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Title: ANALYSIS OF AGE DETERMINATION METHODS FOR YELLOWTAIL ROCKFISH, CANARY ROCKFISH, AND BLACK ROCKFISH OFF OREGON

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Methods and utility of age determination of yellowtail rockfish (Sebastes flavidus), canary rockfish (Sebastes pinniger), and black rockfish (Sebastes melanops) collected off Oregon during 1972 to 1975 are discussed. Structures compared on the basis of the reproducibility of counts of annuli (consistency of readings) were the anal fin pterygiophore, opercle, otolith, scale, and vertebra. The effect of deviations between otolith readings on survival estimates and age-length relationships is presented. Consistency of otolith readings is generally superior to other structures for these three species. For yellowtail, canary, and black rockfish, respectively, 71, 76, and 77% of two independent otolith readings deviated by no more than ± 1 assumed annulus. Consistency of otolith readings of all three species decreases with age. Chapman-Robson and catch curve estimates of survival and age-length relationships, derived from two

readings of the same otolith, are not significantly different at the 95% level for any of the species.

Analysis of Age Determination Methods for Yellowtail Rockfish, Canary Rockfish, and Black Rockfish Off Oregon

by

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
METHODS AND MATERIALS	4
RESULTS AND DISCUSSION	8
Suitability of Structures for Age Determination	8
Consistency of Readings	8
Validity of the Otolith Method	20
Otolith Treatments	22
Scanning Electron Microscopy	24
Crystallization of Otoliths	28
Effect of Deviations of Otolith Readings on Biological Statistics	29
Age Composition	29
Survival	33
Age-Length Relationship	36
LITERATURE CITED	52
APPENDICES	58

LIST OF TABLES

Table		Page
1.	Structures examined from yellowtail, canary, and black rockfish with a description of their suitability for age determination.	9
2.	Estimations of age, number of readable structures, and percent agreement of two independent readings of five structures sampled from 35 yellowtail rockfish landed February, 1975, in Newport, Oregon.	10
3.	Estimations of age, number of readable structures, and percent agreement of two independent readings of five structures sampled from 35 canary rockfish landed January, 1975, in Newport, Oregon.	10
4.	Estimations of age, number of readable structures, and percent agreement of two independent readings of five structures sampled from 35 black rockfish landed November, 1974, in Newport, Oregon.	10
5.	Percent agreement between first and second readings of the same structure and between first readings of different structures (otoliths and scales) sampled from the same yellowtail, canary, or black rockfish caught off Oregon, 1974-75.	12
6.	Deviations of age estimations made from otoliths by reader B from those by reader A for 322 yellowtail rockfish captured off Oregon during 1973-74.	13
7.	Deviations of second age estimations from first age estimations from otoliths made independently by reader A for 481 canary rockfish captured off Oregon during 1972 and 1974.	15
8.	Deviations of second age estimations from first age estimations from otoliths made independently by reader A for 357 black rockfish captured off Oregon during 1973-75.	16

Table		Page

9. Percent utilization of marginal areas of otoliths used for age determination of three species of rockfish captured off Oregon during 1972-75. 18

10. Percent agreement of three independent otolith readings of yellowtail rockfish caught off Oregon, 1972. 20

11. Percent agreement between first and second readings of whole otoliths and between first and second readings of sectioned otoliths, and percent agreement between first readings of whole and sectioned otoliths of canary rockfish caught off Oregon, 1974. 23

12. Treatments applied to otoliths and scales of yellowtail, canary, and black rockfish captured off Oregon during 1972-75. 25

13. Survival estimates based on two independent readings of the otoliths of yellowtail, canary, and black rockfish landed in Oregon, 1973-74. 35

14. Lengths-at-age of male yellowtail rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-74. 38

15. Lengths-at-age of female yellowtail rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-74. 39

16. Constants of the age-length relationship $L = cA^b$ for yellowtail rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-74.

17. Lengths-at-age for male canary rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1972 and 1974. 43

18. Lengths-at-age for female canary rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1972 and 1974. 44

Table		Page
19.	Constants of the von Bertalanffy equation for canary rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1972 and 1974.	45
20.	Lengths-at-age for male black rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-75.	47
21.	Lengths-at-age for female black rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-75.	48
22.	Constants of the von Bertalanffy equation for black rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-75.	50

Appendix Table		Page
1.	Sex, length, age, and depth of capture of 23 yellowtail rockfish with crystallized otoliths caught off Oregon, 1972-74.	58
2.	Sex, length, age, and depth of capture of 27 canary rockfish with crystallized otoliths caught off Oregon, 1972-74.	59
3.	Sex, length, age, and depth of capture of 29 black rockfish with crystallized otoliths caught off Oregon, 1973-75.	60

LIST OF FIGURES

Figure		Page
1.	Drawing of the right otolith (sagitta) from a 4-year old black rockfish as seen under reflected light on a dark background showing the marginal areas used in age determination (O-opaque zone; H-hyaline zone).	17
2.	Scanning electron micrographs of yellowtail rockfish otolith sections showing (A) concentric rings (X100); (B) rings appearing as split and discontinuous grooves (X400) and (C) $CaCO_3$ crystals (X3000).	26
3.	Age composition of 322 yellowtail rockfish obtained by two independent readings of their otoliths; specimens were collected from fish processing plants in Astoria and Coos Bay, Oregon, 1973-74.	30
4.	Mean (vertical line), range (horizontal line), standard deviation of the mean (white bar), and 95% confidence intervals about the mean (black bar) for two otolith age readings of yellowtail, canary, and black rockfish landed in Oregon, 1973-74.	31
5.	Age composition of 353 canary rockfish obtained by two independent readings of their otoliths; specimens were collected from fish processing plants in Astoria and Coos Bay, Oregon, 1974.	32
6.	Age composition of 242 black rockfish obtained by two independent readings of their otoliths; specimens were collected from fish processing plants in Astoria and Coos Bay, Oregon, 1974.	34
7.	Age-length relationships for yellowtail rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-74.	37
8.	Age-length relationships for canary rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1972 and 1974.	42
9.	Age-length relationships for black rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-75.	46

ANALYSIS OF AGE DETERMINATION METHODS FOR YELLOWTAIL ROCKFISH, CANARY ROCKFISH, AND BLACK ROCKFISH OFF OREGON

INTRODUCTION

This thesis reports on an analysis of methods for age determination of yellowtail rockfish (Sebastes flavidus), canary rockfish (Sebastes pinniger), and black rockfish (Sebastes melanops). In 1973, yellowtail, canary, and black rockfish comprised 41, 38, and 4%, respectively, of the total Oregon commercial trawl catch of rockfish consisting of 19 species; moreover, total rockfish landings in 1973 comprised 25% of the total trawl landings (Oregon Department of Fish and Wildlife,[1] unpublished data). Because little is known of the biology of these fishes, the need exists for basic life history data as a basis for better management of these species. Information on age, and on length and weight, are needed for estimates of mortality, growth, and ultimately yield.

