

GREAT LAKES FISHERY COMMISSION

2001 Project Completion Report¹

Determine the level of Chinook salmon wild production in Lake Ontario from 1991-2000

by:

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¹Project completion reports of Commission-sponsored research are made available to the Commission's Cooperators in the interest of rapid dissemination of information that may be useful in Great Lakes fishery management, research, or administration. The reader should be aware that project completion reports have not been through a peer review process and that sponsorship of the project by the Commission does not necessarily imply that the findings or conclusions are endorsed by the Commission.



SYRACUSE UNIVERSITY

DEPARTMENT OF EARTH SCIENCES

November 5, 2001

To: Ann Krause
Research Associate
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2100 Commonwealth Blvd. Suite 100
Ann Arbor, MI 48105-1563

Re: Research report

Great Lakes Fishery Commission (\$7,500) "Determine the level of Chinook salmon wild production in Lake Ontario from 1991-2000." Awarded to Co-PIs Patterson and Stewart.

The funding awarded to the Co-PI's Patterson and Stewart has permitted significant advances in both technical sampling capabilities and life history evaluation of fishes of the Laurentian Great Lakes region. In particular, valuable information on the percentage of wild salmon production in Lake Ontario was obtained.

We examined the early life history of Chinook salmon using $\delta^{13}\text{C}_{(\text{CaCO}_3)}$ and $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values of their otoliths. Because otoliths are accretionary structures that are not resorbed, they serve as excellent recorders of fish life history. $\delta^{13}\text{C}_{(\text{CaCO}_3)}$ values are representative of diet and metabolism, whereas $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values record water temperature and $\delta^{18}\text{O}_{(\text{H}_2\text{O})}$ values. By discretely milling time-specific otolith banding we obtain secular records of diet, temperature and water source.

Our initial experiment relies on the difference in $\delta^{13}\text{C}_{(\text{organic})}$ value of diets between wild individuals that feed on aquatic insects and those fish raised in hatcheries which are fed an artificial diet of predominately marine based carbon (principally the marine fish "menhaden"). Marine based carbon from menhaden has a significantly higher $\delta^{13}\text{C}_{(\text{organic})}$ value than freshwater aquatic insects native to New York and southern Canada. Therefore, we proposed that the difference in $\delta^{13}\text{C}_{(\text{diet})}$ should be reflected in the $\delta^{13}\text{C}_{(\text{CaCO}_3)}$ values of fish recovered from hatcheries and natural stream populations. We captured fish from several streams in the spring and early summer over the last several years. Because the fish were captured before hatcheries released their stock, these fish are assumed to be naturally spawned or "wild".

In figure one $\delta^{13}\text{C}_{(\text{CaCO}_3)}$ and $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values are plotted for several hatchery stocks from New York and Canada. Carbon isotope values are distinctively different for each population. Whole otoliths were extracted from juvenile fish and analyzed for stable isotope values by reaction by reaction with phosphoric acid at 70°C using a Kiel III carbonate preparation device directly coupled to a Finnigan MAT 252 stable isotope ratio mass spectrometer at Syracuse University. All isotope values are reported relative to the Vienna Pee Dee Belemnite standard (VPDB).

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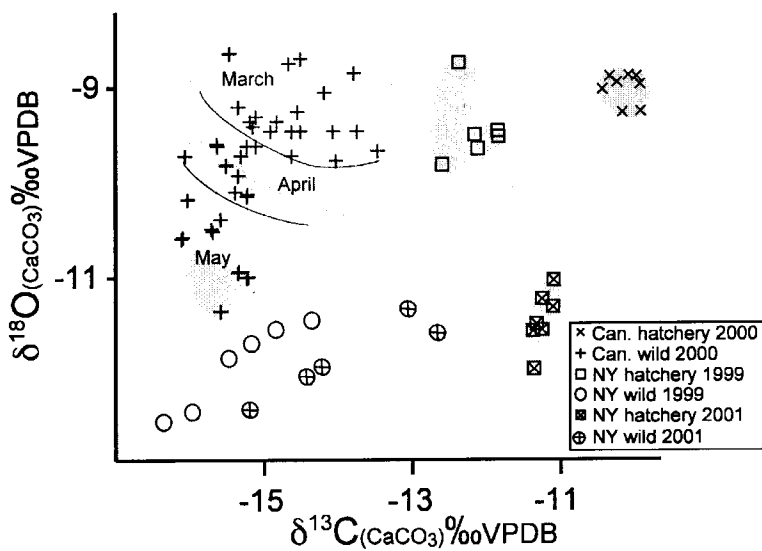


Figure 1- Comparison between juvenile fish from hatcheries and those captured from streams. Marine-carbon based diets have higher $\delta^{13}C_{(DIC)}$ values. These higher values are incorporated and permanently recorded as elevated $\delta^{13}C_{(CaCO_3)}$ values in otoliths. The distinctive differences between 1999 NY wild and hatchery fish led to this research. Generally lower $\delta^{18}O_{(H_2O)}$ values of streams compared to hatchery water that is often derived from wells. Well water tends to remain invariant through a given year whereas stream water fluctuates in $\delta^{18}O_{(H_2O)}$ value with seasonal precipitation.

As expected the higher $\delta^{13}C_{(organic)}$ values of marine based food are recorded by hatchery fish as higher $\delta^{13}C_{(CaCO_3)}$ values. Respectively, the lower $\delta^{13}C_{(organic)}$ values of freshwater aquatic insects are apparent in the $\delta^{13}C_{(CaCO_3)}$ values of fish recovered from natural stream settings. The spread in $\delta^{13}C_{(CaCO_3)}$ values amongst the wild specimens is interpreted to represent the differences in the metabolism and growth rate of naturally spawned fish. Competition for food and optimal position in the stream flow will be significantly greater in natural streams than in controlled hatchery settings.

