Kiyi Age & Size Results

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# Methods

The June tows were cross-contour with a mean beginning depth of 26 m (range: 13-40), ending depth of 106 m (range: 68-144), and distance covered of 1.50 km (range: 1.47-1.53). The tows in July followed a depth contour, had a mean average depth of 186 m (range: 134-255), and a mean distance covered of 0.86 km (range: 0.76-0.91).

# Results

## Summary of Kolmogorov-Smirnov Tests

## comparisons adj.pval  
## 1 Western Arm v. Northern Michigan 0.7040  
## 2 Western Arm v. Northern Ontario 0.0448  
## 3 Western Arm v. Southern Ontario 0.7040  
## 4 Western Arm v. Eastern Michigan 0.0912  
## 5 Northern Michigan v. Northern Ontario 0.0000  
## 6 Northern Michigan v. Southern Ontario 0.7128  
## 7 Northern Michigan v. Eastern Michigan 0.7128  
## 8 Northern Ontario v. Southern Ontario 0.0000  
## 9 Northern Ontario v. Eastern Michigan 0.0000  
## 10 Southern Ontario v. Eastern Michigan 0.9692

## 1-Way ANOVA results for mean TL (part of TABLE 1)

## region n nvalid mean sd min Q1 median Q3 max percZero siglets  
## 1 West 153 153 195.9 18.2 142 184 196 210 232 0 b  
## 2 NoMich 69 69 197.9 19.1 152 185 200 211 240 0 bc  
## 3 NoOnt 355 355 190.3 16.8 126 179 190 204 239 0 a  
## 4 SoOnt 65 65 202.0 22.3 126 187 204 218 253 0 bc  
## 5 EastMich 341 341 202.6 19.7 108 190 203 214 266 0 c

## Warning: Removed 4 rows containing non-finite values (stat\_bin).

## Warning: Removed 10 rows containing missing values (geom\_bar).

A total of 983 Kiyi were sampled in 2014. These fish were between 108 and 266 mm TL with a mean (SD) TL of 197 (19.3) mm. The length distribution of Kiyi from the Northern Ontario region differed significantly from the length distributions of Kiyi captured from all other regions (p<0.045), which did not differ (p>0.091). The Northern Ontario region had fewer longer fish, which resulted in a significantly shorter mean TL (p<0.017; Figure 2). In the subsample of 335 fish, four were juveniles and 60.1% of non-juvenile fish were female.

The examination of length frequencies from 2001 through 2014 revealed distinct modes near 80-100 mm in 2004, 2006, and 2010 (Figure 3). These modes corresponded to age-1 fish as Kiyi hatch at approximately 20 mm in early spring (CITATION). Thus, these cohorts corresponded to ages 11, 9, and 5, respectively, in 2014. There was little evidence for the 2005 cohort in 2007 which suggests few age-9 fish may exist in 2014.

## Between-reader otolith comparisons (TAL v. DHO ages)

## otoAge\_DHO n min max mean SE t adj.p sig LCI UCI  
## 4 5 4 5 4.20 0.2000 1.000 1.00000 FALSE 3.64 4.76  
## 5 59 5 6 5.25 0.0572 4.447 0.00036 TRUE 5.14 5.37  
## 6 68 5 7 6.01 0.0574 0.256 1.00000 FALSE 5.90 6.13  
## 7 10 6 8 6.90 0.1795 -0.557 1.00000 FALSE 6.49 7.31  
## 8 7 8 10 8.29 0.2857 1.000 1.00000 FALSE 7.59 8.98  
## 9 14 7 9 8.57 0.1727 -2.482 0.19272 FALSE 8.20 8.94  
## 10 25 8 11 9.88 0.1200 -1.000 1.00000 FALSE 9.63 10.13  
## 11 53 8 13 10.96 0.1042 -0.362 1.00000 FALSE 10.75 11.17  
## 12 18 10 12 11.44 0.1661 -3.344 0.03075 TRUE 11.09 11.79  
## 13 2 13 13 13.00 NA NA NA FALSE NA NA  
## 14 1 14 14 14.00 NA NA NA FALSE NA NA  
## 15 2 14 16 15.00 NA NA NA FALSE NA NA  
## 16 1 16 16 16.00 NA NA NA FALSE NA NA  
## 20 1 19 19 19.00 NA NA NA FALSE NA NA

