Comparison of Scale and Otolith Ages for Lake Whitefish from the South Shore of Lake Superior

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Abstract - I compared sagittal otolith and scale age estimation methods for lake whitefish (*Coregonus clupeaformis*) collected from along the south shore of Lake Superior during 2007. Whitefish less than nine years of age (from otoliths) were determined to have a greater age interpretation from scales than otoliths, and whitefish greater than nine years of age were determined to have a greater interpretation from otoliths than scales. This study has demonstrated that age estimation varies according to methodology, and that the variation depends on the age of the fish. I recommend with this outcome further study is needed to determine the effects the difference in age estimation between scales and otoliths has on whitefish population dynamics; and to validate older scale age interpretations than otolith age interpretations for younger whitefish.

Lake whitefish (*Coregonus clupeaformis*; hereafter whitefish) have traditionally been a very important fish to the Great Lakes fishery. They were used traditionally as a sustenance fish by Great Lakes tribes until the arrival of the first Europeans. As the region became more populated, the demand for food increased and the first demand for a commercial fishery was created (Brown et al. 1999).

Fisheries biologists use calcified structures like the sagittal otolith (hereafter otolith) and scales to estimate the age of whitefish (Muir et al. 2008 and references therein). Age data is then used to estimate lifespan, growth, and mortality of whitefish. These parameters are used to model the dynamics of whitefish populations, which are used to estimate harvest quotas for the commercial fisheries (Ebener et al. 2005).

Recently, fisheries managers have begun to "question the reliability of the scale method of age estimation" (Muir et al. and references therein, 2008). Unreliable age estimates "have led to uncertainty associated with modeling the dynamics of lake whitefish populations within the Laurentian Great Lakes" (Muir et al. 2008).

The goal of this project is to determine if the interpretation of age differs between scales and otoliths from whitefish collected in Lake Superior. Similar studies like this have been preformed for whitefish from other Great Lakes (i.e. Lake Huron; Muir et al. 2008), but not for Lake Superior.

Methods

Collecting Samples - Scales and otoliths from whitefish were collected from various locations along the south shore of Lake Superior between Apostle Islands in Wisconsin and Marquette, Michigan. Capture methods included both commercial fishery monitoring and scientific assessments. Agencies that donated scale and otolith samples for this study included the Great Lakes Indian Fish and Wildlife Commission (GLIFWC), the Red Cliff Band of Lake Superior Chippewa Indians, and the Keweenaw Bay Indian Community. All whitefish were captured using bottom set nylon gill nets with stretch mesh increasing in size by half inch increments from 2 to 5.5 inches. Total length (TL, in) was recorded from all captured whitefish.

Scales were taken from the region of the fish directly below the rear edge of the dorsal fin and above the lateral line. Otoliths were collected from behind the brain of the fish by turning the head of the fish upside down, grasping it by the eye sockets with one hand and using the other hand to cut away the gills and expose the ventral portion of the prothesus bone. A second cut was then made through the prothesus bone to expose the otoliths. Quick downward pressure was applied to the nose of the fish, opening the cut in the prothesus bone. The otoliths could then be extracted using tweezers.

Scale and otolith samples were placed in an envelope and marked with the capture date, net identification, and envelope number. These envelopes were set aside for several days to dry.

Ageing methods - Whitefish age was estimated by the author from both scales and otoliths. Dried scales were placed into a 10x or 15x microfiche where the annuli could be counted and recorded. Annuli were defined by areas of condensed circuli, depicting slowed winter growth periods; as well as areas where crossing over occurred (Figure 1).

