5.2 An examination of otolith growth increments in relation to somatic growth for Pacific halibut (*Hippoglossus stenolepis*)

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Abstract

Otolith growth has often been used as a proxy for somatic growth in marine and freshwater fish species. Since the International Pacific Halibut Commission maintains a long-term, coast-wide otolith collection, we aimed to determine if otolith growth corresponds with somatic growth in Pacific halibut. Specifically, we looked at otoliths from the 1977, 1987, 1992, and 2002 cohorts from the Gulf of Alaska. Over the past few decades, the International Pacific Halibut Commission has observed a significant decline in Pacific halibut size at age, especially in the Gulf of Alaska. However, we did not find a similar decline in otolith growth during this time period for halibut in this area. For example, in 15-year-old females sampled from the 1977 and 1992 cohorts, there was a 2.45% increase in mean otolith radius during that time period, despite a 14.97% decrease in mean body length for those fish. Additionally, we found that otolith accretion in male and female Pacific halibut does not reflect their large dimorphic size differences. Although factors regulating otolith growth in Pacific halibut are not well understood, otolith growth appears to be independent of somatic growth.

Introduction

The average length, or size-at-age (SAA), for both male and female Pacific halibut has decreased significantly during the last 25 years, particularly in the Gulf of Alaska (Fig.1). Along with decreased recruitment, this has led to a decrease in the exploitable biomass of halibut stocks, and resulted in an increasingly important research focus for the International Pacific Halibut Commission (IPHC). Environmental, ecological, and fishery induced factors could be responsible for the observed decrease in the SAA for this species.

However, for marine fish we do not typically have information on the growth of individuals, unless it is based on tag-recapture experiments. We do not have repeat observations of size for an individual over time, i.e., its growth. Instead, we usually have either observations of SAA for members of the same cohort over time or observations of SAA for the same ages from different cohorts over time. Both of these sources of information are only indirect observations of a growth process. Ideally, we would like to have direct observations of the growth of individuals in order to examine the influences of various factors on the growth process.

Otolith measurements have frequently been used as a proxy for fish length in other species (Kasapoglu and Duzgunes 2013, Vigliola and Meekan 2009). A primary component of our project was to determine if the sizes of Pacific halibut otoliths were related to the somatic sizes for fish of the same ages in different cohorts, and for different sexes of the same age. Since the mean SAA for these cohorts have changed over time, we wished to determine whether the increments of otolith and somatic sizes have changed in a similar manner.

Methods

A subsample of blind-side sagittal otoliths from the IPHC fishery-independent survey-caught halibut was selected from the 1977, 1987, 1992, and 2002 year classes. Typical survey methodology is described by Henry et al. (2017). Samples were selected from multiple IPHC regulatory areas, although we present results from the Gulf of Alaska here. Due to sample limitations, we were unable to use otoliths of the same age from each of these cohorts. Most halibut used in this study were 14 or 15 years old when captured, but 11-year-olds were used for the 2002 year class. We utilized both otoliths that had been previously aged for IPHC stock assessment purposes using the break-and-bake method, as well as some otoliths that had been previously aged with the surface ageing method (Forsberg 2001).

Otoliths that were previously aged by the break-and-bake method had been cut in half transversely and the posterior half was baked (500°F for 10 minutes) to enhance contrast between seasonal growth rings (Fig. 2a,b). For the increment measurements, these otolith halves were cut about 1.5 to 2 mm below the reading surface and mounted on glass slides, with the transverse plane facing upwards. The baked halves were then polished with a Buehler MetaServ™ 2502 polisher/grinder[1] with 1200-grit, then 2500-grit wet/dry sanding discs to smooth the jagged plane of the otolith where the break occurred. For otoliths previously aged with the surface ageing method, the whole otolith was cut transversely on either side of the first year with a Buehler IsoMet™ low-speed saw[1]. The center sections were baked in a toaster oven for 10 minutes at 500° F. The baked sections were then mounted anterior end up on individual glass slides using Loctite IMPRUV® [2] glue and allowed to cure for 12 hours. The sections were then polished down to expose the nucleus using the polishing procedure described above. Polishing progress was monitored using a LeciaTM MZ 6 microscope[3].

Polishing the otoliths improved the clarity of the annual rings and produced better photographs for increment analysis. The mounted otolith sections were photographed and measurements were made using Image-Pro Premier 9.1[4] software. Millimeter measurements were taken in a standard zone on all otoliths: from the origin to the last annulus along a straight line in the area dorsal to the sulcus groove (Fig. 2c).

