Habitat Improvement and Native Fish Loss: The Upper Verde River Fish Mystery

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Beneath the flowing waters of a tranquil stream lies a deceptively complex aquatic ecosystem. All the parts that make up this environment—biologic, geologic, and hydrologic—are closely intertwined. Tweak one aspect of this system, and the result can be a cascade of unexpected events.

Take the upper Verde River, a mere 30 miles of desert stream in Arizona that has scientists scratching their heads. Conventional wisdom dictated that restoring the stream's riparian habitat—the areas along the streambanks—would improve stream conditions, making the waters healthier for native fishes. But instead of seeing a rebound, the population of native fishes has plummeted.

Caught in the center of these confusing events is a small minnow, about 2-3 inches long. The spikedace (*Meda fulgida*, Fig. 1), a federally threatened species, is endemic to the Gila River Basin of Arizona and New Mexico. It's a silvery fish with an olive-gray to brownish back, with vertical black specks along the sides. Spikedace feed primarily on aquatic insects, as well as terrestrial insects that get caught in the water current. A genetically distinct population of spikedace lives in the upper Verde, along with five other native fish species.

In 1994, scientists at the U.S. Forest Service's Rocky Mountain Research Station in Flagstaff, Arizona, began a systematic survey of the fish fauna in the upper Verde, studying the populations of native fishes including the threatened spikedace, as well as introduced fish species like smallmouth bass and green sunfish. They did this by monitoring these fish populations at seven established sites. One of the scientists involved in that study is John Rinne, a fisheries biologist at the research station.

"The reason we started this study was to define fish community structure and how it changes relative to biotic and abiotic factors. Flooding was the primary abiotic factor, instream physical habitat was another. The biological [biotic factor], then, would be the non-native fishes. So we started the study, but we saw that, Oh! This one fish blinked out."

That one fish species that "blinked out" was the spikedace. In the first year of the survey (1994), 428 spikedace were caught. The next year, 72 were taken, followed by a rebound in 1996 with 140 spikedace. Then the fish numbers took a nosedive. In 1997, 1998, 1999, and 2000 no spikedace could be found at any of the seven routinely monitored sites. So Rinne and his colleagues started what they called their "spikedace chase," looking at other sites in the upper Verde. They found about 12 fish in 1997, half as many the following year, and only one spikedace in 1999. This startling trend in spikedace numbers was reflected in the other native fish numbers as well—they were all in a precipitous decline. But not the non-native fishes. They, on the other hand, were doing quite well.

The downturn in spikedace and other native fishes in the upper Verde happened to coincide with efforts to restore habitat along the river's edge. Since the 1890s, livestock grazing had been established along the banks of the Verde. In other parts of the country, livestock grazing along streams had been implicated in degrading aquatic habitat. The lack of vegetation from constant grazing, and destruction of ground-cover that had been trampled over by cattle and sheep, had greatly increased erosion and sedimentation in many streams. Excessive nutrient runoff from livestock waste had polluted the water, making it unfit for many kinds of aquatic life. Therefore, by removing livestock and restoring the stream bank vegetation to approximate pre-grazing conditions, land managers and scientists thought they were doing the right thing.

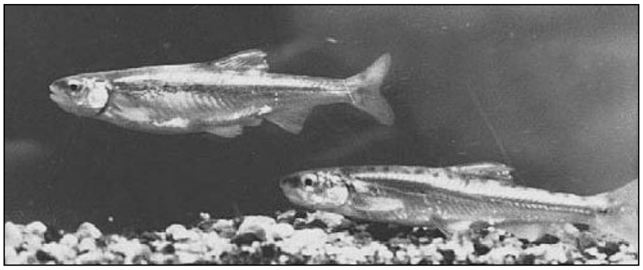

Fig. 1.
The spikedace (*Meda fulgida*), endemic to the Gila River basin of Arizona and Sonora, is a federally threatened species. The specimens shown here, ca. 70 mm in total length, are from the Verde River in Arizona; female above, male below. Photo © John N. Rinne.

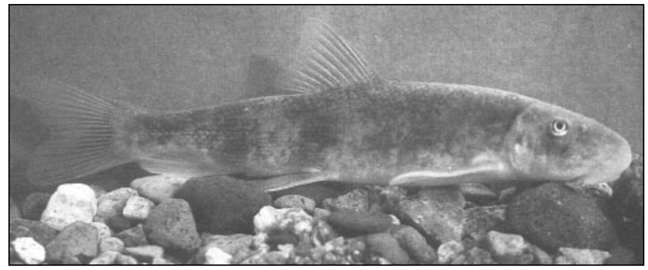

Fig. 2.
Adult desert sucker (*Catostomus clarki*) hang out in pools, moving to swift riffles and runs to feed at night. Young desert sucker inhabit riffles during the day, feeding on algae scraped from stones with well-developed cartilaginous sheaths on their jaws. Photo © John N. Rinne.

