Response of native fish fauna to dams in the Lower Colorado River

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Introduction

As early as 1895 explorers and naturalists came to know the Grand Canyon as a unique system unlike any other river system in North America. One of the Canyon's most distinguishing features, its fish fauna, was described by Evermann and Rutter (1895), both employees of the US Bureau of Fisheries who traveled extensively throughout the Colorado River Basin:

> *"Though the families and species are very few, they are unusual interest to the student of geographic distribution… over 78% of the species of fishes now known from the Colorado Basin are peculiar to… a larger percentage of species peculiar to a single river basin than is found elsewhere in North America."*

The Colorado River has the lowest diversity of fish and highest endemism of river systems in the North America, likely due to the system's isolation and the high variability of temperature and flow conditions in the mainstem and tributaries

The Grand Canyon native fish fauna is comprised of eight species; six endemic to the Grand Canyon and two, Speckled Dace (*Rhinichthys osculus*) and Roundtail Chub (*Gila robusta*), are found throughout the Colorado River Basin. Humpback Chub (*Gila cyhpa*), Bonytail (*Gila elegans*), Colorado Pikeminnow (*Ptychocheilus lucius*), and Razorback Sucker (*Xyrauchen texanus*) are listed or proposed as endangered by U.S. Fish and Wildlife Service. Flannelmouth Sucker (*Catostomus latipinnis*) and Bluehead Sucker (*Catostomus discobolus*) remain relatively common throughout the Lower Basin (Minckley *et al.* 1986).

Effect of dams on native fauna

One of the single largest threats to native fishes in rivers is the construction of dams because they drastically change river ecosystems. Glen Canyon Dam, located at the northern part of the Lower Basin of the Colorado River (Figure 1), was completed in 1966. The Lower Colorado Basin is impeded by six major dams before the river reaches its end in the Gulf of California. Glen Canyon Dam has forever changed the Colorado River flowing through Grand Canyon National Park. More than 90% of the sediment that once flowed through the Grand Canyon is now blocked by the dam. Massive floods that once were churning with fine sediments used to barrel downstream between the Grand Canyon's walls. Although some experimental floods are allowed to flow through the canyon, the timing of water discharge is dependent on irrigation and electricity demand (Cross *et al.* 2011, Topping *et al.* 2003). Water released from Glen Canyon Dam is much clearer and colder at 47F compared to pre-dam flows which fluctuated seasonally from near freezing to 80F. Together, these changes in flow, turbidity, and temperature have enormously changed the Colorado River's natural variability.

Figure 1. Map of the Colorado River Basin which spawns across Wyoming, Utah, Colorado, Nevada, Utah, California, Arizona, and New Mexico. The Grand Canyon is primarily located in Arizona between Glen Canyon Dam and the Hoover Dam.

Source: United States Geological Survey, https://www.usgs.gov/media/images/colorado-river-basin-

Dams have shown negative effects on native fish populations particularly for reproduction, survival, and recruitment. Low temperatures (<15 C) inhibit gonadal maturation and spawning (Minckley 1991) and embryonic development (Marsh 1985). Cold temperatures lowered growth and swimming performance of Colorado Pikeminnow juveniles (Childs and Clarkson 1996) and increased mortality in larvae (Berry 1988). In Razorback Sucker, Flannelmouth Sucker, Humpback Chub, and Colorado Pikeminnow, growth in body length and weight during the larval and juvenile stages was slower at colder temperatures for all species in controlled laboratory experiments (Clarkson *et al.* 2000). Slower growth at these life stages presents a critical challenge to fish: growing to a larger body size quickly means avoiding being eaten by larger predators, if it takes longer to become large then the fish is more likely to be eaten, and over time recruitment in the population will decline (Childs and Clarkson 1996).

In the Lower Basin of the Colorado long-term trends show native fish species exhibit the greatest rates of decline and non-native fishes the highest rates of spread though there are a few notable exceptions (Olden and Poff 2005). For many decades the evidence for widespread replacement of native fish communities by non-native species was largely anecdotal. The first to quantify such a transition was by Olden and Poff (2005) with a dataset containing tens of thousands collected over a century and a half, the SONFISHES database which details the distributions of native freshwater fishes in the Sonoran Desert ecoregion of northwestern Mexico and the southwestern USA over 160 years of research. Native fish species typically showed dramatic declines in the size of their distributions, however the trend varied among species. Colorado Pikeminnow spatial distribution in the Lower Basin of the Colorado has declined by 100% and is therefore extinct from the Grand Canyon system, whereas Flannelmouth Sucker range has decline by 62% since <1960s, and the Roundtail Chub range declined to 6% (Olden and Poff 2005). Across a similar period, rates of expansion of non-native fishes are all positive ranging from 18 km/yr for Rainbow Trout (*Oncorhynchus mykiss*) to 74 km/yr for Fathead Minnow (*Pinephales promelas*). An increase in rarity of native species and increasingly fragmented ranges, raises the chances of becoming locally extinct. And indeed, this is true for

Lower Basin native fish fauna, fragmentation was consistently associated with elevated extinction risk and those species with the most fragmented historic distributions were nearly five times more likely to suffer local extirpations than were species with continuous distributions (Fagan *et al.* 2002).