Results

Growth increments among different cohorts

For this analysis we looked at female Pacific halibut from the Gulf of Alaska (IPHC Regulatory Area 3A), an area where we have observed the largest changes in somatic SAA. The individual cumulative otolith increment curves show relatively little variation among cohorts (Fig. 3). There is also no consistent pattern of change in incremental growth of the otoliths for different cohorts. The growth patterns of fish from the 1987 and 2002 cohorts are similar but with lower variation than either the 1977 or 1992 cohorts, which are also similar to each other. There is also less variation among the different cohorts than would be expected if otolith accretion was correlated with the declining female Pacific halibut SAA during this time period (Fig. 4).

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[2]Loctite Corporation, 26235 First Street, Westlake, Ohio 44145 USA
[3]Leica Microsystems, Inc., 1700 Leider Lane, Buffalo Grove, Illinois 60089 USA
[4]Media Cybernetics, Inc., 401 N. Washington Street, Suite 350, Rockville, MD 20850 USA

An obvious question is whether Pacific halibut sampled for otolith growth increments are characteristic of the broader regulatory area samples which have shown the large changes in SAA over time. Table 1 confirms that the females subsampled for the otolith examinations are representative of the regulatory area population. The average length of age-15 females in the otolith subsample for the 1977 and 1992 cohorts was nearly identical to the average length for all Gulf of Alaska age-15 females measured on our annual survey, for the same cohorts.

Because we only know fish length at the time of capture, we can only make a direct length comparison between Pacific halibut of the same age. In this case, we can compare 15-year-old female halibut from the 1977 and 1992 year classes. For 15-year-old females sampled from the 1977 and 1992 cohorts, there was a 2.45% increase in mean otolith radius during that time period, despite a 14.97% decrease in mean body length for those fish (Fig. 4, Table 1)

Growth increments between males and females

Pacific halibut are strongly sexually dimorphic for SAA between males and females, particularly beyond the ages of sexual maturity (IPHC Staff 2014). If otolith accretion rates were correlated with somatic growth, there should be a similar proportional size difference of the otolith radius between male and female Pacific halibut. However, in the Gulf of Alaska the mean male and female cumulative otolith increments are very similar (only a 6.4% difference at age 15 between the sexes for the 1992 cohort), despite substantially different somatic lengths between sexes (27.2% difference at age 15 for the 1992 cohort) (Fig. 5, Table 2).

Conclusions

The examination of otolith growth patterns among cohorts and between sexes provides strong evidence that otolith growth is decoupled from somatic growth in Pacific halibut. We conclude this based on similarities in otolith growth across different cohorts and environments, and similarities between the sexes, despite strongly dimorphic somatic growth. Indeed, the striking decrease in somatic SAA seen for halibut from the 1970s through the late 1990s is not mirrored in their otolith growth.

Although the factors regulating otolith growth in Pacific halibut are not well understood, otolith growth appears to be independent of somatic growth. Therefore, otolith growth patterns cannot be used to infer changes in somatic growth for Pacific halibut.

Literature Cited

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Table 1. Mean fork length (cm) and mean otolith radius (mm) with standard deviations for age 15 females fromt he IPHC fishery-independent setline survey in the Gulf of Alaska (area-wide and subsample), for the 1977 and 1992 cohorts.

	1977	1992
Fork length (Gulf of Alaska)	119.4 ± 14.5	106.1 ± 15.4
Fork length (subsample)	120.9 ± 12.5	102.8 ± 11.3
Otolith radius (subsample)	1.63 ± 0.14	1.67 ± 0.15

Table 2. Mean fork length (cm) and mean otolith radius (mm) with standard deviations for age 15 femails and males from the IPHC fishery-independent setline survey in the Gulf of Alaska (area-wide and subsample), for the 1992 cohorts.

	Male	Female
Fork length (Gulf of Alaska)	83.9 ± 8.0	106.1 ± 15.4
Fork length (subsample)	80.8 ± 4.3	102.8 ± 11.3
Otolith radius (subsample)	1.57 ± 0.14	1.67 ± 0.15

