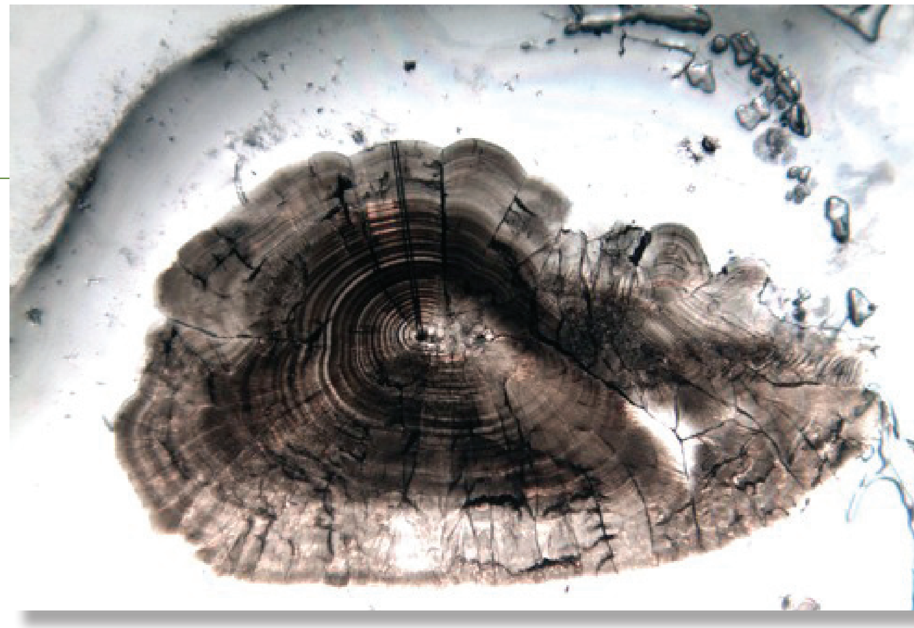
Salmon otoliths reveal increased use of estuary following dike removal

Otoliths—salmon's "in-flight data recorders"—tell the story of transit through estuaries to their lives in the ocean.



Scientists are able to decode some elements of a fish's past in the rings of otoliths, small, pebble-sized hunks of calcium carbonate in its skull.

Pacific estuaries, where the river meets the sea, are becoming better understood as critical to the lives of salmon, thanks in part to their namesake Salmon River on the Oregon coast and to a special part of the fish's anatomy.

Just north of Lincoln City on Oregon's central coast, the Salmon River contains a 1,300-acre estuary. Here, under the shadow of Cascade Head, is a wide prairie of marsh grass and tidal flats bordered by pine and hemlock forests. Biologist Dan Bottom saw the research potential of that estuary more than a decade ago.

Bottom, a research fishery biologist with the National Oceanic and Atmospheric Administration (NOAA) and a courtesy faculty member at Oregon State University (OSU), saw the Salmon River estuary as a "natural laboratory" occasioned by the sequential removal of dikes that had originally been placed to create pasture within the estuary. That removal could help answer how estuary restoration affects a river's salmon population.

"The succession of dike removal projects in 1978, 1987, and 1996 created a series of wetland habitats in different stages of recovery, allowing us to compare the response by salmon and their preferred prey," he said. "We wanted to know do salmon respond immediately, or does it take years or decades of marsh regrowth and succession before there is a measurable effect?"

The dikes were removed following the 1974 Congressional designation of the estuary and the adjacent headlands as the Cascade Head National Scenic Research Area.

According to Bottom, little work had been done in Oregon on the connection between estuary health and salmon populations. "The estuary was sort of the forgotten stepchild of the life cycle of salmon," Bottom said. "Even when people did bother to look at the estuary, they usually studied what was easiest—nice, clean, sandy beaches. No one was looking at the peripheral wetland habitats. They are hard to sample and muddy; 'Why would you go in there?'"

Funding from Oregon Sea Grant, begun in 1998 and sustained for 10 years, provided the base of support that allowed researchers from several agencies and universities to study the impacts of estuary restoration on the Salmon River Chinook population.

The Salmon River estuary turned out to be good for studying the relationship between habitat restoration and salmon not only because of its history but also because of its smaller size. In a larger system like the Columbia River, scientists have a hard time correlating changes in habitat to changes in fish populations. The Salmon River has one Chinook population and has had nearly two-thirds of its estuary restored—a very favorable situation for measuring the salmon response.

