Relationships of Otolith Size to Fish Size and Otolith Ages for Yelloweye *Sebastes ruberrimus* and Quillback *S. maliger* Rockfishes

by

Kristen M. Munk
and
Kathy M. Smikrud

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AUTHORS

Kristen Munk is 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

Kathy Smikrud was a fishery biologist at the Age Determination Unit at the Alaska Department of Fish and Game, Mark Tag and Age Lab, currently a biologist with the Alaska Department of Fish and Game, Sport Fish Division, P.O. Box 240020, Douglas, Alaska 99824, USA. Kathy_smikrud@fishgame.state.ak.us

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ABSTRACT

Sagittae otoliths of yelloweye *Sebastes ruberrimus* and quillback *S. maliger* rockfishes, two demersal shelf rockfish species inhabiting Southeast and Southcentral Alaska waters, were measured, weighed and aged. General relationships were explored among these parameters in relation to fish length, fish weight, and gender, to both document variability in these objective parameters of otolith growth, and to compare them to subjective otolith age estimates. Generally no statistical size difference between left and right sagittae otoliths for any areas of origin were observed for yelloweye rockfish, with a statistically significant difference noted in otolith height for quillback rockfish from one of three management areas. There was good, linear relationship between otolith length and otolith height for both species. The relationship between otolith weight versus otolith length and otolith height was non-linear, as was otolith length and otolith height versus otolith age. Relationships between otolith size and fish size appeared tight, suggesting general coupling of macrostructural otolith to fish growth mechanisms. An otolith index was graphically explored in relation to otolith age and fish length and fish weight, especially to provide emphasis to outliers that suggest these data may be legitimate, albeit extreme examples of fish growth, and not necessarily from aging or port sampling error.

INTRODUCTION

From its first documented use in 1899 (Reibisch 1899), using fish otoliths as age structures has become ubiquitous. Age data are a common and important component of management strategies (Bechtol 2000; O'Connell and Brylinsky 2001). However, ongoing questions of quality of age data introduce uncertainty into management models and their application.

Anomalies or inconsistencies in age data are often believed to be a result of simple misinterpretation of growth patterns by age readers. But while aging error is an inescapable reality in interpreting some otolith growth patterns for many species, expert age readers have long recognized other information in growth patterns that corroborate some anomalous age estimates and/or seemingly inconsistent, extreme, or non-progressive fish length with increasing age. These examples could indicate atypical genetic or environmentally induced growth strategies of fish, perhaps significant for consideration by managers.

Yelloweye rockfish *Sebastes ruberrimus* and quillback rockfish *S. maliger* are two examples of long-lived species (Cailliet et. al. 2001; Munk 2001) and are subjectively described as "moderately easy" to age. They generally co-occur in rocky outcroppings on the continental shelf and are actively fished in commercial fisheries and managed in the "demersal shelf rockfish" assemblage (O'Connell and Brylinsky 2001). Commercial or population survey harvests are sampled for biological data and age structures (otoliths). Otoliths are aged using the "break and burn" technique, where growth patterns are subjectively interpreted using interpretation criteria standardized among aging laboratories in the Pacific Northwest through the Committee of Age Reading Experts (CARE), a working group of the Canada-US Groundfish Committee's Technical Subcommittee. Otolith age estimates have been validated for Southeast Alaska stocks of both yelloweye rockfish (Andrews et al 2002) and quillback rockfish (L. Kerr, Moss Landing Marine Lab, Moss Landing, California, personal communication). All of these studies used otolith samples that were aged at the Age Determination Unit, Juneau, Alaska.

The primary purpose of this study is to provide seminal documentation of measurements of yelloweye rockfish and quillback rockfish otoliths, and simply relate these measurements to objective otolith and fish size measurements and subjective otolith age data. Exploration of these parameters may aid or corroborate conventional otolith age interpretation processes, elucidate unconventional growth histories that result in legitimate though anomalous age data, and suggest additional research to objectively document otolith size relationships for these and other species.

METHODS

Port Samples

Commercial landings (longline and jig gear) of yelloweye rockfish and quillback rockfish in Southeast and Southcentral Alaska were subsampled by Alaska Department of Fish and Game port samplers. Harvest information (management area, gear type, etc), biological data (gender, gonad maturity, fish fork length to the nearest mm, fish weight to 0.1kg), and sagittae otoliths (hereafter referred to as "otoliths"), were collected and matched. Otoliths were cleaned of adhering lymph and blood, and stored dry for several months prior to measuring.

Otolith collections from Alaska made in 2000, 2001, and 2002 were subsampled based upon sample port. Sample data were subdivided by region and management areas. Management areas identified for Southeast Region were East Yakutat (EYKT), Central Southeast Outside (CSEO), Southern Southeast Inside (SSEI), and Northern Southeast Inside (NSEI) (Figure 1). All management areas from Southcentral Region were incorporated into one Southcentral (SCA) group because of small sample size. For yelloweye rockfish, 328 otoliths were selected from the Southeast collections, and 75 otoliths from the Southcentral collections, years 2000–2001. For quillback rockfish, 216 otoliths were selected from only the Southeast collections, years 2000–2002.

Otolith Measurements

Otoliths were measured for length (anterior-posterior) and height (dorsal-ventral) (Figure 2) using a digital caliper with resolution to 0.01mm. Otoliths were weighed using an Ohaus digital balance with resolution to 0.001g. Only otoliths having full aragonite crystal structure or less than 10% vaterite ("crystallized") were utilized in comparisons; otoliths with more vaterite were generally not measured but noted.

Otolith Age Estimates

The ADF&G Age Determination Unit (ADU) in Juneau, Alaska aged otoliths. Otoliths were prepared and aged using the traditional "break and burn" technique. An otolith was split transversely (dorsal-ventral) bisecting the center and then charred (Christensen 1964). Broken surfaces were coated with mineral oil to minimize refractive planes and better reveal growth patterns. The surface was illuminated with reflected light and viewed using a stereomicroscope. Growth patterns were then interpreted and annuli enumerated. Guidelines for pattern interpretation were generally based upon standardized interpretation presented in the CARE Age Reading Manual (CARE 2000), and with allowance for recognition of regional growth patterns.

Otolith Index

An otolith index was developed whereby "mean otolith weight" was divided by "mean otolith length" in order to diminish the effect of length of the otolith on weight; length is primarily established in the fast growing earlier years of growth and contributes disproportionately to the weight component for faster growing specimens. Larger index values generally suggest a relatively older fish and smaller index values suggest a relatively younger fish.

Statistical and Graphical Analyses

We used Microsoft Excel software statistical functions for analyzing otolith measurement data. Symmetry between left and right otoliths within each specimen for otolith length, weight, and height, sorted by management area and gender, was estimated using the paired t-test with level of significance set at 0.05. Specimens not having measurements for both otoliths or identified as "sex unknown" were discarded from this analysis.

We calculated variance, standard deviation, and bias, and their means, for otolith length, height, and weight between left and right otoliths of individual specimens.

Otolith parameters were graphically compared to fish parameters, sorted by management area and gender. Mean values for otolith pairs (left and right otolith) for each specimen were used in graphical comparisons, however, if only one otolith had been measured (due to the companion otolith being broken or excessively crystallized) the measurement from a single otolith was utilized.

RESULTS

Yelloweye Rockfish

Sample Character and Otolith Size Variation

Mean otolith age and age range of the samples are shown in Table 1, with a regional age range of 14–110 years for Southeast samples and 2–68 years for Southcentral samples [Note: historical age range for Southeast Region otolith collections is 4–121 years, and for Southcentral Region collections is 2–79 years]. Table 1 also shows mean values for bias, variance, and standard deviation, for otolith length, height, and weight measures for otolith pairs. Mean bias in otolith length among individual specimens ranged from 0.00 to 2.04mm for Southeast Alaska, and 0.01 to 1.73mm for Southcentral Alaska (management areas, males and females combined). Mean bias for height/weight among individual specimens ranged from 0.00–1.24mm/0.000–.630g for Southeast Alaska, and 0.01–0.74mm/0.000–.051g for Southcentral Alaska (management areas, males and females combined).

No significant differences were observed in size of the left otolith versus right otolith within each yelloweye rockfish specimen (Table 3), however, according to guidelines provided by Rosner (1982), the *P*-values of 0.05 (otolith lengths CSEO males), 0.06 (otolith heights SCA males), and 0.09 (otolith weights SCA females; otolith heights CSEO females) for differences between left and right otoliths have potential or tendency toward statistical significance.

Fish Size Comparison

The objective parameters of fish weight versus fish length (Figure 3) demonstrate a tight, weakly non-linear relationship with strong similarity between males and females for all Southeast management areas. However, with inclusion of young fish, as is the case in the SCA sample, a distinctly non-linear relationship is more visible.

Otolith Size Comparison

Otolith height versus otolith length seems to have a generally tight linear relationship (Figure 4). Otolith parameters of weight versus height and length (Figure 5) show comparable tight, but non-linear relationships. The relationship of these variables for the Southeast management areas appears to be linear, however, these samples lack young fish that, if included, would clearly demonstrate the overall non-linearity in otolith growth. Note that the Southcentral sample does contain young fish, and the nonlinear relationship of these parameters is clearly visible.

Otolith Size versus Fish Size

Objective parameters of otolith length versus fish length (Figure 6) suggest general coupling of these macrostructural size parameters, further establishing credibility in otolith measurement data reflecting the more familiar fish-size relationships. Otolith weights plotted against fish length (Figure 7) and fish weight (Figure 8) demonstrate a generally good relationship of increasing otolith size with increasing fish size. Otolith weight and fish length suggest a weak nonlinear relationship while otolith versus fish weights seems more linear.

Otolith Index and Outliers

The otolith index is plotted against fish length and weight (Figures 9 and 10) to further extend this relationship of parameters. Noticeable outliers are highlighted (cross referenced in Table 5) throughout appropriate figures to demonstrate their conformity in some comparisons and lack of such in others. One outlier to note ("I") occurs in the EYKT graphs. This datum is from an aberrant, vateritic otolith that should have been removed from this data set, though was left to exemplify dissimilarity in crystal formation; it is without true comparison value to other data from aragonitic otoliths.

Objective Fish/Otolith Measures versus Subjective Age Data

Otolith and fish measurements are compared to otolith age estimates (Figure 11, 12, 13, and 14) to draw the final connection between the tangible understanding of increasing fish/otolith size over time, to the subjectively derived age estimates resulting from interpreting growth increments. While most of these data seem more disperse, Figure 14 subtly suggests tightening of the relationships when plotting the otolith age against the otolith index.

Quillback Rockfish

Sample Character and Otolith Size Variation

The overall range in age of quillback rockfish in the samples was 9–81 years. All three management areas had fish >60 years old, with mean sample ages ranging from 24.6 to 31.4 years (Table 2). [Note: historical age range for Southeast Region otolith collections is 3–90.] Mean values for otolith length, otolith height, and otolith weight were generally similar among management areas and gender (Table 2), however SSEI quillback rockfish had slightly lesser values, especially for males.

The *P*-values for both CSEO males (*P*=0.01) and females (*P*=0.03) suggested a statistically significant difference between the height of left and right otoliths within individual specimens (Table 4). However, no significant difference was apparent in other areas or for other parameters (otolith length or otolith weight). Southeast management area NSEI was dropped from this analysis due to small sample size.

Mean bias among otolith pairs for otolith length, height, and weight appear similar for both management areas and sexes (Table 2) (Southeast management area NSEI was dropped from this analysis due to only 1 otolith being measured per fish). Mean variance and standard deviation for physical otolith parameters (length, height, and weight) also were similar, with SSEI males higher (significance not tested).

Fish Size Comparison

Fish weight plotted against fish length (Figure 15) suggests a tight relationship for all management areas. Though weak non-linearity is suggested, samples did not include juvenile fish.

Otolith Size Comparison

Otolith height and length data (Figure 16) show a tight clumping, with suggestion of linearity; however, a more clear relationship cannot be determined due to lack of juvenile fish in the sample. Otolith weight versus otolith height and length (Figure 17) suggests a tight, perhaps nonlinear relationship that is again difficult to recognize due to lack of juvenile fish.

Otolith Size versus Fish Size

Otolith length versus fish length (Figure 18) and fish weight (Figure 19), and fish weight versus otolith weight (Figure 20) demonstrate a tight relationship, especially for CSEO and SSEI, however NSEI seems to have more dispersion in data (note minimal sample size).

Otolith Index and Outliers

In Figures 21 and 22, the otolith index maintains a relatively tight relationship for CSEO and SSEI, however, the data remains somewhat dispersed for NSEI (again, small sample size is suspected). Note the suggestion of gender specific differences for SSEI in Figure 21, with higher index values at smaller fish lengths for female quillback rockfish.

Objective Fish/Otolith Measures versus Subjective Age Data

Subjectively derived otolith ages are compared to objective fish and otolith parameters in Figure 23 through 26. A mostly weak non-linear relationship is noted (Figures 23 and 24), perhaps due to lack of juvenile fish in the samples. It is interesting that the incorporation of subjective age seems to create a tighter relationship with the objective parameter(s) for the problematic NSEI data.