The large spread in $\delta^{18}O_{(CaCO_3)}$ values of Canadian wild specimens is interpreted to reflect the timing of capture. Because $\delta^{18}O_{(CaCO_3)}$ values are related to temperature and $\delta^{18}O_{(H_2O)}$ values, we can clearly see the effect of the seasonal increase in water temperature between individuals captured through the spring and into the early summer. This promising preliminary work led to our proposal and subsequent comparison of hatchery and wild juvenile fish to captured adults. In Figure two $\delta^{13}C_{(CaCO_3)}$ and $\delta^{18}O_{(CaCO_3)}$ values are presented for fish captured in Lake Ontario as well as NY streams.

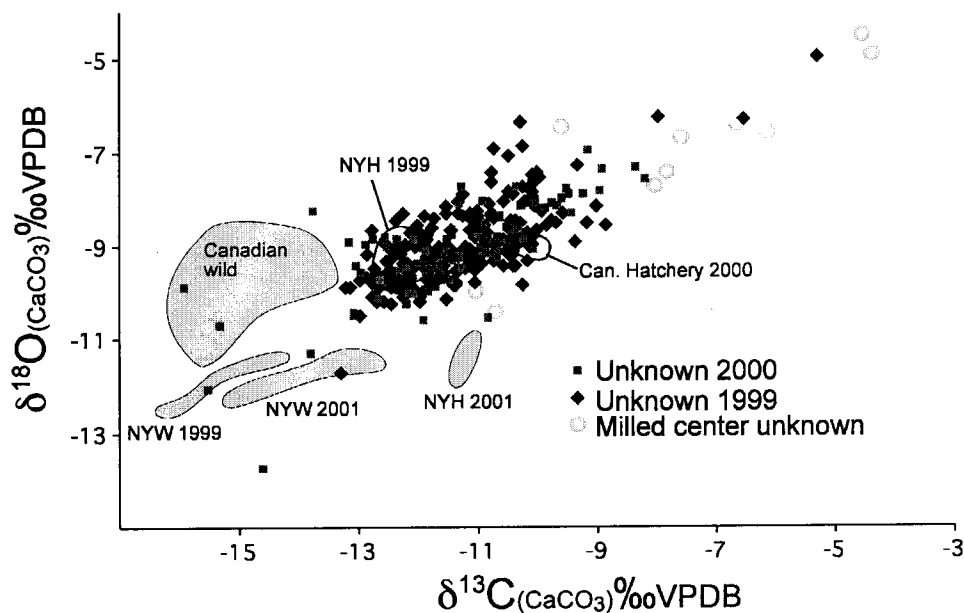


Figure 2- $\delta^{13}C_{(CaCO_3)}$ and $\delta^{18}O_{(CaCO_3)}$ values of whole juvenile otoliths and otolith kernels of adult fish. Because hatchery and wild fishes are easily differentiated in control studies, we can propose origin of adult fish captured during spawning, or sport catches in Lake Ontario. Significantly, our data suggest that very few adult fish originate as natural spawned juveniles. The vast majority (nearly 99%) originate from hatcheries. Samples labeled "unknown 1999 & 2000" were captured during the year listed, but represent age classes from 1994-1999. Samples labeled "milled center unknown" represent age classes from 1988-1994.

Distinctive $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values may be as valuable as $\delta^{13}\text{C}_{(\text{CaCO}_3)}$ values in determining origin. Instead of indicating hatchery vs. wild food, $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values may be critical to determining which stream a fish may come from as well as when in a given year they leave the stream and enter Lake Ontario. Computer assisted micromilling of otoliths can provide life-long records of behavior and environmental conditions. Although not the primary focus of this proposal, our research on Chinook life history benefits significantly from this comparison of juveniles originating from hatcheries.

Thus, this dual isotope system serves as a natural tag in permitting reconstruction of origin without costly tagging programs. Additionally, because we can compare health and numbers originating from specific hatcheries and streams, we can better evaluate and make more informed management decisions. The greater significance of this research will be the general application of these techniques towards management of other species.

We anticipate the submission of at least three manuscripts to peer-reviewed journals for publication. Those currently in preparation include:

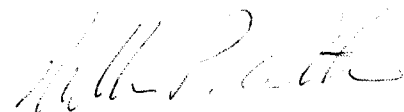
Patterson, W.P., Wurster, C.M., Stewart, T., Smith, N., Sullivan, P. 2002. Differentiation of hatchery-reared and natural spawning Chinook. This research is the primary focus of the discussion above.

Patterson, W.P., Wurster, C.M., Stewart, D.J., Stewart, T. 2002. Life history of Chinook: evidence from $\delta^{13}\text{C}_{(\text{CaCO}_3)}$ and $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values from micromilled otoliths. Details of life history revealed by micromilling adult Chinook otoliths provide a means to establish a life history record that includes preferred temperatures as well as physiology (particularly metabolism) for fish from hatching to capture.

Patterson, W.P., Wurster, C.M., Stewart, D.J., Stewart, T. 2002. Thermal life history of Chinook: implications for bioenergetics. Thermal life history of Chinook: evidence from high-resolution analyses of otoliths (in prep.). A secondary objective of this proposal is the refinement of a thermal life history record for Chinook. $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values from micromilled otoliths indicate that these fish are living at much higher temperatures than was previously thought. Fish occupy water that may reach more than 20°C each summer. These temperatures require a greater intake of food than was previously thought. A $\delta^{13}\text{C}_{(\text{CaCO}_3)}$ based carbon model and the food web implications will be discussed in a separate paper.

If you have any further questions, do not hesitate to contact me. Thank you for funding this interesting project.

Sincerely,



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