# Maintaining the Long-Term Viability of the Humpback Chub in the Grand Canyon

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**The humpback chub is a native fish of the Colorado River that is vulnerable to extinction. Rainbow trout, initially introduced near the Glen Canyon Dam to serve recreational anglers, now thrive downstream and prey on the humpback chub. The U.S. Geological Survey is currently investigating strategies for controlling the trout population that ensure sufficient humpback chub numbers for future survival. We summarize how a new modeling approach provides both management guidance and reveals the implied existence value of the endangered species.**

The humpback chub is named for the large hump on its forehead, which provides stability in whitewater and makes it harder to eat.

—Photo by George Andjreko, Arizona Game & Fish

What is another California condor worth to us? Or an additional flutter of Mission blue butterflies? How valuable are healthier populations of endangered species in general? While managing such species to avoid extinction involves weighing these benefits, extinction is a non-incremental change that is exceedingly difficult to value. Still, extensive resources have been spent on species recovery, demonstrating that their existence is valuable to us. Today, many conservation projects move forward despite the lack of carefully estimated benefits. However, conservation management cannot escape the fact that managers face finite resources and difficult tradeoffs.

It is much easier to value commercially targeted species, like Californian salmon or sturgeon, by using observed market prices, which reflect our willingness to pay. We can weigh the benefits of today's harvest against the option to harvest tomorrow in order to determine how large a fish stock should be.

But where exactly does the value lie in preserving endangered species that are unlikely to be commercially harvested? Sometimes they play a pivotal role in their ecosystem, and we can measure these services via the value of the affected species; wild bees provide much of the pollination services in California agriculture, for example. Other species generate interest (and subsequent value) with their charisma, behavior, or looks; polar bears, sea turtles, and orangutans are regularly featured in zoos and documentaries. But such direct or indirect use values for vulnerable species—by definition low in number—are likely to be small in general and ultimately fail to fully capture what is lost with extinction.

Conservation management is often framed as recovery of a vulnerable population to a chosen target level. For example, biologists might estimate the number of breeding pairs of the northern spotted owl that are needed to achieve a healthy state. An economic approach might then seek to meet this target at the lowest possible cost. Conservation costs might include direct costs of managing the owl, like captive-breeding, or indirect costs, like the foregone stumpage value to the timber industry. The tradeoff of interest is between the cost of stricter management and the change in the likelihood of species survival, often called species viability. The probability of survival stands in for the missing [dollar] benefits when we do not already know the value of a species. Thus, in this environment, instead of managing for profit from commercial use, the focus shifts to managing for viability.

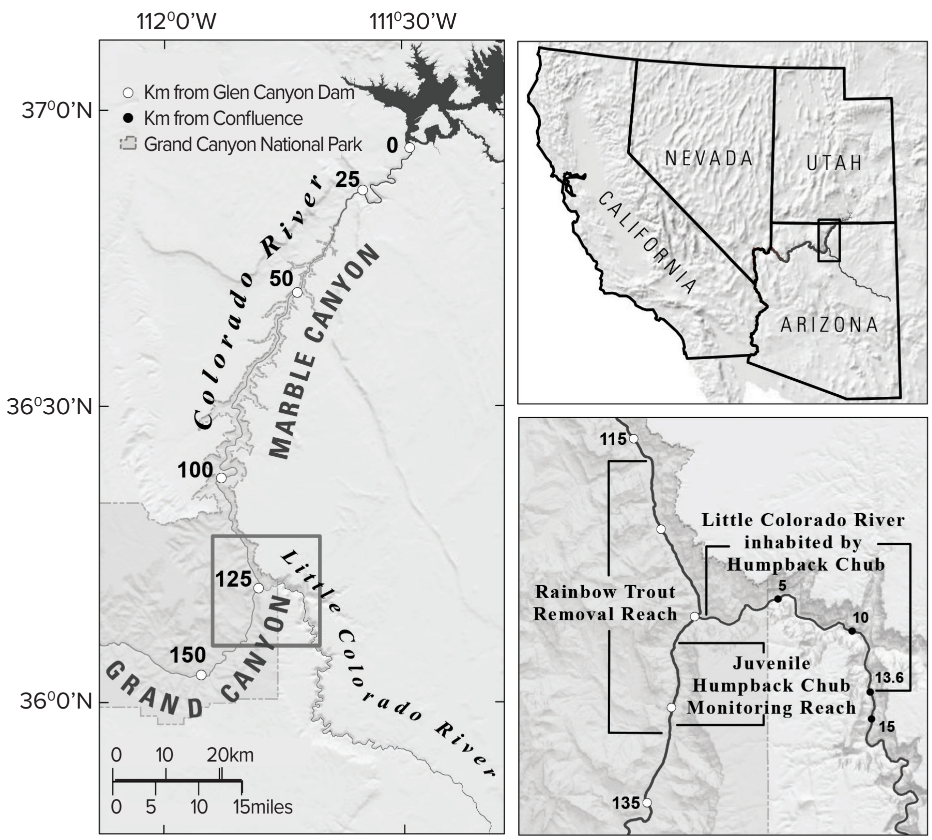
But what is species viability worth, *per se*? In recent analysis, we consider this question for the humpback chub in the southwestern U.S. This species yields no commercial value—it isn't harvested for food, and is not a target of recreational anglers or tourists. But the Endangered Species Act stipulates that such species must be conserved, creating an implied valuation which we can assess. Below, we summarize how our recently developed modeling approach uncovers both the implied existence value of the humpback chub population and a cost-effective policy to sustain it.

