

GREAT LAKES FISHERY COMMISSION

2004 Project Completion Report¹

Application of Stable Isotope Method to Determine Origin of Lake Trout; and Description of Thermal History of Lake Trout During First Year of Life

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February 2004

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February 22, 2004.

Abstract

The suitability of carbon and oxygen isotope analysis in determining the origin of lake trout was investigated. $\delta^{13}C_{(CaCO_3)}$ and $\delta^{18}O_{(CaCO_3)}$ values were measured in otoliths of yearling and late young-of-the-year lake trout from two hatcheries (Allegheny and Harwood) used to raise lake trout for stocking in Lake Ontario, as well as in otoliths of naturally produced (wild) yearling lake trout. The differences in isotope values between the three groups was sufficient to suggest that isotope values can be used to determine origin. Regions corresponding to the first year of life from otoliths from older lake trout were also examined. Older stocked fish had isotope values similar to the Harwood hatchery group, while older fish of unknown origin had isotope values similar either to the Harwood hatchery group, or the wild group. The method will allow determination of origin of lake trout in Lake Ontario, if a catalogue of isotope values of hatchery fish from other years can be compiled.

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Introduction

Recent work on chinook salmon otoliths (Patterson, 2001) showed that the isotope value of the otolith can be used to distinguish between stocked and wild fish. Because otoliths are accretionary structures that are not resorbed, they provide a record of the life history of the fish. The proportion of ^{13}C in the deposited material ($\delta^{13}\text{C}_{(\text{CaCO}_3)}$) reflects the $\delta^{13}\text{C}$ value of the fish's diet ($\delta^{13}\text{C}_{(\text{organic})}$) and its metabolic rate. The proportion of ^{18}O in the deposited material ($\delta^{18}\text{O}_{(\text{CaCO}_3)}$) reflects the $\delta^{18}\text{O}$ value of the water ($\delta^{18}\text{O}_{(\text{H}_2\text{O})}$) as well as the ambient temperature (Patterson et al. 1993). Food, water quality and ambient temperature differ between the wild and hatchery fish during the first year of life, and therefore carbon and oxygen stable isotope values from the region of the otolith representing the first year of life should be indicative of the origin of the fish. The primary objective of this study was to determine if this method can be applied to lake trout in Lake Ontario.

A secondary objective was to document the early-life thermal history of the wild lake trout by examining the chronology of ^{18}O deposition during the first year. This was undertaken in order to maximize the information obtained from the few available otoliths of wild fish. We were, however, not able to extract samples at a sufficiently small resolution, and this objective was not achieved.

Methods

Four groups of fish were analyzed.

1) Small lake trout (YOY and yearlings) collected from hatcheries

Otoliths from hatchery yearlings were obtained from the Harwood Fish Culture Station in Ontario, and from the Allegheny National Fish Hatchery in Pennsylvania. These are the two hatcheries currently rearing lake trout for stocking in Lake Ontario. The hatchery sample consisted of the following fish:

<u>No. fish</u>	<u>Strain</u>	<u>Hatchery</u>	<u>Description</u>
15	Seneca	Harwood	Yearlings collected in May 2001
15	Michipicoten	Harwood	Yearlings collected in May 2001
15	Mishibishu	Harwood	Yearlings collected in May 2001
14	Superior	Allegheny	Young-of-the-year collected in Nov. 2001
15	Seneca	Allegheny	Yearlings collected in May 2001

2) Small naturally produced lake trout

Ten yearling fish caught in the U.S. waters of Lake Ontario in the period 1998-2001 in various surveys conducted by the USGS. They were recognized as wild based on size and external characteristics (Ref?)

3) Large lake trout of known hatchery origin

Twelve fish ranging between 450 and 723 mm (fork length) caught in eastern Lake Ontario in 1998.

4) Large lake trout of unknown origin

Thirteen fish ranging between 428 and 766 mm (fork length) caught in eastern Lake Ontario in 1998 and 1999. Their origin was not unknown because they had no fin clip or coded wire tag, and therefore could be either hatchery fish with lost tag and regenerated clip, or naturally produced fish.

