WALLEYE POLLOCK OTOLITH AGING: COMPARISON OF THE TECHNIQUES USED BY TWO AGENCIES

by

Kristen M. Munk

Regional Information Report No. 5J01-06

Alaska Department of Fish and Game
Mark, Tag, and Age Lab - Age Determination Unit
Division of Commercial Fisheries
Juneau, Alaska

October 2001

WALLEYE POLLOCK OTOLITH AGING: COMPARISON OF THE TECHNIQUES USED BY TWO AGENCIES

by

Kristen M. Munk

Regional Information Report[1] No. 5J01-06

Alaska Department of Fish and Game
Mark, Tag, and Age Lab - Age Determination Unit
Division of Commercial Fisheries
Juneau, Alaska

October 2001

[1] The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate timely reporting of recently collected information, reports in this series undergo only limited internal review and may contain preliminary data; this information may be subsequently finalized and published in the formal literature. Consequently, these reports should not be cited without approval of the authors or the Division of Commercial Fisheries.

AUTHOR

Kristen Munk is a fishery biologist and project leader of the Age Determination Unit at the Alaska Department of Fish and Game, Mark Tag and Age Lab. Alaska Department of Fish and Game, Division of Commercial Fisheries, Headquarters, P.O. Box 25526, Juneau, Alaska 99802, USA. Kristen_Munk@fishgame.state.ak.us

ACKNOWLEDGMENTS

Thanks to William Bechtol for support in this work, Christine Schmale in data collection of otolith morphometrics, and Susan Shirley and Ron Josephson for review of this manuscript. Thanks to NMFS Alaska Fishery Science Center age readers in their participation and interest in resolving age-reading discrepancies

TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

ABSTRACT

The ages of walleye pollock *Theragra chalcogramma* otoliths were evaluated by two agencies to measure consistency in final age data. These agencies' labs use different methodology in reading otoliths. Estimates of precision for samples collected in the Gulf of Alaska and Prince William Sound were: average percent error of 14.42% and 13.38%, and coefficient of variation of 20.40% and 18.92%, respectively. Differences are presumed to result from use of different primary reading surfaces–otolith surface versus charred sagittal transverse section–and different interpretations of the growth pattern.

INTRODUCTION

Walleye pollock *Theragra chalcogramma* are the object of a multimillion dollar fishery in the North Pacific. This fishery is managed by the North Pacific Fishery Management Council (NPFMC) using harvest guidelines provided by their Groundfish Planning Team. These guidelines are based on biological data collected from commercial or survey harvests. These data, including age data derived from otoliths, are used in developing population models and subsequent management strategies

The Alaska Department of Fish and Game (ADF&G) manage and sample pollock populations in state waters. These otolith samples are aged by ADF&G. The National Marine Fisheries Service (NMFS) collects samples from walleye pollock populations outside of state waters, in Alaska's Exclusive Economic Zone. These otolith samples are aged by NMFS. Both agencies provide their respective age data (for example, Bechtol 1998, 1999) to the NPFMC's Groundfish Plan Team for estimating walleye pollock biomass. Consistency between these two agencies in interpreting age from collected age structures is therefore critical

Determining age of walleye pollock has been challenging for many years. Many structures or methods have been examined (Ishida 1954; LaLanne 1977; McFarlane and Beamish 1990). The NMFS Sand Point Lab (hereafter Lab A) in Seattle, Washington, and the ADF&G Mark, Tag, and Age Lab (hereafter Lab B) in Juneau, Alaska, employ slightly different methodologies for producing walleye pollock age estimates from otoliths. To ascertain compatibility of age data resulting from the different methods, they exchanged walleye pollock otolith samples from two locations.

METHODS

Otolith Samples

Commercially trawled walleye pollock were captured in February 2000, near Middleton Island in the Gulf of Alaska (GOA) and near Bainbridge Island in Prince William Sound (PWS), and subsampled. Biological data and structures including length, gender, genetic tissue samples, and sagittal otoliths (otoliths), were collected from 100 specimens from each location. Left and right otoliths were removed, placed into a sample vial, immersed in 50% ethanol, and discretely labeled with sample date, capture location, and specimen number

Common to Labs A and B

Otoliths were examined with a stereomicroscope, using a reflected light source. In the "break and burn" technique, an otolith is snapped in the sagittal-transverse plane, then lightly charred (Christensen 1964) in an alcohol flame. The broken and charred surface is oiled to minimize refraction. In the "surface" viewing technique a cleared, whole otolith is immersed in a dish of water with a darkened background, and the pattern is examined out the rostrum on either the medial or lateral surface.

Lab A Method

Two readers at Lab A read the samples between April and October 2000, with resolution of the final age between readers to represent their lab's estimate of age. The method employed by Lab A for aging walleye pollock involved viewing the growth pattern out the anterior rostrum on the medial surface of a cleared otolith. If the otolith surface pattern is determined to be unclear, the broken and burned transverse surface is examined. Fish length and gender data were available to the age reader and were considered in resolving "outlier" estimates.

Lab B Method

Two readers at Lab B read the samples in March 2000; some resolution of ages occurred between the readers. The cleared surface of walleye pollock sagittae were examined briefly (this practice was for these samples only and is not generally employed by this lab), prior to viewing the broken and burned surface. All final age estimates were based on the pattern visible on the burned sagittal-transverse surface. No fish lengths or gender of fish were used by the readers, nor utilized at any time in resolving questionable patterns or outliers.

Otolith Measurements

Alcohol was decanted from sample vials, and otoliths were air dried for several days within a fume hood with fan-forced ventilation. A whole-unburned, or rejoined-unburned otolith was measured for anterior-posterior length and dorsoventral height using a digital caliper. Otoliths were weighed on an Ohaus digital balance with precision to 0.001 grams. Otoliths with excessive (>10%) vateritic growth were not weighed.

Measurements of Precision

Precision between the two labs was measured and characterized as average percent error (APE; Beamish and Fournier 1981) and coefficient of variation (CV; Chang 1982; Kimura and Lyons 1991). Graphical comparisons were made using age bias plots (Campana et al. 1995). Precision estimates are a measurement of the ability to reproduce an estimate of age through consistent application of interpretation criteria, and are not an indication of accuracy in aging fish unless age validation studies have been completed.

RESULTS

For the plots of age at length from both samples (Figures 1 and 2), only data for specimens receiving an age estimate by both labs were utilized. The adjusted sample size is 99 specimens for GOA, and 93 specimens for PWS. A comparison of mean size at age for each sample location and reading lab are presented in Figures 3 and 4. Labs A and B agreed upon an age estimate in 11 out of 192 specimens, which were also plotted against fish length in relation to the mean size at age. The variance, standard deviation, and CV for gender-specific mean size at age, are presented in Table 1.

Age frequencies from both labs were developed for both age data sets (Figures 5 and 6). For the GOA sample, Lab A identified the 1994 (75%) and 1995 (18%) year classes as the top two modes, while Lab B identified the 1992 (38%) and 1993 (34%) year classes. For the PWS sample, Lab A identified the 1994 (40%) and 1995 (20%) year classes as the top two modes, while Lab B identified the 1992 (29%) and 1993 (20%) year classes.

Sampled fish were classified to gender by examining gonads. The GOA fish sample had 44% males and 56% females, and the PWS fish sample had 58% males and 42% females. The age frequency, by gender, produced by Lab's A and B is shown in Table 2.

The APE and CV between Lab A and Lab B, for the GOA sample were 14.42% and 20.40%, respectively. For the PWS sample the APE and CV were 13.38% and 18.92%, respectively. Walleye pollock are considered to be "moderately difficult" to age, in comparison to typical averages of precision estimates for other species routinely aged at Lab B.

General trends in age-reading error between readers are shown graphically in age bias plots (Figure 7). The straight line is plotted as a reference, with any points falling on the reference line denoting perfect agreement. Lab A consistently produced younger estimates than Lab B.

Fish length was plotted against otolith weight in Figure 8. Otolith length was plotted against otolith weight for both GOA and PWS samples in Figure 9. Otolith weight was plotted against the otolith age for GOA and PWS in Figures 10 and 11, respectively. Four points from aged 0 and 1-year-old walleye pollock (with a perceived slightly higher growth rate based on larger otolith diameter of the first year's growth) from areas other than GOA and PWS were added for reference.