## Case Study: The Humpback Chub

The humpback chub (scientific name *Gila cypha*) is a threatened minnow native to the Colorado River. Large for a minnow (at 20 inches fully-grown), this fish evolved a few million years ago with little predatory pressure. They would thrive in the historic, undammed river, one that was warmer and more turbid, since those historic conditions provide for better spawning and protection from sight predators.

The humpback chub became protected in 1973 under the Endangered Species Act. Historically limited to a few

**Figure 1.** Humpback Chub Habitat of Interest




Notes: The humpback chub range is in northern Arizona, centered roughly 125 km downstream of Lake Powell, at the confluence of the Colorado River and the Little Colorado River. (U.S. Geological Survey)

hard-to-reach sections of the Colorado River, the fish has only been studied in depth fairly recently. Their largest aggregation is at the confluence of the Little Colorado River (where most spawn), and the Colorado River mainstem (where most compete for food and are preyed upon by emigrating rainbow trout), located within Grand Canyon National Park, downstream of Lake Powell and the Glen Canyon Dam (see Figure 1). The humpback chub is currently designated as threatened throughout all of its range, and the possibility of extinction in the future increases without precautionary management action.

The Grand Canyon Monitoring and Research Center of the U.S. Geological Survey (USGS), science provider to the Glen Canyon Adaptive Management program, seeks to evaluate and revise management actions as their understanding of the ecology downstream of the Glen Canyon Dam improves.

One core objective of this research is to guarantee adequate survival of juvenile humpback chub that enter the mainstem from the Little Colorado River, therefore maintaining reproductive potential. This involves both protecting the Little Colorado spawning grounds and establishing an appropriate habitat in the mainstem.

The rainbow trout originate from a sport fishery just downstream of Lake Powell and the Glen Canyon Dam. As a non-native species, they disrupt Grand Canyon habitat when they migrate downstream by competing for food and preying on resident juveniles, like the humpback chub.

At present, the leading management option for controlling the rainbow trout is the use of electrofishing trips intended to reduce the population of downstream émigrés to the humpback chub habitat in the Colorado/Little Colorado confluence. These trips take roughly a week and consist of drifting down the river while stunning and removing a significant amount of adult rainbow trout.

The humpback chub is an interesting case study because both the conservation goal and the conservation means have already been established by the Grand Canyon Monitoring and Research Center. Heavy investment in natural science research in the Colorado River watershed has created opportunities to improve management. It is a critical economic and environmental zone, with overlapping and competing concerns from electricity generation to tourism that weigh against conservation objectives, like that of the humpback chub.

## Managing for the Long-Run Survival of the Humpback Chub

Our conservation goal is to maintain a healthy humpback chub abundance over time, so that the likelihood of dropping below a minimum viable population threshold is acceptably small. Specifically, we seek to ensure that the population near the confluence does not fall below 4,000 individuals at any point over the next 20 years, with 90% confidence. Meeting this target is a necessary step towards species recovery.

