Canyon Dam altered the conditions of the Colorado River within the Grand Canyon by creating water temperatures are now much colder, and stable, than historical conditions. Fish native to the Grand Canyon are well adapted to variations in water temperature, however they thrive in warmer water temperatures that are no longer experienced during the summer. Colder water year-round is an issue because native fish grow more slowly, have reduced swimming performance, and lower embryonic hatching success compared to warm water conditions (Marsh, 1985; Robinson and Childs 2001). Additionally, much of the sediment that was previously washed downstream is now held behind the Glen Canyon Dam in Lake Powell. The calmer backwater habitats that were especially important for juvenile native fish are now less common and are harder to replenish when they erode away due to the limited sediment available to be deposited downstream (Converse et al., 1998).

There are currently numerous species of non-native fish in the Grand Canyon that were introduced by humans. Two species of management concern are the rainbow and brown trout. Rainbow trout were introduced to support a recreational fishery near Lee’s Ferry. Despite ending the stocking program, the population is now self-sustaining and the trout have spread downstream. Non-native species are a major concern for native fish populations because they increase competition for food and habitat and can also be predators of native fish (Yard et al., 2016). Trout are particularly piscivorous and appear to favor eating native fish over non-native prey despite non-native species representing a higher proportion of the fish community (Yard et al., 2011). Non-native species such as trout have benefitted from the installation of the Glen

Canyon Dam because they thrive in colder water temperatures and less turbid waters (Clarkson and Childs 2000; Ward and Bonar 2003).

The Glen Canyon Dam has altered the Colorado River through the Grand Canyon and the fish community within it. Management actions are needed if native fish species are to persist in the Grand Canyon. In particular, management actions that balance the interests of native fish conservation with recreational angling, human water and power needs, and river recreation within the Grand Canyon are needed to create support for native fish conservation. Three of the main actions implemented, discussed below, are the physical removal of non-native species, translocating endangered humpback chub to new tributary habitats, and high flow experiments.

Management Strategies to Promote Native Fish Populations

Controlling Non-Native Fish Populations

Managing non-native species within the Grand Canyon and Colorado River Basin remains a challenge due to competing management interests. Anglers enjoy fishing for introduced fish species such as trout which contribute to the decline of native species. As native species continue to decline, management agencies are actively trying to control and reduce the number of non-native fish present throughout the basin. As managers are tasked with protecting native species, especially federally endangered species including the Humpback Chub, one proposed solution is to physically remove non-native species from particular reaches of the Colorado River. Physical removal is time and labor intensive, as well as expensive, but it remains a viable option because there are few alternatives. Chemical control measures are not a good option because of their potential to harm native fish and concerns for ecosystem health (Tyus and Saunders 2000). Rainbow trout and brown trout are the main targets for removal efforts as they are top predators of native fish (Yard et al., 2011).

A large non-native species removal plan was completed from 2003-2006 to target non-native trout in the primary humpback chub habitat near the Little Colorado River (Coggins et al., 2011, Fig. 1). Over the course of three years, biologists removed non-native fish species caught using electrofishing in the study reach. In a control reach the trout caught by electrofishing were counted and released. After 23 removal trips during the study the proportion of non-native fish was reduced from over 90% to 50%. The targeted removal of rainbow trout appeared to be particularly successful by reducing their abundance from 95% to 10%. However, the results were complicated by a concurrent reduction in rainbow trout abundance in the control reach which suggests additional environmental factors may also have contributed to the decline of rainbow trout within the study reach (Coggins et al., 2011). Additionally, brown trout removal efforts in Bright Angel Creek began in 2010 to increase populations of native blue head and flannelmouth suckers and speckled Dace with success in reducing adult trout numbers and increasing the abundance of native species by 2017 (Schelly et al., 2017). Removal efforts were successful enough to support the translocation of Humpback Chub to Bright Angel Creek in 2018 (National Park Service).