The otoliths from the small fish were micromilled to obtain one or more samples representing the first year of life. The otoliths from the large fish were embedded flat in epoxy on microscope slides, ground down to expose the material deposited during the first year of life, and single samples were micromilled for analysis.

The number of analyzed samples from each fish varied (Appendix A). Most hatchery yearlings and young-of-the-year had only a single otolith analyzed, but due to a misunderstanding 12 of the Allegheny samples had both otoliths analyzed. Up to three samples from each otolith were analyzed, resulting in maximum total of 6 replicate samples per fish. Eight of the ten wild yearling samples were successfully analyzed, using one otolith per fish, and up to three samples per otolith. Older fish of both known and unknown origin were represented by single samples.

Samples were roasted *in vacuo* for 1 hour at 200 degrees C to remove volatiles that may interfere with the $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values. Sample aliquots were analyzed using a Finnigan MAT 253 stable isotope ratio mass spectrometer directly coupled to a Kiel-III automated carbonate preparation device. Carbon dioxide was generated by reaction of carbonate with 2 drops of anhydrous phosphoric acid in individual reaction vessels at 70 degrees C. Individual samples were run using a micro-inlet which reduces sample "memory" and permits analysis of 10-200 micrograms of carbonate. All isotope values are reported relative to the Vienna Pee Dee Belemnite standard (VPDB).

Results

Hatchery versus wild

$\delta^{13}\text{C}_{(\text{CaCO}_3)}$ and $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values of otoliths from the small fish are shown in Figure 1. Values fall into three groups according to fish origin - Harwood hatchery, Allegheny hatchery and wild. The 95% bivariate confidence ellipses indicate a high degree of separation between the groups. Three observations outside of these groups are evident (arrows), however, in all three cases these are just single measurements among two or three made on the same fish, with the other measurements falling within their respective groups. This suggests possible inconsistencies in measurement techniques, and the observations should be treated as outliers.

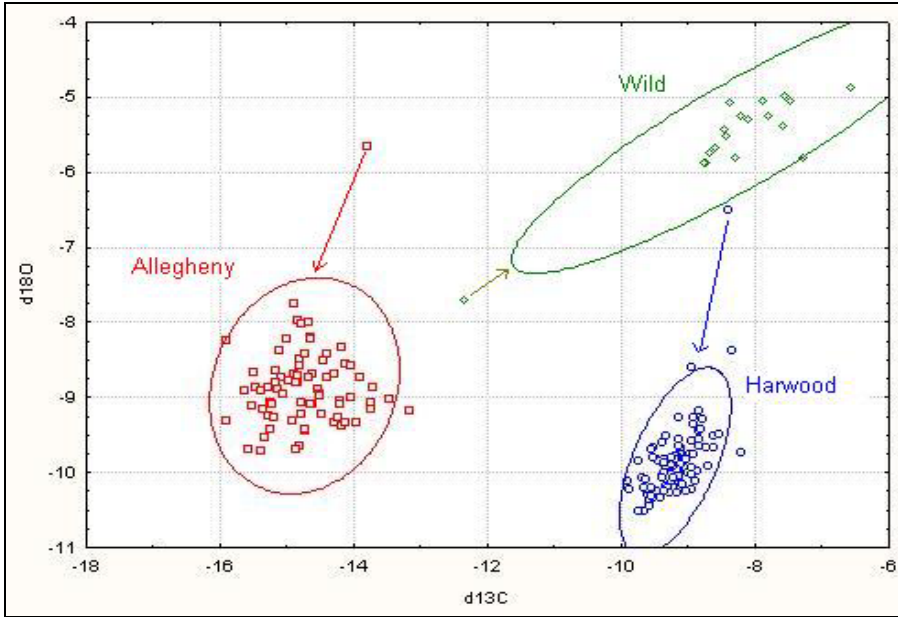


FIGURE 1. Plot of $\delta^{13}\text{C}_{(\text{CaCO}_3)}$ versus $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values measured in otoliths from the small fish. Multiple readings per fish, strains within hatchery not distinguished. Ellipses indicate 95% bivariate confidence regions. Arrows point to groups to which outliers belong.