Status of Grand Canyon native fish species

In the Grand Canyon four of the eight native fish species have been listed as federally endangered under the Endangered Species Act: the Humpback Chub, Razorback Sucker, Colorado pikeminnow, Bonytail Chub. Only the Razorback Sucker and Humpback Chub are still found throughout the Grand Canyon, though both are rare. Speckled dace is the only native fish species that is common in the park (Figure 2).

Humpback chub

The humpback chub once lived throughout the entire Colorado River system, but presently is restricted to six populations. The largest population is within the Grand Canyon, but they are almost exclusively found at the confluence with the Little Colorado River. Since the mainstem waters are relatively cold in spring and summer, humpback chub spawn in the warmer waters of the Little Colorado tributary. Adults prefer turbulent, high gradient stretches of the Colorado River, whereas juveniles prefer shallow, low-velocity, backwater pools. Humpback chub primary predators are brown and rainbow trout which occur throughout the Grand Canyon, and especially upstream in the tailwater of Glen Canyon Dam (Kaeding and Zimmerman 1983). Humpback chub were listed as endangered in 1967 (U.S. Fish and Wildlife Service 1990).

Razorback sucker

Razorback sucker were federally listed as endangered in 1991, but were endangered under Colorado law since 1979. Growing to as long as three feet, this species is one of the largest species of suckers in North America. Historically its distribution was spread throughout the entire Colorado River Basin, but today Lake Mead and Mohave are the only populations with wild fish (Historical Native Fishes of Glen and Grand Canyons). Once thought to be absent from the Grand Canyon for many decades, there have been recent sightings of larval razorback suckers at multiple locations throughout the Grand Canyon (Minckley 1991).

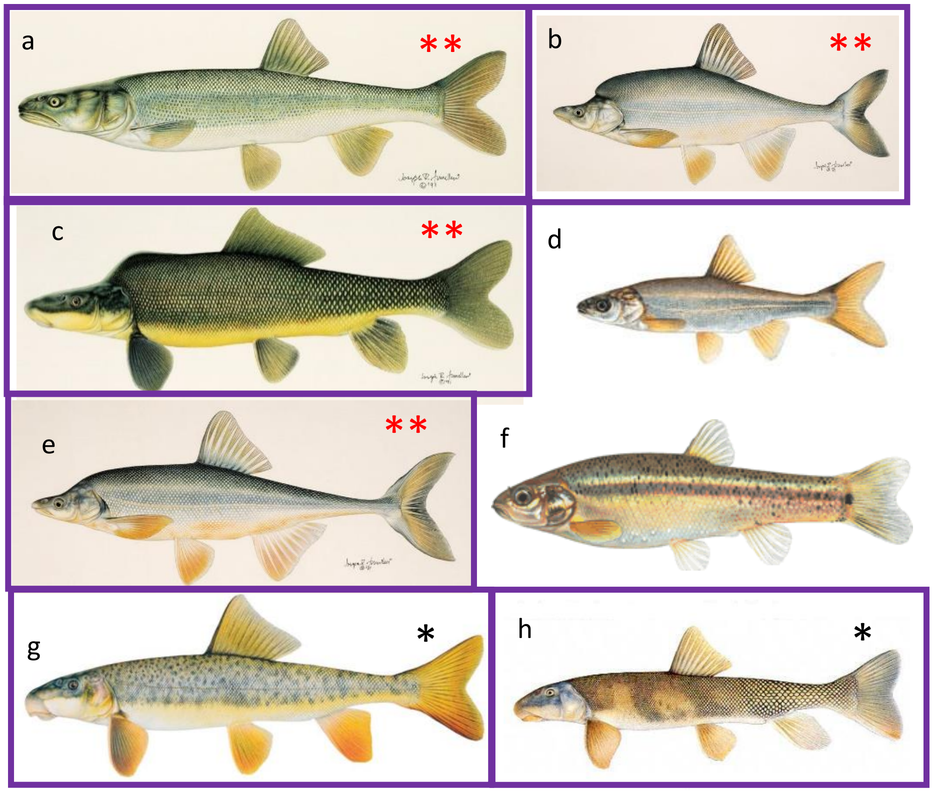

Figure 2. Native fish species of the Grand Canyon, a) Colorado Pikeminnow, b) Humpback Chub, c) Razorback Sucker, d) Roundtail Chub, e) Bonytail Chub, f) Speckled Dace, g) Flannelmouth Sucker, and h) Bluehead Sucker. The purple box indicates which species are endemic to Grand Canyon. Only Speckled Dace (f) and Roundtail Chub (d) are found throughout the Colorado River Basin. Flannelmouth Sucker (g) and Bluehead Sucker (h) are the only two species commonly found today, indicated by a single black star. Two red stars indicate which species are federally listed under the Endangered Species Act. All images were illustrated by Joseph R. Tomelleri, http://www.coloradoriverrecovery.org/general-information/the-fish/humpback-chub.html