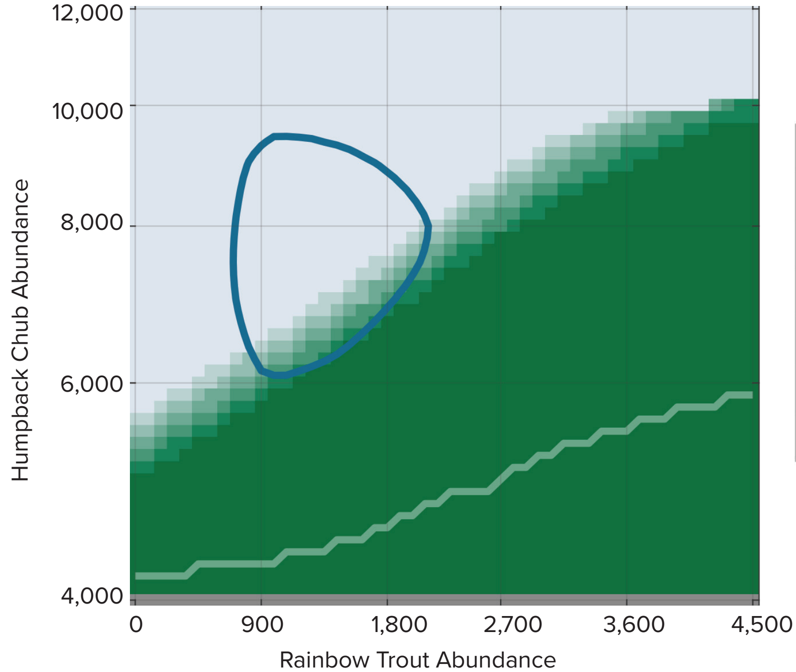
Of course, we would like to do this as cheaply as possible. So, for any population size of humpback chub or rainbow trout, we want to determine the lowest amount of management effort required to meet the conservation goal. We are also interested in knowing the existence value of the humpback chub implied by this policy and how high we should keep the population in order to keep the probability of extinction acceptably small.

Figure 2 shows the ideal number of electrofishing trips needed, depending on how many humpback chub and rainbow trout are in the management area. Dark green signifies that the maximum possible effort is needed (six trips in a year), while gray indicates trips should be suspended (see color bar key on the right). Not surprisingly, more trips are ideal when there are few humpback chub or many rainbow trout; guidance centers on how effort should respond as the populations move away from this extreme.

At present, after years of rainbow trout management, humpback chub and rainbow trout populations are estimated to reside in the upper-northwest of Figure 2, where immediate action is not prescribed. This suggestion is in agreement with the current USGS strategy. However, the humpback chub population is sensitive to ecosystem shocks, such as temperature, turbidity, food availability, and rainbow trout abundance, so the population is not yet considered to be safely self-sustaining. Should the situation degrade in the future, Figure 2 prescribes the number of electrofishing trips needed to maintain viability of the species cost-effectively.

The conservation goal for humpback chub is achievable at current population levels. But this is not the case for all possible levels of humpback chub and rainbow trout. If we ever find ourselves in a position below the light green line in Figure 2, we are less than 90% likely to stay above the 4,000 fish threshold even with maximum effort. This does not mean we give up on controlling the rainbow trout population; this region emphasizes that there exist cases—however unlikely—in which achieving the conservation goal with the desired level of confidence isn't possible. As the humpback chub population declines, the increasing possibility of dropping below the threshold is what drives the effort to maintain healthier states, i.e., "safety in numbers."

**Figure 2.** Recommended Management Effort (Number of Yearly Rainbow Trout Electrofishing Trips) in Response to Humpback Chub and Rainbow Trout Populations




Note: This management effort strategy successfully meets the conservation goal for population states above the light green line, and tends to result in populations within the blue circle 50% of the time.

In contrast to the approach outlined here, conservation programs typically set an ad hoc, inflexible population target to rebuild towards. Rather than trying to maintain a specific population size, we let the implied existence value of the humpback chub reveal how large a population should be in order to keep it safely out of harm's way. To avoid our minimum viable abundance threshold of 4,000 humpback chub, the policy results in population numbers typically far higher. The region of Figure 2 denoted by the blue circle is where we expect the long-run population to reside around 50% of the time, given our prescribed course of action.