The investigation was based on analysis of samples taken off Oregon from 1972 to 1975. The overall objective was to determine if an acceptable technique(s) could be developed for age determination of yellowtail, canary, and black rockfish occurring in waters off Oregon. Specific objectives were: (1) to determine if counts of

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[1] Formerly the Fish Commission of Oregon.

annuli on aging structures can be reproduced consistently; and (2) to determine if deviations between successive counts of annuli significantly affect estimates of survival and the age-length relationships.

General references on aging of fish are Graham (1929), Chugunova (1963), and Bagenal (1974). Blacker (1974) gives an excellent review on the use of otoliths, Lee (1920), Van Oosten (1929), and Regier (1962) discuss the scale method, while Menon (1950) reports on the use of bones for age determination of fish.

Considerable effort has been expended on age determination of commercially important species of Sebastes in the North Atlantic. Perlmutter and Clarke (1949) used scales to age juvenile redfish (S. marinus), but did not include older fish in the study because of difficulty in discerning annuli. Kelly and Wolf (1959) reported complete agreement (100%) between independent readings of redfish otoliths with less than ten annuli, but agreement between readings for fish from 7 to 20+ years was only 31%. Sandeman (1961) used scales for juvenile redfish (< 5 years), but found otoliths to be superior for older fish. Further aging studies were conducted on S. marinus by Kotthaus (1961), Surkova (1961), and Kosswig (1971), on S. viviparus by Trout (1961a), and on S. mentella by Trout (1961b), and Kosswig (1971).

The majority of work done on the biology of rockfish of the North Pacific Ocean was conducted on the Pacific ocean perch,

S. alutus (Westrheim, 1958; Gritsenko, 1963; Lyubimova, 1964; Chikuni and Wakabayashi, 1970; Chikuni, 1971 and 1975; Gunderson, 1974); little research has been done on yellowtail, canary, or black rockfish. Agreement between readings of Pacific ocean perch otoliths decreased from 100% for 0-zone otoliths to 26% for 19-zone otoliths (Westrheim, 1973). Phillips (1964) found both scales and otoliths gave valid age estimations for 10 species of California rockfish, including S. flavidus and S. pinniger, but used scales because they were obtained with less effort. Miller and Geibel (1973) preferred scales to otoliths for blue rockfish (S. mystinus) off California, because scales allowed greater ease in back-calculation of growth. Wales (1952), working on the same species, reported that scales were easier to read than otoliths. Chen (1971) found scales were frequently regenerated on rockfish of the subgenus Sebastomus, so he used otoliths for age determination.

Otoliths were used to age copper rockfish (S. caurinus) in Puget Sound (Patten, 1973) and northern rockfish (S. polyspinis) in the Gulf of Alaska (Westrheim and Tsuyuki, 1971). There are no published reports on the life history of S. melanops, although Miller (1961) indicated that the ages of several specimens were estimated.

METHODS AND MATERIALS

Most fish used in this study were sampled from the commercial trawl landings in Astoria and Coos Bay, Oregon, from 1972 to 1975. Sex, length to the nearest centimeter, and weight to the nearest gram were recorded, and one or both saccular otoliths (sagittae) were extracted. Anal fin pterygiophores (largest), opercles, otoliths, scales, and several anterior vertebrae were sampled from carcasses obtained from fish processing plants in Newport, Oregon, from 1974 to 1975. Juvenile fish were collected on research cruises on the Oregon continental shelf from 1972 to 1974, and by SCUBA and by hook-and-line in Yaquina and Tillamook Bays from 1973 to 1975.

Otoliths were stored in a 50:50 solution of glycerine and water and read using reflected light on a dark background utilizing a binocular dissecting microscope at 10X. Otolith sections 0.3 mm thick were obtained with a Gillings-Hamco thin sectioning machine after being embedded in polyester casting resin. Scales were cleaned, dried, and mounted between glass slides or impressed on acetate cards and read using an Eberbach scale projector with a 48 mm objective. Opercles, pterygiophores, and vertebrae were heated in a detergent-water solution at 50 C for 20 min to remove adhering tissue and air-dried. Opercles were examined with the naked eye; pterygiophores and vertebrae were examined by use of a binocular dissecting microscope at 10X. In addition to the above, various other bony structures were examined along with different scale and otolith treatments reported to be successful for other species. These were found not to be useful for aging these three rockfish.

One year of the life of the fish was assumed to be represented by an opaque zone followed by a hyaline zone on otoliths (Kelly and Wolf, 1959; Westrheim, 1973; Blacker, 1974; Dark, 1975; Lear and Pitt, 1975) as well as on opercles, pterygiophores, and vertebrae. A scale annulus was defined as a zone of closely-spaced circuli (check) following a zone of widely-spaced circuli (Van Oosten, 1929; Tesch, 1968). True annuli are represented by pronounced hyaline zones on otoliths and bony structures and by pronounced checks on scales. Indistinct zones or zones that are split or discontinuous were considered accesory (false) annuli. A zone that obviously interrupts the periodicity of the pattern of zonation was considered to be accessory unless it occurred in many fish in the same sample.

Consistency of readings of aging structures was measured by the ability of the reader to reproduce successive, independent counts of annuli. To insure independence there was a period of several months between most otolith readings. When the period was less than two weeks, a five digit code number was assigned to each structure to prevent possible memorization of previous age estimations. Independent readings of yellowtail rockfish otoliths were made by two people, while those of canary and black rockfish were made by the same person.

Sectioned otoliths for scanning electron microscopy were etched for five min in 1% HCl, washed in water, dried, vacuum coated with Pd/Au, and observed using an International Scientific Instruments MINI-SEM scanning electron microscope, model MSM-2, operated at 15, 000 volts.