$\delta^{13}\text{C}_{(\text{CaCO}_3)}$ and $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values measured in otoliths from large fish are shown in Figure 2, superimposed on values from the small fish. The values from large fish of known hatchery origin (circles) generally fall in the region corresponding to Harwood yearlings. This could be expected, since the fish were captured in Canadian waters, where due to limited movement of stocked fish, few U.S.-stocked (Allegheny) lake trout are captured. One stray observation falls into the wild fish grouping, and a plausible explanation is that the sample was micromilled from a region of the otolith that did not correspond to the first year of life, and therefore represents “lake” conditions.

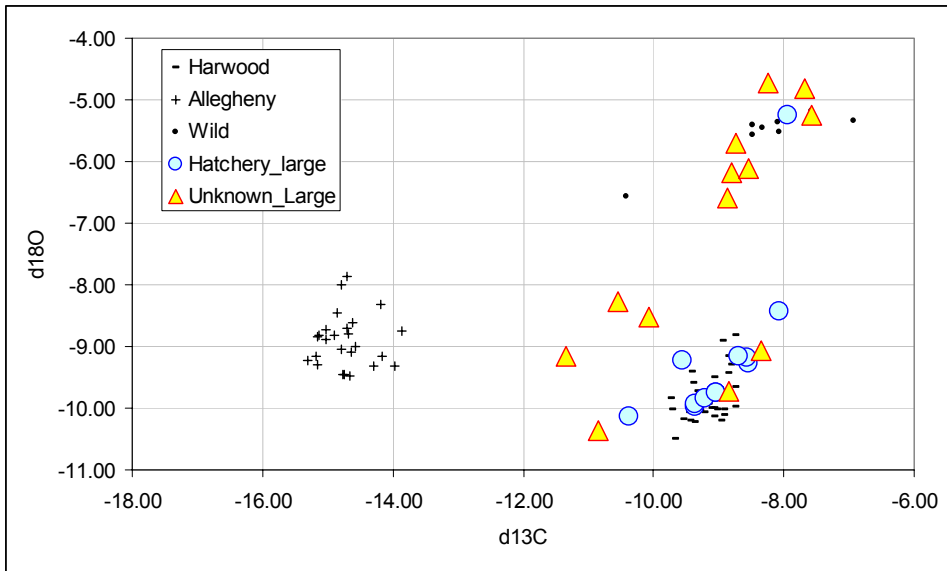


FIGURE 2. Plot of $\delta^{13}\text{C}_{(\text{CaCO}_3)}$ versus $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values measured in otoliths from large fish. Averaged (by fish) values from small fish are also shown as small symbols for comparison.

$\delta^{13}\text{C}_{(\text{CaCO}_3)}$ and $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values from unknown fish (Fig. 2, triangles) appear to fall into two groups, one in the region of the Harwood hatchery group, and one in the region of the wild group. No discriminate function analysis and formal classification of the unknown large fish was attempted at this point because we do not have baseline information from corresponding year classes (see discussion). It may be reasonable, however, to assume that fish with $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values less than -8.0‰ are hatchery fish (Harwood), while those above -8.0‰ are wild.

Within-hatchery patterns

Differences between strains reared in the same hatchery are apparent (Fig.3). The two strains from the Allegheny hatchery examined in this study came from two different years of rearing (Seneca: 2000 year class, Superior: 2001 year class), and while the two groups show similar $\delta^{13}\text{C}_{(\text{CaCO}_3)}$ values, there is an obvious difference in $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values. $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values are related to water quality and temperature, and in this case the higher values observed in the Senecas are probably due to the fact that the fish were sampled as 15 month olds in May, having experienced two cold temperature periods, while the Superiors were sampled as 9 months olds in November, having experienced only one cold period.