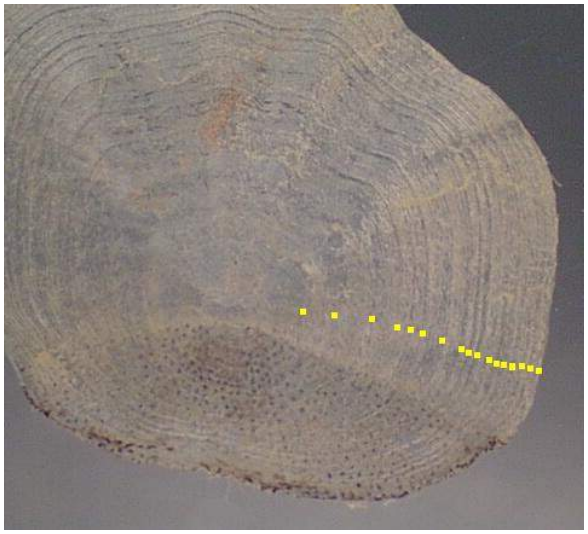

Figure 1. Dried whitefish scale with annuli marked (yellow dots). This individual was interpreted to be 17 years of age using this scale, and is the same individual as the otolith shown in Figure 2.

Otoliths were prepared using the crack and burn method. Otoliths were placed on a hard, flat surface and broken into two halves using a razor blade. The broken pieces were then placed over an open candle flame for a few seconds to brown the edges. The structures were then placed into modeling clay, with the burnt, cut edge facing up, under a 10x to 20x dissecting microscope where the annuli could be counted and recorded (Figure 2). Annuli here represent a period of slowed growth, hence depicting darker lines for winter growth periods.

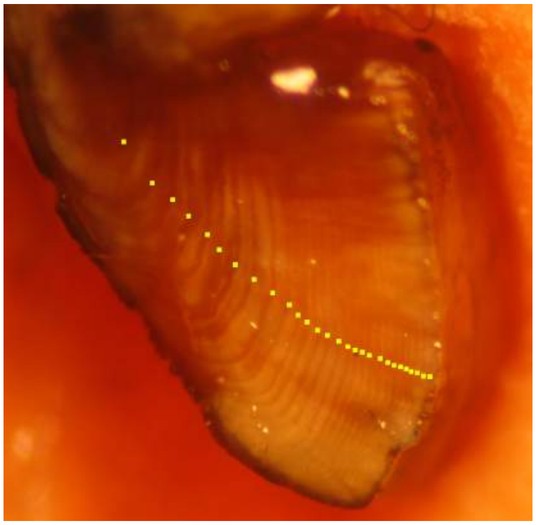

Figure 2. Prepared whitefish otolith with annuli marked (yellow dots). This particular individual was interpreted to be 28 years of age, and is the same individual as the scale in Figure 1.

All scale ages were recorded onto a datasheet that contained columns for envelope number and scale age, but not length. This was preformed to ensure that the reader did not receive any information regarding the length or capture location of the fish. Once all scales assessed, the age estimates were recorded into a database where length, date, set identification, and envelope number had been previously recorded. The same process was followed for recording otolith age estimates.

Analyses - Fish for which both scale and otolith age structures were not obtained were not included in this analysis. After an initial analysis, fish with an otolith age greater than 15 were excluded from further analysis to eliminate ages that had small sample sizes (n<5) and, consequently, very wide confidence intervals (Table 1).

Table 1. Number (n) of whitefish in each otolith age class included in the initial age comparison.

Otolith Age	3	4	5	6	7	8	9	10	11	12
n	7	14	18	26	42	43	61	52	34	7

Otolith Age	13	14	15	16	17	18	19	20	25
n	14	6	8	1	2	2	2	2	1

Thus, a thorough age comparison was performed only for fish with an otolith age less than 16 where both scale and otolith structures existed.

Subsets were created to separate otolith ages three through nine, from otolith ages nine through 15. This subset was done to more clearly demonstrate a shift from interpreting scale ages that were older than otolith ages to interpreting otolith ages that were older than scale ages. Age nine was included in both subsets because this age represented where the shift occurs.

I performed a one-way analysis of variance (ANOVA) to determine how mean length changes with the age of whitefish. This analysis was used to determine if a length at which scales under-estimated otolith age could be identified. A few outliers were removed for the ANOVA analysis, but the data showed fairly normal distribution, and fairly equal variances (Figure 3).