DISCUSSION

Otolith Size Differences

There were no clear statistical differences observed between left and right sagittae otoliths for yelloweye rockfish; there was, however, a statistical difference suggested for height differences between left versus right otoliths from quillback rockfish for some areas. The latter is puzzling; there seems no biological reason for one otolith to be larger (taller) than the other. On occasion there is certainly pronounced, though infrequent asymmetry between left and right otoliths of some fish—either in size and shape as an element of either polymorphic crystallization or malformation—but our data and casual visual observation suggested general uniformity in size, shape, and crystal structure (aragonite). It is possible that imperceptible but consistent malformation between left versus right otoliths was present. However, this may be an artifact of the process for two possible reasons.

First, few otolith specimens were discarded for partial vaterite. Specimens were included if vaterite component was subjectively minor (<10%). While determination of the frequency of vateritic otoliths was not a goal, casual observation noted that less than 1% (2 partial, 1 complete) of yelloweye rockfish otoliths were found to be unacceptably vateritic (all from different management areas), and 2.24 % of quillback rockfish were noted as completely (n=3) or partially (n=2) vateritic (from two different management areas). However, if partial-vaterite otoliths were prone to occur (possibly by management area or gender), and these low volume vateritic otoliths were mistakenly included in the sample data, then length, height, or weight differences might be evidenced between one otolith vs. the other. Incidence and classification of asymmetries (shape and matrix) has been anecdotally noticed to have more or less species or area-specific differences, and need to be examined further with larger-sized and geographically more diverse samples. In addition, some differences could also be attributed to undetected otolith breakage. Otolith crenulations (located dorsally) and pointy rostrums are fragile, especially in quillback rockfish, and small portions which break off will obviously slightly decrease weights or height of individual otoliths. Future otolith measurements will include more thorough assessment of otolith intactness and crystal type/proportion.

Otolith Size versus Fish Size

Otolith growth is generally thought to uncouple from somatic growth at a very early age. A variety of factors influence the degree or timing of this uncoupling (Moksness et al 1995). Most, if not all, of these studies deal with growth at the microstructural level, daily increments, generally within the first year of growth. While rigorous analyses were not completed (nor were they the purpose of this study), graphical representations herein suggest general coupling of otolith and fish growth at the macrostructural level. Within the otolith, length/height seem to uncouple from a time-dependant otolith weight. This is why researchers abandoned otolith surface aging in the 1970's for the more reliable aging of the transverse axis ("break and burn"). Additional older years' growth did not accumulate in the dorso-ventral (height) nor anterior-posterior axes (length), but rather continued to accrete to the medial axis (thickness, which is not easily measured though is revealed in weight).

Otolith Index

Otolith growth, and therefore size, is a function of time and likely both genetic predisposition and environmental variation processes which affect growth. But large otolith size or fish size does not always indicate the oldest representatives for that species; in fact, the oldest aged fish often have otoliths that are smaller than younger animals. Some outliers show unusually small fish length and otolith length at extended age. Mulligan and Leaman (1992) have also observed that "old fish are shorter than intermediate-aged fish".

The otolith index values had a mildly discernible effect of tightening relationships between some otolith and fish parameters, however they did exaggerate some outlier events, reinforcing the speculation that "small otoliths are not always from young fish". The anterior-posterior growth axis, "otolith length", is consistently the largest axis in otoliths and often mistakenly conveys the concept that otolith size (length), therefore "age" to most observers, suggests an older fish. Age readers are aware of this fallacy, and emphasize the importance of the medial axis relative to otolith length in overall consideration of age: "big" otoliths are not necessarily from old fish and "small" otoliths are not always from young fish, but thickness in a small otolith is indicative of a very old fish.

Early otolith growth provides a large component of otolith weight; if the animal experiences "fast growth", the otolith is longer and early annual growth zones relatively larger prior to transition to slower growth (personal observation), therefore exaggerating weight of the otolith at age. If the animal experiences "slow growth", the animal has relatively smaller zones and transitions to even slower growth sooner, resulting in a smaller otolith length. Its otolith weight would be less than one that experienced "fast growth" and had larger otolith zones. The otolith index minimizes the "growth effect" (fast versus slow) to some degree and had a positive effect in comparing data for these species. In the case of the NSEI quillback rockfish data, where otolith ages are compared to the otolith index, the data seems to tighten. Anecdotally, extremely close spacing of annuli is often recognized in quillback rockfish. Called "compressed zones", these zones may have 5–10 years within them (with the belief we are likely under aging them, if anything), and where an overall compressed zone weight might be less than or equivalent to a single, more typical old-aged annual growth zone. The effect would be a very small otolith (length and weight) and therefore a high otolith index, at a very high age.

It is instructive to follow some identified outliers throughout the graphical comparisons to understand the components of otolith size in relation to fish size (especially note outliers C, E, F, and G throughout all graphs). Frequently, outliers are cast as examples of sampling or aging error if age is disproportionate to an expected fish length, and may be discarded from further consideration or modeling by the manager. Additionally, an inexperienced age reader might resort to including additional fish size information in developing a more "plausible" or "believable" interpretation of age/growth that is inaccurate.

Objective versus Subjective

Use of objective otolith and fish measurements clearly draw some strong connections between the two effects. Contrasting these to subjectively derived age data lends at least a casual statement of credibility to subjective age data, but may also provide additional insight into growth scenarios. Aging of some species is relatively straightforward, with good accuracy in age estimates likely. Other species can be extremely difficult to age, not only to nominal year class but also to actual age range for the species. Assessing relationships of objective fish and otolith parameters may serve to substantiate correctness of an age range previously developed from subjective otolith age data. Presuming accuracy in identifying the age range, nominal age data may be evaluated by incorporating objective otolith parameters, perhaps further revealing error previously thought to be indeterminate—that is, it may reveal error of bias against a specific growth scenario, which would put management for that component at risk.

CONCLUSIONS

No statistical size differences were observed between left and right sagittae otoliths for yelloweye and quillback rockfishes. Two exceptions to this are 1) a borderline significance for some yelloweye rockfish otolith length or heights, and 2) quillback rockfish otolith height for some management areas. These differences will be explored and refined in the future by increasing sample size and improving measurement protocols to prevent recognition error or measurement artifacts.

Objective measurements of sagittae otoliths of yelloweye and quillback rockfishes from Southeast and Southcentral Alaska were documented and general relationships explored. Generally good, tight relationships were suggested for all objective parameters for otoliths and fish measurement, with more dispersion in data for quillback rockfish from NSEI. The latter will be explored and refined by increasing sample size.

Trends in linearity, or not, were noted, with the clear need to include juvenile specimen data in all samples. Generally, the relationship between otolith length versus otolith height seemed to be linear. Otolith length versus weight seemed to be non-linear (more obvious in the sample incorporating juvenile specimens). This is perceived in age determination as the continuing deposition of annular increments in the medial axis after cessation of deposition in the anterior-posterior axis. This comparison could be useful in revealing an older age range for a species, in absence of objective validation of age.

Objective measurements of fish length versus otolith weight suggested a tight, non-linear relationship. With the assumption that otolith weight continues to increase over time upon cessation of otolith length and height growth (suggested in this document), this comparison supports the notion that fish length cannot be utilized as an indication of age for yelloweye and quillback rockfishes. The non-linearity in otolith length versus otolith weight also reveals an inflection point that may correspond to growth transitions (from faster to slower over time) also demonstrated in somatic fish growth.

Preliminary graphical analyses suggest that size differences among management areas should be further explored: there may be population-specific growth of importance to managers.

Otolith index values were instructive and may prove useful in clarifying outliers in datasets. Otolith index values seemed to tighten relationships with other objective and subjective parameters.

Age data outliers, revealed by otolith index values and or otolith measurements, were suggested to result from variation in fish growth and not necessarily from ageing error.

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Table 1. Sample, age, and mean otolith size and variation in Southeast and Southcentral Region yelloweye rockfish, separated by management area and gender.

Management Area		*n*	Age Range	MEAN OTOLITH				MEAN BIAS			MEAN VARIANCE			STD DEV		
				Age	Length (mm)	Height (mm)	Weight (g)	Length (mm)	Height (mm)	Weight (g)	Length (mm)	Height (mm)	Weight (g)	Length (mm)	Height (mm)	Weight (g)
EYKT	females	44	20-90	41.8	19.86	9.77	0.49	0.340	0.183	0.019	0.1258	0.0281	0.0006	0.3547	0.1676	0.0246
	males	27	23-103	42.3	20.34	9.87	0.51	0.379	0.224	0.014	0.1217	0.0411	0.0002	0.3489	0.2026	0.0126
CSEO	females	50	17-110	37.1	18.89	9.14	0.43	0.388	0.188	0.014	0.1448	0.0410	0.0002	0.3805	0.2024	0.0141
	males	48	19-102	34.9	18.79	9.10	0.41	0.310	0.193	0.012	0.0949	0.0354	0.0001	0.3081	0.1880	0.0116
SSEI	females	41	18-97	50.9	18.51	9.25	0.46	0.354	0.182	0.015	0.1200	0.0300	0.0000	0.3400	0.1800	0.0160
	males	37	14-98	36.0	17.84	9.04	0.38	0.250	0.139	0.010	0.0502	0.0162	0.0274	0.2241	0.1273	0.1656
SCA	females	36	4-68	35.6	17.89	8.97	0.41	0.398	0.169	0.010	0.1700	0.0200	0.0100	0.4200	0.1500	0.1200
	males	31	2-65	33.4	17.76	8.90	0.39	0.450	0.215	0.012	0.1900	0.0400	0.0001	0.4300	0.2100	0.0100

Table 2. Sample, age, and mean otolith size and variation in Southeast Region quillback rockfish, separated by management area and gender.

Management Area		*n*	Age Range	MEAN OTOLITH				MEAN BIAS			MEAN VARIANCE			STD DEV		
				Age	Length (mm)	Height (mm)	Weight (g)	Length (mm)	Height (mm)	Weight (g)	Length (mm)	Height (mm)	Weight (g)	Length (mm)	Height (mm)	Weight (g)
CSEO	females	51	15 - 68	30.8	14.37	7.46	0.224	0.25	0.16	0.009	0.050	0.030	0.00007	0.230	0.180	0.008
	males	54	14 - 81	29.2	14.42	7.11	0.207	0.31	0.12	0.006	0.110	0.010	0.00003	0.330	0.110	0.005
SSEI	females	50	9-66	29.6	14.19	7.36	0.216	0.26	0.16	0.006	0.063	0.018	0.00003	0.250	0.136	0.006
	males	31	9-42	24.6	13.73	6.89	0.174	0.31	0.25	0.007	0.184	0.064	0.00011	0.429	0.253	0.010
NSEI	females	20	19 - 62	31.4	14.50	7.37	0.237	***	***	***	***	***	***	***	***	***
	males	9	18 - 61	28.9	14.45	7.47	0.228	***	***	***	***	***	***	***	***	***

Table 3. Symmetry in size of left versus right otoliths in individual yelloweye rockfish specimens from Southeast and Southcentral Regions in Alaska, differentiated by the paired t-test (α=0.05), separated by management area and gender.

Management Area		Paired t-test (two tail)			
		n	Length	Height	Weight
EYKT	females	30	0.71	0.41	0.92
	males	21	0.35	0.43	0.98
CSEO	females	36	0.68	0.09	0.95
	males	35	0.05	0.77	0.31
SSEI	females	40	0.20	0.07	0.94
	males	36	0.27	0.71	0.60
SCA	females	26	0.41	0.74	0.09
	males	24	0.85	0.06	0.50

Table 4. Symmetry in size of left versus right otolith in individual quillback rockfish specimens from Southeast Region, Alaska, differentiated by the paired t-test (α=0.05), separated by management area.

Management Area		Paired t-test (two tail)			
		n	Length	Height	Weight
CSEO	females	36	0.17	0.01	0.43
	males	48	0.12	0.03	0.54
SSEI	females	43	0.17	0.57	0.20
	males	26	0.92	0.10	0.31

Table 5. Fish and otolith measurement data for outliers tracked throughout figures.