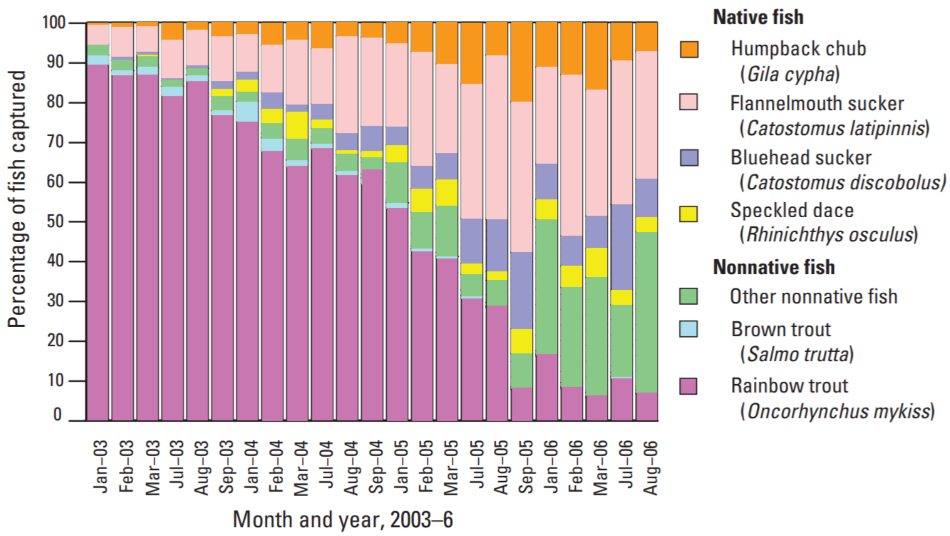

Figure 1. Proportion of native and non-native fish during a 2003-2006 electrofishing and non-native fish removal study, from Coggins et al. 2011.

Although the success of the removal efforts of Coggins et al. (2011) remain unclear, physical removal efforts are still a favorable solution to managing non-native predators. A major concern about physical removal is the cost and effort associated with it, but implementing high levels of rainbow trout control when the population is moderately high was found to be the most cost-effective solution when increasing the juvenile humpback chub population is the goal (Bair et al., 2018). The success of removals is largely dependent on water temperatures and the frequency of removal efforts due to the temperature sensitivity of trout and Humpback Chub populations and the ability of trout to migrate downstream from Lee's Ferry (Bair et al., 2018). If trout migration frequency is low, two removal efforts per year may be sufficient to control populations, but if trout migration rates are high, even three efforts per year may not be enough to maintain target trout population levels (Hilwig and Makinster 2010). Overall, an external review by the United States Geological Survey determined that physical removal efforts should continue to control rainbow trout populations near the Little Colorado River. A target goal of 80% removal of non-native fish has been recommended and supported (Hilwig and Makinster 2010; Mueller 2005). Plans and discussions for continued physical removal are ongoing as there are many details to be decided such as which species and age classes should be targeted, how to remove and dispose of removed fish, and where and when to target removals (Runge et al., 2011).

Humpback Chub Populations within the Grand Canyon

Humpback chub are currently found in both the upper and lower Colorado River basins. There is limited data on the historical distribution of humpback chub within the Lower Basin, but they may have been found all the way to the present-day Hoover Dam (Miller, 1955). Currently, the largest populations of humpback chub are found in the Little Colorado River and its confluence with the Colorado River. In addition, there are smaller populations that persist within the Colorado River and have been increasing in abundance since 2006. The consistent releases of cold water from the Glen Canyon Dam are thought to be a major driver of the reduction in humpback chub range and distribution due to the negative effects of cold temperature on spawning and recruitment (Marsh 1985). With the limited range and spawning habitat for humpback chub restricted primarily to the Little Colorado River, the species is particularly vulnerable to any natural or anthropogenic changes within the Little Colorado River. As a result, it is a major conservation goal to have secondary spawning populations within the Lower Basin to create population redundancy.

Translocation, the human facilitated movement of individuals from a source population to another habitat location within their historical range, was attempted with humpback chub at two locations to try to create population redundancy. Translocation was first attempted by moving a subset of fish from the Little Colorado River to Shinumo Creek, another Colorado River tributary (Fig. 2). Between 2008-2010, 902 juvenile humpback chub were moved from the Little Colorado River to Shinumo Creek. Initial results were promising. Although emigration from Shinumo Creek was high (up to 59% per year), humpback chub grew and survived at similar rates as those in the Little Colorado and Colorado Rivers (Spurgeon et al., 2015). Shinumo Creek seemed like a potential refuge for humpback chub, however fire and flooding events in 2014 extirpated the population in Shinumo Creek (Healy et al. 2019).

A second translocation effort was attempted from 2011-2016 (Healy et al., 2019). During that time between 250-500 humpback chub were moved from the Little Colorado River to a hatchery for 8-12 months before being released into Havasu Creek. Havasu Creek is a Colorado River tributary with few non-native fish, a similar water chemistry and habitat quality to the Little Colorado River, and a warm thermal regime favorable for the growth and reproduction of humpback chub. Initial results of the translocation indicate it was successful. The survival rate of humpback chub in Havasu Creek was equal to or higher than in the Little Colorado River. By the end of 2017 there was evidence of humpback chub reproduction in Havasu Creek as well as several age classes present which confirms the translocated juvenile fish were recruiting to maturity (Healy et al., 2019). While Havasu Creek is a step towards creating population redundancy and stability for humpback chub in the Lower Basin, isolated populations are still vulnerable to disturbance. Continued monitoring of humpback chub populations in Havasu Creek and other locations within the Lower Basin are needed to understand how the species will be affected by these translocations in the future. Following extensive brown trout removal efforts, humpback chub were translocated to Bright Angel Creek in 2018 where monitoring and translocation efforts are ongoing (National Park Service).