## symTest df chi.sq p  
## 1 McNemar 1 0.01369863 0.90682745  
## 2 EvansHoenig 3 2.67032967 0.44529303  
## 3 Bowker 17 26.58601399 0.06442533

## n R ACV APE PercAgree  
## 266 2 2.791 1.973 72.56

## 0 1 2 3   
## 72.5564 24.4361 2.6316 0.3759

## 0 1 2 3   
## 72.5563910 24.4360902 2.6315789 0.3759398

## 0 1 2+   
## 72.556 24.436 3.008

## 0 1 2+   
## 72.556391 24.436090 3.007519

## Otolith-scales comparisons (only TAL ages)

## otoAge\_TAL n min max mean SE t adj.p sig LCI UCI  
## 4 3 4 4 4.00 NA NA NA FALSE NA NA  
## 5 12 3 5 4.00 0.213 -4.69 0.00264 TRUE 3.53 4.47  
## 6 11 4 6 4.36 0.203 -8.05 0.00006 TRUE 3.91 4.82  
## 7 3 5 6 5.33 0.333 -5.00 0.03911 TRUE 3.90 6.77  
## 8 5 5 8 5.80 0.583 -3.77 0.03911 TRUE 4.18 7.42  
## 9 4 5 5 5.00 NA NA NA FALSE NA NA  
## 10 9 5 7 5.56 0.294 -15.12 0.00000 TRUE 4.88 6.23  
## 11 9 4 8 5.56 0.475 -11.47 0.00002 TRUE 4.46 6.65  
## 12 3 5 6 5.33 0.333 -20.00 0.00747 TRUE 3.90 6.77  
## 13 1 6 6 6.00 NA NA NA FALSE NA NA  
## 16 1 6 6 6.00 NA NA NA FALSE NA NA

## symTest df chi.sq p  
## 1 McNemar 1 53 3.335484e-13  
## 2 EvansHoenig 8 53 1.078460e-08  
## 3 Bowker 21 53 1.375276e-04

Ages were estimated by two readers from 288 thin-sectioned otoliths. Of these otoliths, 22 (7.6%) were deemed unreadable (cracked or cloudy image) and were removed from further consideration. Ages estimated from the two readers perfectly agreed for 72.6% of the otoliths, agreed within one year for 97.0% of the otoliths, had a between-reader ACV of 2.8, and showed no significant systematic bias (p=0.445; Figure 4). However, the mean estimated age for the second reader was slightly greater when the first reader estimated an age of 5 (95% CI: 5.1-5.4; p<0.001) and slightly lower when the first reader estimated an age of 12 (95% CI: 11.1-11.8; p=0.0). Mean scale age for each otolith age was less than the otolith age for all observed otolith ages with adequate sample sizes (p<0.039; Figure 5).

## otoAge  
## 4 5 6 7 8 9 10 11 12 13 14 15 16 20   
## 4 67 60 10 7 13 26 60 11 2 1 1 2 1

## # weights: 24 (14 variable)  
## initial value 116.448726   
## iter 10 value 97.933610  
## iter 20 value 84.011548  
## iter 30 value 81.971416  
## iter 40 value 81.791215  
## iter 50 value 81.597639  
## iter 60 value 81.552338  
## final value 81.552021   
## converged

## # weights: 40 (28 variable)  
## initial value 116.448726   
## iter 10 value 102.930833  
## iter 20 value 87.205385  
## iter 30 value 75.060868  
## iter 40 value 73.215994  
## iter 50 value 72.469245  
## iter 60 value 72.180247  
## iter 70 value 72.164010  
## iter 80 value 71.959781  
## iter 90 value 71.783247  
## iter 100 value 71.659561  
## iter 110 value 71.337803  
## iter 120 value 71.206109  
## iter 130 value 71.200400  
## iter 140 value 71.199582  
## final value 71.199576   
## converged