Outlier	Species	Management Area	Fish Length (mm)	Fish Weight (kg)	Sex	Otolith Age (years)	Otolith Length (mm)	Otolith Height (mm)	Otolith Weight (g)	Otolith Index (wt/len)	Comment
A	YE	EYKT	695	7.57	female	47	20.12	11.15	0.559	0.0278	
B	YE	EYKT	725	7.82	female	53	22.00	11.05	0.702	0.0319	
C	YE	EYKT	670	5.24	male	103	22.11	11.04	0.904	0.0409	
D	YE	CSEO	670	6.18	female	48	21.65	10.59	0.626	0.0289	
E	YE	CSEO	675	7.07	female	110	22.30	10.03	0.729	0.0327	
F	YE	CSEO	680	5.29	male	102	23.21	10.28	0.890	0.0383	
G	YE	SSEI	560	2.80	female	94	20.78	10.36	0.723	0.0348	
H	YE	EYKT	630	4.65	male	30	21.00	9.31	0.454	0.0216	
I	YE	EYKT	605	4.84	female	65	20.96	9.53	0.461	0.0220	Left oto crystallized
J	YE	CSEO	445	1.93	female	48	17.62	8.55	0.326	0.0185	
K	QB	CSEO	355	0.85	female	21	13.73	6.69	0.317	0.0230	
L	QB	NSEI	410	1.26	female	61	16.79	8.60	0.364	0.0220	only 1 otolith
M	QB	NSEI	440	1.78	male	61	16.32	8.97	0.443	0.0270	only 1 otolith

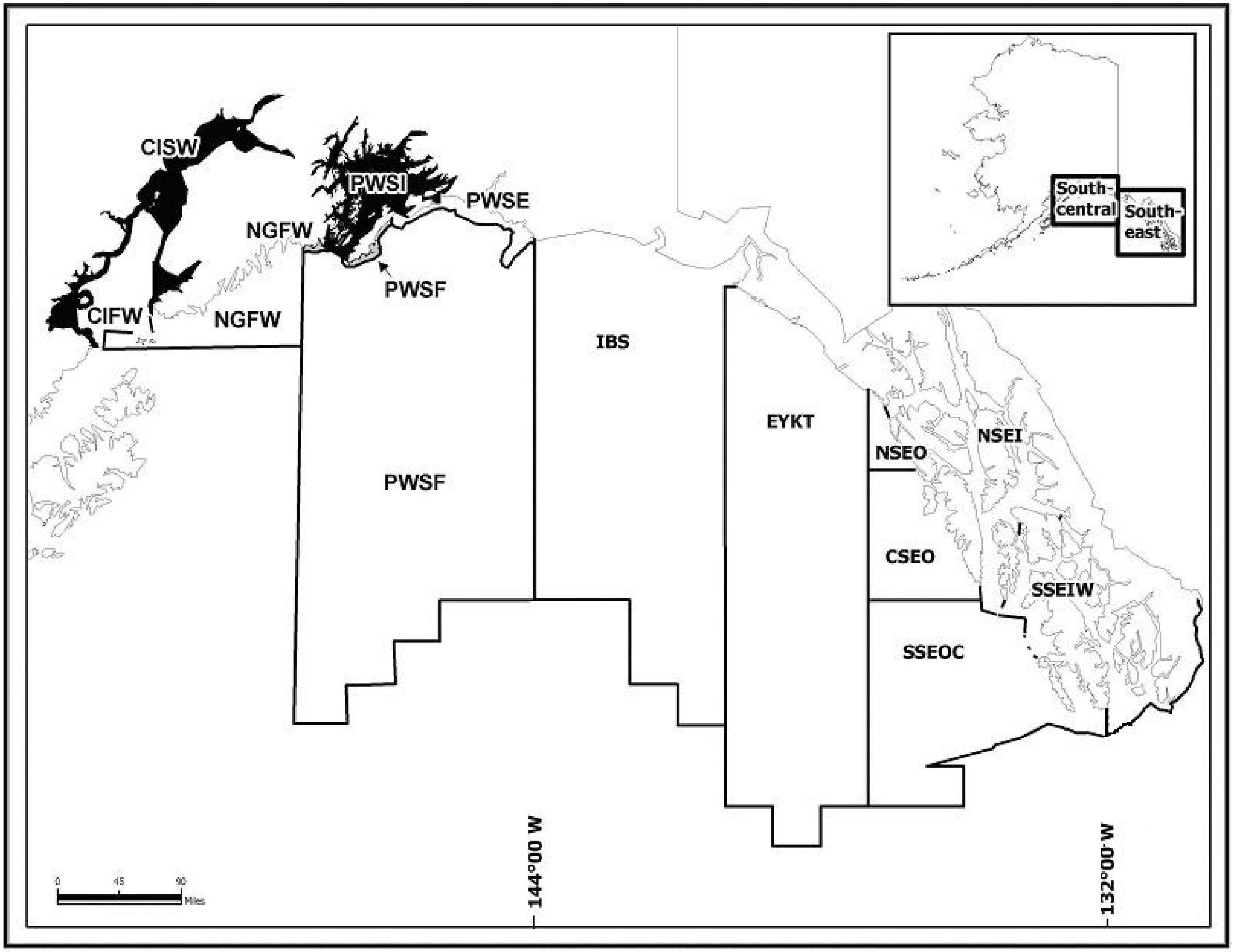

Figure 1. Map of Alaska identifying Southeast and Southcentral management areas.

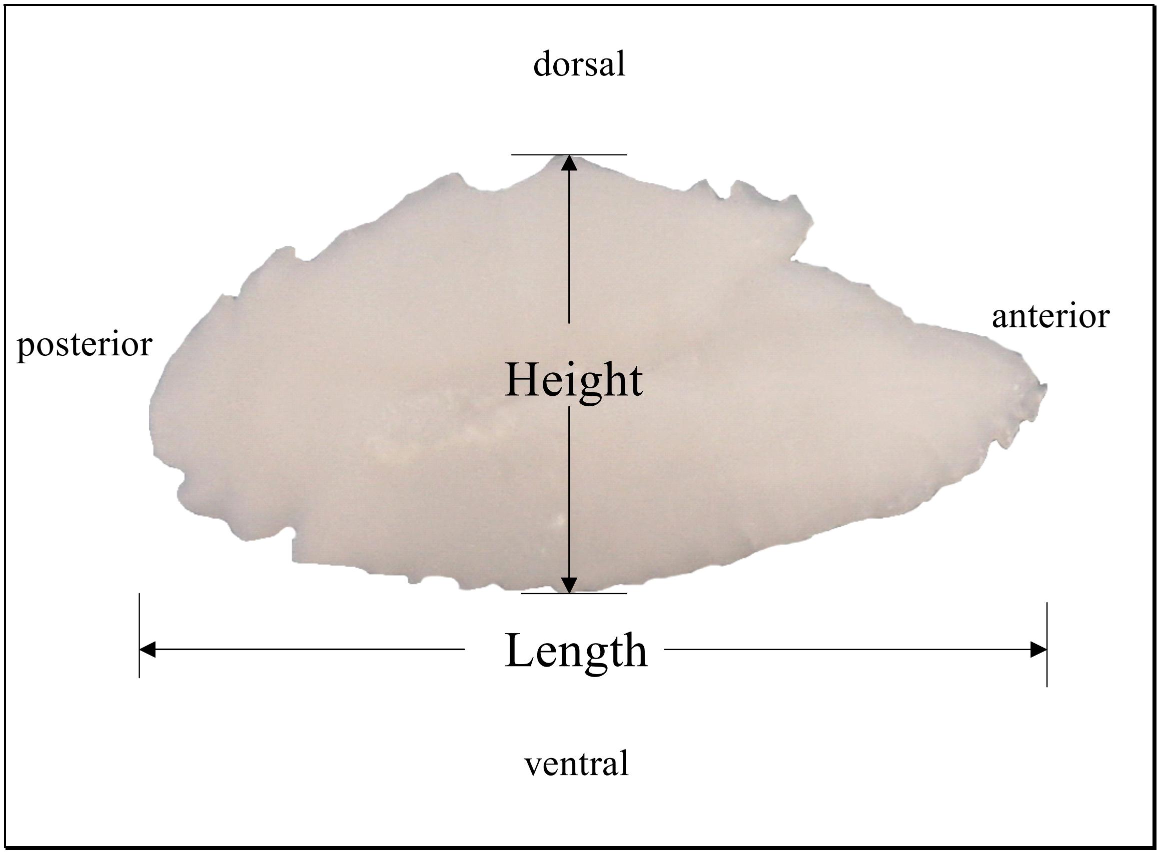

Figure 2. Sagitta otolith showing measurement axes for otolith length and otolith height.

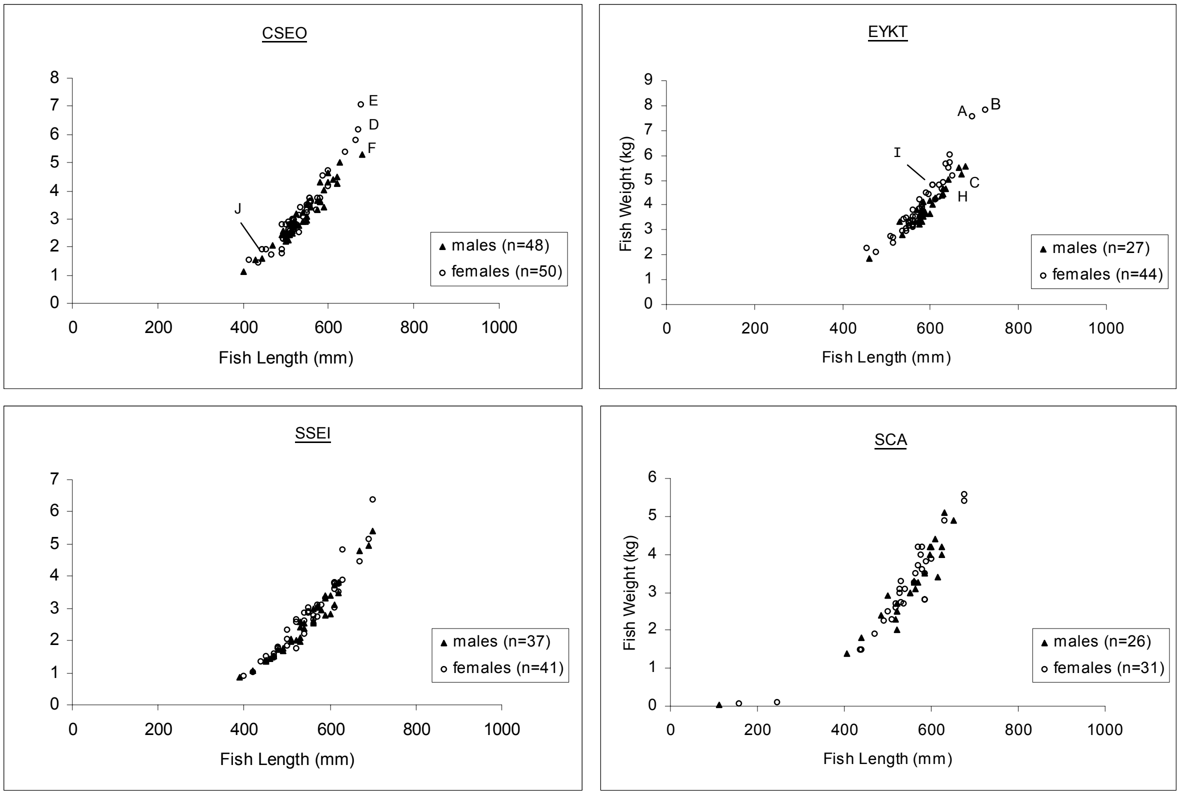

Figure 3. Yelloweye rockfish fish weight versus fish length, by management area and gender for port sample collection years 2000 and 2001.

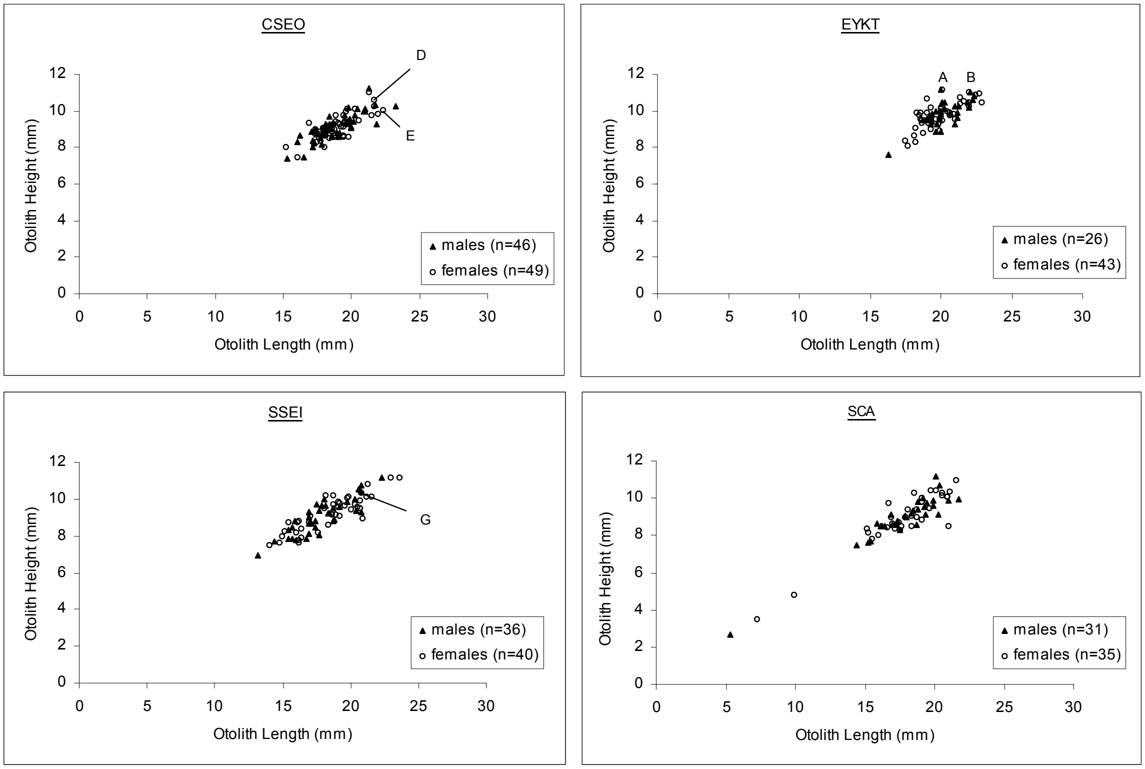

Figure 4. Yelloweye rockfish otolith height vs. otolith length, by management area and gender for port sample collection years 2000 and 2001.