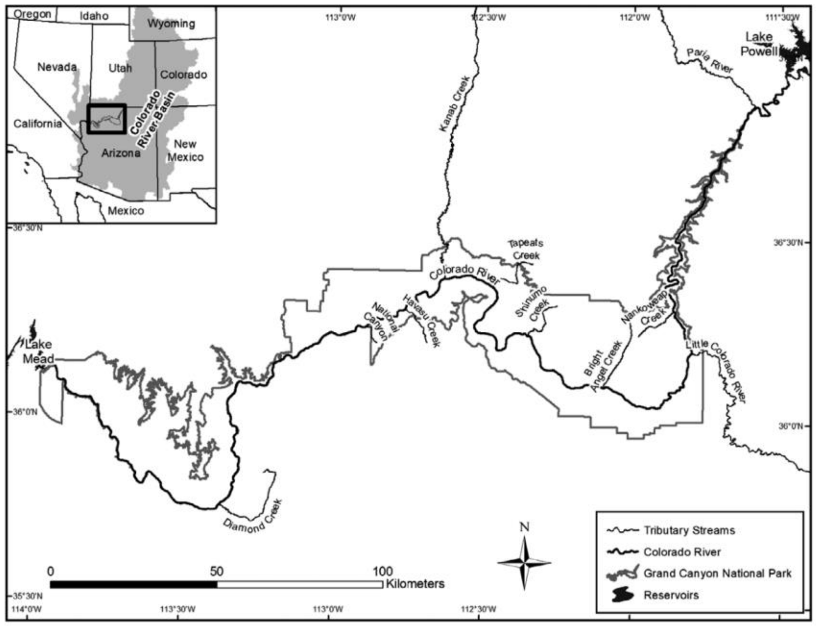

Figure 2. Map of the Colorado River and tributaries with humpback chub including the Little Colorado River source population, Shinumo, Havasu, and Bright Angel Creeks. From Healy et al., 2019.

While the translocations of humpback chub are promising, Shinumo and Havasu Creeks have a limited carrying capacity and may not be able to support populations large enough to provide the population redundancy needed (Healy et al., 2019; Pine et al., 2013). However, recent sampling in the western Grand Canyon suggests populations of humpback chub may be naturally expanding in the Colorado River farther downstream from the Glen Canyon Dam (Rogowski et al., 2018; Van Haverbeke et al., 2017). Increased catch rates during sampling in the western Grand Canyon suggest the population of humpback chub is expanding. Additionally, the chub caught were from multiple size classes which can be an indicator of successful natural recruitment. Van Haverbeke et al. (2017) believe the localized increase in abundance and recruitment of chub may be influenced by emigration from the Little Colorado River or the sites with recently translocated fish. Perhaps the biggest driver of humpback chub abundance is the increase in water temperature of the western Grand Canyon since 2005. Water temperatures within the Western reach of the Grand Canyon in recent years have been above 16 °C which is optimal for growth and survival across humpback chub life stages (Van Haverbeke et al., 2017). If water releases from Glen Canyon Dam remain warm, the Colorado River within the western Grand Canyon may become a natural area of population redundancy for the humpback chub. Combined with the translocations of chub within the Lower Basin, the future for this endangered fish is looking better.

Glen Canyon Dam High Flow Experiments

High Flow Experiments (HFEs) are a management action that does not specifically target fish but has numerous positive and negative effects on the fish communities below the Glen Canyon Dam. HFEs are targeted periods of high flows above powerplant capacity that mimic the natural variable floods and high flows that occurred before the Glen Canyon Dam was built (Melis 2011). The HFEs were conducted with the goal of establishing sandbar habitat for river recreation. However, by changing the flow and riparian habitat the fish of the river were also affected. There have been several HFEs in recent years, but the fish community effects following the March 1996, November 2004, and March 2008 HFEs have been the most well-studied to date.

The HFEs appear to have the greatest effects on non-native rainbow trout that dominate the reach of the river at Lee's Ferry. The rainbow trout population was the highest on record following the 2008 HFE and stayed high through 2009 indicating the effects were long-lasting (Korman et al., 2010; Makinster et al., 2010) (Figure 3). The population increase is likely due to improved spawning habitat following the HFE resulting in the largest recruiting cohort which was then sustained by an increase in the aquatic invertebrate populations, a major food source for juvenile trout (Rosi-Marshall et al., 2010). Since trout populations also increased after in 1997 following the March 1996 HFE, the timing of spring HFEs appear to be particularly beneficial to trout because the recruitment of early life stages improves.