## # weights: 21 (12 variable)  
## initial value 62.269125   
## iter 10 value 52.901438  
## iter 20 value 45.627822  
## iter 30 value 44.421150  
## iter 40 value 43.783794  
## iter 50 value 43.647608  
## iter 60 value 43.631611  
## final value 43.631553   
## converged

## # weights: 35 (24 variable)  
## initial value 62.269125   
## iter 10 value 55.875090  
## iter 20 value 46.150807  
## iter 30 value 41.669798  
## iter 40 value 40.190120  
## iter 50 value 39.845994  
## iter 60 value 39.845505  
## final value 39.845500   
## converged

## # weights: 24 (14 variable)  
## initial value 147.640349   
## iter 10 value 91.530461  
## iter 20 value 80.573443  
## iter 30 value 79.727843  
## iter 40 value 79.678066  
## iter 50 value 79.488038  
## iter 60 value 79.239517  
## iter 70 value 79.225957  
## iter 80 value 79.185163  
## iter 90 value 79.138047  
## iter 100 value 79.117073  
## iter 100 value 79.117073  
## iter 110 value 79.116822  
## iter 110 value 79.116822  
## iter 110 value 79.116822  
## final value 79.116822   
## converged

## # weights: 40 (28 variable)  
## initial value 147.640349   
## iter 10 value 109.614631  
## iter 20 value 78.447321  
## iter 30 value 74.236369  
## iter 40 value 73.139920  
## iter 50 value 72.374475  
## iter 60 value 72.121566  
## iter 70 value 72.118663  
## iter 80 value 72.009779  
## iter 90 value 71.963608  
## iter 100 value 71.945278  
## iter 110 value 71.923034  
## final value 71.887075   
## converged

## # weights: 27 (16 variable)  
## initial value 83.494534   
## iter 10 value 71.760544  
## iter 20 value 62.485035  
## iter 30 value 61.495422  
## final value 61.446200   
## converged

## # weights: 45 (32 variable)  
## initial value 83.494534   
## iter 10 value 68.081420  
## iter 20 value 60.735889  
## iter 30 value 55.198374  
## iter 40 value 54.813371  
## iter 50 value 54.266929  
## iter 60 value 54.006789  
## iter 70 value 53.734126  
## iter 80 value 53.734089  
## iter 80 value 53.734089  
## iter 80 value 53.734089  
## final value 53.734089   
## converged

## # weights: 27 (16 variable)  
## initial value 134.030699   
## iter 10 value 109.180779  
## iter 20 value 96.335820  
## iter 30 value 94.744365  
## iter 40 value 94.180752  
## iter 50 value 94.131627  
## iter 60 value 93.289753  
## iter 70 value 92.823595  
## iter 80 value 92.611963  
## iter 90 value 92.520794  
## iter 100 value 92.472483  
## iter 110 value 92.464311  
## final value 92.464277   
## converged

## # weights: 45 (32 variable)  
## initial value 134.030699   
## iter 10 value 112.757472  
## iter 20 value 97.870901  
## iter 30 value 88.551911  
## iter 40 value 85.635416  
## iter 50 value 84.478347  
## iter 60 value 84.307223  
## iter 70 value 84.219986  
## final value 84.219972   
## converged

## # weights: 27 (16 variable)  
## initial value 566.883941   
## iter 10 value 420.357197  
## iter 20 value 398.345132  
## iter 30 value 397.260774  
## iter 40 value 397.153779  
## final value 397.153450   
## converged

## # weights: 45 (32 variable)  
## initial value 566.883941   
## iter 10 value 486.382244  
## iter 20 value 393.187558  
## iter 30 value 387.288917  
## iter 40 value 386.087843  
## iter 50 value 385.814169  
## iter 60 value 385.788968  
## iter 70 value 385.783108  
## final value 385.783088   
## converged