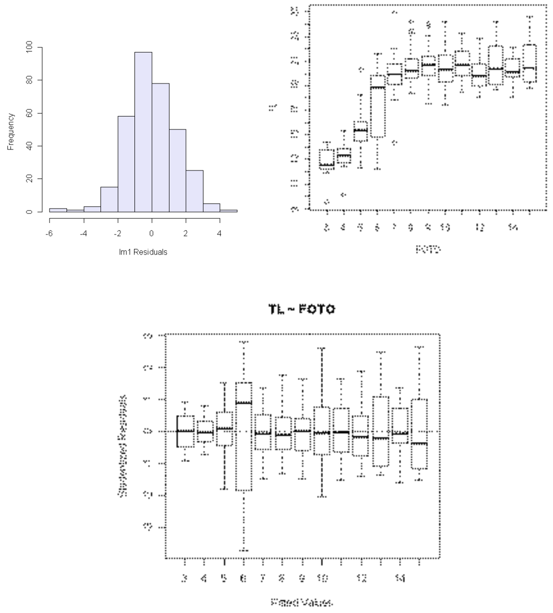

Figure 3. One-Way Analysis of Variance (ANOVA) assumption checks, showing outliers that needed to be removed (top right), distribution of data (top left) and a plot of the residuals (bottom).

The one-way ANOVA showed a significant difference between at least two of the mean lengths at age. Thus I preformed a Tukey HSD multiple comparison on the data to see what ages were significantly different. Once I did that, I compared the ages that were significantly different to the lengths that corresponded to those ages to see if significantly similar lengths corresponded to the differences between otolith and scale ages.

Analyses were conducted using the R statistical language version 2.7.2 with the FSA package (Ogle 2008). All analyses were performed at an $\alpha=0.05$ significance level.

Results

Significant differences in ages interpreted from scales and otoliths of the whitefish were observed for ages three, seven and eight, 10 through 13, and 15 (Figure 4). The Bowker's (Hoeing) test of symmetry showed there were no significant asymmetries difference between scale and otolith ages for whitefish (p=0.1883).

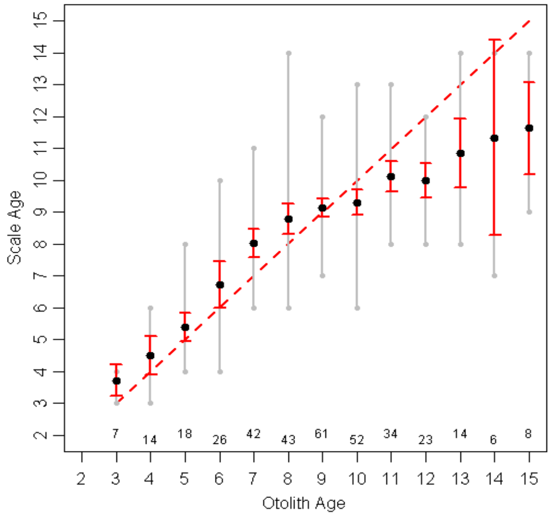

Figure 4. Mean scale age for each otolith age 3 to 15 for lake whitefish with 95% confidence intervals (vertical red lines) and ranges (vertical grey lines). The diagonal red dashed line represents agreement between scale and otolith ages.

The three through nine otolith age subset showed a tendency to estimate an older age with scales than with otoliths (Figure 4). Bowker's (Hoeing) test of symmetry showed that the data was not symmetric, (p=0.00005); therefore proving that there is a tendency to interpret an older age with scales than with otoliths for these younger fish. However, all scale ages from age three to age eight appeared on average to be about one age higher than the otolith age (Figure 4). Thus, there is the possibility of a systematic error in age assessment for these younger fish where extra annuli may have been counted on the scales of these younger fish or a growth increment on the otoliths may have been missed.

The age nine through 15 subgroup showed a trend toward assigning older ages to whitefish from the otoliths than from the scales (Figure 4). Again, the Bowker's (Hoeing) test of symmetry showed that the data was not symmetric (p<0.0005); therefore there is a tendency to assign a younger age to whitefish with scales than with otoliths.