DISCUSSION

Differences in procedures and in the final estimated age of walleye pollock were apparent between Lab A and Lab B. Lab A primarily used the otolith surface and makes specimen data (fish length, gender) available to the age reader, while Lab B primarily used the burned sagittal-transverse section and did not make specimen data available to the reader. One may propose that the more accurate method would show increasing fish length at age and would reveal a more accurate depiction of fish age. Both Labs produce data that seem to satisfy this expectation.

It is common in large collections to encounter at least a few specimens for which age patterns are more clear and enumeration of annuli are more assured. These patterns may represent a biased selection with certain growth characters (possibly intermediate to faster growing specimens with sufficient resolution of annuli) that result in the unambiguous patterns, or, serendipitous preparation of the specimen which favorably portrays the growth pattern. The data from the few specimens agreed upon by Labs A and B are not numerous enough to weight; however, these plotted data also generally satisfy the expectation of increasing length at age.

Upon noting the results of the comparison, both labs reflected on their effort. Lab A believed the age data they produced was an accurate depiction of the age structure of the samples. They had excellent within-lab precision (not reported herein) and held this as testimony to their ability in estimating true fish age. As further testimony, one Lab A participant reported that modes in these samples from year 2000 had advanced one age class, based upon graphical comparisons to age data from 1999 samples which Lab A had read previously. An ability to track modes in producing age data from one year to the next is generally held as evidence to suggest a reasonably accurate depiction of age of specimens. Important assumptions in mode tracking as an indicator of "accuracy" in interpreting age of the fish are: 1) readers are not aware of, or do not allow knowledge of prior year class strengths to influence age estimations; 2) information such as fish length is not utilized at any stage of the decision process; and 3) the species' age structure has been validated for the aging technique utilized.

Lab B generally believed their data were accurate, but also believed that, if anything, they may have slightly underestimated age of the samples. They do not always age samples serially to collection year and were not aware of popular modes when producing these data. They observed that the ability to correctly interpret the transitional otolith growth pattern (from early faster growth to later slower growth), and the apparent non-uniform intra-annual and interannual deposition of otolith material (possibly resulting from interannual environmental flux), made interpretation difficult and would likely lead to high variability in age estimates between readers. However, they believed that without using length or gender data, their method would still result in a reasonably accurate trend in age class assignments despite seemingly contradictory age-at-length information. They observed that some specimens that possessed reasonably clear growth patterns were surprisingly smaller in length at age than expected, and they did not correct for these outliers because these appeared to portray a notable growth aspect of the species or population.

Randomly sampled and fully gender-mixed populations (e.g., species with schooling behavior) are generally expected to result in nearly a 1:1 ratio of male and female specimens. The latter is generally true for both GOA (44 males, 55 females) and PWS (58 males, 42 females) fish samples. Lab A age data suggest that year class sex ratios–with emphasis on the two modes–do not necessarily match that for the overall sample. Lab B age data suggest that year class sex ratios do generally match the overall sample. These trawl caught walleye pollock are assumed to be from a fully gender-mixed population; however, this cannot be proven.

Some operational differences in the age determination process between Lab A and Lab B have easy explanations for characterizing the different outcome in age estimates. In the 1970s, surface viewing of otoliths fell out of favor when it was apparent that fish in a later, slowing growth phase accreted less material out the anterior-posterior growth axes and instead continued deposition of material on the medial (inside) surface; hence, later deposited annuli are not visible on the surface. Therefore, surface-viewing of otoliths may underestimate age for older fish, sometimes dramatically (Boehlert and Yoklavich 1984; Wilson and Boehlert 1990). McFarlane and Beamish (1990) also noted this for Bering Sea pollock stocks. Mosher (1954) observed that "the slower growth-rate of these fish producing annuli closely crowded near the margin of the otolith" contributed to difficulty in aging walleye pollock from the otolith surface. One can expect to see a high level of agreement between readers of otoliths from young fish when all annuli are visible and widely separated on the surface. The level of agreement between readers will decline for older fish, potentially sharply after some threshold age when the annuli are consistently absent from the lateral, anterior-posterior surface, yet visible on the medial, sagittal transverse surface. Species with dynamic differences in interannual growth or population-specific growth, such as walleye pollock, are especially susceptible to interpretation errors.

Recognition of a transition zone, a second operational difference which may contribute to error, is not clearly revealed through this study. Otolith weight is known to increase disproportionately to increasing fish length (Pawson 1990) as the fish ages. This generally suggests loss of visible annuli along the otolith's sagittal axes, with an increasing number of annuli visible on the otolith's transverse axes, after a threshold age. The disappearance of annuli from the otolith surface suggests a slowing of fish growth. This slowing is highly variable as to when it begins (though it generally follows onset of sexual maturity of the animal, reported to be age 2 for pollock) and the rate at which it progresses. The latter results in growth patterns which are not as straightforward to discern. Population-specific growth patterns add to the variability within data, with growth differences (as perceived through otolith growth patterns) between the GOA versus PWS walleye pollock noted by several readers in this study. Population-specific growth differences have also been noted by other researchers (Ishida 1954; Mosher 1954; Janusz 1988; McFarlane and Beamish 1990). Growth patterns in walleye pollock otoliths suggest a range of rates of slowing down, slow to rapid, before moving to more consistent growth. Lab B accepts the notion of "transitional growth," which generally begins at age 3 for walleye pollock. Recognizing and correctly interpreting these transition zones, or not, may yield a range of small-to-great error in estimating fish age. Plots of otolith length to otolith weight may reveal this growth inflection, presumed to be analogous to the transition zone in otolith growth patterns.

This study showed that the different reading methods used by Lab A and Lab B result in differences in the resulting age data. It suggests caution to fishery managers and the NPFMC Groundfish Plan Team members in combining data from NMFS Sand Point Lab and the ADF&G Mark, Tag, and Age Lab for walleye pollock assessments. Refining age estimation methods of walleye pollock will continue; however, the NPFMC should further encourage all appropriate avenues to enable age validation studies and improve age determination methods of walleye pollock.

LITERATURE CITED

Beamish, R.J., and D.A. Fournier. 1981. A method for comparing the precision of a set of age determinations. Canadian Journal of Fisheries and Aquatic Sciences 38:982–983.

Bechtol, W.R. 1998. Prince William Sound walleye pollock: current assessment and 1999 management recommendations. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A98–41, Anchorage.

Bechtol, W.R. 1999. Prince William Sound walleye pollock: current assessment and 2000 management recommendations. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A99–33, Anchorage.

Boehlert, G.W., and M.M. Yoklavich. 1984. Variability in age estimates in *Sebastes* as a function of methodology, different readers, and different laboratories. California Fish and Game 70(4):210–224.

Campana, S.E., M.C. Annand, and J. I. McMillan. 1995. Graphical and statistical methods for determining the consistency of age determinations. Transactions of the American Fisheries Society 124:131–138.

Chang, W.Y.B. 1982. A statistical method for evaluating the reproducibility of age determination. Canadian Journal of Fisheries and Aquatic Sciences 39:1208–1210.

Christensen, J. M. 1964. Burning of otoliths, a technique for age determination of soles and other fish. Journal du Conseil Permanent International pour l'Exploration de la Mer 29:73–81.

Ishida, T. 1954. On the age determination and morphometrical differences of the otolith of Alaska pollock in the Hokkaido Coast. Bulletin of the Hokkaido Regional Fisheries Research Lab 11:36–37. (in Japanese; Translated by the National Marine Fisheries Service, International Activities, Washington DC).

Janusz, J. 1988. Geographic variation in the otolith growth pattern of walleye pollock. Pages 267–272 *In* Proceedings of the international symposium on the biology and management of walleye pollock. Alaska Sea Grant College Program Report AK-SG-89-01, Fairbanks.

Kimura, D.K., and J.L. Lyons. 1991. Between-reader bias and variability in the age-determination process. Fishery Bulletin 89:53–60.