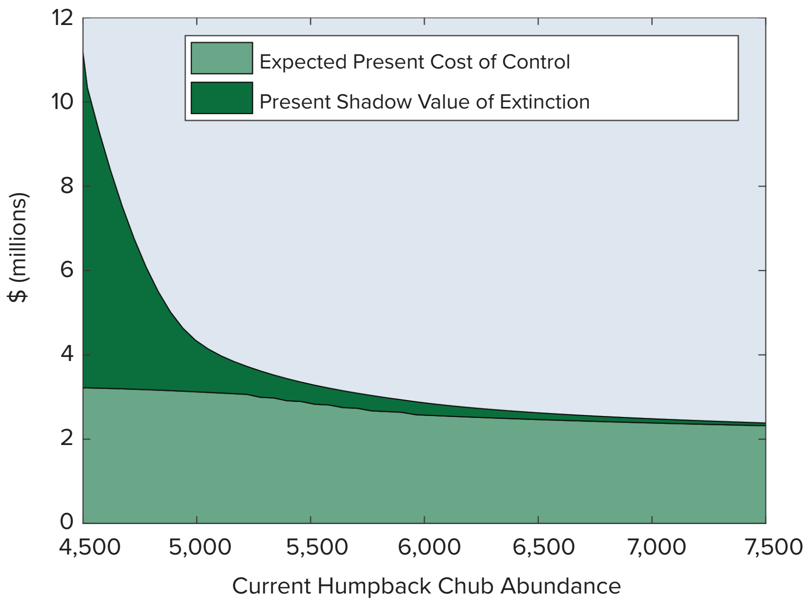
## Where is the Value in Preserving the Humpback Chub?

In the past, values for humpback chub were estimated through a series of valuation surveys, which estimated marginal values of $1.75 per U.S. household for a 1% increase in humpback chub abundance. While the valuation is substantial, this information is insufficient for the kind of decision making discussed above since the marginal value is not constant but rather increases drastically as the population declines.

Instead, as part of our modeling approach, we first imagine that there is a level of loss incurred when the humpback chub falls below a population threshold for extinction. We then search for a particular value for this loss that is just large enough to motivate enough costly effort to safely avoid the extinction threshold. The loss level identified can be interpreted as an implied existence value (the value of a viable population that is consistent with the conservation goal). This implied existence value is a sort of "shadow" value, i.e., a helpful uncovered value that substitutes for the lack of an explicit market-based value.

The estimated shadow value (implicit existence value) in this case is $380 million. We can then calculate how costly it is to allow the population level to approach this extinction level.

**Figure 3.** Expected Present Costs of Electrofishing Trips and the Perceived Future Loss from Extinction




We do so by evaluating the present value of the loss, based on the likelihood and time to an extinction event. For example, if we maintain a humpback chub population within the blue circle of Figure 2, the present value of the loss is only around $100,000 (for reference, each electrofishing trip costs $75,000). If the population is instead near the minimum viable threshold, where the conservation objective becomes more intimidating, then this number is in the tens of millions of dollars. In this way, the conservation objective transforms into an economic measure that incentivizes the ideal management response as populations fluctuate.

In Figure 3, we hold rainbow trout constant at 900 individuals and show how the present value and electrofishing (control) costs vary with the humpback chub population. As conditions for the humpback chub deteriorate, the conservation goal becomes more salient; the present shadow value increases and eventually dominates the actual costs of control. In a relatively safe state, non-viability is not an immediate issue, and the present shadow value is low.

The existence value of the humpback chub is high, and the expected present costs of action are too. This is because the requirements for its conservation are quite restrictive, and many unobserved factors influence the humpback chub stock, making its evolution hard to predict. This finding, which shows just how large existence values can be, is likely to repeat when the model is applied to other species.

## Beyond Conservation Objectives

The Endangered Species Act aims to provide a framework to conserve and protect endangered and threatened species and their habitats. While conservation of such species can be highly costly, this legal requirement implies larger social benefits in avoiding extinction.

Policy often emphasizes viability-style goals over requirements of economic optimality. For example, many scientists and policy analysts enthusiastically recommend sufficient greenhouse gas emissions abatement to remain below a temperature threshold (beyond which the risk of catastrophe increases dramatically), rather than identifying some globally-efficient emissions path. Putting the modeling focus on these one-shot, irreversible "tail events" reflects the stated objective.

When we consider how to avoid dire events like massive forest fires, disease outbreaks, or disastrous floods, we face outcomes without easily estimable values, but the willingness to take costly preventative measures implies some revealed preference for safety. By giving attention to a more literal "viable control" paradigm, we can develop rational management approaches and a better understanding of the latent value embedded in policy language.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### For additional information, the authors recommend:

Donovan, P., L.S. Bair, C.B. Yackulic, and M.R. Springborn. "Safety in Numbers: Cost-Effective Endangered Species Management for Viable Populations." *Land Economics*, reprint: **https://piercedonovan.github.io/files/papers/donovan_safety_in_numbers.pdf.**

Grand Canyon Monitoring and Research Center: **https://www.gcmrc.gov/gcmrc.aspx.**