The three strains from the Harwood hatchery have very similar isotope values, but some differences in $\delta^{13}\text{C}_{(\text{CaCO}_3)}$ values seem to exist, especially between the Mishibishu and Michipicoten strains at the two extremes. All Harwood samples came from the same year, and were reared in nearly identical temperature conditions. They were also fed identical series of diets, but on different schedules as they progressed through their first year of life (pers. comm., D. Roseborough, MNR, Harwood Fish Culture Station). $\delta^{13}\text{C}_{(\text{CaCO}_3)}$ values are related to diet and metabolism, and the differences between strains may reflect the variations in timing of the various feeds during the first year.

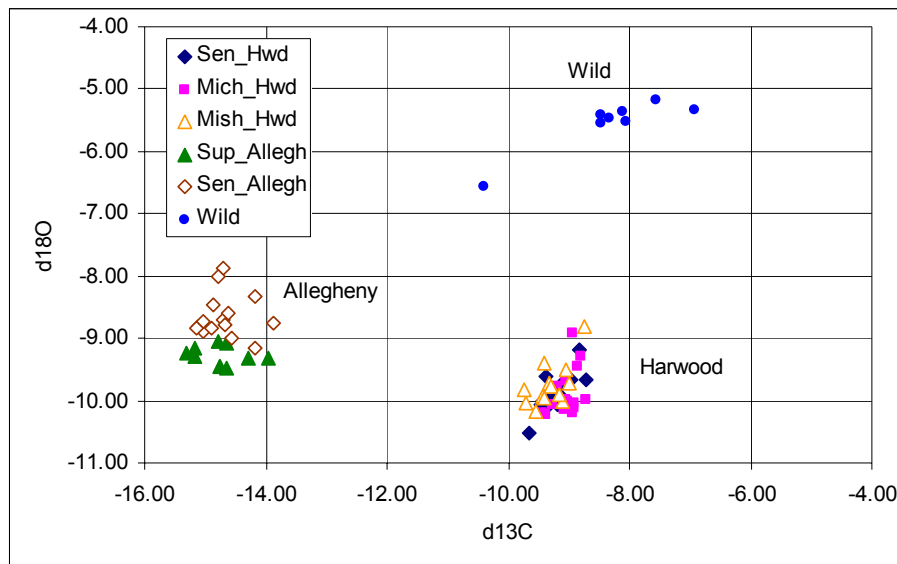


FIGURE 3. Plot of $\delta^{13}\text{C}_{(\text{CaCO}_3)}$ versus $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values from otoliths of small fish averaged by fish, hatchery fish distinguished by strain.

Discussion

$\delta^{13}\text{C}_{(\text{CaCO}_3)}$ and $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values in otoliths of yearling lake trout can be used to determine the origin of the fish. Examination of otoliths from yearling or younger fish suggests that the variation between the three groups currently found in Lake Ontario (Allegheny, Harwood and wild) is sufficiently large compared to variation within the groups, to be useful in classification of unknown fish. Examination of otoliths from larger fish of known origin suggests that material extracted from the first-year region of the otolith retains the characteristic isotope composition, thereby allowing older fish to be classified. Examination of otoliths from large fish of unknown origin suggests that the fish can be classified by similarity to previously identified groups.

Additional issues will need to be addressed before stable isotope analysis can be used to classify the origin of lake trout in Lake Ontario. The small but obvious difference in $\delta^{18}\text{O}_{(\text{CaCO}_3)}$ values between two strains and year classes of small fish from the Allegheny hatchery demonstrate that characteristic first-year isotope values can change between year classes. Similar differences in $\delta^{13}\text{C}_{(\text{CaCO}_3)}$ values can be expected due to changing hatchery feeds. Therefore it will be necessary to characterize all candidate hatchery groups (hatcheries, years and possibly strains) to establish baseline information used to inform the classification. Archival materials from known-origin fish in Lake Ontario should be sufficient to allow this analysis. Further work will also need to be done to develop micromilling techniques that insure reliable extraction of otolith material corresponding to first year of life.

References

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Future communications

We anticipate submission of a manuscript to a peer-reviewed journal for publication.