

PEARCE FERRY RAPID AS AN INVASIVE FISH BARRIER

The water elevation of Lake Mead, Arizona, has been continually dropping over the past two decades due to drought (1). When lake waters were at their maximum, a large amount of sediment that was picked up by the Colorado River in the Grand Canyon was deposited in the lake, where the water slowed. Since the water has receded, those sediments that were once submerged under Lake Mead are once again in the river's path. The Colorado River has been carving through these sediments, finding a new path compared to the route it took before the Lake was initially filled. As a result of this new path, the river now cascades over a section of boulders known as Pearce Ferry Rapid. This class VI rapid, considered 'un-runnable' by rafters and boatmen due to its steep and tumultuous flow pattern, may be impassable to fish trying to move upstream. In fish biology, a barrier is any structure that restricts the physical movement or genetic flow of fish (2). Waterfalls and rapids within river systems, when high and steep enough, are one of these barriers to fish passage (3). Although large rapids may isolate fish communities, in the context of the Grand Canyon the beneficial outcomes from the creation the Pearce Ferry rapid (figure 1) as an invasive fish barrier may outweigh the disadvantage of blocked migration routes for native fish.



Figure 1: Pearce Ferry Rapid in 2020. Photograph by Stephannie Fernandes.

The southwestern climate has seen a decades-long drought that has persisted since 2000 (1,4). Because drought conditions bring less water into the Colorado River Basin (runoff from the Rocky Mountains has yielded only 42% of the long term average during the drought), the water elevation in Lake Mead has dropped significantly (4,5). Parts of the river that were flooded with lake waters since Hoover Dam was completed in 1935 have become daylighted again (6). The Colorado River in this section now carves through lake sediments that were built up over half a century (figure 2) (6). Rivers follow the path of least resistance: because the river is carving through lake sed-

iments, it now follows a different path to the one it took before Lake Mead was created (7). While the river has been eroding away the softer sediments in its path, it has uncovered a set of steep bedrock and large boulders, in effect digging itself into the newest and most intense rapid within the Grand Canyon, known as Pearce Ferry Rapid (figure 4).

The Birth of Pearce Ferry Rapid

For all rapids in the Grand Canyon, the intensity and flow of the water, generally determined by precipitation events in upstream tributaries and from water releases from Glen Canyon Dam, can dramatically change the

position and strength of waves in the rapids (8). Pearce Ferry rapid is continually changing, with river waters eroding a knickpoint (a sharp change in channel slope) that exposes a steep bedrock ridgeline (7). Pearce Ferry rapid has a ~10m drop where the water cascades over a Miocene era conglomerate ledge – this solid bedrock layer is resistant to erosion when compared to the softer sediments below it, allowing for the rapid’s waterfall to grow and steepen (7).

Pearce Ferry rapid may be a useful tool in limiting nonnative fish invasion within the Grand Canyon. Because the rapid is so tall and tumultuous, fish downstream may not be able to jump and swim over it (6). However, depending on the species of fish and the quantity and pattern of flow, some barriers may not be completely impregnable (9). A waterfall’s height, the speed of flow, the depth of water in the pool below the fall, and the water velocity in the run leading up to the waterfall all have an impact on how many fish can overcome it (10,11). Fish species with higher migratory drive are adapted to have stronger swimming, jumping and climbing abilities, and are known to be able to pass barriers of different heights (11,12). Some migratory fish species, such as salmonids, are known to jump out of water 3-5 body lengths to hurdle objects (13,14), including small log jams and beaver dams (15). Tropical gobies, known as good climbers, are only fully extirpated upstream of barriers that are at least 32m tall (16). To complicate the matter, some cyprinid fish, known for preferring slower-moving waters, are known to bypass fish barriers during large floods when banks and floodplains are inundated, circumnavigating the barriers completely (17). Information about the jumping ability of native and non-native fishes in the Grand Canyon is currently unknown, but it is likely that the fusiform body shape of many of these warmwater non-natives makes their jumping ability comparable to that of trout, which would not be able to surpass Pearce Ferry Rapid. Because flow is completely constricted within the channel due to the consistency of Glen Canyon Dam releases, and because the rapid is 10m tall, has no significant plunge pool, and sees very fast moving water in the run leading up to the rapid, it is unlikely that fish that exist downstream of the rapid, invasive or otherwise, can successfully bypass it.

The Grand Canyon Fish Community
 Freshwater fishes are one of the most globally imperiled groups of animals and exhibit some of the highest rates of extinction (18). The two largest threats for