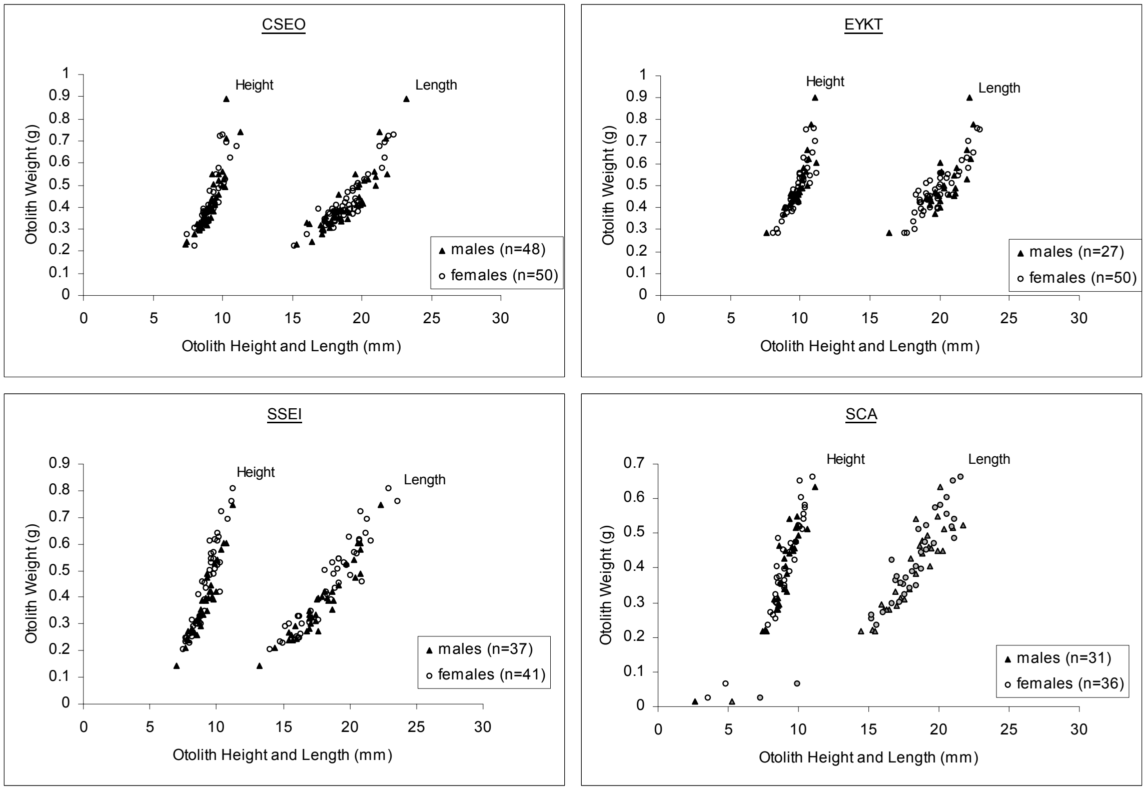

Figure 5. Yelloweye rockfish otolith weight versus otolith height and length, by management area and gender for port sample collection years 2000 and 2001.

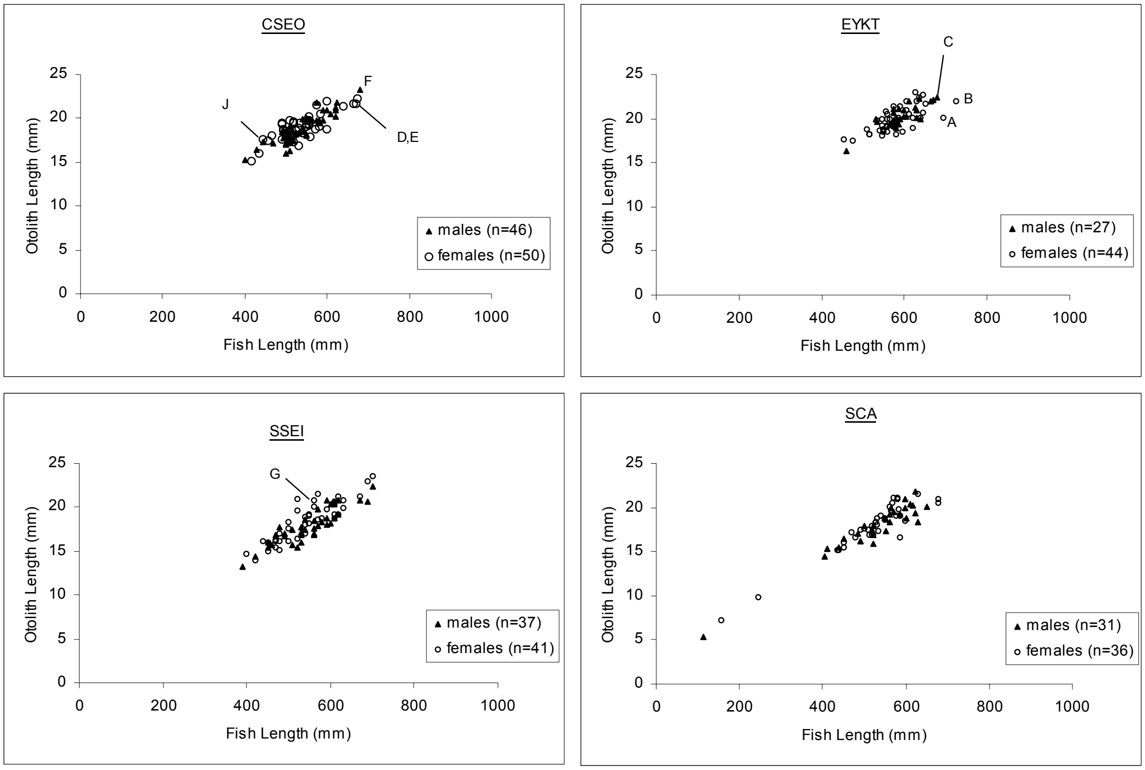

Figure 6. Yelloweye rockfish otolith length versus fish length, by management area and gender for port sample collection years 2000 and 2001.

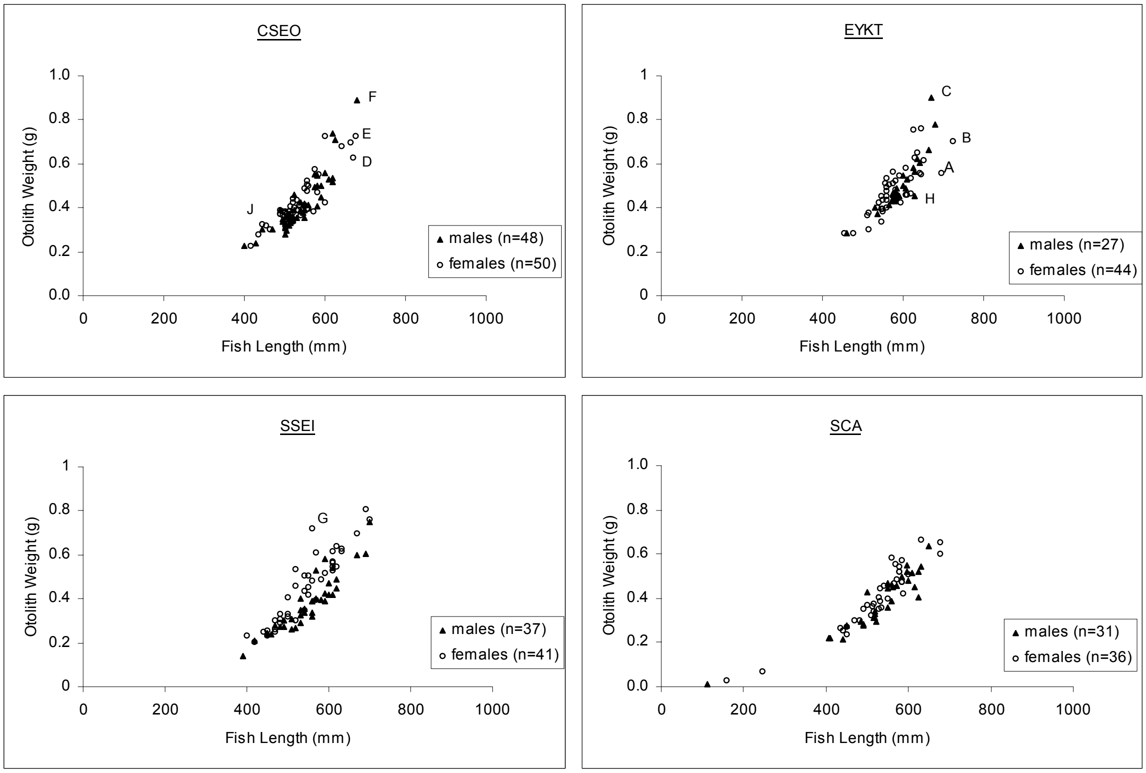

Figure 7. Yelloweye rockfish otolith weight versus fish length, by management area and gender for port sample collection years 2000 and 2001.

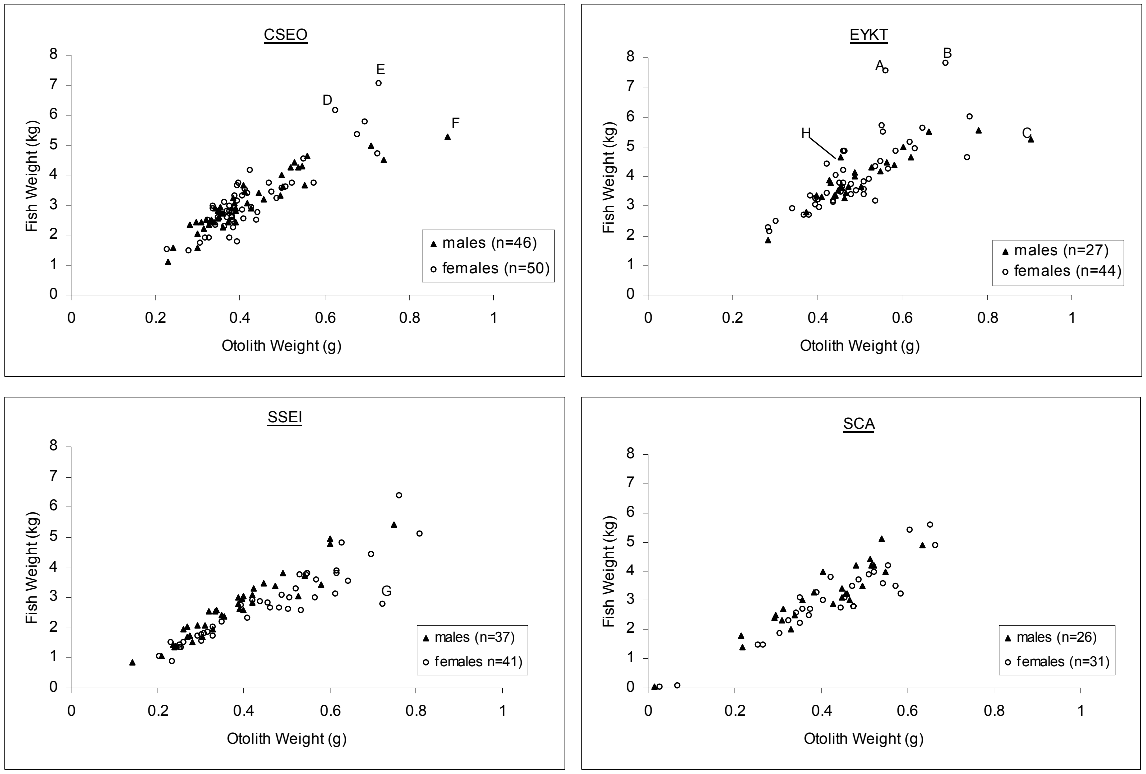

Figure 8. Yelloweye rockfish fish weight versus otolith weight, by management area and gender for port sample collection years 2000 and 2001.