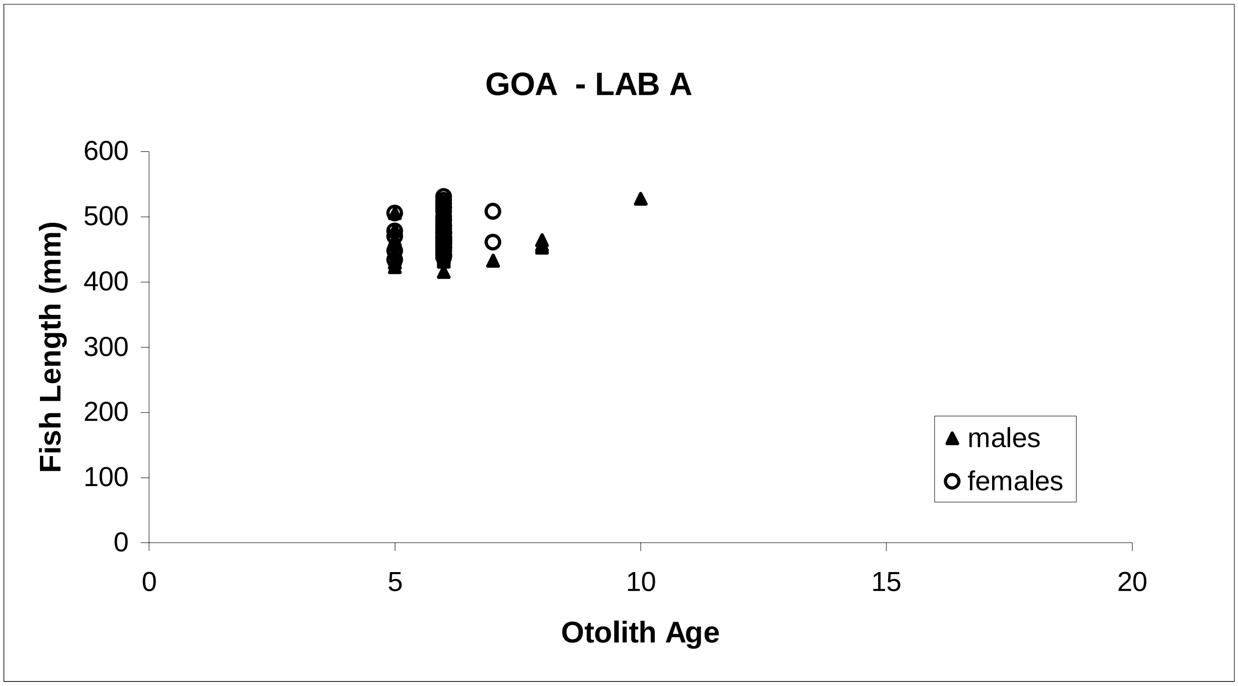
Lalanne, J.J. 1977. The validity and consistency of age determination from otolith of Pacific pollock (*Theragra chalcogramma*). Annual Report 1977 to the North Pacific Commission.

McFarlane, G.A., and Beamish, R.J. 1990. An examination of age determination structures of walleye pollock (*Theragra chalcogramma*) from five stocks in the Northeast Pacific Ocean. Pages 37–56 *In:* L.-L. Low, editor. Proceedings of the symposium on application of stock assessment techniques to gadids. International North Pacific Fisheries Commission Bulletin No. 50.

Mosher, K.H. 1954. Use of otoliths for determining the age of several fishes from the Bering Sea. Journal du Conseil 19(3):337–344.

Pawson, M.G. 1990. Using otolith weight to age fish. Journal of Fish Biology 36(4):521–531.

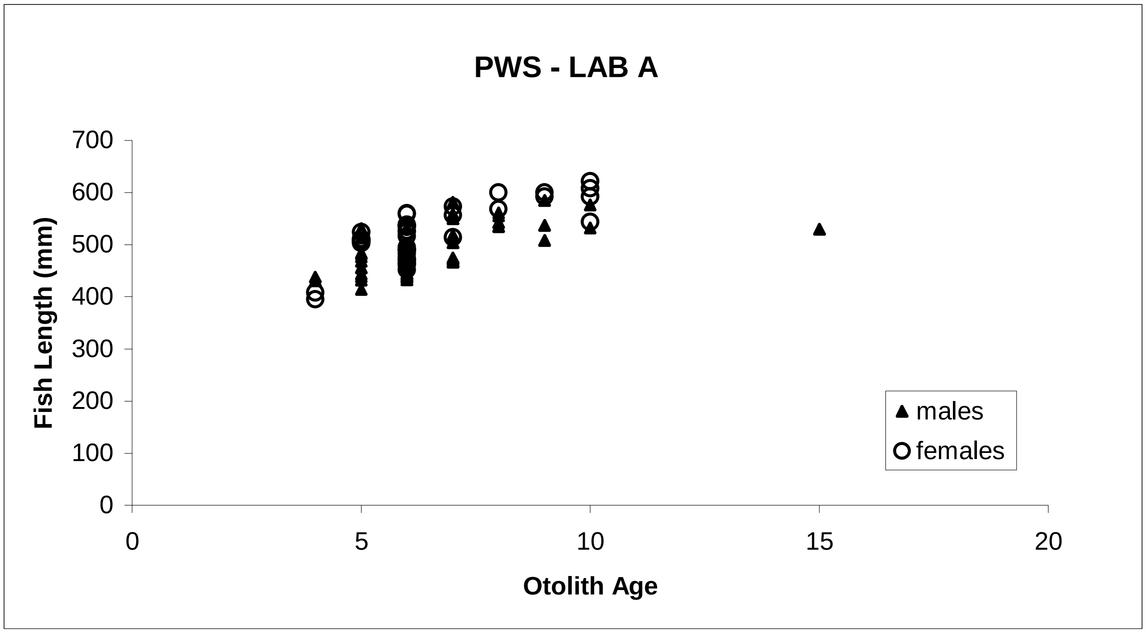
Wilson, C.D. and G.W. Boehlert. 1990. The effects of different otolith ageing techniques on estimates of growth and mortality for the splitnose rockfish, *Sebastes diploproa*, and canary rockfish, *S. pinniger*. California Fish and Game 76(3):146–160.



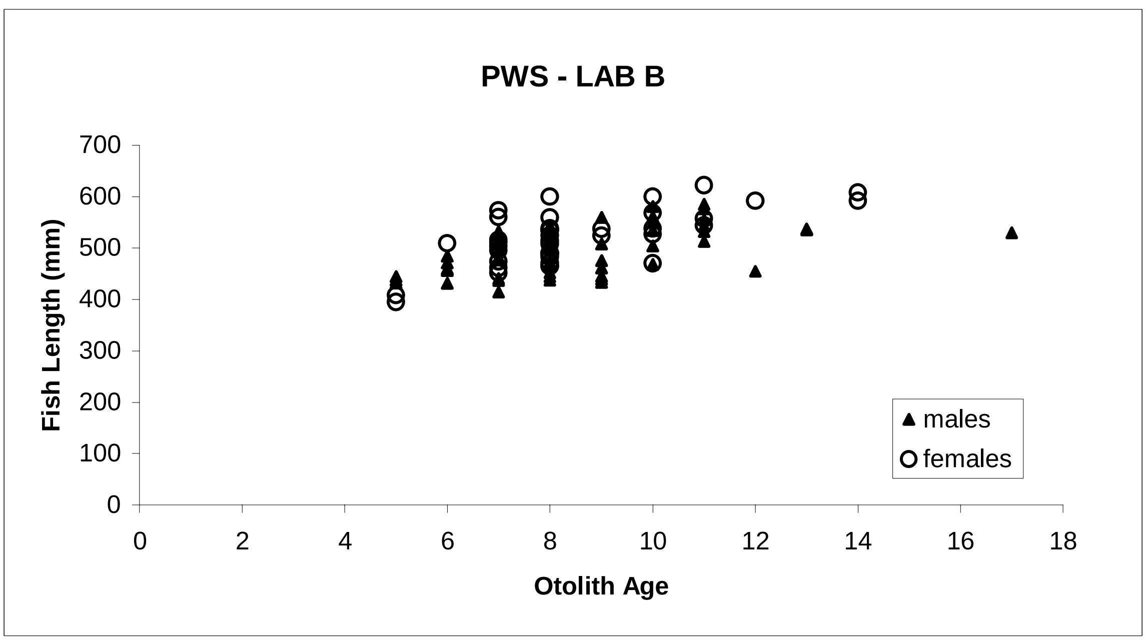
a)

b)

Figure 1. Age at length for GOA samples, produced by Lab A (a) and Lab B (b).



a)



b)

Figure 2. Age at length for PWS samples, produced by Lab A (a) and Lab B (b).

