Occurrence of Vaterite in Otoliths from Wild and Stocked Fish Populations

Heather L. Allamon[1], Jeffrey G. Miner[1], John R. Farver[2], Christopher T. Boehler[1]

[1]Dept. of Biological Sciences, Bowling Green State University, [2]Dept. of Geology, Bowling Green State University

Introduction:

Otoliths, or "ear stones," are structures composed of calcium carbonate that help fish to detect sound and aid fish with balance and orientation. The calcium carbonate of the otoliths can occur in different polymorphs including aragonite, vaterite, and calcite. These polymorphs have the same chemical formula but they differ in their crystalline structure. Sagittal otoliths are usually composed of aragonite but abnormal otoliths made of vaterite have been reported. The stress of hatcheries including density effects and temperature stress is hypothesized to initiate the switch to vaterite, although other stresses such as food deprivation, stocking stress, or perhaps some combination of stresses may be required for otoliths to switch from aragonite to vaterite. Vateritic otoliths are less dense and tend to be slightly larger that the normal aragonite forms. The lower density and larger size could impact the functioning of the hearing and balance systems because the motion between the otolith and the sensory epithelium stimulates hair cells that then relate information about body position and sounds in the surrounding environment to the fish. This could make the fish more vulnerable to predators. We compared the proportion of vaterite in fish from naturally reproducing populations with the proportion in fish from hatcheries.

The objective of this study was to see if hatcheries do indeed produce fish with a higher proportion of vateritic otoliths than do naturally reproducing populations of fish so that future work can determine what causes the switch to vaterite, how detrimental vaterite is to a fish, and what hatcheries can do to stock fish more efficiently.

Note: Otoliths are of importance because they act as natural data loggers. They can be used to determine the age of a fish because the otoliths grow in concentric rings. Otoliths also contain information that can be used in stock identification and to track migration histories. Most otoliths start as aragonite (at least in steelhead trout), but then parts of the growing otolith can switch from aragonite production to vaterite production.

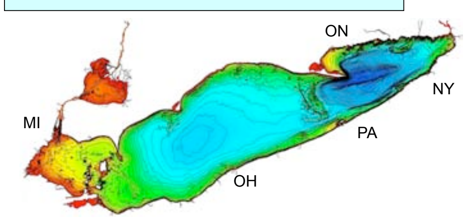
Methods:

Field Sampling:

- 2008, steelhead trout samples were obtained from hatcheries in MI, OH, PA, and NY
- July 7th and 8th 2009, yearling steelhead trout samples were collected from naturally reproducing populations from tributaries of Chautauqua Creek and Cattaraugus Creek in New York

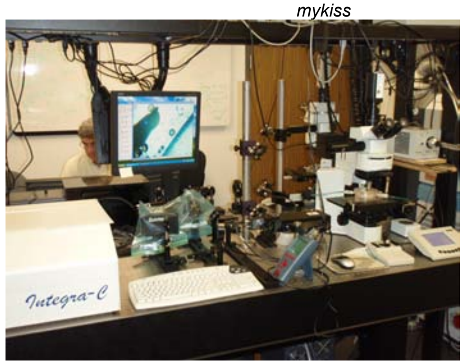
Lab Prep and Analysis:

- Otoliths were extracted, rinsed with hydrogen peroxide and then rinsed with water, and left to dry in 1mL plastic vials. The otoliths were embedded in epoxy and left to cure. The otoliths were then cut in transverse sections with a low speed wafering saw with a diamond impregnated blade. The sections were polished with 2000 grit sandpaper and 10 micron lapping film. Lastly, they were mounted to glass slides with Krazy Glue.
- Analyzed with Fs-LA-ICPMS in Windsor (Femto Second - Laser Ablation- Inductively Coupled Plasma Mass Spectrometry) That is, a laser cut small pieces of otolith and these pieces were passed to a mass spectrometer for elemental analysis.