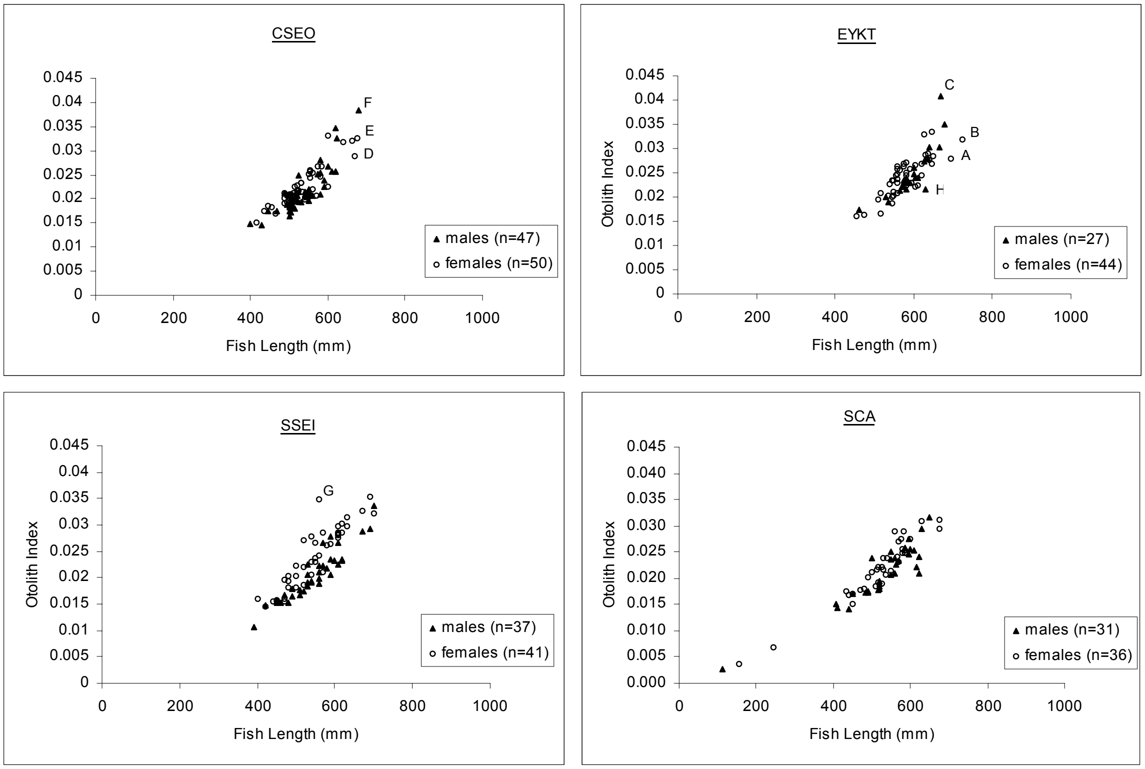

Figure 9. Yelloweye rockfish otolith index versus fish length, by management area and gender for port sample collection years 2000 and 2001.

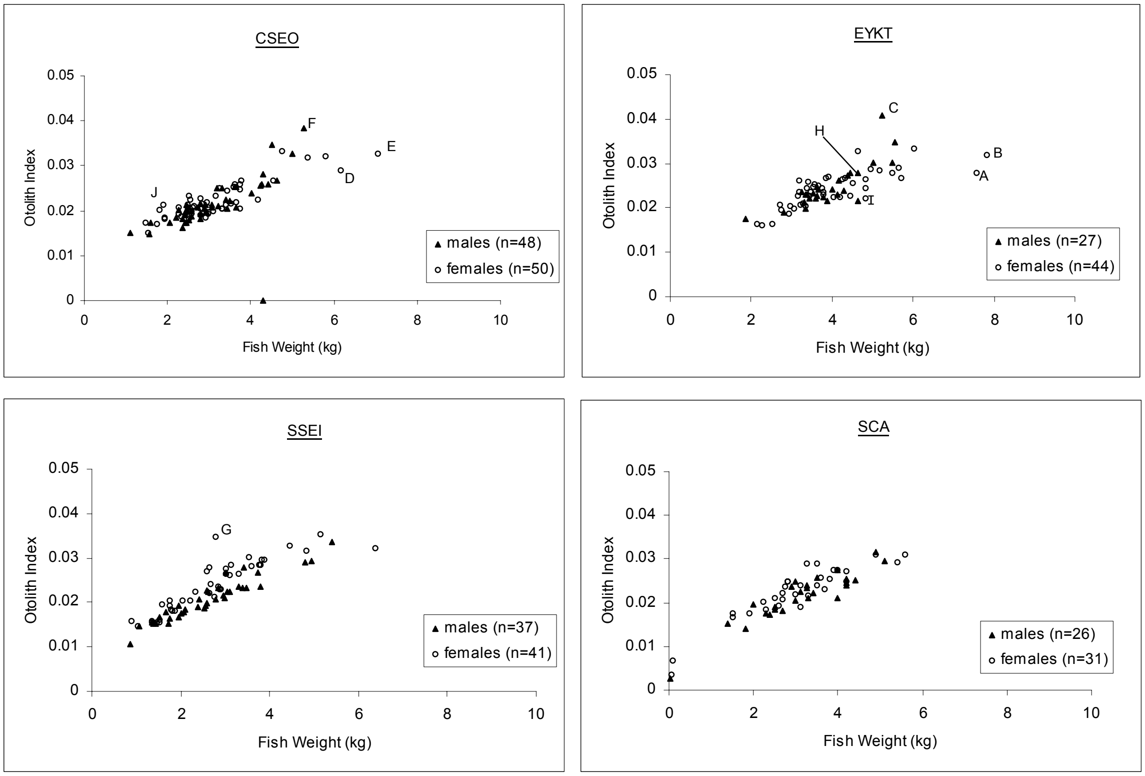

Figure 10. Yelloweye rockfish otolith index versus fish weight, by management area and gender for port sample collection years 2000 and 2001.

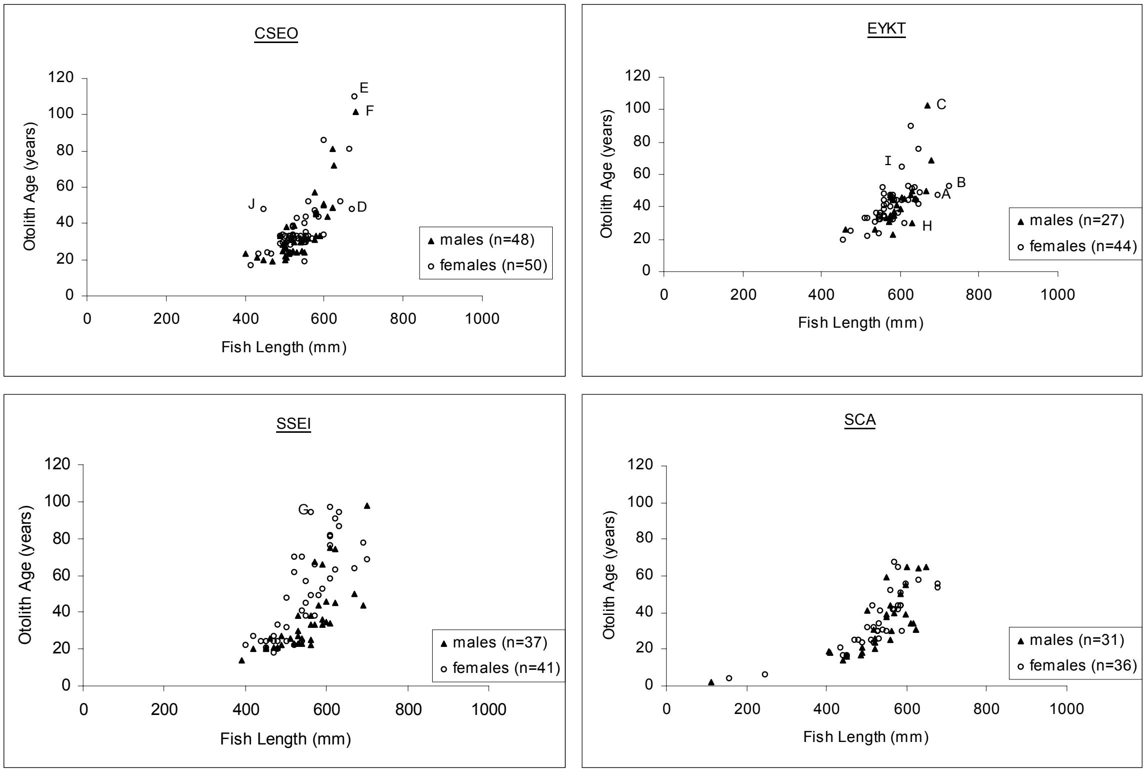

Figure 11. Yelloweye rockfish estimated otolith age at fish length, by management area and gender for port sample collection years 2000 and 2001.

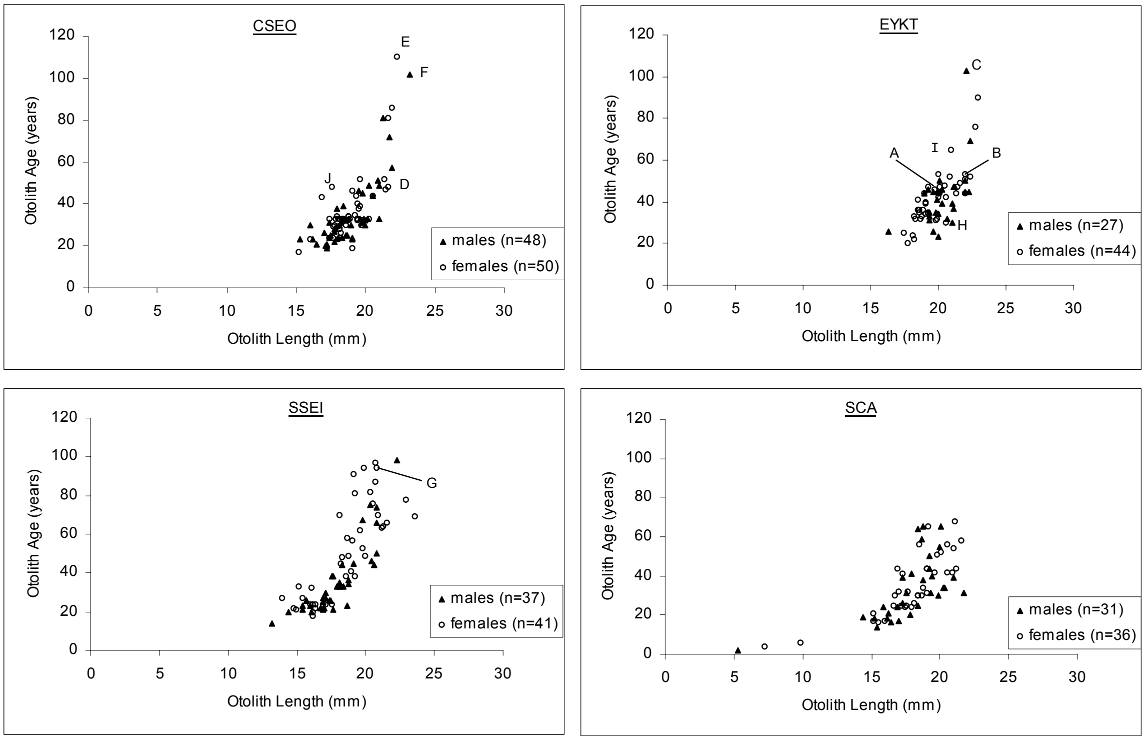

Figure 12. Yelloweye rockfish estimated otolith age versus otolith length, by management area and gender for port sample collection years 2000 and 2001.

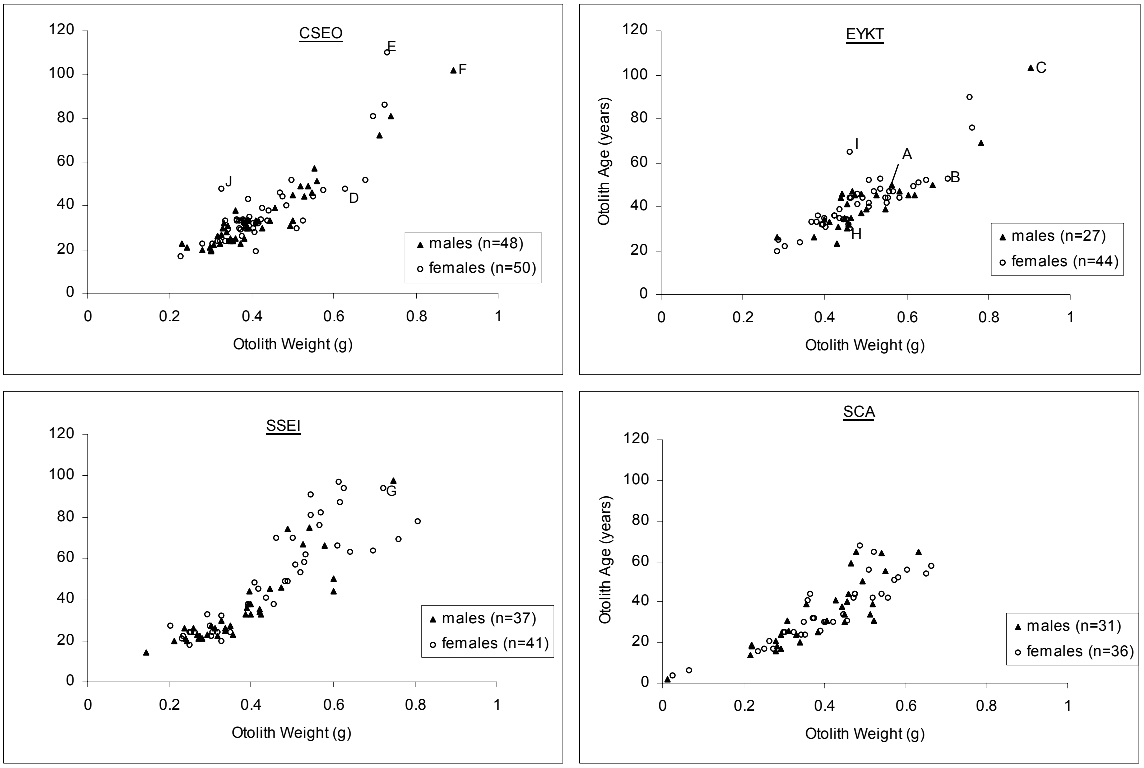

Figure 13. Yelloweye rockfish estimated otolith age versus otolith weight, by management area and gender for port sample collection years 2000 and 2001.