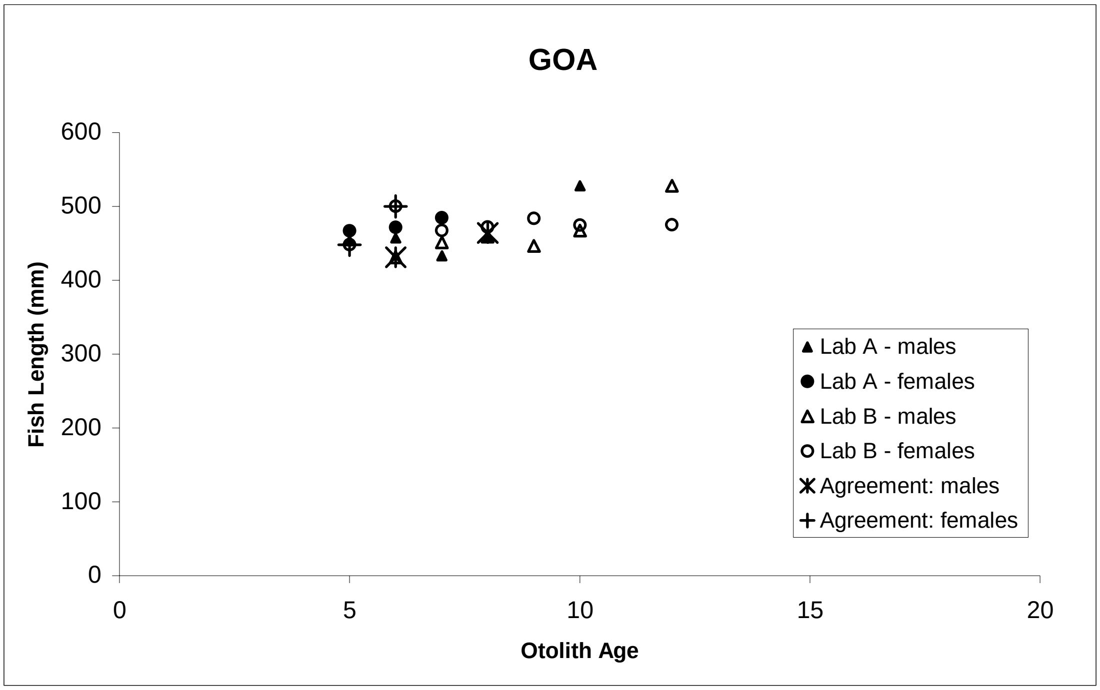


Figure 3. Comparison of Lab A and Lab B mean size at age for GOA walleye pollock.

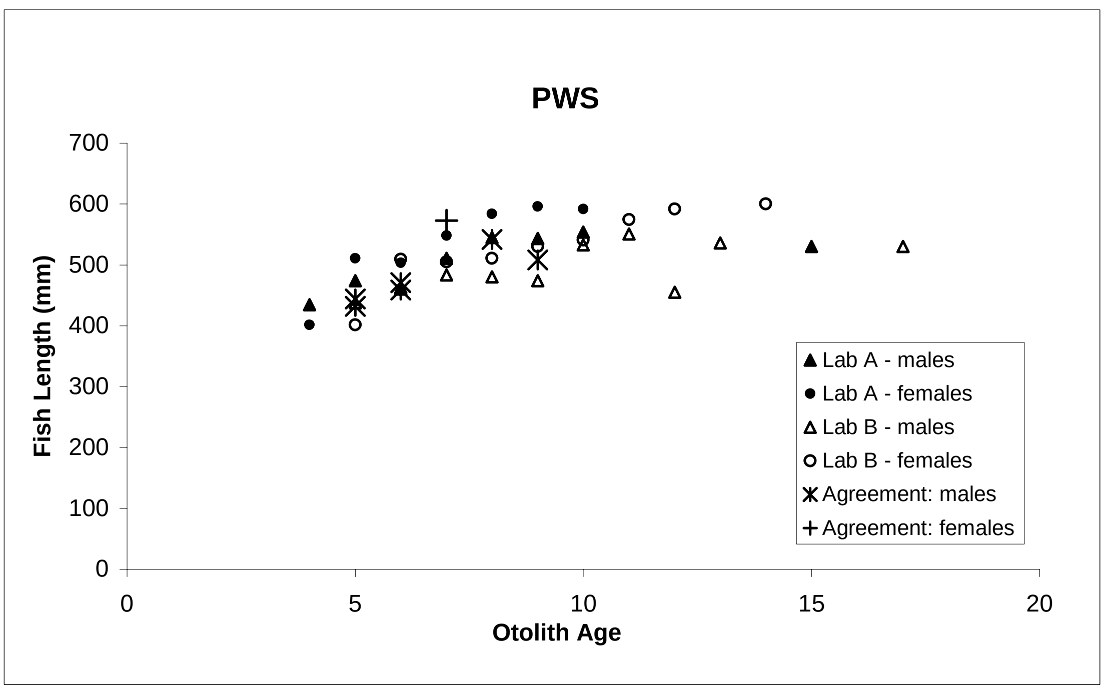


Figure 4. Comparison of Lab A and Lab B mean size at age for PWS walleye pollock.

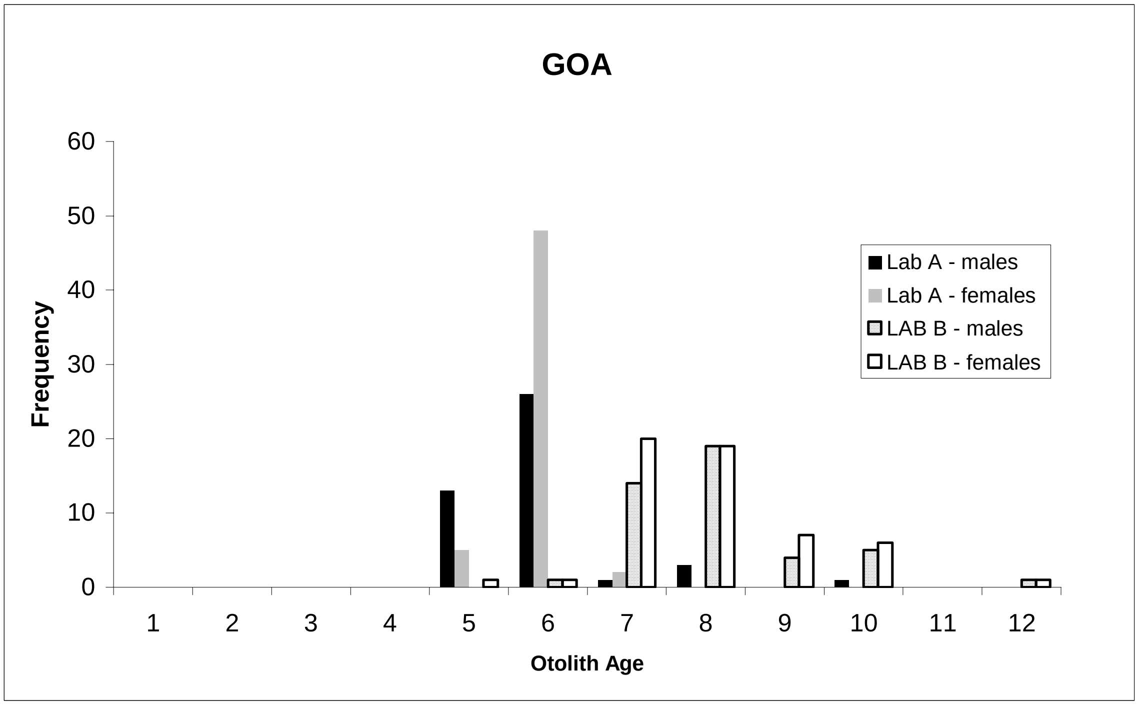


Figure 5. Comparison of Lab A and Lab B age frequency of GOA walleye pollock.