Age composition data were described graphically by FISHPLOT, a computer plotting routine based on the method of Hubbs and Hubbs (1953). Survival estimates were obtained by the Chapman-Robson (Robson and Chapman, 1961) and catch curve (Ricker, 1975) methods. The age-length relationship of yellowtail rockfish was described by the equation $L = cA^b$, where L = length (cm), A = estimated age (yr), and c and b are constants. The age-length relationships for canary and black rockfish were described by the von Bertalanffy growth-in-length equation with the computer program BGC-2 (Abramson, 1965) using the method of least squares weighted according to sample size (Tomlinson and Abramson, 1961).

A total of 71 young unsexed black rockfish, mostly young-of-the-year, was used in the age-length analysis. Their corresponding lengths were applied to both males and females, with the assumption that there were little or no sexual differences in length at these younger ages. The assumption was based on the fact that growth curves for male and female Pacific ocean perch obtained by Westrheim (1973) for fish from Oregon to British Columbia and by Gunderson (1974) for Washington samples, were nearly identical at ages less than six years.

RESULTS AND DISCUSSION

Suitability of Structures for Age Determination

Only five structures, the anal fin pterygiophore, opercle, otolith, scale, and vertebra, were suitable for estimation of age. The criterion used to determine suitability for aging was the presence of enumerable growth zones. Most structures examined did not satisfy this criterion because: (1) they were not sufficiently calcified to reveal distinct growth zones, or (2) calcification was evident but growth zones were not discernible (Table 1). The above five structures were examined further to determine whether successive, independent estimates of age were consistent.

Consistency of Readings

Percent agreement between two independent counts (readings) of assumed annuli by the same person on anal fin pterygiophores, opercles, otoliths, scales, and vertebral centra sampled from the same yellowtail, canary, or black rockfish is presented in Tables 2, 3, and 4. Agreement ±1 assumed annulus is also given. Agreement was low for all structures and species except otoliths of canary rockfish. This high agreement resulted from a preponderance of young fish (age 7) in the sample. Agreement between otolith readings for yellowtail and canary rockfish was superior to agreement between

Table 1. Structures examined from yellowtail, canary, and black rockfish with a description of their suitability for age determination.

Structure	Description
Anal fin pterygiophore	enumerable zones present
Anal spine	zones present, but not enumerable
Articular	insufficient calcification
Asteriscus	insufficient calcification
Basipterygium	zones present, but not enumerable
Ceratohyal	insufficient calcification
Cleithrum	zones present, but not enumerable
Dentary	zones present, but not enumerable
Epihyal	insufficient calcification
Hypurals	insufficient calcification
Interopercle	zones present, but not enumerable
Lachrymal	insufficient calcification
Lapillus	insufficient calcification
Maxilla	zones present, but not enumerable
Mesopterygoid	insufficient calcification
Neurocranial bones	insufficient calcification
Opercle	enumerable zones present
Pelvic fin rays	zones present, but not enumerable
Postcleithrum	insufficient calcification
Premaxilla	zones present, but not enumerable
Sagitta	enumerable zones present
Scale	enumerable zones present
Subopercle	insufficient calcification
Supracleithrum	zones present, but not enumerable
Vertebral centrum	enumerable zones present

Table 2. Estimations of age, number of readable structures, and percent agreement of two independent readings of five structures sampled from 35 yellowtail rockfish landed February, 1975, in Newport, Oregon.

Structure	Agreement (%) Exact	±1	Estimated age (yr) Min.-max.	Mean	No. readable
Anal pterygiophore	24	59	9-18	12.5	29
Opercle	-	-	-	-	3
Otolith	24	71	10-18	15.2	34
Scale	16	59	8-15	11.2	32
Vert. centrum	11	49	8-18	12.9	35

Table 3. Estimations of age, number of readable structures, and percent agreement of two independent readings of five structures sampled from 35 canary rockfish landed January, 1975, in Newport, Oregon.

Structure	Agreement (%) Exact	±1	Estimated age (yr) Min.-max.	Mean	No. readable
Anal pterygiophore	33	76	7-20	9.5	33
Opercle	10	48	4-18	7.8	31
Otolith	77	97	5-22	8.9	35
Scale	31	69	7-23	10.7	32
Vert. centrum	31	60	5-18	8.9	35

Table 4. Estimations of age, number of readable structures, and percent agreement of two independent readings of five structures sampled from 35 black rockfish landed November, 1974, in Newport, Oregon.

Structure	Agreement (%) Exact	±1	Estimated age (yr) Min.-max.	Mean	No. readable
Anal pterygiophore	19	66	5-18	9.6	32
Opercle	39	75	5-18	9.2	28
Otolith	40	74	6-15	10.7	35
Scale	23	61	7-16	10.7	31
Vert. centrum	14	54	6-18	10.3	35

readings of other structures, with 71 and 97% agreement ±1 assumed annulus, respectively. For the sample of black rockfish, otoliths and opercles were equally readable with 74 and 75% agreement ±1 assumed annulus, respectively.

Means of the two readings of the five structures agreed fairly well for black rockfish indicating that counts of assumed annuli on the structures were similar. Means were not similar for these structures from yellowtail and canary rockfish.

A number of samples of each structure were not read due to crystallization and breakage of otoliths, regeneration of scales, and poor calcification of opercles and pterygiophores. There were more readable vertebral centra and otoliths than any of the other structures. Many opercles were not readable, especially those sampled from yellowtail rockfish, where 32 of 35 could not be used for age determination.

Consistency of otolith and scale readings was compared in greatest detail. A chi-square test for paired data corrected for continuity revealed that exact agreement between otolith readings was significantly greater than exact agreement between scale readings for yellowtail ($P < 0.05$)[2] and black rockfish ($P < 0.005$) (Table 5). No significant difference between otoliths and scales for canary

[2]Probability of a greater chi-square value.

rockfish exists (P > 0.90). Percent agreement between first readings of each structure was low. Values for yellowtail, canary, and black rockfish were 53, 39, and 43% agreement ±1 assumed annulus, respectively.

Table 5. Percent agreement between first and second readings of the same structure and between first readings of different structures (otoliths and scales) sampled from the same yellowtail, canary, or black rockfish caught off Oregon, 1974-75.

	Within structures				Between structures		
	Otolith		Scale				
Species	Exact	±1	Exact	±1	Exact	±1	N
S. flavidus	42	80	26	60	14	53	89
S. pinniger	37	73	36	70	15	39	91
S. melanops	48	81	26	54	11	43	98

In terms of consistency of readings, the otolith is probably the best structure of those examined for age determination of yellowtail, canary, and black rockfish; yet, even this method is questionable. Deviations of yellowtail rockfish otolith readings by two readers generally increased with age of the fish (Table 6). Reader B tended to assign higher ages than reader A for the entire range of ages, as evidenced by the negatively skewed distribution of deviations. For canary rockfish otoliths read twice by the same person, deviations

Table 6. Deviations of age estimations made from otoliths by reader B from those by reader A for 322 yellowtail rockfish captured off Oregon during 1973-74.