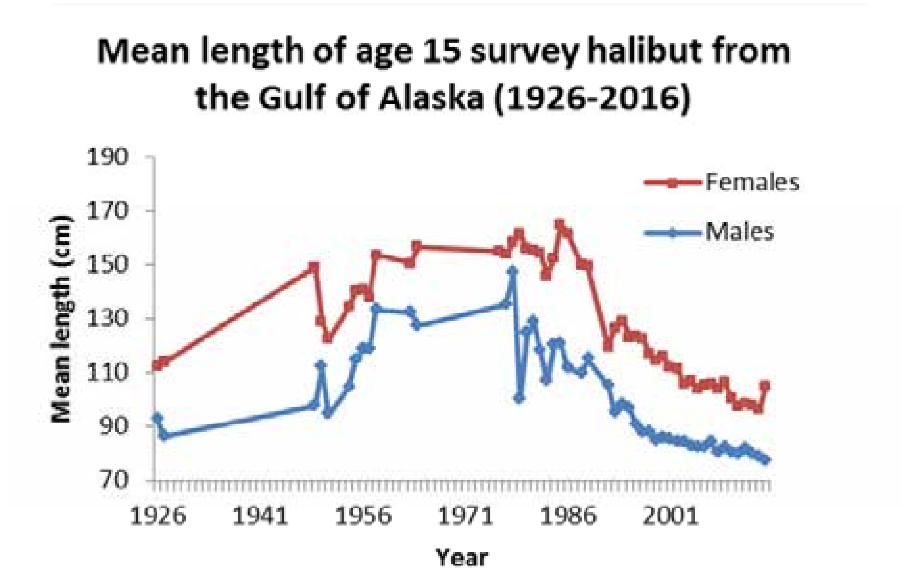
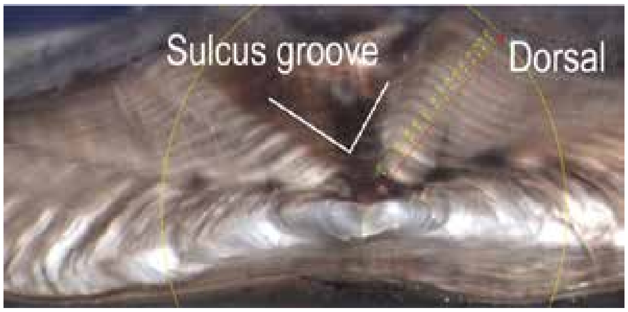
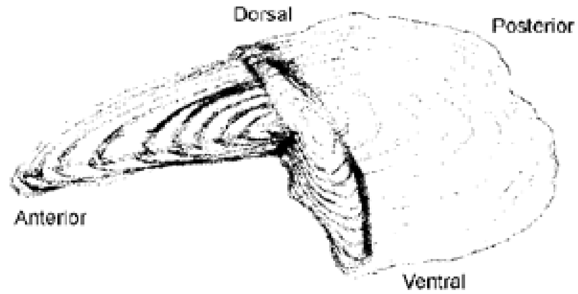
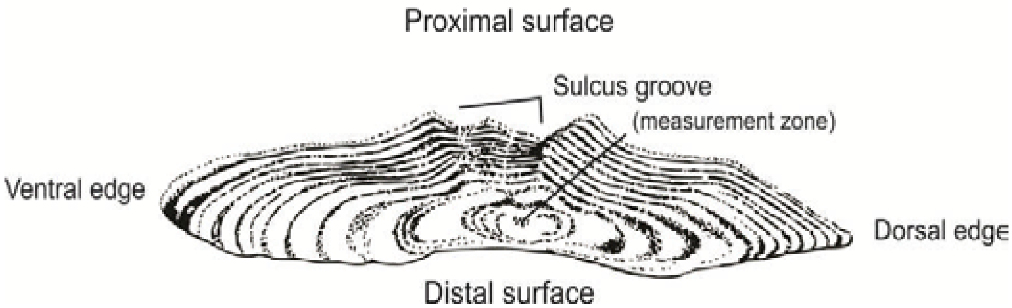


Figure 1. Mean length at age 15 in male and female Pacific halibut caught on IPHC fishery-independent setline surveys. Note: surveys not conducted in all years.





a. **b**.



c.

Figure 2. Images of Pacific halibut otoliths. a. otolith cross-section showing transect where increment distances were measured; b. Three-dimensional diagram of a saggital halibut otolith; c. cross-section of otolith showing points of reference and increment measurement zone.