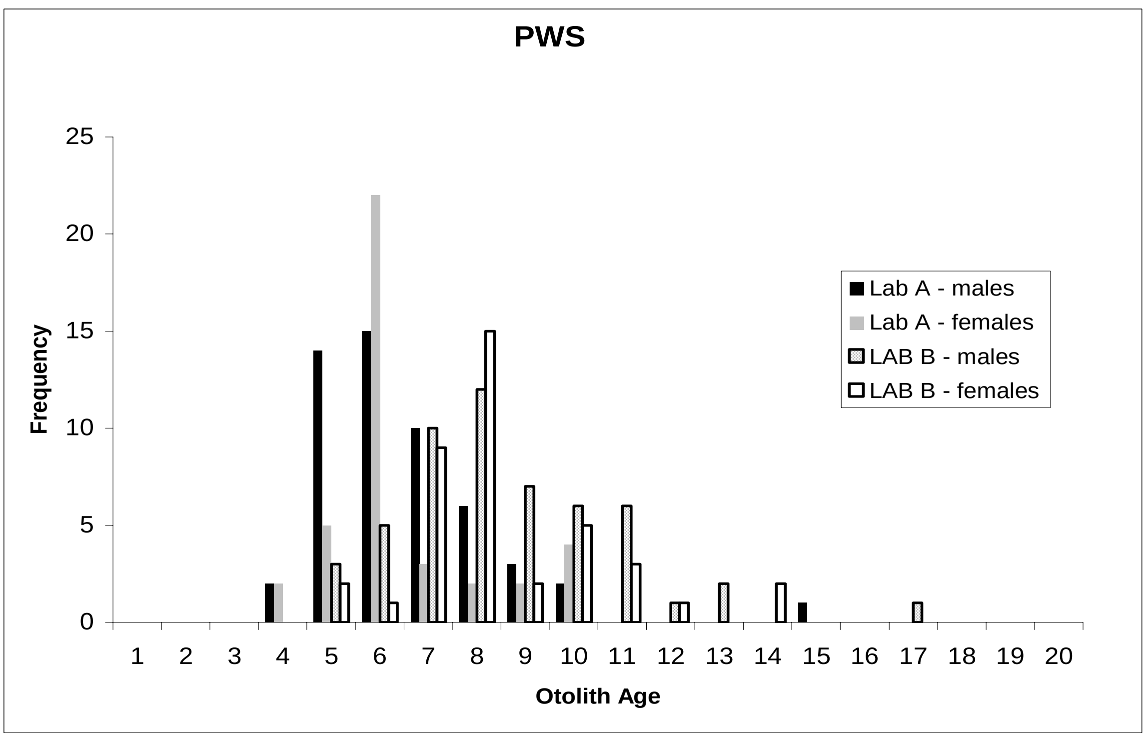
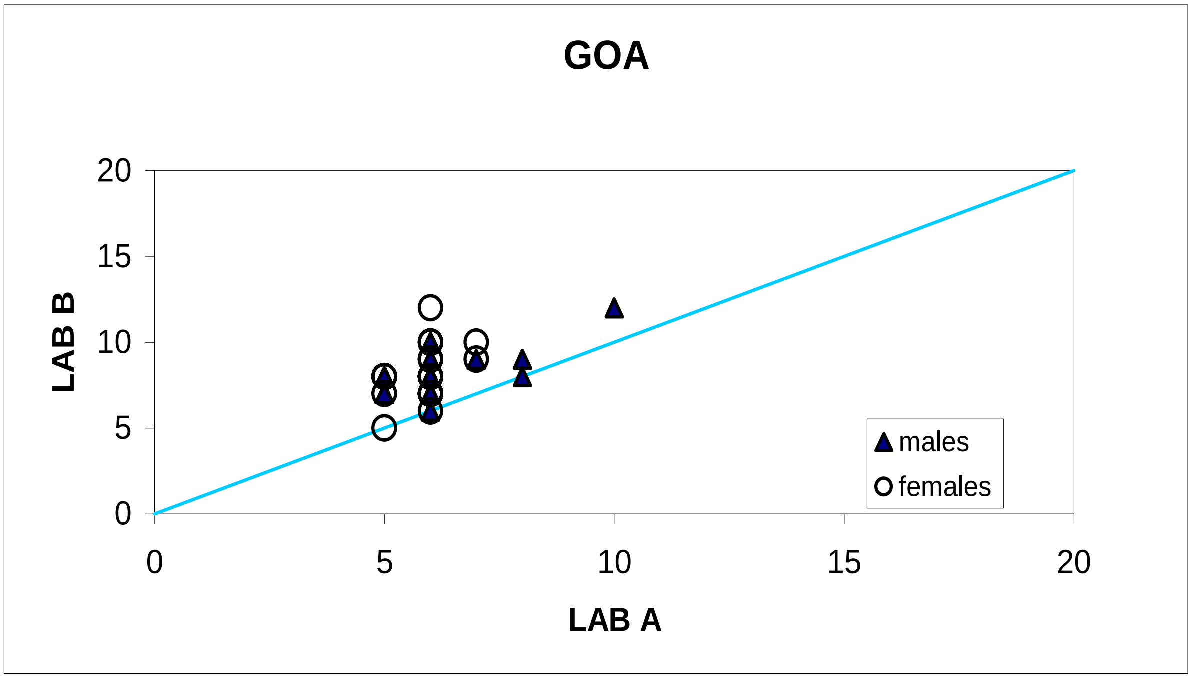
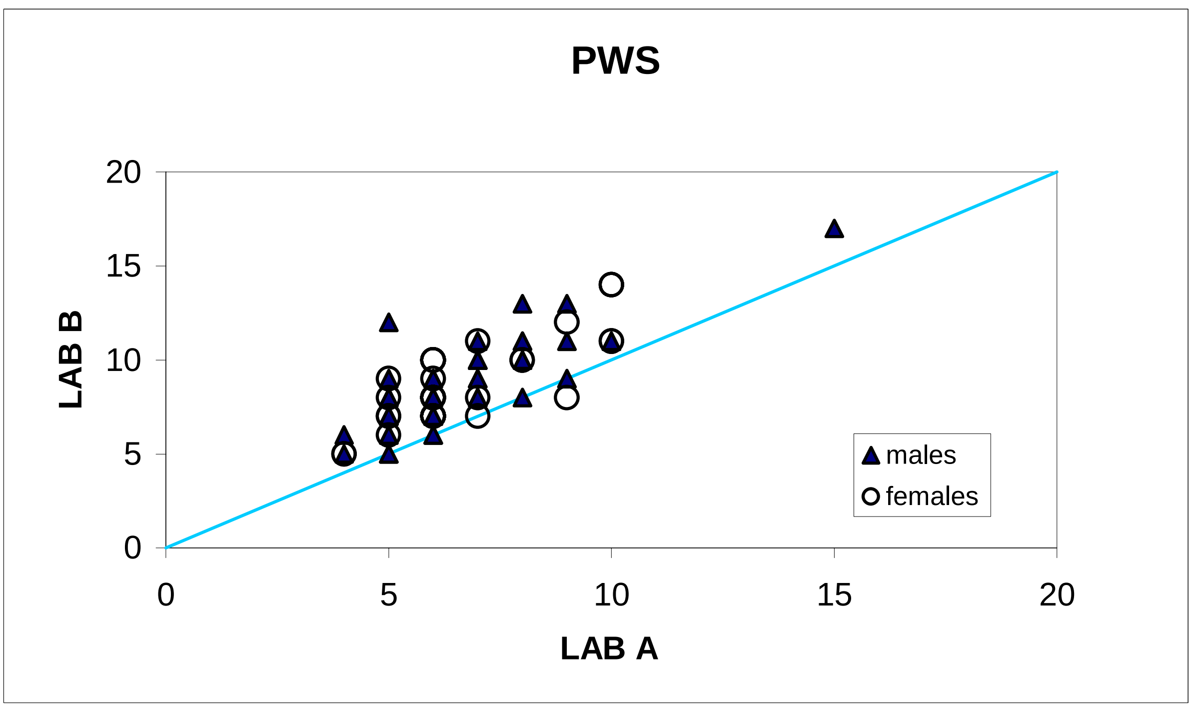


Figure 6. Comparison of Lab A and Lab B age frequency of PWS walleye pollock.