Deviation	Estimated age																
(A-B)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
+5												1					1
+4												0	3				3
+3							1				1	0	0		1		3
+2							1	3	3	1	5	0	1	2			16
+1						4	5	7	11	7	4	3	2	1			44
0	0	0	0	5	5	13	13	20	20	9	3	2	3	1	0	1	95
-1	1	2	6	8	6	9	12	15	15	6	6	2	1				89
-2		0	1	3	3	7	9	3	6	5	5	1	0				43
-3		0		1	1	1	1	2	2	3	0	1	0				12
-4		1					2	2	0	2	1	3	1				12
-5									1	1							2
-6								1	0								1
-7									0								0
-8									1								1
T	1	3	7	17	15	34	44	53	59	34	25	13	11	4	1	1	322
%±1	100	67	86	76	73	76	68	79	78	65	52	54	55	50	0	100	71
%±2	100	67	100	94	93	97	91	91	93	82	92	62	64	100	0	100	89

of readings initially increased and then stabilized with increasing age (Table 7). The distribution of deviations is slightly skewed in the negative direction, indicating that the second reading was somewhat higher than the first. Deviations of readings of black rockfish otoliths read twice by the same person also increased with age of the fish (Table 8). The distribution of deviations is skewed considerably in the positive direction, indicating that the second reading was substantially lower than the first. For yellowtail, canary, and black rockfish, respectively, 71, 76, and 76% of the two readings deviated by no more than ±1 assumed annulus (Tables 6, 7, and 8). In a study on Pacific ocean perch by Westrheim (1973), 85% of two otolith readings by different people deviated by no more than ±1 zone. Kelly and Wolf (1959) reported 59.7% agreement ±1 year for otoliths of 7-20+ year-old redfish.

Several explanations exist for the observed deviations between readings. Due to the presence of split zones and the irregularity of the marginal areas on older rockfish otoliths, different readings may be obtained from different areas of the same otolith. There are eight major marginal areas that can be used in age determination (Figure 1); two or three generally give superior results depending on the species in question (Table 9). However, these favored areas are not consistently readable from one otolith to the next in any sample. Therefore, there is no specific area that can be used consistently on all the

Table 7. Deviations of second age estimations from first age estimations from otoliths made independently by reader A for 481 canary rockfish captured off Oregon during 1972 and 1974.

Deviation	Estimated age																							
$(R_1 - R_2)$	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
+5																		1						1
+4															1			2	1					4
+3								1	1						2		1	2						7
+2				1			5							2	5	3	2		1			3	1	23
+1			1	2	8	10	5	2	1	1	3	2	6	6	12	4	3	5						71
0	0	6	4	20	36	14	6	5	4	8	14	14	23	21	7	3	5	1	2	3	0	0	2	198
-1	1	3	1	6	2	1	3	1	1	4	8	16	20	8	8	2	4	2	2	1	2		1	97
-2							1		2	1	3	10	7	5	5	2	2	6		1				45
-3									2	3	4	1	3	2	2	1				1				19
-4											1			1	1	2				2				7
-5												1				1								2
-6							1				1			1	1						1			5
-7														1										1
-8																								
-9																								
-10																								
-11														1										1
T	1	9	6	29	46	25	21	9	11	17	34	44	59	48	44	18	17	19	6	8	3	3	4	481
%±1	100	100	100	97	100	100	67	89	55	76	74	73	83	73	61	50	71	42	67	50	67	0	75	76
%±2	100	100	100	100	100	100	95	89	73	82	82	95	95	88	84	78	94	74	83	63	67	100	100	90

Table 8. Deviations of second age estimations from first age estimations from otoliths made independently by reader A for 357 black rockfish captured off Oregon during 1973-75.

Deviation	Estimated age																			
$(R_1 - R_2)$	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
+7																			1	1
+6																		3		3
+5														1	2					3
+4										2	2	1		4	2	3	1	1	1	17
+3												2	4	4	1	3			1	15
+2								2	3	6	3	3	5	3	6	2	4			37
+1					3	2	2	1	4	9	7	6	7	7	3	1	1	1		54
0	43	45	5	1	5	2	6	13	8	14	13	13	11	6	4	1	1	0	0	191
-1		3	1			1	3		2	3	4	1	3	2	1	1				25
-2		1								1	1	1		2		1				7
-3												2	1							3
-4																				
-5													1							1
T	43	49	6	1	8	5	11	16	17	35	30	29	32	29	19	12	7	5	3	357
%±1	100	98	100	100	100	100	100	88	82	74	80	69	66	52	42	25	29	20	0	76
%±2	100	100	100	100	100	100	100	100	100	94	93	83	81	69	74	50	86	20	0	88