Despite the riparian restoration, the upper Verde today is not the same place it was 120 years ago. As people settled the area, they brought with them the familiar trappings of their lives back East. One such activity was sportfishing. Not only did they bring the sport, they brought their favorite sportfish, too. Smallmouth bass, green sunfish, and channel catfish were among some of the new arrivals to the upper Verde. And these fish changed the biological character of the river.

The riparian habitat restoration that had been initiated in 1997 changed the stream. It was now 30% to 50% deeper, and 50% narrower. And the fish had responded to these new conditions. Data from subsequent fish surveys indicated an overall decline in all fish species. However, the non-native fish were much more abundant than the natives. One possible reason? "Predation," said Rinne, pointing to data collected on one of the natives, the desert sucker (*Catostomus clarki*, Fig. 2).

"Of 167 desert suckers, 130 of them were adults. There were very few young-of-year or babies. That's a problem. So if you're a smaller fish out there, you're not doing well. And why is that? Maybe they're getting eaten. We know there are smallmouth bass in there, and they're predatory, and green sunfish too, so we're beginning to look at predation by non-native fishes as one of the big factors causing the marked decline in native fishes in the upper Verde River."

This theory was reflected in the survey data as well. Of the six native fishes, it was the three smaller ones, longfin dace (*Agosia chrysogaster*, Fig. 3), speckled dace (*Rhinichthys osculus*, Fig. 4), and spikedace that were declining the most, suggesting that the little fish were being overwhelmingly preyed upon at all life stages by the larger non-native fishes.

There was a third major player to consider in the dynamics of the upper Verde: the hydrology of the stream. Research has shown that many desert fishes depend on ecological disturbances for their survival. At one small stream in south-central Arizona that had been studied for about 25 years, said Rinne, "Some years, certain fish species are very, very abundant and, typically, it's after a flood. And then, a year or two later, you can't find any of these same fish species. Therefore, there may be some innate [mechanism], or something inherent within spikedace, that may be a survival tendency, [as] they come and go."

If a flooding event somehow brought about large numbers of native fishes, perhaps by creating ideal spawning conditions or by flushing out the non-native fishes, that could explain the large numbers of spikedace seen in 1996 in the upper Verde. The batch of 1996 had been preceded by a small flooding event. Since then, no large water flows had occurred in the upper Verde. So, were the spikedace and other native fishes undergoing a natural decline in response to the lack of flooding? Would there be a surge in their populations when the next flood occurred?

But first, what causes the population explosion in some native fishes after a flood? Different desert fishes have different substrate requirements for spawning and egg development. During a flood, the rapid flow of water invigorates the ecosystem, resorting different types of substrate—sand, gravel, pebbles, cobbles, boulders—to create new spawning habitat for different species. It's a process Rinne calls "disturbance."

Said Rinne, "I've got a hypothesis based on some of the data we have collected in different streams in the arid Southwest . . . these native species are perhaps disturbance species, that is, they've done well through the eons of time, clear back in the Pleistocene, in disturbance. We as human beings don't like to be disturbed, but native fish may indeed count on disturbance to make their living. There may be more disturbance species out here in the West than what we would have for a Mississippi fauna. So if you begin to remove a system from being a disturbance-type system, maybe the non-native fishes can gain an advantage, and that is what we're working on right now. We don't know that for sure."

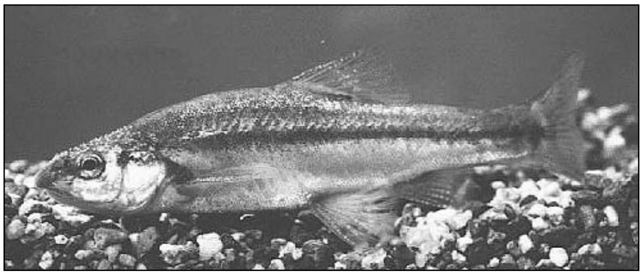

Fig. 3.
In streams that lose their flow due to evaporation during the day, longfin dace (*Agosia chrysogaster*) adults survive by burying themselves in mats of moist algae; at night, the dace come out and forage in what is often only a few millimeters of water. Photo © John N. Rinne.