## # weights: 27 (16 variable)  
## initial value 566.883941   
## iter 10 value 420.357197  
## iter 20 value 398.345132  
## iter 30 value 397.260774  
## iter 40 value 397.153779  
## final value 397.153450   
## converged

## # weights: 99 (80 variable)  
## initial value 566.883941   
## iter 10 value 481.956885  
## iter 20 value 480.943179  
## iter 30 value 480.509884  
## iter 40 value 472.433670  
## iter 50 value 369.306900  
## iter 60 value 361.362908  
## iter 70 value 359.422827  
## iter 80 value 358.636414  
## iter 90 value 358.390541  
## iter 100 value 358.080123  
## iter 110 value 357.961735  
## iter 120 value 357.915728  
## iter 130 value 357.895996  
## iter 140 value 357.880313  
## iter 150 value 357.869126  
## iter 160 value 357.857775  
## final value 357.855216   
## converged

## Comparison df1 df2 pvalue  
## 1 By sex within West 14 364 0.1094377  
## 2 By sex within NoMich 12 168 0.8176118  
## 3 By sex within NoOnt 14 469 0.4160692  
## 4 By sex within SoOnt 16 272 0.4938146  
## 5 By sex within EastMich 16 456 0.4194103  
## 6 By sex, Pooled regions 16 2032 0.1208433  
## 7 By region, Pooled sexes 64 1984 0.1036033

Kiyi for which a consensus otolith age estimate was obtained were used to generate ALKs. Four Kiyi less than 140 mm TL (all of the juvenile fish) were excluded from all ALK analyses because of sample size considerations. An additional seven fish that were estimated to be age-13 or older were also removed from the analysis that compared ALKs among regions because of sample size considerations. Age-length keys did not differ significantly between sexes within any region (p>0.109) or among regions when sexes were pooled (p=). Despite this finding, to minimize the loss of any regional differences in the relationship between age and length, region-specific observed age-length keys were generated and used to assign ages by region to the 979.000 sampled Kiyi that were longer than 140 mm.

## Warning: The maximum observed length in the length sample (239) is greater  
## than the largest length category in the age-length key (220).  
## The last length category will be treated as all-inclusive.

## Warning: The maximum observed length in the length sample (253) is greater  
## than the largest length category in the age-length key (230).  
## The last length category will be treated as all-inclusive.

## Warning: The maximum observed length in the length sample (266) is greater  
## than the largest length category in the age-length key (240).  
## The last length category will be treated as all-inclusive.

## [1] FALSE

## otoAge  
## region 4 5 6 7 8 9 10 11 12 13 14 15 16 20  
## West 0 23 31 3 7 17 24 37 5 0 6 0 0 0  
## NoMich 0 15 12 7 0 1 8 9 8 3 0 1 0 5  
## NoOnt 7 90 79 11 0 5 14 132 16 0 0 0 0 0  
## SoOnt 1 11 12 2 4 3 2 24 3 0 0 0 2 0  
## EastMich 9 88 45 4 9 25 55 88 6 7 0 0 3 0

## Warning in chisq.test(age\_freq2): Chi-squared approximation may be  
## incorrect

##   
## Pearson's Chi-squared test  
##   
## data: age\_freq2  
## X-squared = 149.39, df = 28, p-value < 2.2e-16

## Warning: Removed 11 rows containing non-finite values (stat\_count).

## png   
## 2

The age distribution was bimodal in each region (Figure 6) with an upper mode centered at age-11 in all five regions and a lower mode that consisted of nearly equal numbers of age-5 and age-6 fish in all regions except for Eastern Michigan where there were nearly twice as many age-5 as age-6 fish. The age distribution, after age-4 and 5 fish were pooled and age-11 and older fish were pooled within each region for sample size reasons, differed significantly among regions (p<0.001). Variability around the age-11 mode and the relative frequency of intermediate aged (ages 7-9) fish appeared to explain much of the difference in age distribution among regions.