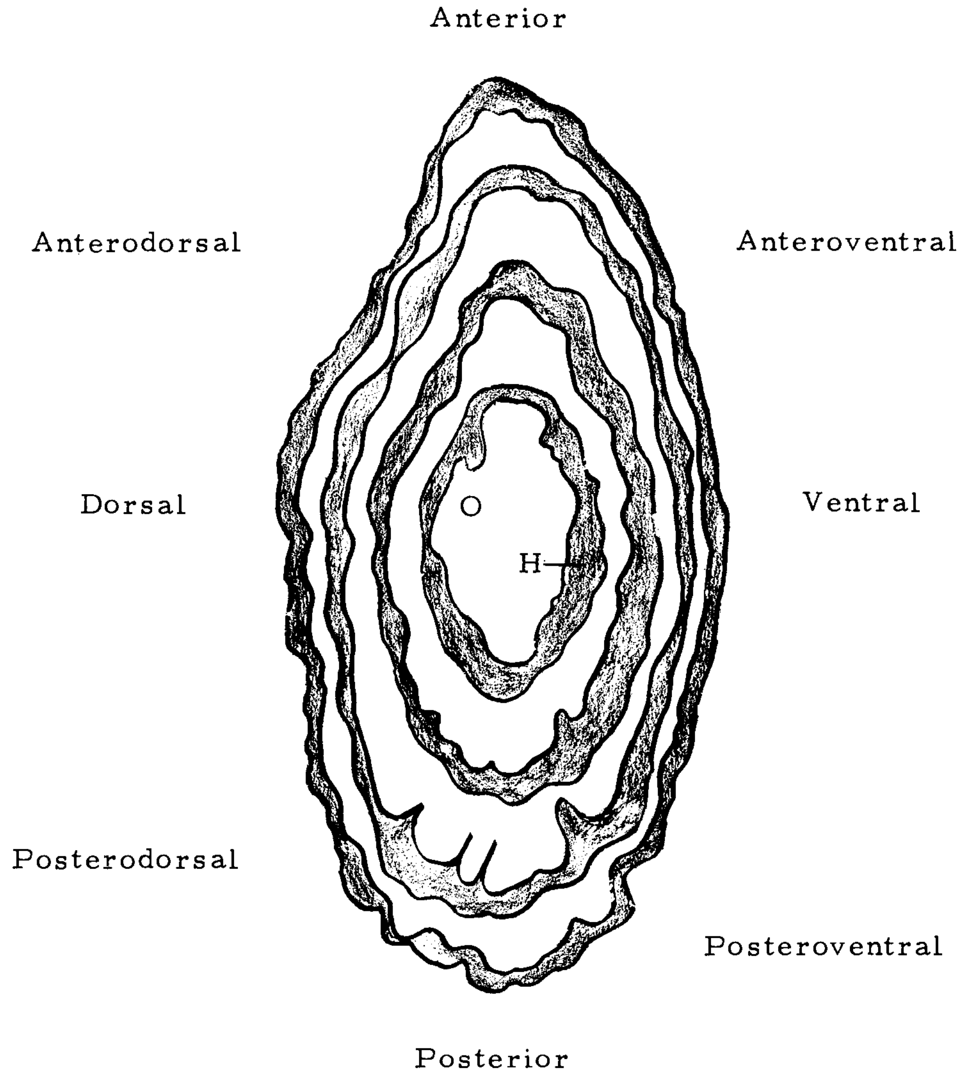

Figure 1. Drawing of the right otolith (sagitta) from a 4-year old black rockfish as seen under reflected light on a dark background showing the marginal areas used in age determination (O-opaque zone; H-hyaline zone).

Table 9. Percent utilization of marginal areas of otoliths used for age determination of three species of rockfish captured off Oregon during 1972-75.

Area	Species (%)		
	S. flavidus	*S. pinniger*	*S. melanops*
Anterior	56	1	48
Anterodorsal	8	17	7
Dorsal	9	37	21
Posterodorsal	4	20	6
Posterior	19	25	16
Posteroventral	4	1	3
Ventral	0	0	0
Anteroventral	1	0	0
Total otoliths	656	559	324

otoliths, making it possible that two different areas could be read on two independent readings of the same otolith. Indeed, a comparison of areas used by readers A and B for yellowtail rockfish otoliths shows that of the readings that disagreed, 71% were made on different areas of the otolith. Whereas, of the readings that agreed, only 56% were made on different areas.

Discrepancies in counts of annuli also are probably a function of the difficulty in defining the type of outer edge on otoliths. If an otolith had two opaque zones, each followed by a hyaline zone, plus an additional opaque zone on the outer edge, then an age of 2 was assigned. If an additional hyaline zone existed on the edge of the above otolith, then an age of 3 was assigned. But since the zones on the outer edge of older rockfish are indistinct because of slow growth at older ages, it is conceivable that discrepancies of one year could exist between independent readings of the same area of a particular otolith.

A third cause of discrepant counts is that entire samples of otoliths were often exceptionally opaque, or conversely, transparent, possibly due to the storage medium and/or length of storage. Annuli on otoliths such as these are difficult to distinguish.

One could question the use of only two readings to assess the consistency of otolith readings. Two counts may not be representative of the discrepancies that could exist. A third count could result in a different conclusion regarding the consistency of readings. To answer this question, a sample of 198 yellowtail rockfish otoliths was read independently three times with a week between readings. A chi-square test for independent data corrected for continuity indicated no significant differences among the three exact agreement statistics ($P > 0.95$) (Table 10). In this case, consistency of readings was not changed by the addition of a third reading.

Table 10. Percent agreement of three independent otolith readings of yellowtail rockfish caught off Oregon, 1972.

	Agreement between readings (%)		
	1 vs 2	2 vs 3	1 vs 3
Exact	32	34	30
±1	72	70	69

Validity of the Otolith Method

Until the data needed for validation can be collected, it is assumed for the purposes of this study that one opaque and one hyaline zone are laid down each year on otoliths of rockfish in Oregon. Van Oosten (1929) and Graham (1956) listed methods used to provide indirect evidence of the validity of age readings of scales and other structures. The commonly applied methods are observation of a dominant year-class over a period of years, and analysis of seasonal changes of the margin of some anatomical structure. Westrheim (1973) was able to follow the yearly progression of a dominant year-class of S. alutus for a period of several years and also demonstrated, by examination of the marginal zones on the otolith, that the hyaline zone is formed annually on juvenile fish. Kelly and Wolf (1959) found that one opaque and one hyaline zone are laid down each year on otoliths of young S. marinus. Dark (1975) presented strong evidence that one opaque and one hyaline zone are deposited each year on otoliths of young Pacific hake (Merluccius productus). Similar evidence exists for English sole, Parophrys vetulus (Palmen, 1956), rex sole, Glyptocephalus zachirus (Hosie, 1975), and Greenland halibut, Reinhardtius hippoglossoides (Lear and Pitt, 1975).

Unfortunately, similar tests could not be conducted in this study due to the absence of any obviously dominant year-classes in the fish sampled, and due to inadequate samples of young fish from a sufficient number of months throughout the year to permit demonstration of the seasonal changes in the margin of the otolith. As Dark (1975) discovered for older Pacific hake, otoliths from older rockfish are not suitable for this method, because zones on the outer edge are narrow and therefore difficult to distinguish until late in the growing season. Moreover, due to the irregular growth of otoliths of older rockfish, different marginal areas provide different results.