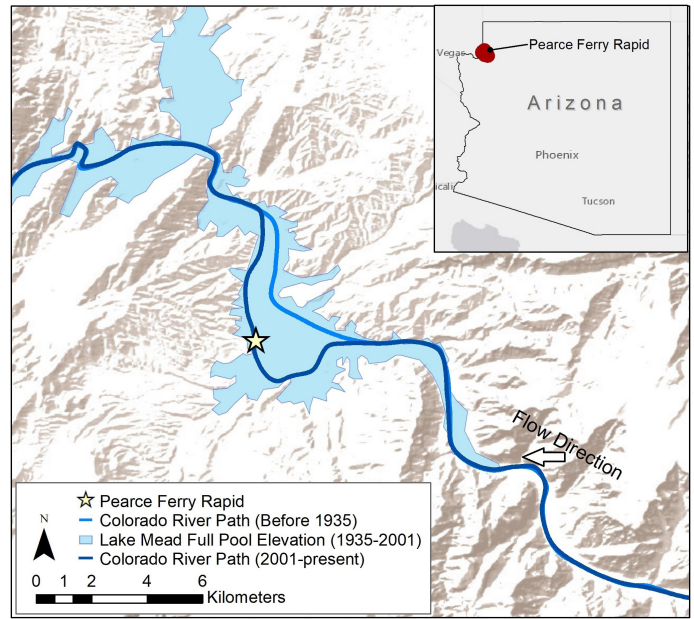


Figure 2: Map of the Pearce Ferry rapid site, with original river path before Lake Mead was filled in 1935, Lake Mead elevation at when the reservoir is at full pool, and new river path since drought has reduced lake water level.



Figure 3: Example species in the community of fish in Lake Mead and the Grand Canyon. Warmwater invasive species include smallmouth bass (A, photograph by Shutterstock), green sunfish (B), and channel catfish (C, photograph by USFWS). Coldwater invasive species include rainbow trout (D, photograph by Mike Anderson) and fathead minnow (E, photograph by Barry W. Smith). Native fish include humpback chub (F), flannelmouth sucker (G) and speckled dace (H, photograph by Giordano).

native freshwater fish survival are habitat alteration and nonnative fish takeover (19). In the southwestern United States, the negative impact nonnative fish have on native fish eclipses the impact of habitat alteration; restoring habitat in this region does not lead to biological recovery unless native fish are removed (20).

The Colorado River has the highest number of introduced fish species in the continental USA (21). In the Grand Canyon, rainbow trout and fathead minnow are the most abundant nonnative species (6). These fish are in high abundance upstream of the Little Colorado River, while native fish dominate the portion of the river downstream of this tributary (6), likely because the Little Colorado River's warm waters bring up the temperature of the Colorado River (22). Most of the introduced fishes in the southwest are piscivores, which is particularly detrimental in a watershed where many native fish evolved in predator-limited waters (20) (figure 3).

The native fish community found in the Grand Canyon today includes humpback chub, speckled dace, bluehead sucker, and flannelmouth sucker, while razorback suckers, roundtail chub, Colorado pikeminnow and bonytail have been extirpated (23). Nonnative fish in the Grand Canyon include rainbow trout, brown trout, common carp, fathead minnow, red shiner, plains killifish, gizzard shad and striped bass; these fish thrive in cold water (6). Warm water adapted invasive species that thrive in the large reservoir lake ecosystems along the Colorado River include walleye, smallmouth bass, largemouth bass, green sunfish, threadfin shad, and channel catfish (6,24,25). Warm water invasives may prove more detrimental to the native fish population in the Grand Canyon than cold water invasives because they fill the same function and have similar diets and habitat requirements that native fish do, which causes them to compete directly with native fish for niche space (26). The cold water that comes out of Glen Canyon

Dam at the top of the Grand Canyon may prevent these warmwater species for colonizing the uppermost part of the canyon, but the western Canyon, near Lake Mead, has water warm enough to support these species (6). The westernmost part of the Grand Canyon has the highest abundance of native fish since the early 2000's and the best habitat for juvenile fish growth (6). From upstream, Glen Canyon Dam has acted as a fish barrier, protecting the Grand Canyon from invasive fish from Lake Powell, but there had been nothing blocking invasion into the Western Canyon until the formation of Pearce Ferry Rapid (6). It is likely that the correlation between native fish success in the western canyon for the past two decades and the formation of Pearce Ferry Rapid is not insignificant.

Barriers fragment river systems, separating riverine species populations into distinct communities and limiting migration (2,27–30). Although this discontinuity may lead to extirpation or restricted gene flow for native fish (31–33), disruption of connectivity in rivers often favors generalists species (9), which may be beneficial in the Grand Canyon because many of the non-extirpated species are generalists. During flood events, there is a disproportionate number of non-native fish that get swept downstream in comparison with native fishes (34), which could lead to a higher proportion of natives in the Grand Canyon if non-natives are swept downstream of Pearce Ferry Rapid.

Another fish barrier, similar to Pearce Ferry Rapid, has formed in the Colorado River Basin along the San Juan River. Known as Piute Farms Falls, this

feature was similarly created when the river took a new path after lake levels lowered, and acts as a successful fish barrier between Lake Powell and the San Juan River (35). On rivers and streams in the Gila River Watershed, fish barriers were created to block upstream movement of non-native fish to protect federally listed endangered native fish (36). As of 2018, those efforts have been largely successful on the eight streams they were built on (36). In one of these cases, Fossil Creek, a fish barrier was created and all non-native fish were removed, which has led to the reestablishment of native fish populations (37). On the Blue River, Colorado, nonnatives continued to be absent and natives were flourishing upstream of a manually created fish barrier 5 years after the barrier was built (38).

There is a lack of published data on fish jumping performance and fish barrier heights, which causes managers to rely on trial and error when evaluating the efficacy of barriers (13). Pearce Ferry Rapid's role as a potential barrier to fish movement is currently being studied by the Arizona Game and Fish Department and BIO-WEST; monitoring of fish movement above and below the rapid began in July, 2020 (39).

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February 2021

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