Scientists are able to gauge the immediate impact of restoration by measuring the numbers of fish that use the restored area and the benefits they derive from occupying the site. Bottom and his colleagues found that juvenile salmon began using the restored marshes very soon after the dikes were removed. The small salmon fed on insects and other organisms within the marsh and grew rapidly before leaving the estuary for their ocean rearing grounds. But fishery managers also are interested in the number of adult salmon that return to their home streams to spawn and perpetuate the fishery. Determining the effects of restoration on the number of salmon that return to spawn, often years later, is difficult.

Bottom and his colleagues needed a technique to tie estuary restoration to the long-term performance of the population. Were salmon that used the restored area as juveniles contributing to returning salmon adult numbers?

To find this out, the researchers examined structures in the fishes' skulls called otoliths. Otoliths are the in-flight data recorders of fish. Small, pebble-sized hunks of calcium carbonate, they help to provide balance and serve a function similar to the inner ear in humans. When removed, they show layers of concentric circles that look like the rings of a tree. Like a forester reading a tree's life history in its rings—years with fire, drought, or rain—scientists are able to decode some elements of a fish's past in the rings of its otoliths.

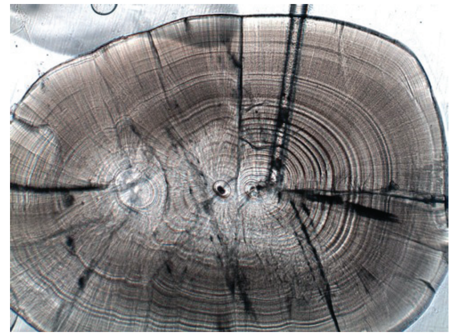
Unlike tree rings, the rings of an otolith are accreted daily, so the events they describe have a higher resolution in time than the events a tree's rings describe. Each of these rings, in its chemical signature, holds information about the environment the fish was traveling through when the ring was created. Otolith research leader Eric Volk, with the Alaska Department of Fish and Game, measured strontium, an element plentiful in salt water but much lower in fresh water, to pinpoint the day that the fish moved from the freshwater into the saltwater environment.

By comparing this entry time to the fish's age and size, the researchers began to understand the wide array of life histories—the different ways in which salmon complete their life cycles—that the Salmon River Chinook were expressing. Rearing in different parts of the river and migrating from freshwater to saltwater at different times or sizes are some of the life history strategies that salmon typically exhibit. Scientists believe these diverse strategies protect the population from catastrophic environmental change and are an indicator of population health.

Before restoration of the estuary, the life histories the salmon showed were much less diverse. "Grazing and dikes eliminated a lot of habitat that supported this life-history diversity" said Eric Volk. "Without the restored habitats," he said, "fry come into the estuary and don't have many places to hide out and feed, so they go into the ocean sooner and fall victim to size-selective predation."

After restoration, many new life-history strategies began to reappear, as described in an article published in 2010 in the *Transactions of the American Fisheries Society*. Scientists call one of these strategies that was unavailable to salmon before restoration "early fry migration."

Immediately after emerging from the gravel, these juvenile fry leave the river for the estuary. Scientists used to think that early fry migrants were excess, unlucky fish that could not find food or shelter in the river and were doomed to perish in the predator-rich and saline estuary. But by analyzing otoliths of adults returning to spawn, the researchers found that the former early migrants were a large part of adult returns. In one of the post-restoration years they examined, 17 percent of the juveniles leaving for the ocean were early fry migrants to the estuary. Adult returns from the ocean that year showed that a third of the returns had been early fry migrants.



Close-up of an otolith reveals tree-like rings used to decode a fish's life history.

"The salmon are able to express this pattern of behavior, but when most of the estuary's marshes were diked, the habitat wasn't there to support it," Bottom said.

Through their examination of otoliths, Volk and his colleagues may have found a way to measure the effects of restoration on a river's salmon population. By comparing their findings with data collected before the Salmon River estuary was restored, they were able to estimate the role the restored estuary plays in promoting a diversity of life histories. They also showed that the protected Salmon River estuary is important to the study of Pacific Northwest salmon.

"There is now a much greater recognition," said Bottom, "in part due to the Salmon River work, that marsh and wetlands in the estuary are a critical part of salmon biology."

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