The ANOVA analysis showed that there was a difference in mean length between at least two of the different age groups (p<0.005). Fish aged between three and five had a similar mean length, and fish between seven and 15 had a similar mean length. However, age six whitefish had a significantly larger mean length from the age three through five group, and a significantly smaller mean length than the age seven through 15 group (Figure 5).

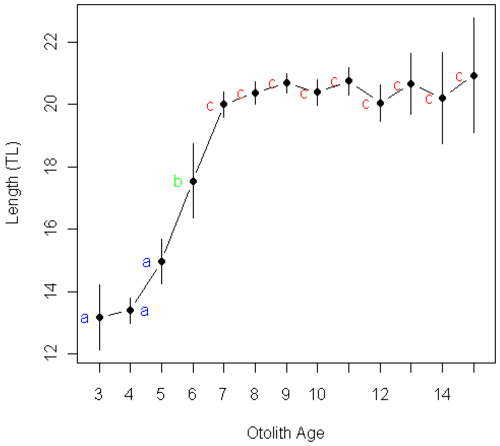

Figure 5. One-Way Analysis of Variance on the Lake Superior whitefish data, showing the length at otolith age of the whitefish is similar for ages three to five (a, blue), six (b, green), and seven through 15 (c, red).

A common length at which otoliths should be start being taken cannot be determined because the smallest length from the whitefish aged seven through fifteen is 17.4 inches, and the largest length from the whitefish aged three through five is 20.3 inches (Appendix A). This leaves a potential that a fish between 17.4 inches and 20.3 inches could be in either the age three through five category, the age six category, or the age seven through 15 category. Because there is a difference between otolith and scale aging techniques for all ages except age nine, I would suggest taking otoliths from all whitefish in order to generate the ages interpreted by the otoliths.

Discussion / Recommendations

I have determined that otoliths result in a different estimated age than scales do for lake whitefish in Lake Superior. Scales provide a greater age for otolith ages less than age nine and a younger age for otolith ages greater than age nine. Whitefish in Lake Huron show a similar pattern in that scale ages exceeded otolith ages for whitefish under age six and otolith ages exceeded scale ages for whitefish over age six (Muir et al. 2008). Because this was observed in both Lake Huron and now in Lake Superior, I recommend that studies be undertaken to validate the reason for interpreting higher scale ages than otolith ages for younger whitefish.

I would like to suggest a length at which otoliths must be used to identify age of lake whitefish. However, even though there were significant differences in mean length-at-otolith-age there was also significant overlap in observed lengths at age. Thus, I cannot yet suggest a length for which otoliths must be used.

Now that it has been determined that scale ages produce a different age estimate than otoliths do for whitefish in Lake Superior, I recommend further studies to describe how this difference changes the estimated lifespan, growth, and mortality of whitefish populations. A change in these dynamics could also lead to a potential change in harvest quotas set for the commercial fisheries.

Acknowledgements

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Appendix A. Length at Age

-showing the maximum length at the age three through five category, and the minimum length at age for the age eight through 15 category, as highlighted

```
Age  n NAs Valid n     Mean St. Dev.   Min. 1st Qu. Median 3rd Qu.  Max.
3    7   0       7 12.66592 1.631479  9.567   12.22  12.56   13.84 14.41
4   14   0      14 13.30990 1.200573 10.160   12.88  13.35   13.90 15.35
5   18   0      18 15.44405 1.908126 12.360   14.54  15.35   16.05 20.30
6   26   0      26 17.54146 2.933047 12.200   15.04  18.83   19.78 21.60
7   42   0      42 19.97310 1.676201 14.370   19.12  19.90   20.78 24.90
8   43   0      43 20.59535 1.383397 18.400   19.60  20.20   21.15 24.20
9   61   0      61 20.73279 1.329251 17.500   19.80  20.70   21.40 24.00
10 52   0      52 20.37885 1.483416 17.400   19.30  20.30   21.50 24.20
11 34   0      34 20.74412 1.246861 18.500   19.80  20.70   21.73 23.20
12 23   0      23 20.03478 1.380583 18.000   18.95  19.80   20.75 22.80
13 14   0      14 20.64286 1.695113 18.700   19.23  20.35   22.02 24.20
14  6   0       6 20.20000 1.395708 18.000   19.77  20.10   20.95 22.10
15  8   0       8 20.92500 2.191379 18.800   19.45  20.40   21.45 24.60
```