Colorado pikeminnow

Listed in 1967 along with the humpback chub, and then fully protected in 1973 with the passage of the Endangered Species Act, the Colorado pikeminnow, has been extirpated from the Grand Canyon for many decades. The last recorded sighting in the Grand Canyon was in 1972 after Glen Canyon Dam was built. Populations of Colorado pikeminnow today persist north of Glen Canyon Dam in the upper Colorado River Basin, in the Green River, Gunnison River, White River, San Juan River, and Yampa River (Grand Canyon's Extirpated Fish Species: National Park Service). Colorado pikeminnow is one of the largest freshwater fish species and was formerly an important source of food for both Native Americans and early European settlers (U.S. Fish and Wildlife 2002b).

Roundtail chub

The Roundtail chub shares the same Genus as the humpback chub, *Gila*. Roundtail chub were likely extirpated from the Grand Canyon by the late 1960s after the construction of Glen Canyon Dam. Of the three species of chub (Humpback, Roundtail, and Bonytail), Roundtail is the most abundant species in the Colorado River system outside the Grand Canyon (Holden and Stalnaker 1975).

Bonytail chub

Of all the Colorado River's native fishes Bonytail is the most critically endangered. A number of hatcheries support refuge populations in the Colorado River system, but no reproducing populations exist in the wild. Although the species was once abundant throughout Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming populations declined drastically and it was listed as endangered in 1980. Unfortunately, not much is known about the behavior or ecology of Bonytail prior to the construction of dams and introduction of non-native fish species (U.S. Fish and Wildlife Service 2002a).

Management and recovery strategies

1. *Restore pre-dam river flows: controlled flooding*

Prior to the establishment of dams, floods were an integral part of ecology in the Grand Canyon (Minckley 1991). Floods in the late spring and throughout the summer were important spawning cues for native fishes because they restructured habitat along the riverbanks and created backwaters which are important habitat for rearing larval and juvenile fishes that dispersed from spawning areas (Valdez and Wick 1983). Fishes native the Grand Canyon appear to be especially resistant to flooding, having coexisted with extremely variable annual flows. Non-native fishes however, show much less tolerance for flooding (Meffe and Minckley 1987). Since Glen Canyon Dam has stopped the flow of sediment through the canyon and dramatically tamed the highly variable annual flows, the US Department of Interior has considered using controlled high releases (i.e., flood) since 1994 (Clarkson *et al.* 2000). High releases were expected to rebuild sandbars, deposit nutrients, restore backwater channels, and provide at some dynamics of a natural system.

So far, many controlled floods from Glen Canyon Dam have been released and the impacts on native fish species is mixed. The floods are expected to suspend sand that has fallen to the river bottom during periods of low water flow and deposit it along the river banks where it will be above water after the flood recedes. Overgrown vegetation will be pushed back by the creation of sand banks which are useful for river rafters but also provide backwater habitat for native fishes. In addition to habitat creation, controlled floods are also expected to negatively impact non-native fish species because these more of these taxa evolved in systems with extensive flood plain habitat and are more likely to seek refuge from floods by drifting downstream to more quiet waters (Ross and Baker 1983). In a study by Hoffnagle *et al.* (1999), changes in distribution, abundance, and habitat use of 11 fish species, four native (Humpback Chub, Flannelmouth Sucker, Bluehead Sucker, Speckled Dace) and seven non-native (Common Carp, Fathead Minnow, Plains Killifish, Red Shiner, Reside Shiner, Brown Trout, and Rainbow Trout) were examined before and 2.5 and 6 months after the controlled flood in 1996. Overall, native Colorado River fishes were largely unaffected, while non-native species showed displacement downstream and initially low catch rates following the flood. However, after the controlled flood released from Glen Canyon Dam in 2008, biomass levels of non-native brown trout dramatically increased (Cross *et al.* 2011) opposite of what was observed post-flood in 1996.

2. Monitoring programs

Both state and federal agencies are actively monitoring Grand Canyon fishes and taking steps to recover native fish populations. Monitoring is also being done outside of the canyon throughout the entire Colorado River Basin. The Upper Colorado River Endangered Fish Recovery Program is comprised of universities, non-profits, local environmental groups, water and power interests, and state and federal agencies above Glen Canyon Dam. Together, the Recovery Program helps to reconcile demand on water resources and restoration of native habitat with species recovery plans (Upper Colorado River Endangered Fish Recovery Program).