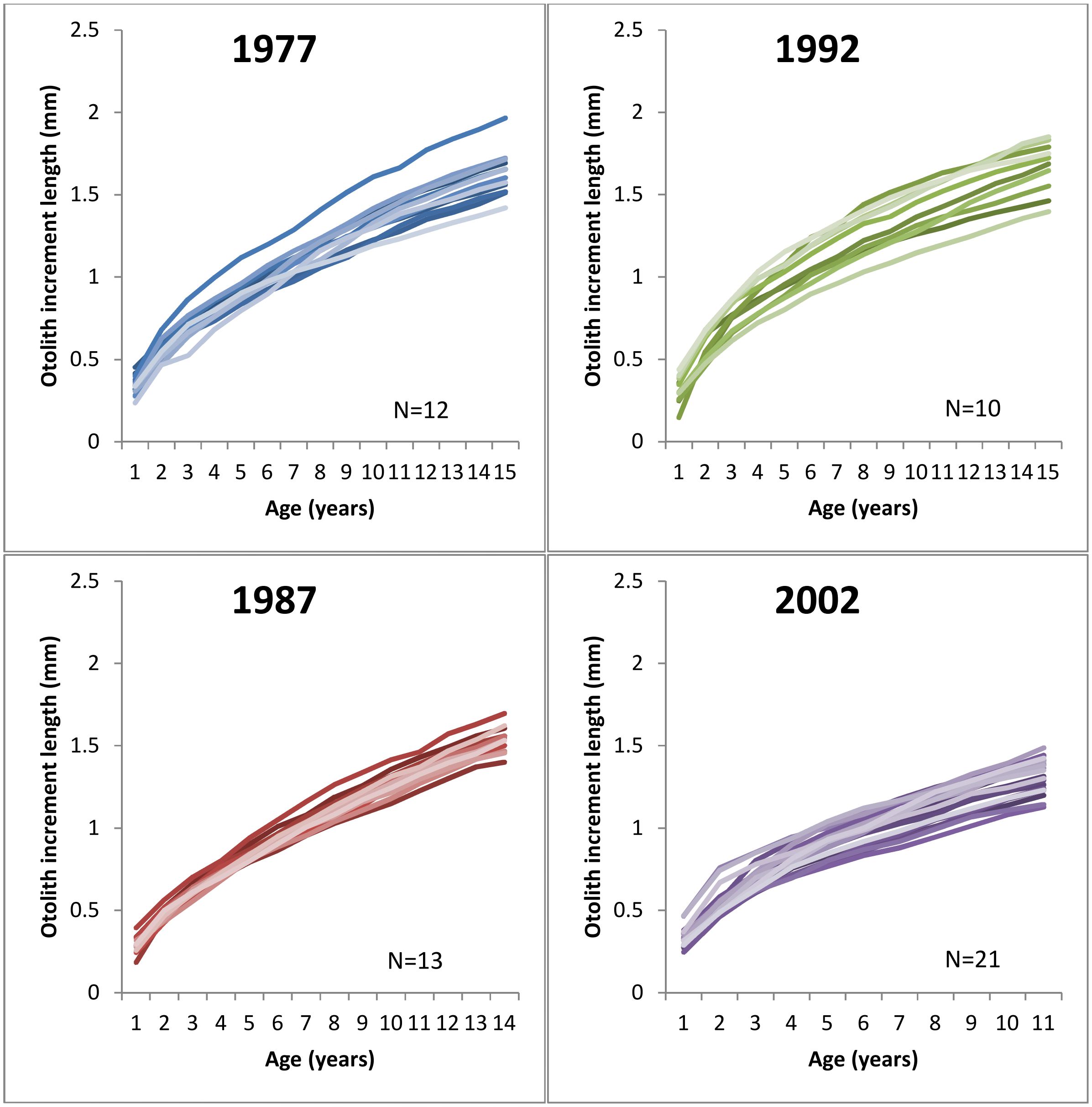


Figure 3. Individual cumulative otolith increments at age in survey-caught female Pacific halibut from the Gulf of Alaska (IPHC Area 3A) for four different cohorts.