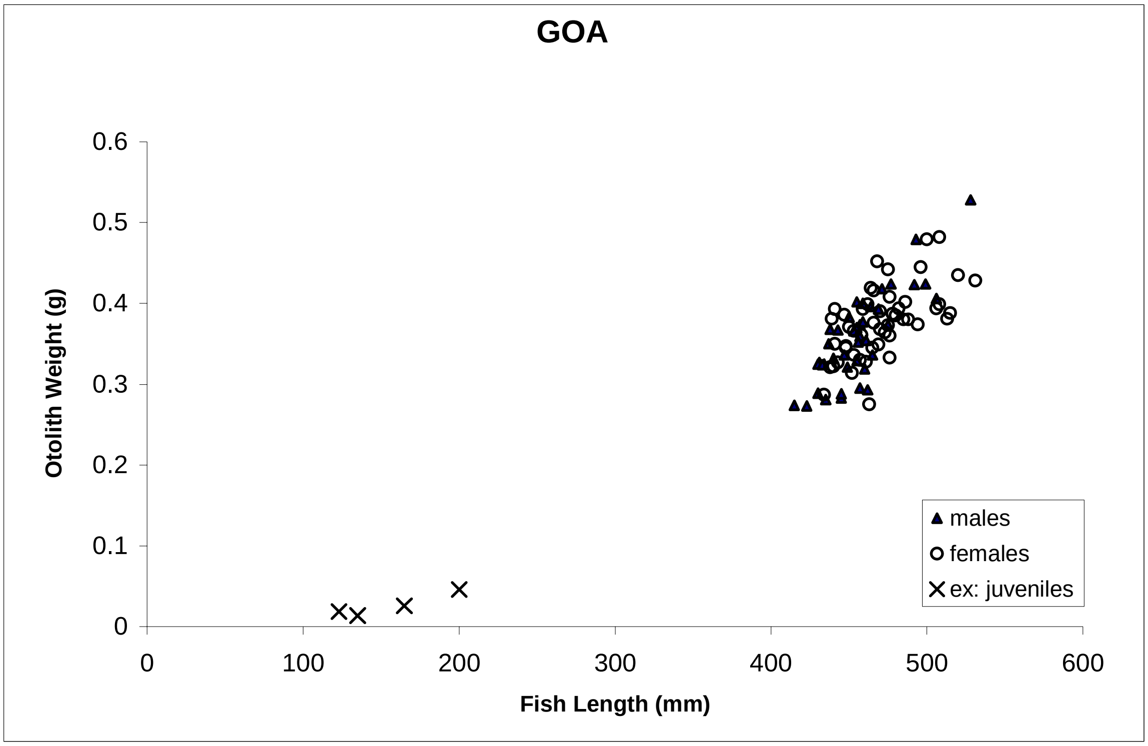


a)

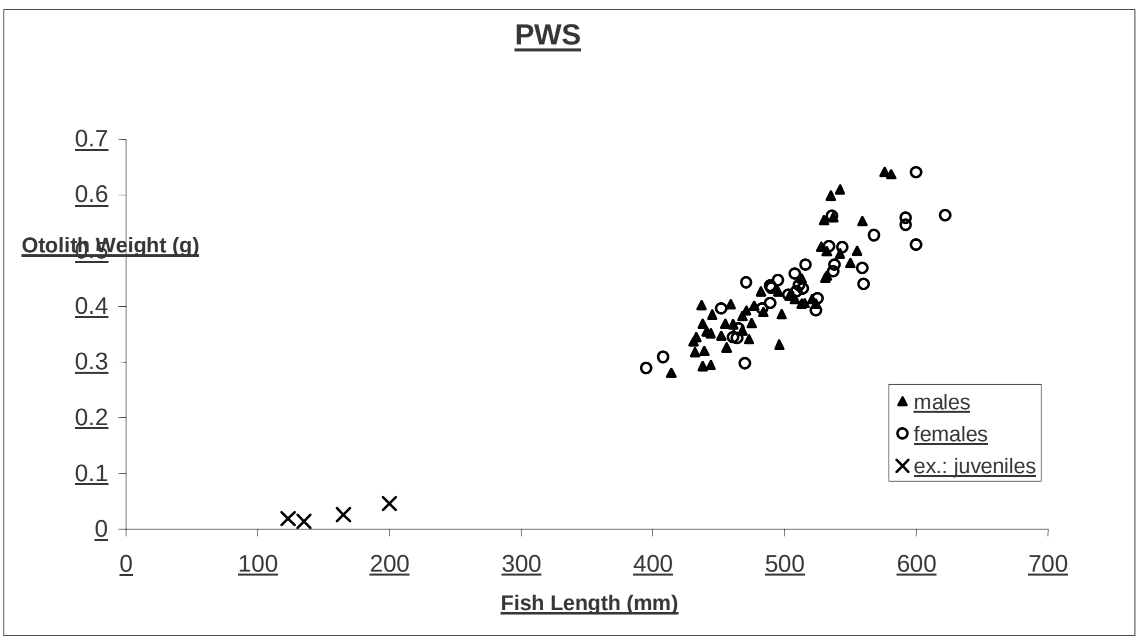


b)

Figure 7. Age bias plots comparing Lab A and Lab B, GOA (a) and PWS (b) walleye pollock age estimates.

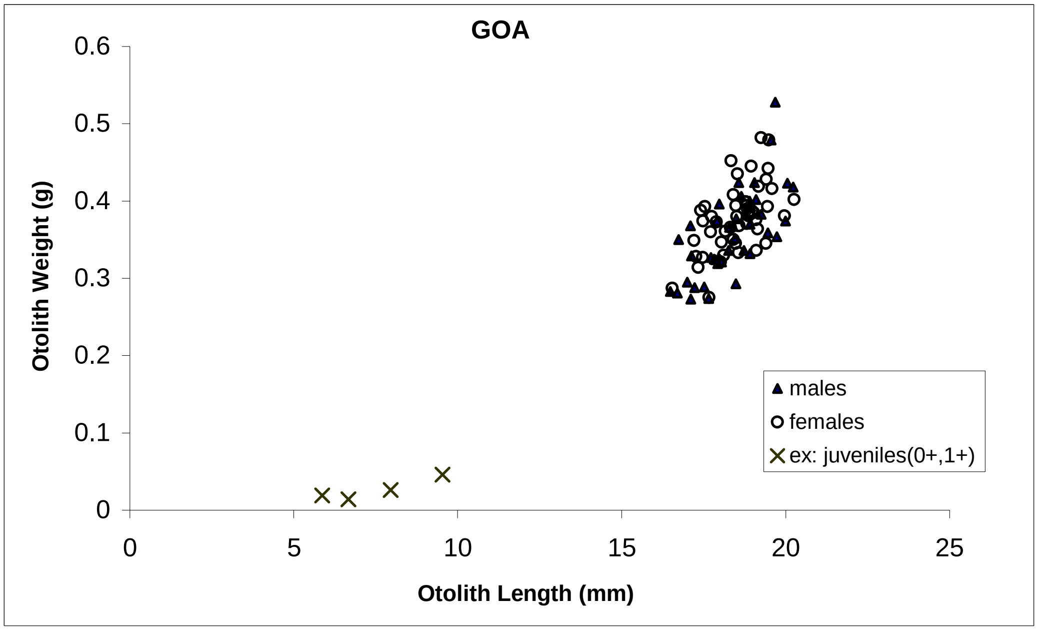


a)