Within the Grand Canyon monitoring is done under the supervision of multiple partners under the umbrella of the Glen Canyon Dam Adaptive Management Program (GCDAMP). Under this program, the U.S. Geological Survey (USGS) coordinates monitoring all the way to Pearce Ferry, approximately 300 miles downstream of Glen Canyon Dam. Since monitoring occurs within Grand Canyon National Park, USGS partners with the National Park Service (NPS), Arizona Game and Fish Department (AGFD), and the U.S. Fish and Wildlife Service (USFWS). To monitor fish populations, trips are done in May through October, and the sample sites are distributed throughout the river corridor. Electrofishing is used to capture fish (Upper Colorado River Endangered Fish Recovery Program).

3. Translocation and stocking fish populations

In 2009 the National Park Service partnered with the Bureau of Reclamation, USFWS, and AGFD and began a project to translocate juvenile Humpback Chub from the Little Colorado River to other Grand Canyon tributaries. The translocations are part of a conservation effort to help build reproductive satellite populations throughout the park by taking individuals from the viable population in Little Colorado River. Since then, multiple translocations of Humpback Chub have occurred. The tributaries provide excellent rearing habitat and some are even free of non-native fish that may act as competitors or predators to juvenile Humpback. Most translocations to Shinumo Creek have remained and Humpback growth rates are comparable to those in the Little Colorado River (National Park Service: Translocation of Endangered Humpack Chub to Shinumo Creeks)

Fish hatcheries are another way that Grand Canyon Park officials and other agencies have been bolstering native fish populations. The Utah Department of Natural Resources operates a hatchery to raise endangered fish species for the Colorado River. The Ouray National Fish Hatchery, located in Colorado, aims to restore self-sustaining wild populations of Coloardo pikeminnow, Humpback Chub, Bonytail, and Razorback Sucker. Offspring from wild fish are held in ponds and then spawned during the spring. To maximize genetic diversity, matings between pairs of fish are strategically planned by researchers. The eggs from these spawning events are reared at the hatchery in individual tanks and once fish are large enough they are tagged with small electronic tags. These tags allow managers to keep track of where hatchery-raised fish travel once they are out in the wild. Once hatchery fish are large enough they are released into the Colorado River where field crews continue to monitor survival and spawning (U.S. Fish and Wildlife Service: Colorado River Fishery Project).

4. *Non-native fish removal*

Although dams have had a substantial influence on native populations, some argue that the introduction of non-native fish into the Colorado River is what continues to suppress native populations from rebounding. Many of the non-native fish were purposefully introduced to support recreational fisheries, including Carp, Channel Catfish, Brown and Rainbow Trout, Large- and Smallmouth Bass. Others introduced by accident when fishermen release their bait fish into the river (Minckley 1991).

Some efforts have been made to remove non-native fishes throughout the Grand Canyon. Electrofishing is a popular tool to capture fish. In Bright Angel Creek, a tributary in the Grand Canyon, the National Park Service also use a weir to catch fish. Bright Angel Creek is especially of interest because it once supported large numbers of native fishes, including Humpback Chub, and is the main spawning site for Brown Trout, which are voracious predators of native fishes. Tagged Brown Trout that spawned in Bright Angel Creek have been found more than 26 miles away, in the Little Colorado River. National Park Service officials believe that if the Bright Angel Creek trout population is drastically reduced then the frequency of trout found throughout the park will go down (National Park Service: Bright Angel Creek Trout Reduction)

Future of Grand Canyon native fishes

Native fish populations in the Grand Canyon appear to be dangerously on the edge of extinction. We have seen their precipitous decline over the past 50 years and hope for self-sustaining wild populations could be unrealistic at this point. Two major threats have kept native populations at their all-time low: 1) the construction of dams and 2) the presence of non-native fishes. Even if native fish populations could adapt to post-dam river habitat conditions, voracious non-native predators and strong competitors keep native populations low.

Unfortunately, reversing the effects of these two threats may be insurmountable. Dam removal is a costly process and it takes time for a river system to recover. However, there may be some restoration plans that, if adopted, would restore water temperature to mimic historical levels. For example, installation of a selective-withdrawal temperature control device on Glen Canyon Dam would allow warm and cold water to pass through and could be varied annually to reflect seasonal variability (Bureau of Reclamation 2004). Other strategies of preserving native fish populations include supplementation with hatcheries, translocation of breeding individuals from self-sustaining populations, and captive breeding programs. These proposals are not without their downsides; disease can be rampant in hatchery fish tanks, translocated individuals may struggle to thrive in new habitat, and captive breeding does not necessary restore native ecosystems. The Grand Canyon fish fauna have seen better days.

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