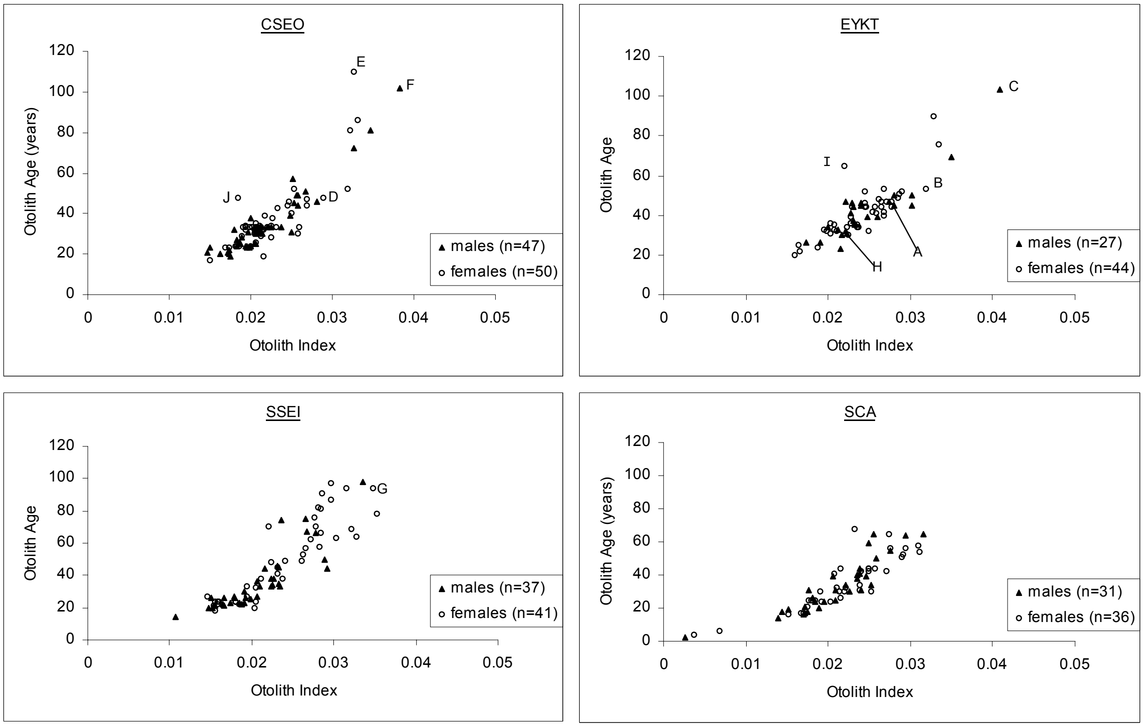

Figure 14. Yelloweye rockfish estimated otolith age versus otolith index, by management area and gender for port sample collection years 2000 and 2001.

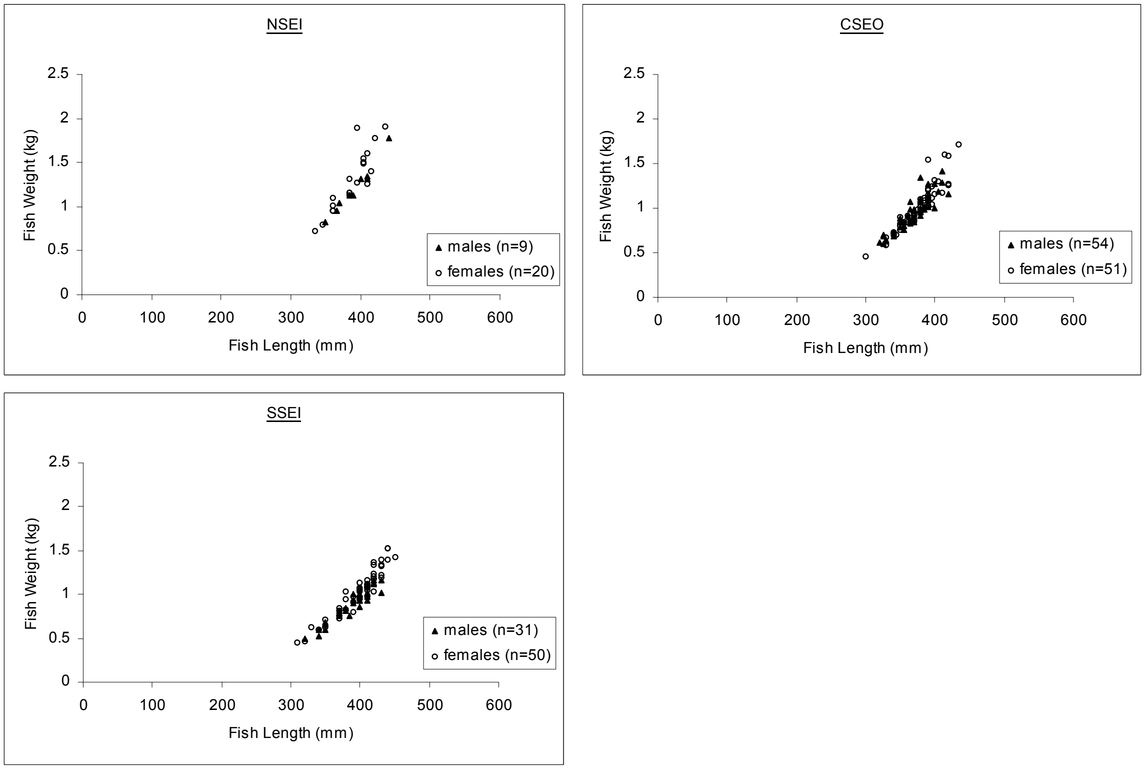

Figure 15. Quillback rockfish fish weight versus fish length, by management area and gender for port sample years 2000, 2001,and 2002.

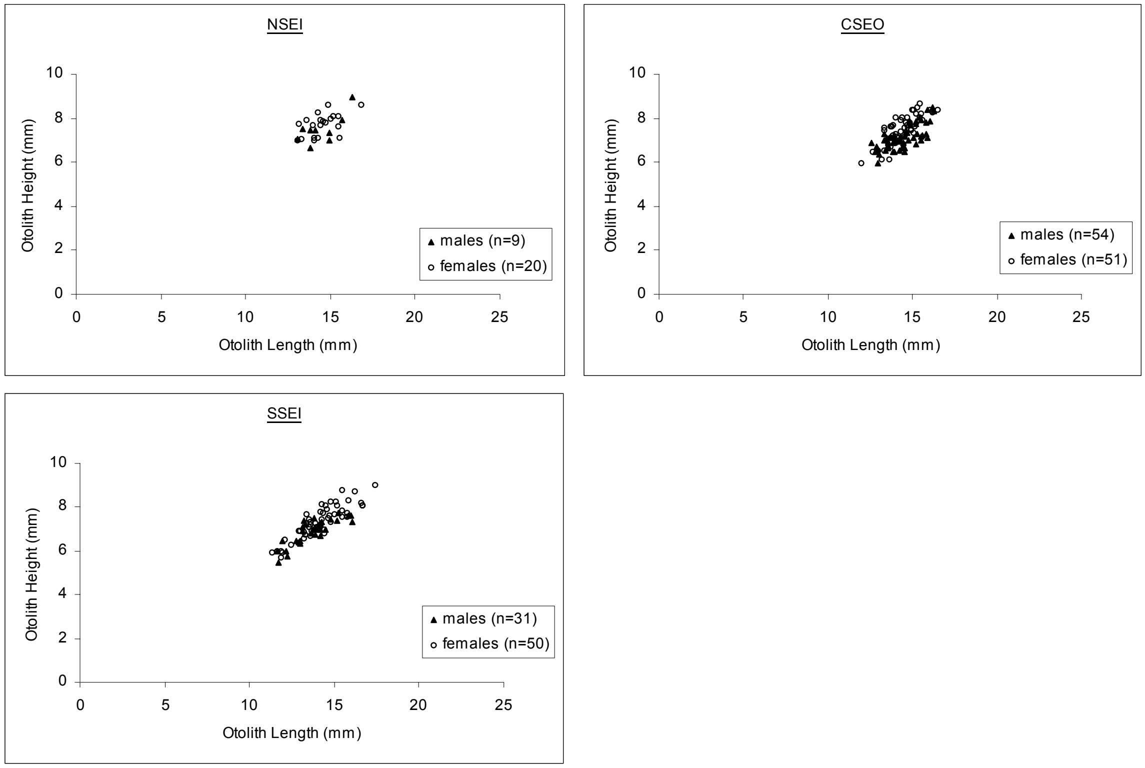

Figure 16. Quillback rockfish otolith height versus otolith length, by management area and gender for sample years 2000, 2001, and 2002.

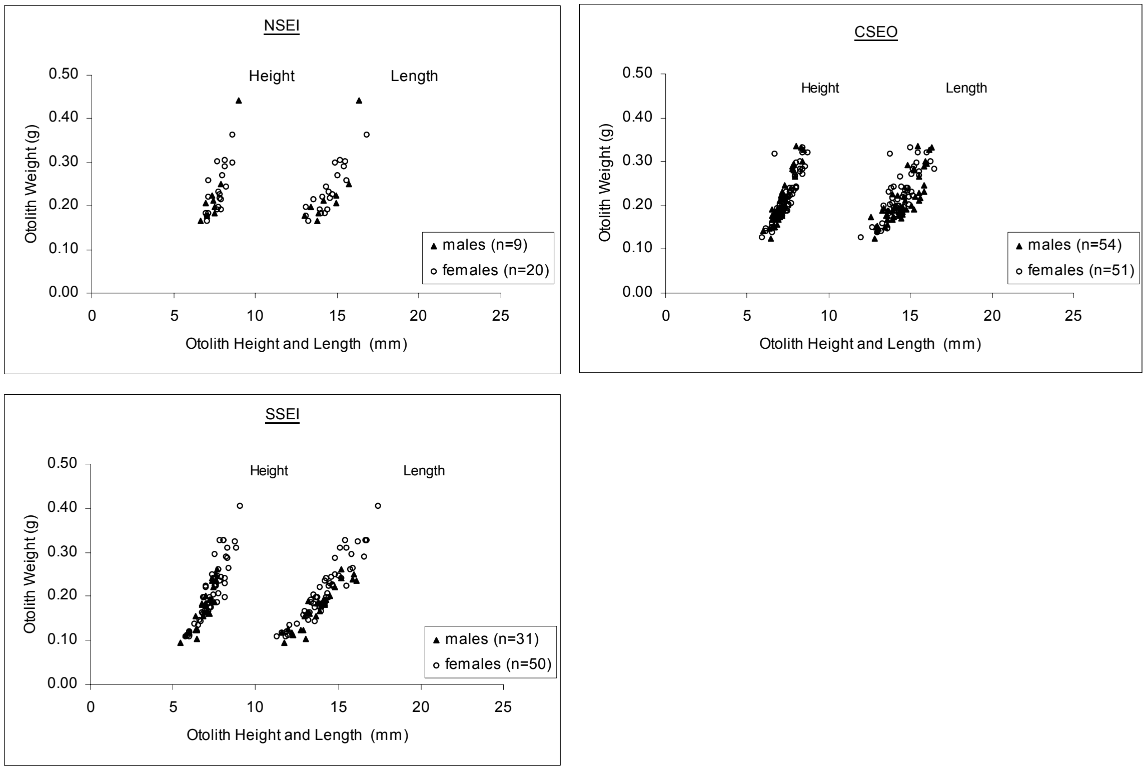

Figure 17. Quillback rockfish otolith weight versus otolith height and length, by management area and gender for sample years 2000, 2001, and 2002.

