It was a clear morning in late May. We were in Andy Hutchinson’s dory Cottonwood, with its light green gunnels riding above a red keel. The Colorado was flat as we rowed past Olo Canyon near river mile 146. Suddenly a fish broke the limpid green surface, leaping about two feet up, arcing its body sideways, before gravity exerted its pull. As with bird-watching, I only caught a few details: that this fish was about eight inches long, its tail section was thinly tapered, and the tail itself flared out into a wide fork. Having already seen the bluehead and flannelmouth suckers, rainbow trout, and carp with their golden scales, by process of elimination I realized this was the fish I’d been studying for over four years, but had never seen alive: the humpback chub, _Gila cypha_.

This desert river fish, native to the Colorado River drainage basin, was only declared a separate species in 1946. It is one of a handful of endemic (native) species, and one of only four that survive today in Grand Canyon. The alterations of the river’s natural regimes to electrify and water the West eliminated habitat and connectivity of fish and other aquatic life. The humpback chub, a pinkish, nearly scale-less minnow adapted to the sediment-laden pre-Glen Canyon Dam river, was an original member of the federal Endangered Species List in 1967.

Fast forward to 2009. By this time, many agencies and academic scientists had studied this rare fish. It was known to spawn in the Little Colorado River, the Colorado’s largest tributary and one which is only moderately disturbed. Tagging and tracking fish had revealed aspects of the chub’s population ecology, but little was known about their life when young. My colleague Bill Pine from the University of Florida was anxious to study this life stage. He invited me into his project because of my arcane knowledge about otoliths, the tiny ear-stones in fishes’ inner ears. Each fish has three pairs of otoliths, which function like parts of a gyroscope, maintaining balance and aiding in hearing. These are not true bone, but are instead composed of calcium carbonate that precipitates on a gossamer-thin sheath of protein. The amazing thing is that this process occurs each and every day, and when fish are young, daily growth rings are formed, much like the annual rings in a tree. Indeed, older fish are aged to the year by this method, much as foresters determine the age of trees. Only because these are so small, fitting under the braincase, microscopes are needed to see the rings.
Even more amazing, the chemical composition of the otoliths reveals much about how the fish spent their lives. Water dissolves ions from rock and soil, and depending on local conditions, may bear a specific “fingerprint” of different trace elements and isotopes that can be measured with sensitive instruments. Since the otoliths keep growing throughout life, if a fish moves from a water body with “fingerprint x” to one with “fingerprint y,” this is recorded in the growth rings—a chemo-chronology not unlike a Rosetta Stone.

Starting out, we didn’t know which mix of chemical tracers would be useful, so we began by surveying the waters of Grand Canyon—the main stem of the Colorado as well as its major tributaries—for many trace elements and isotopes. Quickly we learned that the main stem of the river, which is dominated by what comes out of Lake Powell upstream, is chemically the same from top to bottom of the Canyon, at least to Diamond Creek where our surveys ended. We also found some differences in several of the tributaries, notably the Little Colorado. And, in what amounted to an afterthought, we conducted an analysis that produced a whopper of a tracer, one that clearly differentiated Daddy Colorado from Little Colorado. The difference in that tracer was caused by the deep groundwater bubbling up out of Blue Spring, some ten miles up the Little Colorado. This source water is highly carbonated, and as it emerges from the depths it de-gasses, precipitating minerals and creating the milky blue water and travertine dams that the Little Colorado is famous for. That de-gassing also produces a chemical marker that distinguishes the chubs’ natal stream from the big river.

The trouble with the tracer was that it was tough to measure in tiny otoliths. My post-doctoral research associate, Todd Hayden, had to travel to one of only three labs in the country that had the appropriate instrumentation, a secondary ion beam mass spectrometer, and then he only had a week of “beam time.” Nevertheless, he confirmed our suspicions, and we were able to correlate this tracer with easier to measure proxies. Not only did the chemistry show us when fish moved between rivers, but because the Colorado River is so cold—a near constant 50°Fahrenheit—the temperature differential caused the chubs’ daily growth rings to contract when they migrated from their warmer “Little Colorado nursery” into the main stem.

By careful combination of ring-counting and chemistry, we could pin-point just when the baby chubs moved out to the main stem Colorado. We could tell how old they were—to the day!—and how large they were. And we could do this not only in young fishes, but also in adult fish. In a sense, we asked each fish, “How old were you, and how big were you, when you ventured out into the cold, clear waters of the Colorado?”

We learned that humpback chubs make multiple visits back and forth between the main stem and the home waters. In many cases, it was as if a chub had a summer home and a winter home. Although seasonality is tough to determine in this system, given that the main stem river is warmer in winter than the Little C., we think that at least some individuals use the big river in winter.

What we ultimately learned—and wanted to know—was that the chances of surviving out in the main stem backwater of the Little Colorado allowed us to be able to distinguish use of different habitats during a fish’s life. The dots represent sampling points.

Examples of otoliths viewed under the microscope. Left: a lapillus otolith from a 29-day-old juvenile. Right: a lapillus otolith from a 28-year-old adult chub. The scale bar represents 100 micrometers (about 0.004 inches).
stem were greatly improved, the longer the young chubs stayed in their nursery grounds. This was consistent with much of what’s been learned about other fish species in many parts of the world. But now we had proof—the chubs had revealed their secrets. This resolved an open question about how important the Little Colorado is to the population (answer: very!), and also provides insights into what other tributaries, with similar chemical properties, could also be managed to restore humpback chub populations. One of the most important of these is Havasu Creek, on river left just downstream of mile 157. Havasu is also a “travertine stream,” and indeed, experimental stocking of chubs yielded successful spawning earlier this year.

Otoliths shed a great deal of light on the ecology of this mysterious fish. The information we learned is helping those who care about humpback chub to understand their ecology better, and along with other studies, improve their management.

Karin E. Limburg

Department of Environmental and Forest Biology, State University of New York College of Environmental Science and Forestry

FURTHER READING:

FOOTNOTES:
1. Trace elements are defined as those whose concentrations are trace: less than 100 parts per million. Isotopes are like “flavors” of an element, differing only in the number of neutrons, which affects the atomic mass. Measuring ratios of heavy to lighter isotopes provides insight into many physical, chemical, and biological processes.