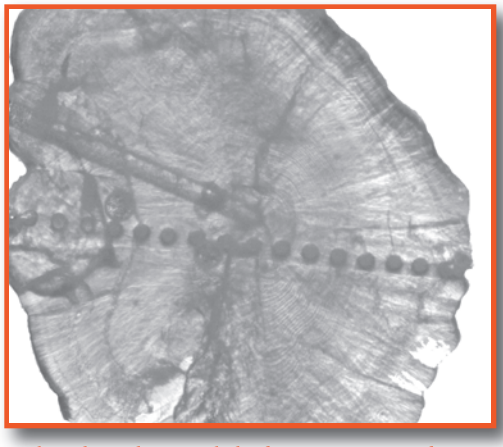
Otolith Growth and Microchemistry to Determine Variability in Recruitment Success of Delta Smelt

James Hobbs, Department of Geography, UC Berkeley

SUMMARY

This project employed otolith geochemistry to study the recruitment patterns and growth rates of delta smelt before and during the Pelagic Organism Decline (POD) in the San Francisco Bay-Delta. The delta smelt was selected as the target species for the analysis because of its imperiled status (it is on both state and federal endangered species lists) and because it is one of several pelagic species in the Bay-Delta whose numbers have plummeted since the 2002–04 period, during which time water exports rose by 30 percent. The delta smelt, in many ways, can be thought of as the proverbial canary in the coal mine — a species whose status mirrors the ecological health of its surroundings.

Among the study's key conclusions: 1) the delta's interior is no longer healthy habitat for delta smelt; 2) since the POD, the smelt's spawning grounds have moved from the delta's interior to the Cache Slough region on the lower Sacramento River, and 3) larval delta smelt growth rates have declined by more than 25 percent since the POD, consistent with the theory that the region's species are struggling to keep nourished.



J. Hobbs/UC Davis

A slice through an otolith about 1.2 mm in diameter. The spots and lines are scars from the laser.

In terms of management implications, otolith analyses of smelt killed in the massive water-pumping plant in the south delta suggest that smelt in the Cache Slough region can be entrained into the pumping system during years of below-normal precipitation. This is an extremely noteworthy discovery, as the slough is more than 30 miles from the intake.

The proposal to build a peripheral canal with intake systems just upstream of Cache Slough, to capture fresh water before it flows into the delta, would bring remnant delta smelt closer to the brink, the former CALFED Science Fellow reports.

BACKGROUND

An otolith is a bone-like structure in a fish's ear that accretes daily layers of calcium carbonate and protein matrix. The thickness of each layer reflects growth rates, similar to tree rings.

In addition to being able to age fish and study their growth, each layer is imprinted with the chemistry of the water in which the fish was residing at the time. With a precision laser, it is possible to translate the series of chemical imprints into a history of a migratory fish's whereabouts.

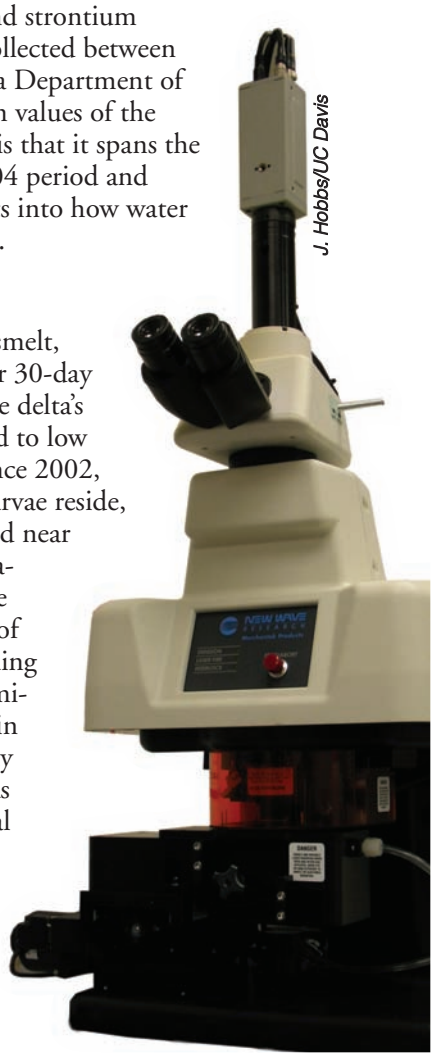
The chemical fingerprint selected for this project was the ratio of two strontium isotopes, $^{87}Sr/^{86}Sr$. Strontium is a common constituent of water and is so structurally similar to calcium that it is incorporated into bone, and otoliths. The ratio varies with rocks and ages of rocks in a watershed and is an appropriate fingerprint for sediment provenances of the Bay-Delta, as both the Sacramento and San Joaquin rivers flow through different geologies. There is also a strong east-west gradient in the isotope ratio as river waters converge within the delta and move west, mixing with bay waters.

PROJECT

Otoliths from more than 1,000 delta smelt were analyzed for their age, growth and strontium isotope ratios. The smelt were collected between 1999 and 2007 by the California Department of Fish and Game. One of the main values of the dataset analyzed for this project is that it spans the onset of the POD in the 2002–04 period and thus can provide detailed insights into how water diversions cause ecosystem stress.