Otolith Treatments

Results indicate that consistency of otolith readings is superior to that of scales or other structures for the three species of rockfish, but agreement of otolith readings still may be unsatisfactory. Further treatments were applied to the otolith to try to improve consistency of readings. Sectioning of otoliths looked promising, especially for those from older fish whose otoliths become thick, opaque, and irregular in shape as age of the fish increases. Annuli are difficult to see when viewing the distal (external) surface of the whole otolith. Sectioning initially appeared to improve visibility of annuli. Moreover, Blacker (1974) noted that annuli are laid down only on the proximal (internal) surface of the otolith during later years in the life of fishes such as sole (*Solea solea*), plaice (*Pleuronectes platessa*), turbot (*Scophthalmus maximus*), redfish, and horse mackerel (*Trachurus trachurus*). Hence, these annuli are not seen when the distal surface of the otolith is used for age determination. The investigator thereby underestimates the age of the fish.

Exact agreement between readings of whole and sectioned otoliths of canary rockfish (37 vs 21%) differed by 16% (Table 11). A chi-square test for paired data corrected for continuity revealed that there was a significant difference between the two ($P < 0.025$).

Percent agreement between first readings of whole and sectioned otoliths was low with a value of 51% ±1 assumed annulus (Table 11). Mean estimated age of the two readings for each technique was 14.0 and 14.7 years for whole and sectioned otoliths, respectively. The similarity of the means indicates that the phenomenon reported by Blacker (1974) probably does not occur in canary rockfish otoliths. Ages were not substantially underestimated by reading the distal surface of the whole otolith.

Table 11. Percent agreement between first and second readings of whole otoliths and between first and second readings of sectioned otoliths, and percent agreement between first readings of whole and sectioned otoliths of canary rockfish caught off Oregon, 1974.

Agreement	Within technique		Between techniques
	Whole	Sectioned	(Whole vs sectioned)
Exact	37	21	21
±1	71	57	51
N	91	91	91
Mean est. age	14.0	14.7	

Sectioning did not improve consistency of readings of canary rockfish otoliths. Moreover, it is not possible to follow specific annuli completely around the sectioned otolith to determine if an assumed annulus is split. Whole otoliths allow the reader a choice of marginal areas to read, whereas sections do not.

Additional treatments were applied to otoliths and scales with little success. Table 12 lists these treatments along with a description and the result.

Scanning Electron Microscopy

Although scanning electron microscopy (SEM) is not practical for routine age determinations, it produces good resolution of surface structure on rockfish otoliths. SEM is an expensive and time consuming technique. Because obtaining a micrograph including all the annuli at a magnification high enough to resolve them is not practicable, the technique was eliminated as a practical tool for age determination. However, at sufficient magnifications ($\geq$ 100X), the surface structure of portions of the otolith can be seen in detail.

With the aid of SEM, Blacker (1975) demonstrated that the etched surface of a plaice otolith consisted of areas of numerous concentric rings followed by areas with few or no rings, and that these areas corresponded, respectively, to the hyaline (slow-growth) and opaque (fast-growth) zones of the same otolith viewed by reflected light. A similar pattern exists on otoliths of yellowtail rockfish (Figure 2A). The concentric rings appear as grooves which may be split or discontinuous (Figure 2B). These grooves are apparently the site of concentric organic lamellae found in the hyaline zone (Blacker, 1975). On the surface of the cut otolith one can see

Table 12. Treatments applied to otoliths and scales of yellowtail, canary, and black rockfish captured off Oregon during 1972-75.

Treatment	Description	Result
	Otoliths	
Baking	Lawler and McRae (1961)	Resolution not improved
Burning	Christensen (1964)	Difficult to obtain consistent effect
Scanning electron microscopy	Liew (1974), Blacker (1975)	Impracticable to view entire otolith in detail
Surface microscopy	Smith (1968)	Zones indistinct
Alizarin red S staining	In 1% KOH to obtain purple color	Stain not readily taken up
Methyl violet stain	Albrechtsen (1968)	Stain taken up, but zones indistinct
Silver nitrate stain	1% aqueous solution	Stain not taken up
	Scales	
Polarized light microscopy	Kosswig (1971)	Zones near focus indistinct