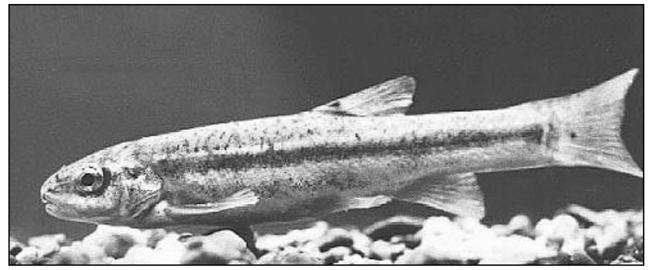

Fig. 4.
In the intermittent streams of the desert southwest, speckled dace (*Rhinichthys osculus*) need increased water flow caused by flash floods or the scouring of substrate caused by spring runoff from snowpack and midsummer rains to induce spawning. Photo © John N. Rinne.

Perhaps a combination of factors were responsible for the low numbers of spikedace and other natives in the upper Verde: they were undergoing a natural decline in the absence of flooding, but it was a decline further exacerbated by a change in habitat that favored non-native fish.

"Historically," continued Rinne, "spikedace probably fluctuated extremely with alternating cycles of drought, flood, and other disturbance events. They do that currently, but the problem is that now we have superimposed a lot of management and other anthropogenic influences on top of these natural events, and it makes it tough for a species to sustain themselves. How much can they withstand? A parallel: look at your own personal health. Can you take the stress, take the high blood pressure, the high cholesterol levels . . . how many different negatively impacting factors can your body withstand before you just don't make it? You tolerate some of those things, and compensate, but once you get too many things imposed upon you, it's very difficult to basically sustain life."

One way to truly restore the upper Verde to its original condition is to get rid of the non-native fish, a very daunting task even for just 30 miles of stream.

"It's not like a terrestrial system with plants where you just go out there and cut 'em and remove 'em and that's it. The fish can move around, they can hide."

Table 1. Fish populations at seven sampling sites in the upper Verde River, 1994-2000. Data from the following publication: "Status of Spikedace in the Verde River, 1999: Implications for Management and Research" by John N. Rinne, USDA Forest Service Rocky Mountain Research Station, Flagstaff, AZ. Published in Hydrology and Water Resources in Arizona and the Southwest: Proceedings of the 1999 Meetings of the Hydrology Section, vol. 29, *Arizona-Nevada Academy of Sciences*.

	1994	1995	1996	1997	1998	1999	2000
NATIVE SPECIES							
longfin dace (*Agosia chrysogaster*)	1319	12	282	21	13	2	1
desert sucker (*Catostomus clarki*)	2644	328	471	231	126	167	137
Sonora sucker (*Catostomus insignis,* Fig. 5)	1810	322	654	240	125	118	197
headwater chub (*Gila nigra,* Fig. 6)	776	341	259	50	64	25	20
spikedace (*Meda fulgida*)	428	72	140	0	0	0	0
speckled dace (*Rhinichthys osculus*)	171	25	68	1	12	2	7
NON-NATIVE SPECIES							
yellow bullhead (*Ameiurus natalis*)	31	29	9	40	33	15	22
common carp (*Cyprinus carpio*)	23	6	13	19	9	4	15
red shiner (*Cyprinella lutrensis*)	1473	97	275	2238	1047	545	1594
channel catfish (*Ictalurus punctatus*)	5	2	0	1	0	0	0
mosquitofish (*Gambusia affinis*)	0	0	0	3	6	59	227
flathead catfish (*Pylodictis olivaris*)	0	1	1	1	1	0	0
green sunfish (*Lepomis cyanellus*)	4	29	6	8	21	49	95
smallmouth bass (*Micropterus dolomieu*)	14	10	32	35	66	104	48
fathead minnow (*Pimephales promelas*)	7	0	0	0	0	0	1
Total Fish	8705	1274	2210	2888	1523	1090	2364
Percentage Native	82	86	85	19	22	29	15

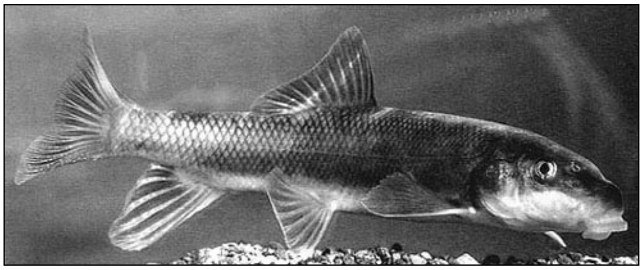

Fig. 5.
Sonoran sucker (*Catostomus insignis*) are largely carnivorous, but sometimes they will eat the seeds of cottonwood trees, lifting their heads out of the water to clumsily "suck" in seeds that accumulate on the surface. Photo © John N. Rinne.