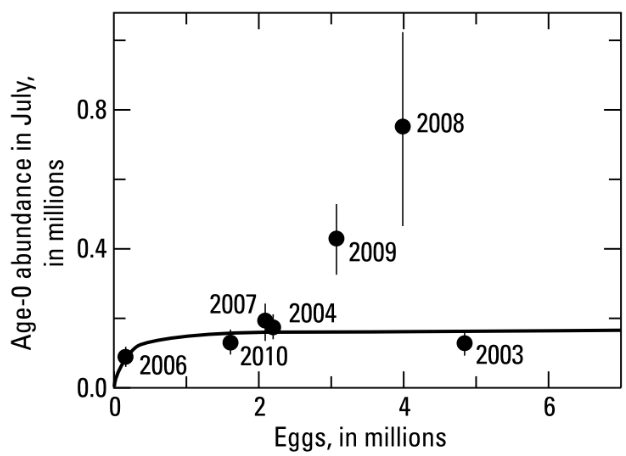

Figure 3. The relations between the number of viable rainbow trout eggs deposited in the Lees Ferry reach and the resulting population size of age-0 trout on July 15, 2003–09 (no data collected in 2005). The thick black line shows the best-fit curve (relation) between the number of viable eggs and age-0 trout abundance using data from 2003 to 2007 only. From Korman and Melis 2011.

The effects of HFEs on native fish species are less clear. Overall there seems to be a net negative on native species like the humpback chub. The primary benefit of HFEs to native fish is the creation of backwater habitat which are favored spawning and rearing areas. However, the beneficial effects of the additional habitat created may be overshadowed by the negative effects of HFEs. The water released from the dam during HFEs is cold. humpback chub can't reproduce successfully, their swimming ability is decreased, and they grow more slowly in colder waters (Melis 2011). To reduce direct and indirect mortality of humpback chub from high flows and low temperatures it is suggested that spring HFEs would be best. Additionally, the increase in rainbow trout is likely detrimental to humpback chub by increasing competition and risk of predation. While most of the rainbow trout are found near Lee's ferry, the high flows and increased number of individuals in that area led to increased numbers of trout found near the confluence of the Little Colorado River, the primary humpback chub habitat. The advantage of spring timed HFEs to rainbow trout therefore creates a management conflict as both species may fare better under spring HFEs, but the benefits to rainbow trout can create larger threats to humpback chub. It should be noted that determining the specific effects of HFEs on humpback chub populations is difficult due to the short time period of the HFEs (roughly 2-7 days) and because it takes about 4 years for humpback chub to reach maturity. Since potential benefits of HFEs to humpback chub appear to weak and short lived, HFEs are not a useful tool for the purpose of humpback chub conservation (Melis 2011).

The effects of HFEs on other native fish are not as pronounced. The creation of backwater habitat would benefit many species including speckled dace, flannelmouth sucker and bluehead sucker, however there were no observed changes in the populations of those species following the HFEs (Makinster et al., 2010; Valdez et al., 2001). The effects of rainbow trout, low temperatures, and high flows do not negatively affect native dace and suckers that are found farther downstream to the extent that humpback chub are likely to be affected (Melis 2011). Food availability downstream is also not affected by HFEs for these species (Shannon et al, 2001; Rosi-Marshall et al., 2010). Spawning habitat of native fish also experienced stronger negative effects than that of non-native trout. Even short (1 day) HFEs could be detrimental to flannelmouth sucker spawning habitat but beneficial to rainbow trout, whereas HFEs of 8 days or more became destructive to the spawning habitat of both species (Yao et al., 2015). In general, native fish species do not see strong benefits from HFEs conducted below Glen Canyon Dam.

Conclusions

There is no single management action that will maintain the native fish population in the Grand Canyon. The success of native fish management will require the continuation of non-native fish species removals as well as management of water temperature, sediment loads, and food webs within the river (Dodrill et al., 2015). The Colorado River in the Grand Canyon will likely continue to maintain a viable trout fishery in Lee's ferry while native fish species continue to persist downstream. As the removal of non-native species downstream continues, there will likely be increases in the number of native fish species. The translocations of humpback chub and the expansion of humpback chub habitat into the western Grand Canyon provide optimism for the future of this species, so much so that it has been proposed to down list the humpback chub from its endangered status pending further review (USFWS 2018). Furthermore, fish surveys conducted from 2014-2018 suggest that native fish species are now more abundant than non-native fish in the river reach from Bright Angel Creek to Pearce Ferry (Kegerries et al. 2019). There is hope for the future of native fish species in the Colorado River through the Grand Canyon as native fishes appear to be regaining dominance, a rare occurrence in rivers of the desert southwest.

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