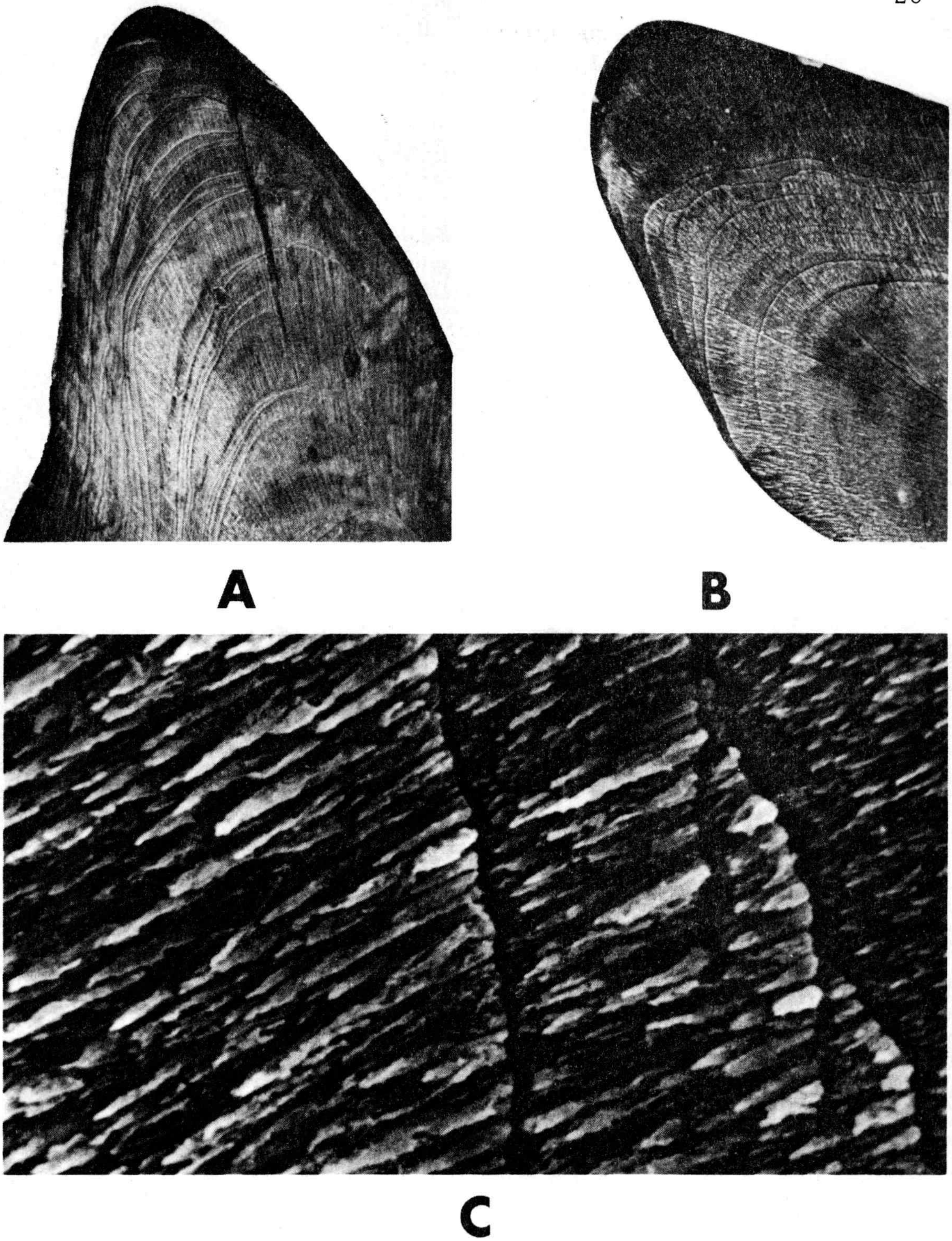

Figure 2. Scanning electron micrographs of yellowtail rockfish otolith sections showing (A) concentric rings (X100); (B) rings appearing as split and discontinuous grooves (X400) and (C) $CaCO_3$ crystals (X3000).

calcium carbonate ($CaCO_3$) crystals (Hickling, 1931; Degens et al., 1969; Liew, 1974) that run perpendicular to and are interrupted by the concentric grooves (Figure 2C).

If the composition of the zones on rockfish otoliths is similar to that of plaice, then it follows that all or most of the organic material is laid down in the hyaline or slow-growth zone. This may be due to a decreased rate of calcium deposition during the slow-growth season, and a resulting increase in the proportion of organic material deposited. Irie (1960) found that the calcification rate of otoliths of Mylio macrocephalus decreased as temperature decreased and the calcification rate of Lateolabrax japonicus otoliths decreased as food consumption decreased. A decrease in temperature and food consumption is generally associated with the slow-growth season. Panella (1971) reported that both $CaCO_3$ and organic material were deposited during fast- and slow-growth seasons on otoliths of Merluccius bilinearis, Urophycis chuss, and Gadus morhua, but the ratio of organic to inorganic constituents was higher in the slow-growth zone.

The differences in composition of the zones as evidenced by this and other studies may explain the opaque-hyaline nature of annuli on otoliths. The higher proportion of inorganic material ($CaCO_3$) in the fast-growth zone may be responsible for its relative opacity, while the relative transparency of the slow-growth zone could be explained by a higher proportion of organic material and/or a decrease in calcification.

Crystallization of Otoliths

At least one of the two otoliths was partially or completely crystallized in 23 of 1116 (2.1%) yellowtail rockfish, 27 of 666 (4.1%) canary rockfish, and 29 of 302 (9.6%) black rockfish. The occurrence of this phenomenon was not specific to a certain sex or to a particular length, age, or depth range (Appendix Tables 1, 2, and 3). Only one of the two otoliths usually was affected, but both were crystallized in some cases.

Rockfish otoliths may be unreadable due to crystallization, because the normal structure is either partly or completely obscured. Palmork and Taylor (1963) reported that the $CaCO_3$ of crystallized otoliths of cod (*Gadus morhua*) is in the form of calcite or a combination of calcite and vaterite. Normal teleost otoliths contain $CaCO_3$ in the form of aragonite (Carlstrom, 1963). Causes of crystallization are not known. It has been found to occur in many fishes of varying habitat and geographical distribution and in juveniles as well as adults.[3]

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[3] Personal communication, letter dated 4 June 1975 from John E. Fitch, California Department of Fish and Game, 350 Golden Shore, Long Beach, California 90802.

Effect of Deviations of Otolith Readings on Biological Statistics

Age Composition

The frequencies of two independent readings of yellowtail rockfish otoliths made by different readers generally correspond for ages 9 to 15 (Figure 3). Correspondence is lower for younger and older age groups. The two distributions are approximately normal with means of 12. 2 and 12. 8 years, respectively. Figure 4 graphically demonstrates that the means are not significantly different, because the 95% confidence intervals for the means overlap. For the two distributions, the standard deviations are similar and the ranges are equal, but the minimum and maximum values disagree by one year (Figure 4).

Frequencies of age readings for canary rockfish derived from two independent readings by the same person correspond over most of the ranges of ages (Figure 5). Discrepancies are apparent at ages 11, 14, and 20, however. Again, the distributions are approximately normal with means of 13. 6 and 14. 2 years for first and second readings, respectively. The means are not significantly different at the 95% level (Figure 4). The standard deviations are similar, while the maximum ages disagree by two years.