Appendix B. R Commands

Age Comparison

```
library(FSA)
library(NCStats)
library(xlsReadWrite)
wf <- read.xls("WF
  DATA.xls",sheet="data")
attach(wf)
str(wf)
detach(wf)
wf1 <- Subset(wf,OTO>0)
wf2 <- Subset(wf1,SCALE>0)
wf3 <- Subset(wf2,TL>0)
attach(wf3)
str(wf3)
wf.ale <-
  age.comp(OTO,SCALE,col.lab="Otolit
  h Age",row.lab="Scale Age")
summary(wf.ale,what="symmetry")
plot(wf.ale)
detach.all()
  wf4 <- Subset(wf3,OTO<16)
attach(wf4)
str(wf4)
wf.ale <-
  age.comp(OTO,SCALE,col.lab="Otolit
  h Age",row.lab="Scale Age")
summary(wf.ale,what="symmetry")
plot(wf.ale)
Summarize(TL~factor(OTO))
```

Age Comparison Above Age 8

```
detach.all()
wf5 <- Subset(wf4,OTO>=9)
attach(wf5)
wf.ale <-
  age.comp(OTO,SCALE,col.lab="Otolit
  h Age",row.lab="Scale Age")
summary(wf.ale,what="symmetry")
plot(wf.ale)
Summarize(TL~factor(OTO))
```

Age Comparison Below Age 8

```
detach.all()
wf6 <- Subset(wf4,OTO<=9)
attach(wf6)
wf.ale <-
  age.comp(OTO,SCALE,col.lab="Otolit
  h Age",row.lab="Scale Age")
summary(wf.ale,what="symmetry")
plot(wf.ale)
Summarize(TL~factor(OTO))
```

One Way ANOVA

```
library(NCStats)
library(MASS)
library(xlsReadWrite)
wf <- read.xls("WF
  DATA.xls",sheet="data")
str(wf)
wf1 <- subset(wf,OTO>0)
wf2 <- subset(wf1,SCALE>0)
wf3 <- subset(wf2,TL>0)
wf4 <- subset(wf3,OTO<16)
wf5 <- subset (wf4,SCALE<16)
wf5$FOTO <- factor(wf5$OTO)
attach(wf5)
plot(TL~FOTO)
detach(wf5)
wf6 <- wf5[-
  c(223,225,232,217,209,194,32,18,17
  ), ]
attach(wf6)
plot(TL~FOTO)
detach(wf6)
wf7 <- wf6[-c(125,32,16,312), ]
attach(wf7)
boxplot(TL~FOTO,xlab="Otolith
  Age",ylab="Length
  (TL)",notch=FALSE,col="lavender")
lm1 <- lm(TL~FOTO)
residual.plot(lm1)
hist(lm1$residuals,col="lavender",m
  ain=NULL,xlab="lm1 Residuals")
anova(lm1)
wf.mc <- glht(lm1, mcp(FOTO =
  "Tukey"))
summary(wf.mc)
confint(wf.mc)
fit.plot(lm1,xlab="Otolith
  Age",ylab="Length (TL)",main="")
add.sig.letters(lm1,lets=c("a","a",
  "a","b","c","c","c","c","c","c","c
  ","c","c"),pos=c(2,4,2,2,2,2,2,2,2
  ,2,2,2,2),col=c("BLUE","BLUE","BLU
  E","GREEN","RED","RED","RED","RED"
  ,"RED","RED","RED","RED","RED"))
```