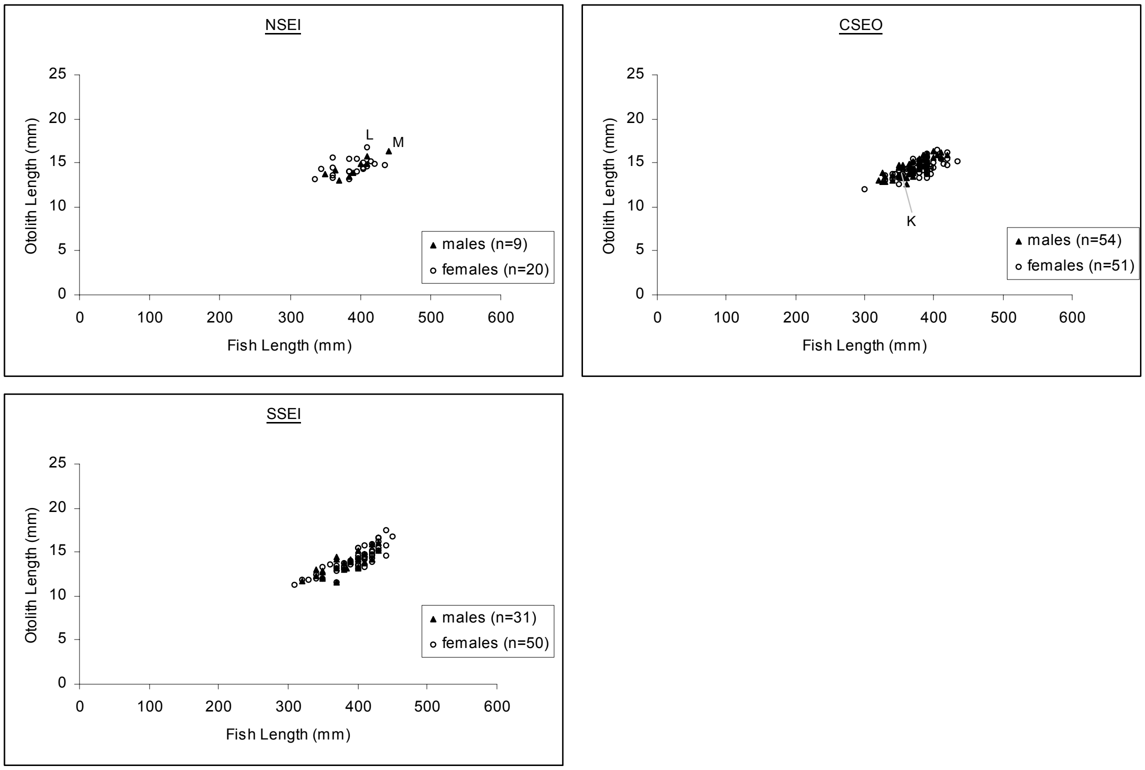

Figure 18. Quillback rockfish otolith length versus fish length, by management area and gender, for port sample years 2000-2002.

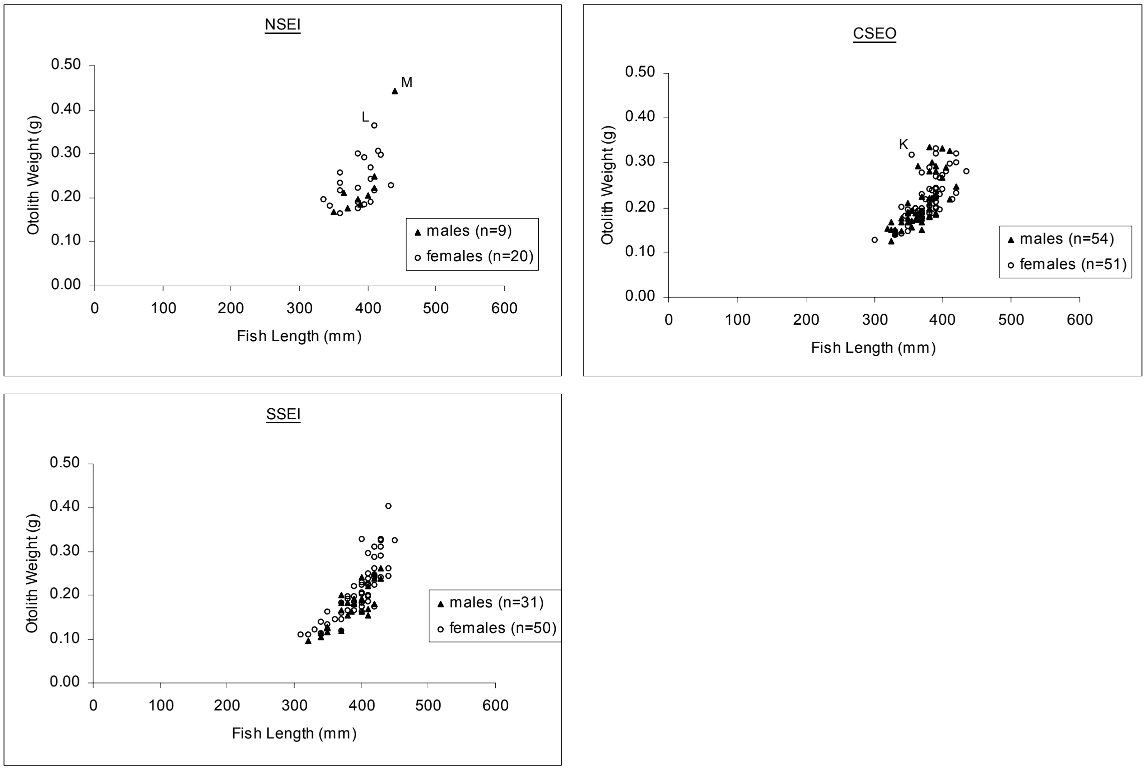

Figure 19. Quillback rockfish otolith weight versus fish length, by management area and gender, for port sample years 2000-2002.

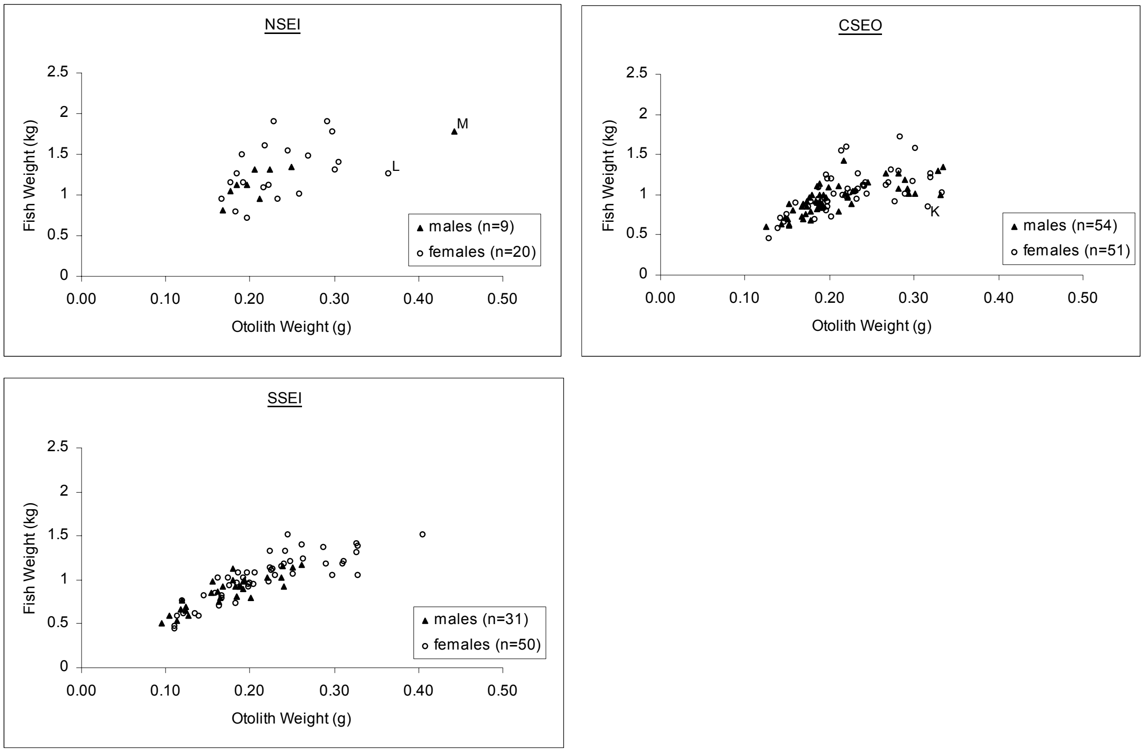

Figure 20. Quillback rockfish fish weight versus otolith weight, by management area and gender, for port sample years 2000-2002.

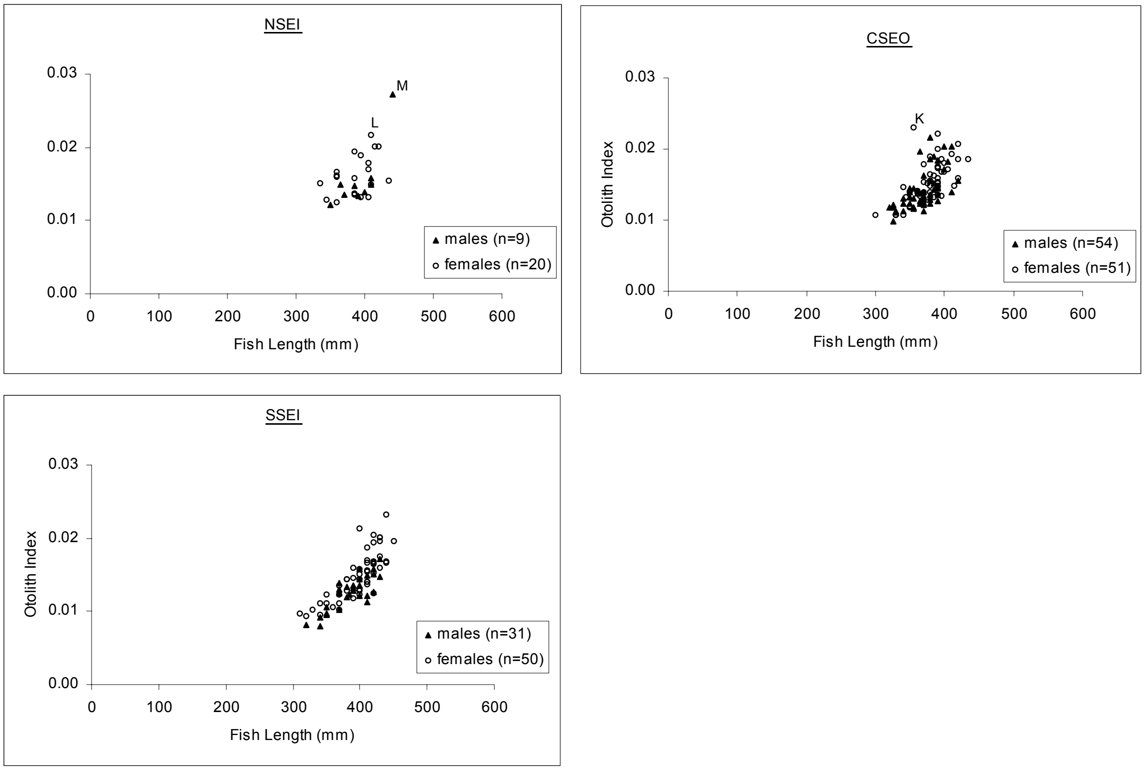

Figure 21. Quillback rockfish otolith index versus fish length, by management area and gender, for port sample years 2000-2002.

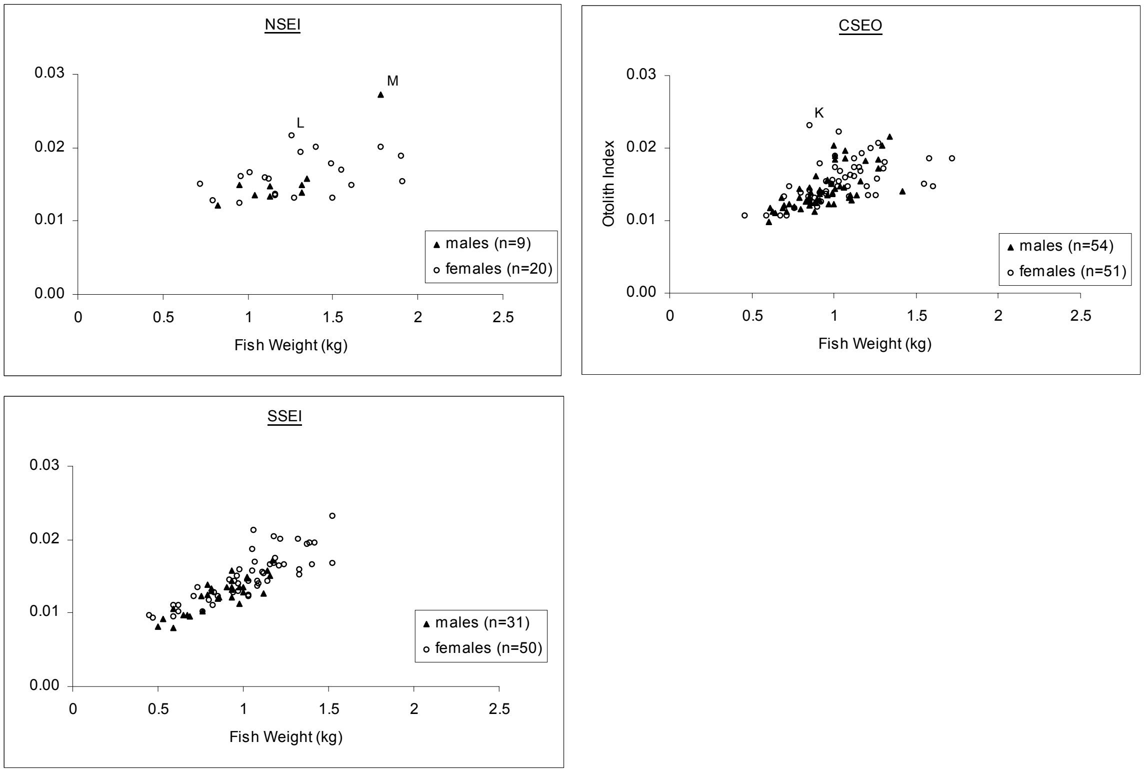

Figure 22. Quillback rockfish otolith index versus fish weight, by management area and gender, for port sample years 2000-2002.