RESULTS

Based on otolith analyses, delta smelt, before 2002, typically spent their 30-day larval period in freshwaters of the delta's interior and as juveniles migrated to low salinity waters of Suisun Bay. Since 2002, there has been a shift in where larvae reside, as currently most larvae are found near Cache Slough on the lower Sacramento River. Moreover, since the POD, an increasing proportion of the remnant population is spending more time in freshwater before migrating to low-salinity nurseries in Suisun Bay. During the extremely wet year of 2006, Suisun Bay was also the primary habitat for larval rearing.



J. Hobbs/UC Davis

Sophisticated lasers can extract material from otolith rings for chemical analysis.

A delta smelt.
J. Hobbs/UC Davis

In six of the seven years of this study, fish that spent their juvenile period in interior delta waters had very poor recruitment. In other words, most of these fish perished before reaching adulthood. Meanwhile, juveniles reared in low-salinity waters (less than 2.0 parts per thousand salinity; i.e., Suisun Bay) appeared to exhibit greatest recruitment success. The outlier year was 2005, during which time there were heavy May rains, resulting in high late-season outflow and poor recruitment of fish rearing as juveniles in Suisun Bay. These observations highlight the effects of inter-annual variability of freshwater outflow on where fish spend their larval and juvenile periods. The observations also underscore the important role of life-history variability in species survival.

From 1999 to 2007, larval growth rates declined by more than 25 percent. Delta smelt have yearlong life expectancies and are born from March through May. For fish born in March and April, growth rates declined substantially more than 25 percent, as compared to May-born fish. The leading theory for why growth rates have slowed is that fish are not getting enough to eat. Consistent with this is the observation that copepods — the preferred food for the fish — are not as abundant in the Bay-Delta as they once were. The loss of zooplankton would also explain declines in other of the region's pelagic species.

In 2000 and 2001, the CALFED Science Fellow obtained otoliths from fish that had been killed in the pumping system in the south delta. Fish from the 2000 cohort were shown to have spent their larval period in interior delta waters. Notably, however, fish from the 2001 cohort originated in Cache Slough, more than 30 miles from the intake system. The otolith chemistry thus provides the first evidence that water diversion during dry years such as 2001 can be lethal to fish as far away as Cache Slough.

BENEFITS

Otolith geochemistry shows that the lower Sacramento River in the Cache Slough region serves as a freshwater refuge for delta smelt. This freshwater refuge is particularly crucial to the species now that the interior delta has been so dramatically altered. Because of this project's findings, California Department of Water Resources and Interagency Ecological Program are further investigating the Cache Slough region's ecological function, while the Bay-Delta Conservation Plan has identified the area as a top candidate for restoration.

PUBLICATIONS

Hobbs, J.A., W.A. Bennett, N. Ikemiyagi, and E. Brown. Looking back to go forward: The application of otolith growth and microchemistry to determine spatial-temporal variability in recruitment success for delta smelt. San Francisco Estuary and Watershed Sciences. 2010. In prep.

PRESENTATIONS

Hobbs, J.A., R. Quinones, B. Hodge, P. Allen and D. Portz. The use of strontium isotopes ^{87}Sr:^{86}Sr to manage threatened, endangered and commercially important species in the Western US. 4th International Otolith Symposium, Monterey, 2009.

Hobbs, J.A.,W. Bennett and B. Lynn Ingram. Looking back to go forward: Stock structure dynamics revealed with otolith geochemistry for an endangered estuarine fish. CALFED Science Conference 2008.

Hobbs, J.A., W. Bennett and N. Ikemiyagi. Looking back to go forward: Stock structure dynamics revealed with otolith geochemistry for an endangered estuarine fish. State of the Estuary 2007.

Hobbs, J.A. Comparing laser ablation techniques to reconstruct the movements of estuarine fish. American Fisheries Society National Meeting, San Francisco, 2007.

Hobbs, J.A., W. Bennett and B. Lynn Ingram. Spatio-temporal variability in delta smelt stock structure pre-post POD years. CALFED Science Conference 2006.

MENTORS

Research: Lynn Ingram, Professor of Geography, UC Berkeley, and William Bennett, Fish Ecologist, UC Davis

Community: Ted Sommer, Senior Environmental Scientist, California Department of Water Resources

CONTACT

James A. Hobbs
Researcher Scientist
Interdisciplinary Center for Inductively Coupled Plasma Mass Spectrometry
UC Davis
707-480-0188
jahobbs@ucdavis.edu

Sea Grant

This publication is sponsored by a grant from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, under grant number NA10OAR4170060, Project number C/P-1. The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its sub-agencies. The U.S. government is authorized to reproduce and distribute for governmental purposes. This document is available in PDF on the California Sea Grant website: www.csgc.ucsd.edu.

California Sea Grant, University of California, San Diego, 9500 Gilman Drive, Dept. 0232, La Jolla, CA 92093-0232
Communications Phone: 858-534-4440