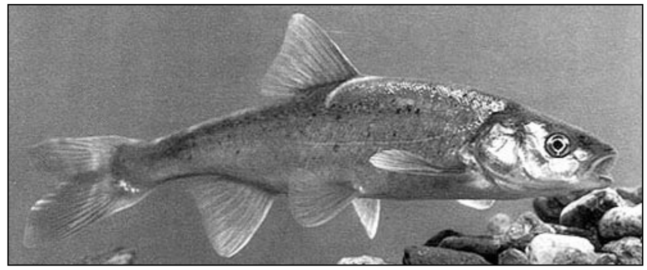

Fig. 6.
Headwater chub (*Gila nigra*) occupy middle to headwater reaches of middle-sized streams, usually seeking cover near obstructions, large pools, and undercut banks. This 17.5 cm [7 in] specimen is from Arizona's Aravaipa Creek. Photo © John N. Rinne.

The most powerful technique is to use a fish toxin to remove the non-native fishes (native fishes would be collected prior to treatment and held in a safe place, then returned later to the stream after the toxin had cleared out). "But it's very difficult to get all those fish out because you have backwater vegetation where fish toxins never get to. You also have areas where there is underflow . . . fish toxin never gets there."

Rinne and colleagues also looked at electrofishing, a method that involves passing a low current into the water to stun the fish, bringing them to the surface for easy capture. They tested the efficiency of this method at three test sites. The results were both discouraging and encouraging. First, it was impossible to remove all non-native fish because of dense in-stream aquatic vegetation. Furthermore, removing smallmouth bass, for instance, simply resulted in increased numbers of green sunfish, another predatory species. However, the good news was that native fishes did respond by increasing recruitment (numbers of young) each year.

Another strategy for keeping spikedace and other native fishes around is to increase their numbers, or at least set aside habitat specifically for them. In the large Colorado River, fish species like the humpback chub (*Gila cypha*), bonytail chub (*Gila elegans*), and razorback sucker (*Xyrauchen texanus*) still swim in the wild thanks to captive propagation efforts.

Said Rinne, "If for some reason we get flow [from a flooding event] and sizable numbers [of spikedace], certainly more than we have now, we better try to hold the species and be ready to rear it in refugiums until we can figure out what to do. . . . We need to look at some of these tributary streams on the Verde River or the feasibility of creating side channel refugia on-site for propagating and holding stocks there."

Getting spikedace stocks from another river in the Gila River Basin, though, is not an option because the upper Verde spikedace is genetically distinct from other spikedace populations in other parts of the Gila River Basin.

A mere 30 miles of stream has turned out to be more complicated than anyone ever imagined. Scientists and land use managers from the U.S. Forest Service, Arizona Game and Fish Department, and the U.S. Fish and Wildlife Service have not given up on the spikedace and other native fishes of the upper Verde. They are continuing to study the complicated dynamics of this system, and looking at other ways to save the native fish.

Meanwhile, another threat is looming over the horizon. As human populations at the headwaters of the upper Verde increase, so does the demand for water. Studies have indicated that if the upper Verde is tapped as a source of water to quench the thirst of future desert towns, the river could run dry at least two out of every 30 years. No water, no fish.

And so it will continue: the constant tug-of-war between the needs of an increasing human population and a dwindling wildlife habitat.

Acknowledgments

Special thanks to Dr. John N. Rinne, research fisheries biologist at the Rocky Mountain Research Station (U.S. Forest Service) at Flagstaff, Arizona, for his time and patience in explaining the upper Verde native fish situation to me, for providing us with the latest (2000) data on the fish surveys, and contributing the fish photographs in this article. I'm also grateful to Chris Scharpf (editor, *American Currents*) for his thoughtful review of the initial draft of this article and for providing some basic information about spikedace.

Editor's note: The headwater chub (*Gila nigra*) was previously known as a subspecies of roundtail chub (*G. robusta grahami*). The name was changed in Ms. Gonzaga's manuscript to reflect the most current nomenclature.