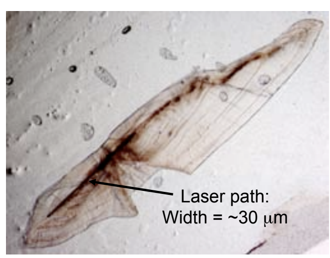


Electroshock fishing

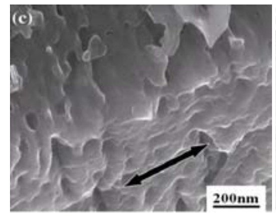
Steelhead trout, *Oncorhynchus mykiss*



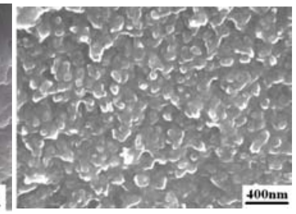
Laser ablation - inductively coupled mass spectrometer (LA-ICPMS) at the University of Windsor, Great Lakes Institute for Environmental Research



Laser traverse through transverse section of otolith analyzed with ICPMS



Aragonite



Vaterite

The two calcium carbonate forms of otolith look very different under scanning electron microscopy (Li et al. 2009) and have diagnostic elemental signatures

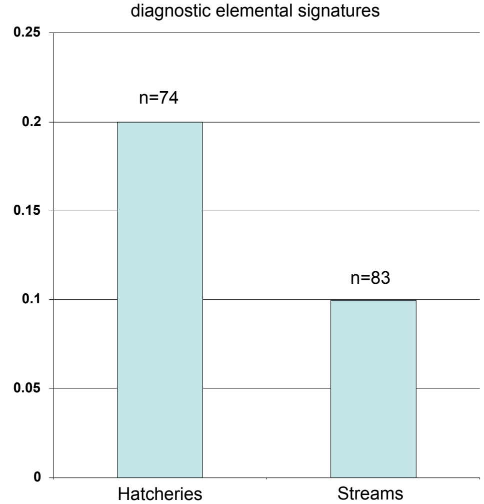


Figure 1. Proportion of yearly steelhead trout in hatcheries and naturally spawned in New York streams with vaterite in one randomly determined otolith from each fish. Significantly more fish from hatcheries had vaterite in an otolith than was expected given the distribution from the streams ($\chi^2_{0.05,1}$=3.73, one-tailed test).

Whole otolith

Results:

- We tested the distribution of vaterite and aragonite in fish from hatcheries versus the expected distribution from the fish in the New York streams and found that a significantly higher proportion of hatchery fish had vaterite in an otolith ($\chi^2_{0.05,1}$=3.73, $p < 0.05$, one-tailed test).
- Approximately 20% of the hatchery fish had vaterite in an otolith, while less than 10% of stream steelhead otoliths contained vaterite (Fig. 1).

Discussion:

- These results suggest that the higher proportion of hatchery fish with vaterite is due to something happening to the fish in the hatchery because the source populations of the two groups is similar (at least PA and NY stream fishes come from the same source: Lake Erie). Any number of stresses, or some combination of stresses, may be causing the switch to vaterite.
- Alternatively, fish in streams with a vaterite otolith may face higher mortality than fish with a vaterite otolith in hatcheries, which would suggest that the occurrence of vaterite is actually the same across hatcheries and streams, but that vaterite in otoliths presents a problem for fish in natural systems.
- Further work should be done to determine whether stress causes fish to terminate production of aragonite and start production of vaterite in otoliths, and whether the stress is more likely to occur in a hatchery or stream. Also, research should be conducted to determine whether vaterite in otoliths has detrimental effects on a fish's survival rate compared to aragonite-only otoliths.

Acknowledgments:

We would like to thank all those who helped with this project: SETGO, University of Windsor, Great Lakes Institute for Environmental Research for use of equipment, Audrey Maran, and AEFL members.

Relevant References:

- Gauldie, R. W. 1990. The morphology and periodic structures of the otolith of the Chinook salmon (*Oncorhynchus tshawytscha*), and temperature-dependent variation in otolith microscopic growth increment width. *Acta Zoologica* 72: 159-179.
- Ma, T., M. Kuroki, M.J. Miller, R. Ishida, K. Tsukamoto. 2007. Morphology and microchemistry of abnormal otoliths in the ayu, *Plecoglossus altivelis. Environmental Biology Fisheries* 83: 155-167.
- Oxman, D.S., R. Barnett-Johnson, M. E. Smith, A. Coffin, D. L. Miller, R. Josephson, and A.N. Popper. 2007. The effect of vaterite deposition on sound reception, otolith morphology, and inner ear sensory epithelia in hatchery-reared Chinook salmon (*Oncorhynchus tshawytscha*). *Canadian Journal of Fisheries and Aquatic Science* 64: 1469-1478.
- Tomas, J., and A. J. Geffen. 2003. Morphometry and composition of aragonite and vaterite otoliths of deformed laboratory reared juvenile herring from two populations. Journal of Fish Biology 63: 383-1401.