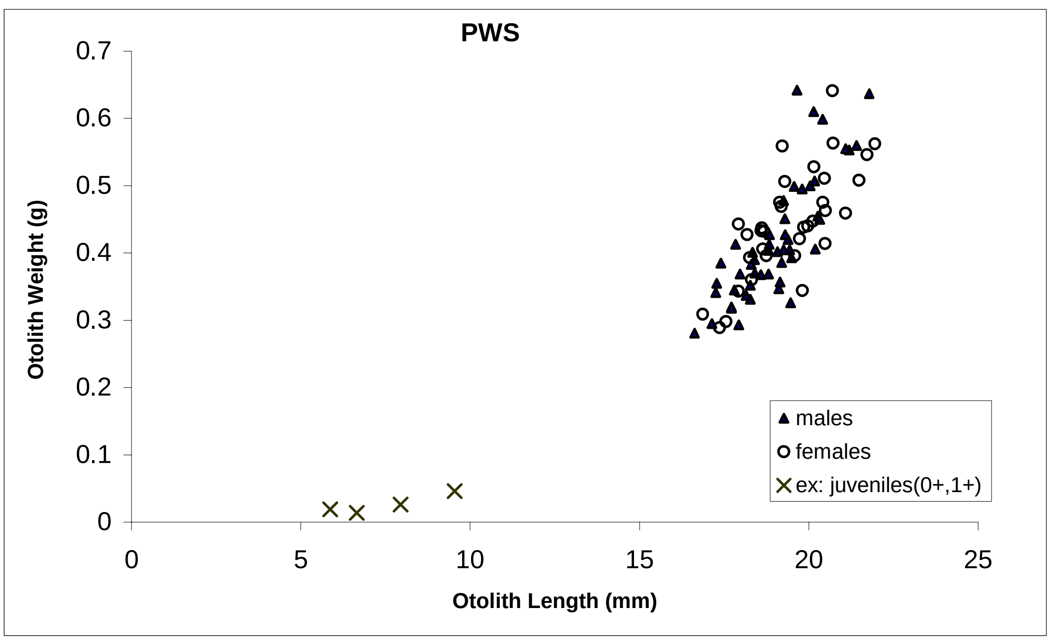


b)

Figure 8. Fish length versus otolith weight for GOA (a) and PWS (b) walleye pollock (non GOA or PWS walleye pollock juveniles are plotted for general reference).

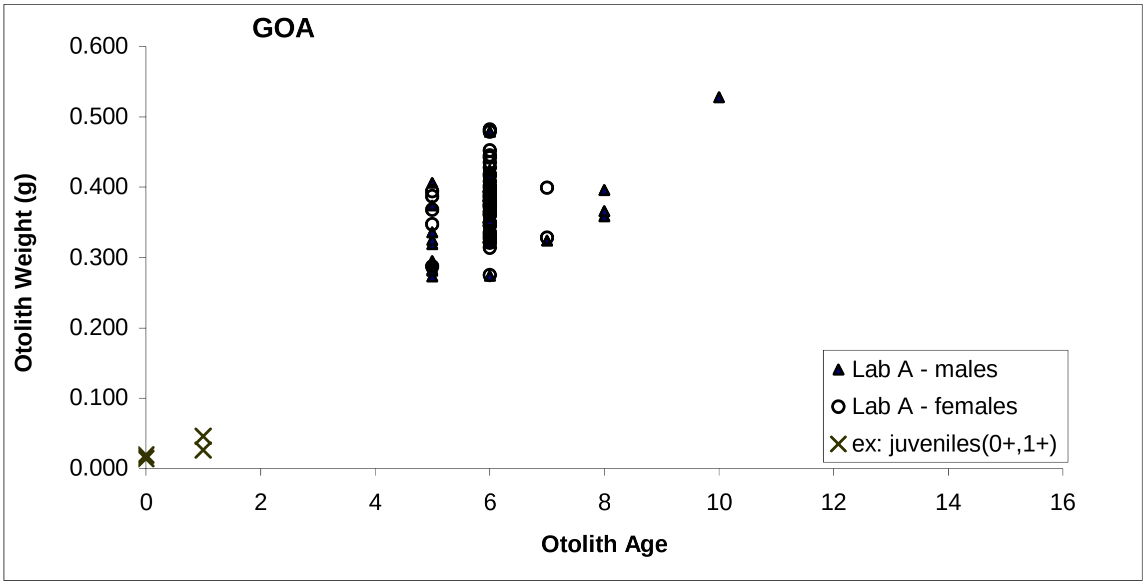


a)

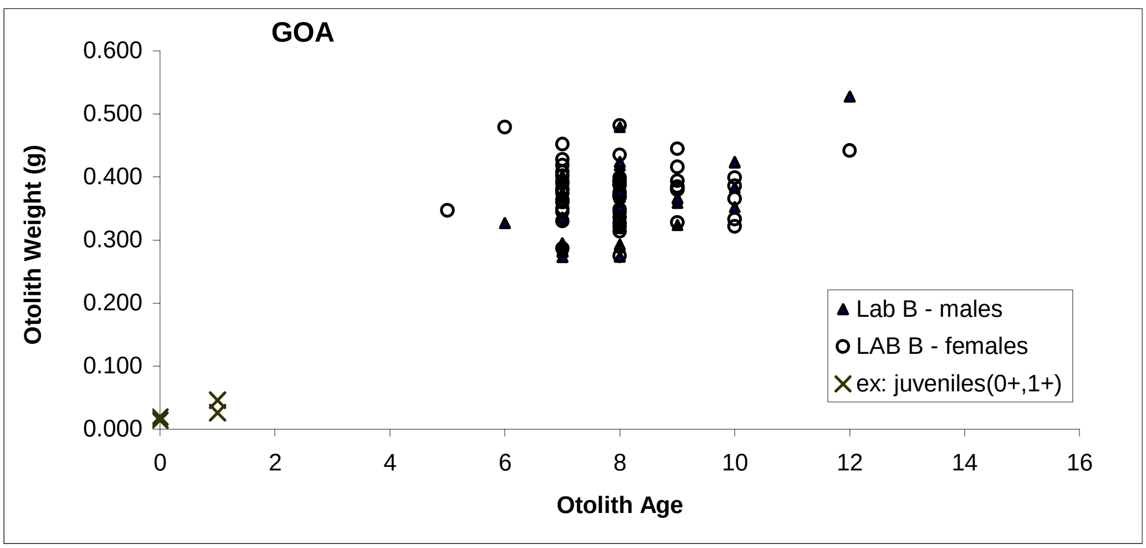


b)

Figure 9. Otolith length versus otolith weight for GOA (a) and PWS (b) walleye pollock (non GOA or PWS walleye pollock juveniles are plotted for general reference).

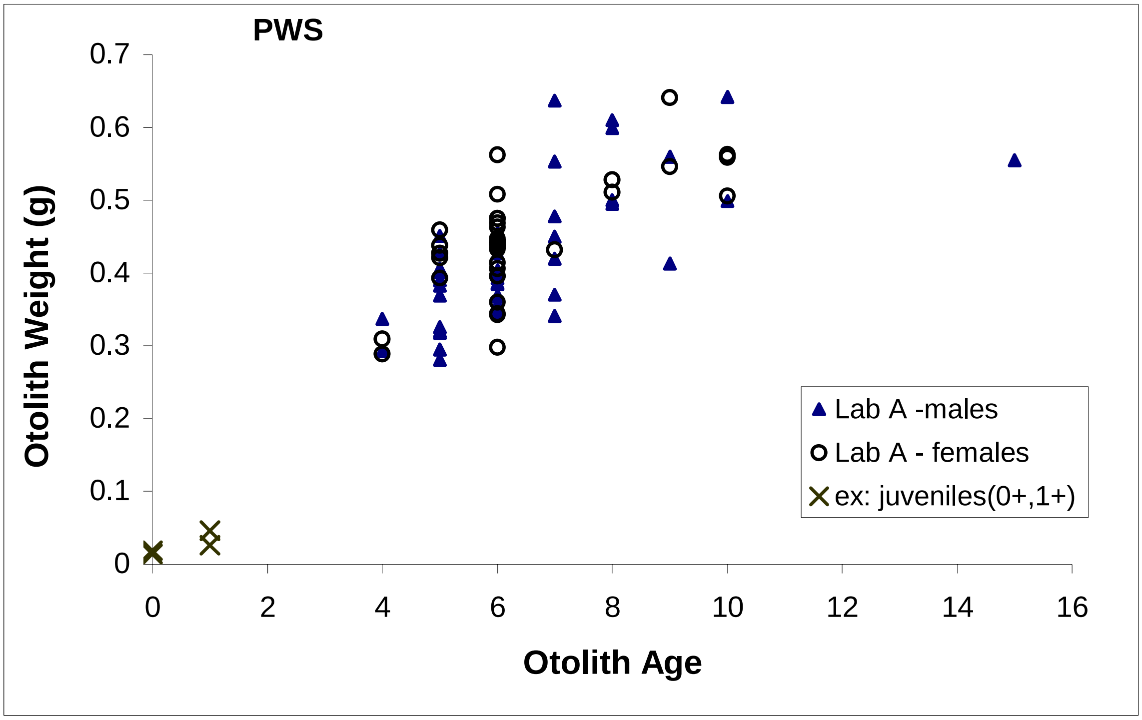


a)