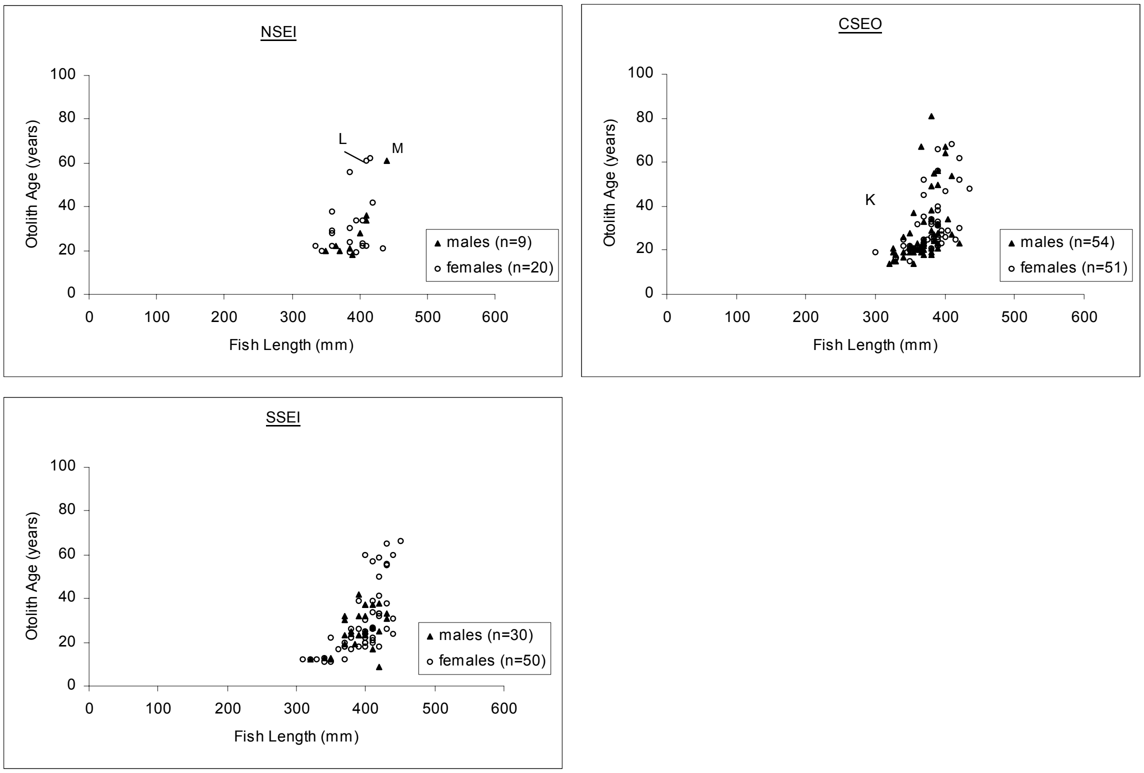

Figure 23. Quillback rockfish estimated otolith age at fish length, by management area and gender for port sample years 2000-2002.

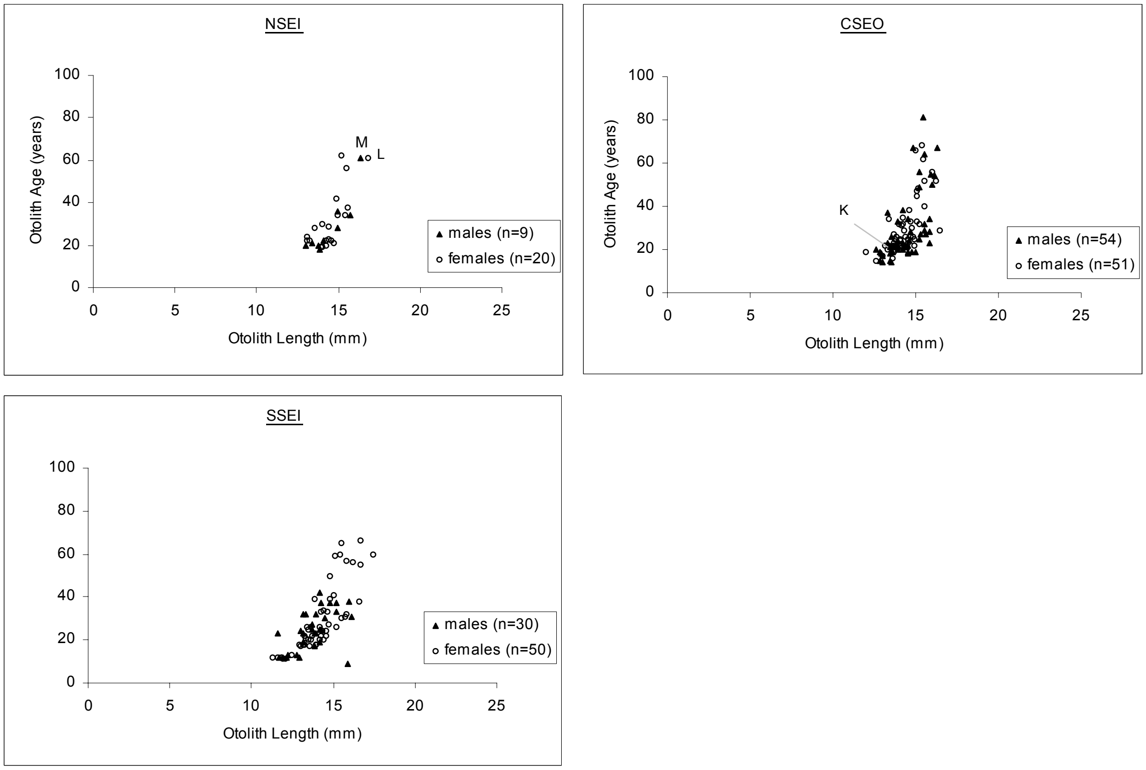

Figure 24. Quillback rockfish estimated otolith age at otolith length, by management area and gender for port sample years 2000-2002.

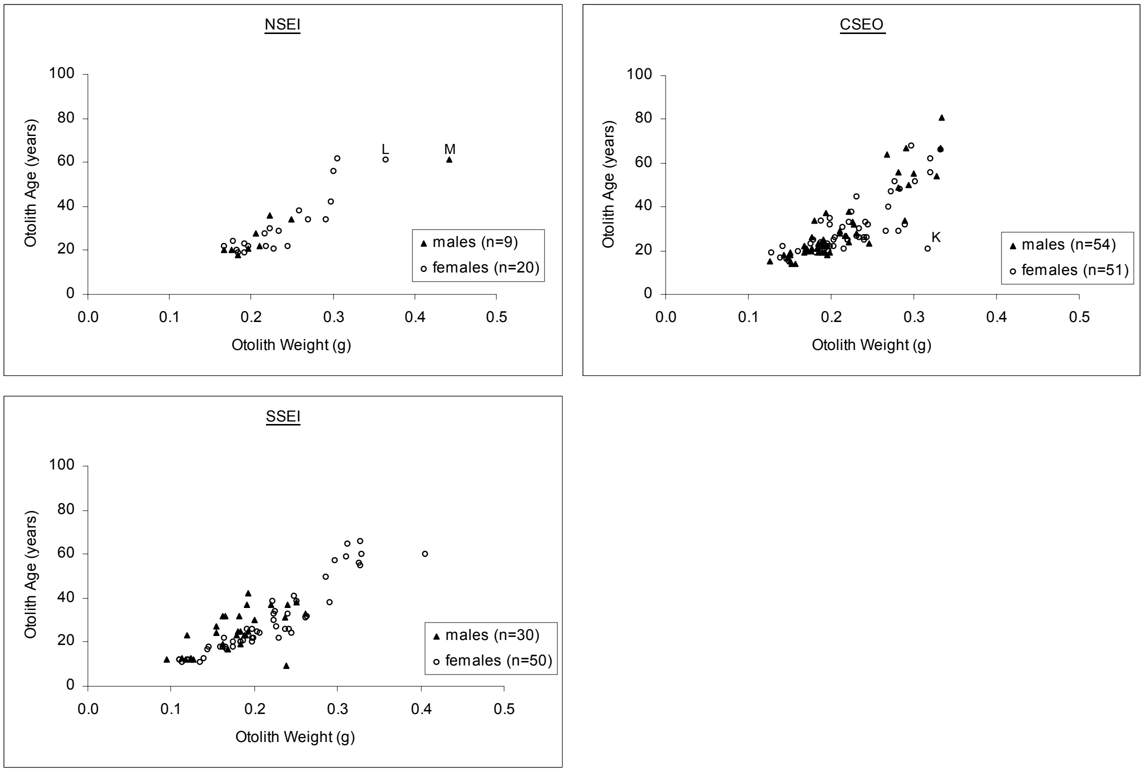

Figure 25. Quillback rockfish estimated otolith age at otolith weight, by management area and gender for port sample years 2000-2002.

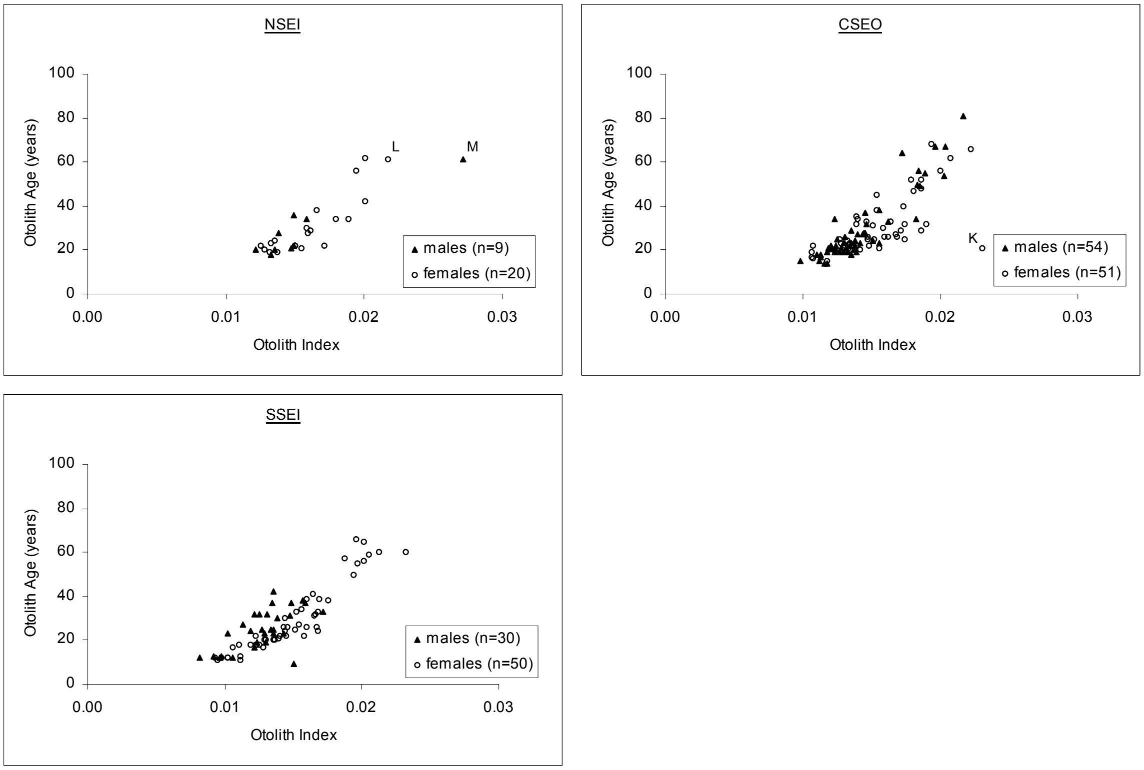

Figure 26. Quillback rockfish estimated otolith age at otolith index, by management area and gender for port sample years 2000-2002.