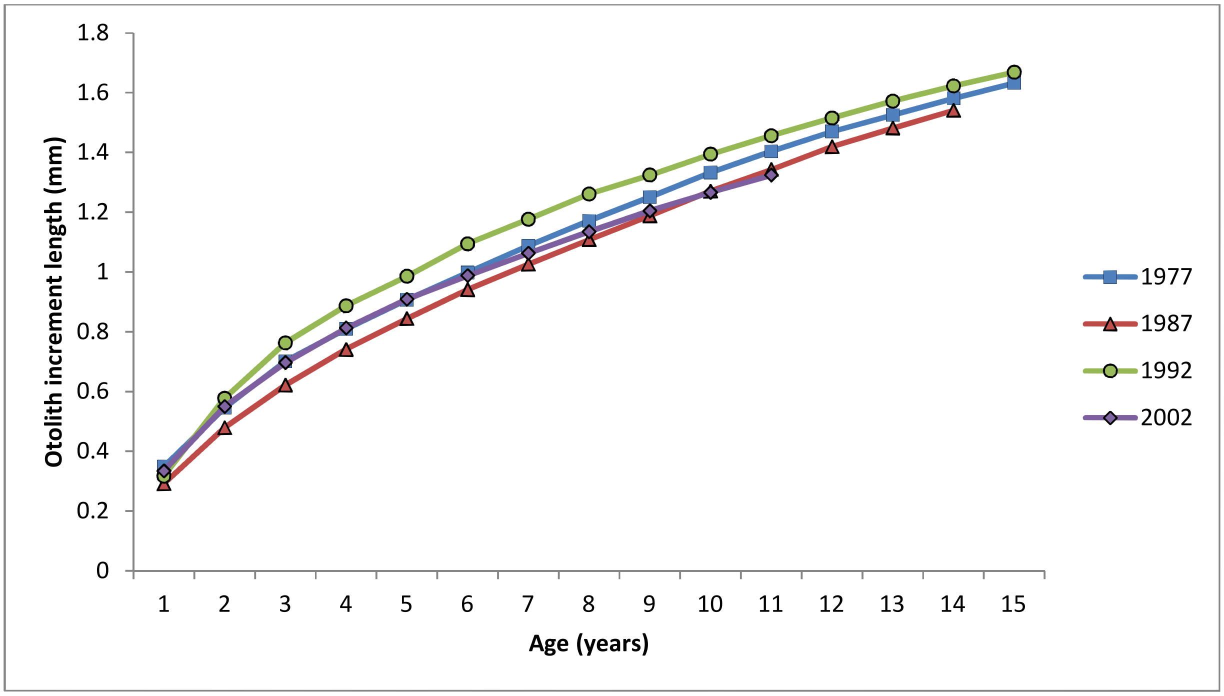


Figure 4. Mean cumulative otolith increment growth at age in survey-caught female Pacific halibut from four different cohorts in the Gulf of Alaska.

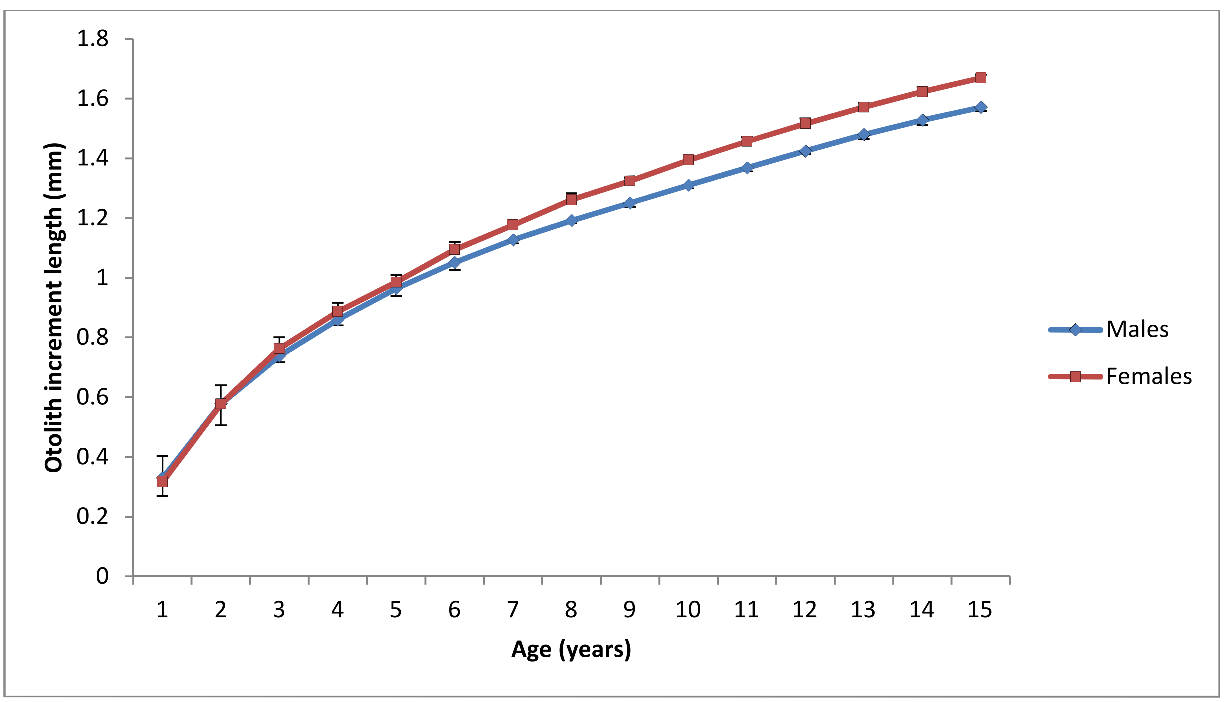


Figure 5. Mean cumulative otolith increment growth at age in survey-caught male and female Pacific halibut from the Gulf of Alaska, in 1992.