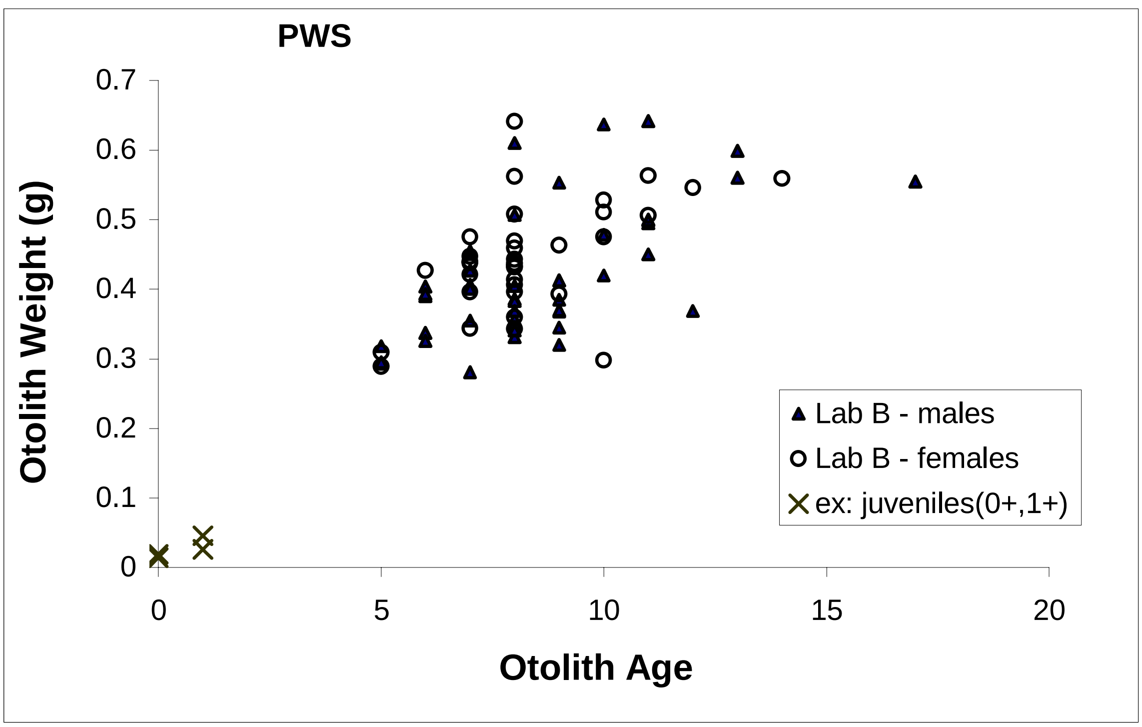


b)

Figure 10. Otolith weight versus age for GOA walleye pollock, Lab A (a) and Lab B (b).



a)



b)

Figure 11. Otolith weight versus age for PWS walleye pollock, Lab A (a) and Lab B (b).

Table 1. Sample size, mean length at age, and precision statistics of age data produced for GOA and PWS walleye pollock, by Lab A and Lab B.

GOA

	LAB A - males					LAB B - males				
AGE CLASS	n=	len (mm)	var	sd	cv	n=	len (mm)	var	sd	cv
1										
2										
3										
4										
5	13	453	520.94	22.82	0.05					
6	26	457	396.08	19.90	0.04	1	431	0.00	0.00	0.00
7	1	433	0.00	0.00	0.00	14	451	164.03	12.81	0.03
8	3	458	31.00	5.57	0.01	19	459	618.25	24.86	0.05
9						4	447	115.67	10.75	0.02
10	1	528	0.00	0.00	0.00	5	467	289.80	17.02	0.04
11										
12						1	528	0.00	0.00	0.00
13										
14										
15										
16										
17										
TOTAL	44					44				

	LAB A - females					LAB B - females				
AGE CLASS	n=	len (mm)	var	sd	cv	n=	len (mm)	var	sd	cv
1										
2										
3										
4										
5	5	467	775.20	27.84	0.06	1	448	0.00	0.00	0.00
6	48	472	563.02	23.73	0.05	1	500	0.00	0.00	0.00
7	2	485	1104.50	33.23	0.07	20	467	475.27	21.80	0.05
8						19	472	624.25	24.99	0.05
9						7	484	312.24	17.67	0.04
10						6	475	1216.57	34.88	0.07
11										
12						1	475	0.00	0.00	0.00
13										
14										
15										
16										
17										
TOTAL	55					55				

PWS

	LAB A - males					LAB B - males				
AGE CLASS	n=	mean len (mm)	var	sd	cv	n=	mean len (mm)	var	sd	cv
1										
2										
3										
4	2	435	24.50	4.95	0.01					
5	14	474	1333.36	36.52	0.08	3	438	36.00	6.00	0.01
6	15	463	763.64	27.63	0.06	5	460	388.70	19.72	0.04
7	10	511	1715.57	41.42	0.08	10	484	1811.53	41.43	0.09
8	6	545	118.97	10.91	0.02	12	480	1089.84	33.01	0.07
9	3	543	1512.33	38.89	0.07	7	474	2049.57	45.27	0.10
10	2	554	968.00	31.11	0.06	6	533	1688.80	41.10	0.08
11						6	551	736.30	27.13	0.05
12						1	455	0.00	0.00	0.00
13						2	536	2.00	1.41	0.00
14										
15	1	530	0.00	0.00	0.00					
16										
17						1	530	0.00	0.00	0.00
TOTAL	53					53				

	LAB A - females					LAB B - females				
AGE CLASS	n=	mean len (mm)	var	sd	cv	n=	mean len (mm)	var	sd	cv
1										
2										
3										
4	2	402	84.5	9.19239	0.0229					
5	5	511	61.5	7.84219	0.01535	2	402	84.5	9.1924	0.0229
6	22	503	1170.32	34.21	0.06797	1	509	0	0	0
7	3	548	931	30.5123	0.05568	9	505	1702	41.255	0.0817
8	2	584	512	22.6274	0.03875	15	511	1460	38.21	0.0748
9	2	596	32	5.65685	0.00949	2	531	84.5	9.1924	0.0173
10	4	592	1153	33.9559	0.05741	5	541	2363.8	48.619	0.0899
11						3	574	1746.33	41.789	0.0728
12						1	592	0	0	0
13										
14						2	600	128	11.314	0.0189
15										
16										
17										
TOTAL	40					40				

Table 2. Frequency of gender classification of GOA and PWS walleye pollock samples, from observation of gonads and age class assignment by Lab A and Lab B.

		GOA				PWS			
Sample Frequency		males = 44%; females = 56%				males = 58%; females = 42%			
Age data set freq.		males = 44%; females = 56%				males = 57%; females = 43%			
		LAB A		LAB B		LAB A		LAB B	
YR CLASS	AGE	males	females	males	females	males	females	males	females
1999	1								
1998	2								
1997	3								
1996	4					2%	2%		
1995	5	13%	5%		1%	15%	5%	3%	2%
1994	6	26%	48%	1%	1%	16%	24%	5%	1%
1993	7	1%	2%	14%	20%	11%	3%	11%	10%
1992	8	3%		19%	19%	6%	2%	13%	16%
1991	9			4%	7%	3%	2%	8%	2%
1990	10	1%		5%	6%	2%	4%	6%	5%
1989	11							6%	3%
1988	12			1%	1%			1%	1%
1987	13							2%	
1986	14								2%
1985	15					1%			
1984	16								
1983	17							1%	