Otolith reading frequencies for two independent readings by the

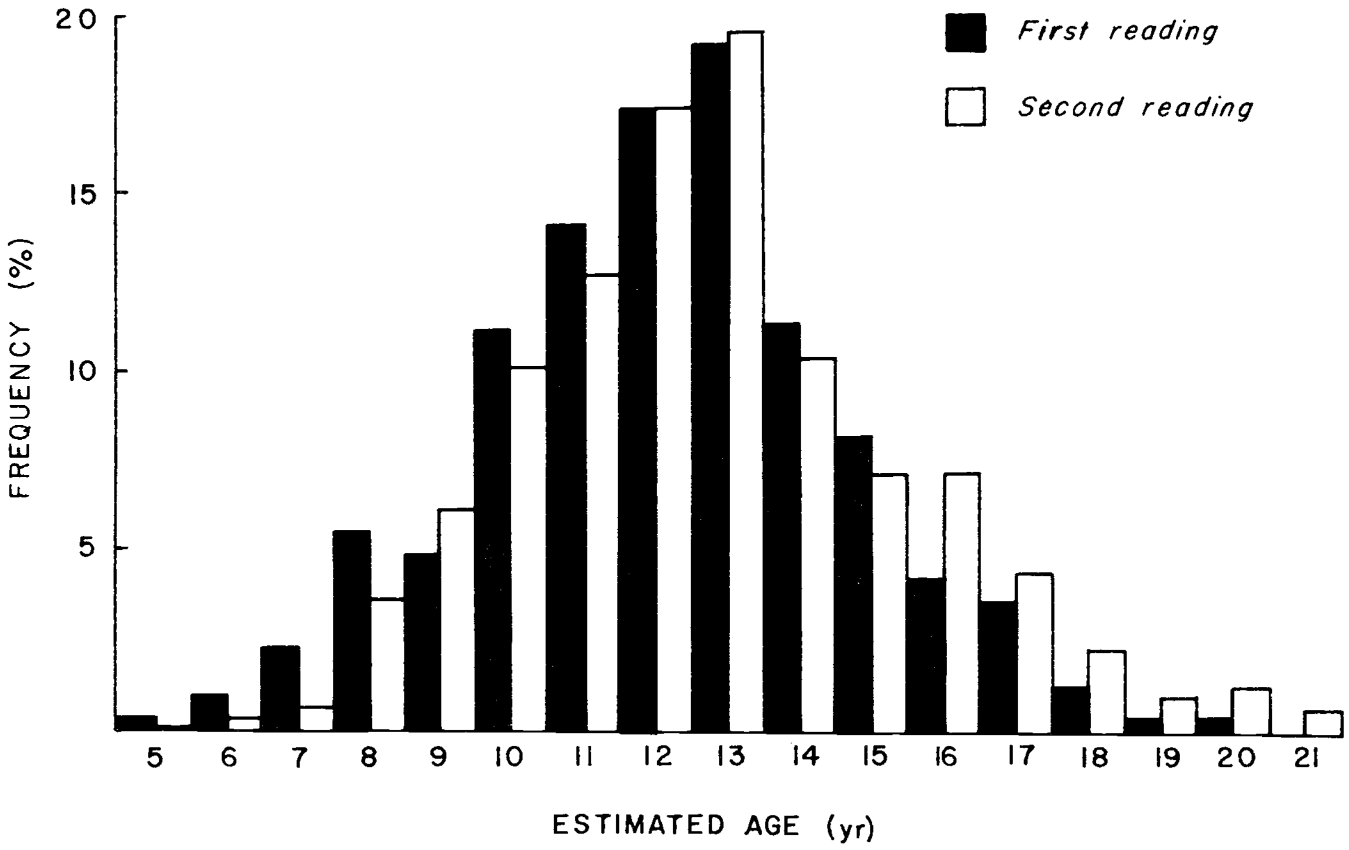

Figure 3. Age composition of 322 yellowtail rockfish obtained by two independent readings of their otoliths; specimens were collected from fish processing plants in Astoria and Coos Bay, Oregon, 1973-74.

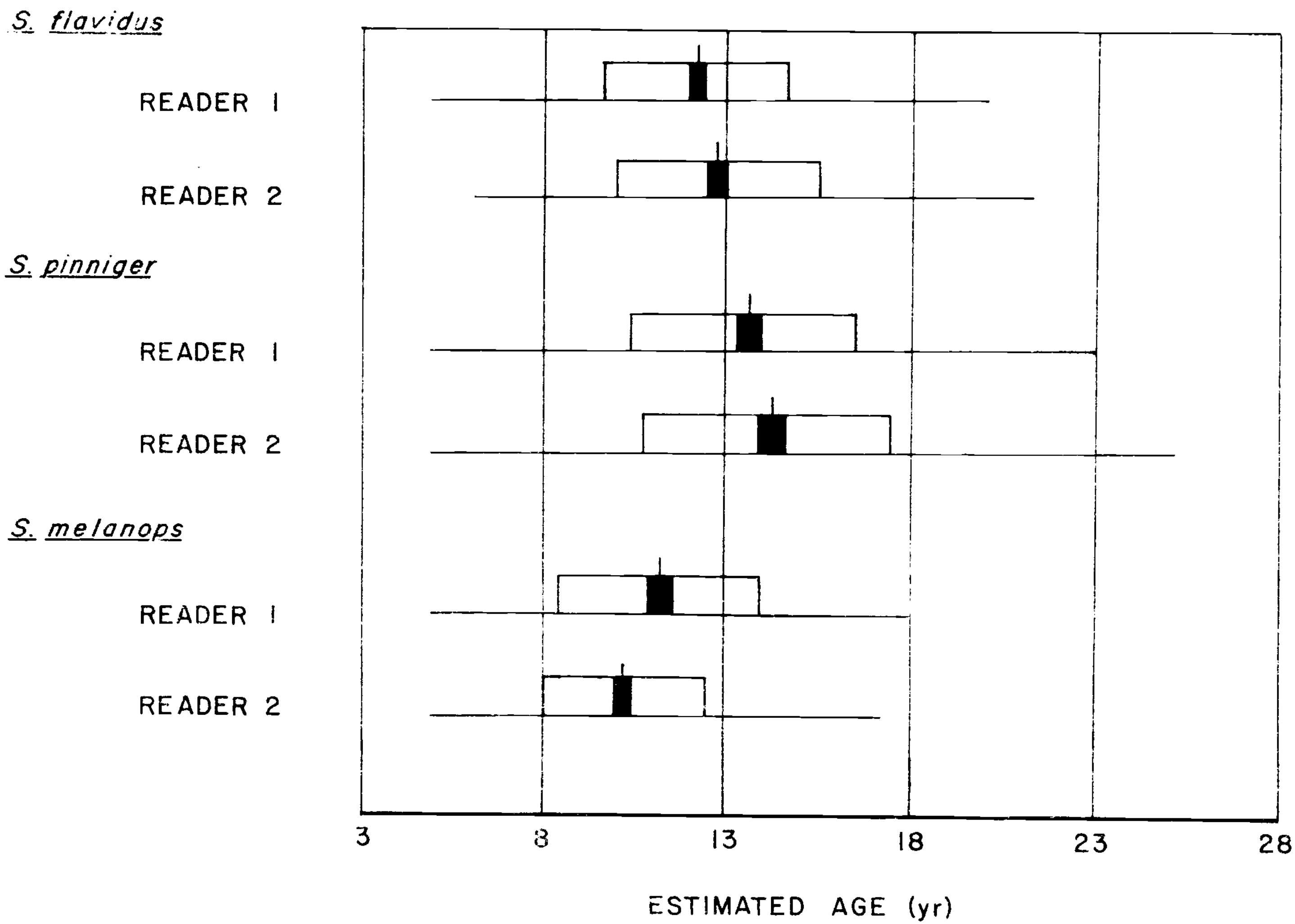

Figure 4. Mean (vertical line), range (horizontal line), standard deviation (white bar), and 95% confidence intervals about the mean (black bar) for two otolith age readings of yellowtail, canary, and black rockfish landed in Oregon, 1973-74.

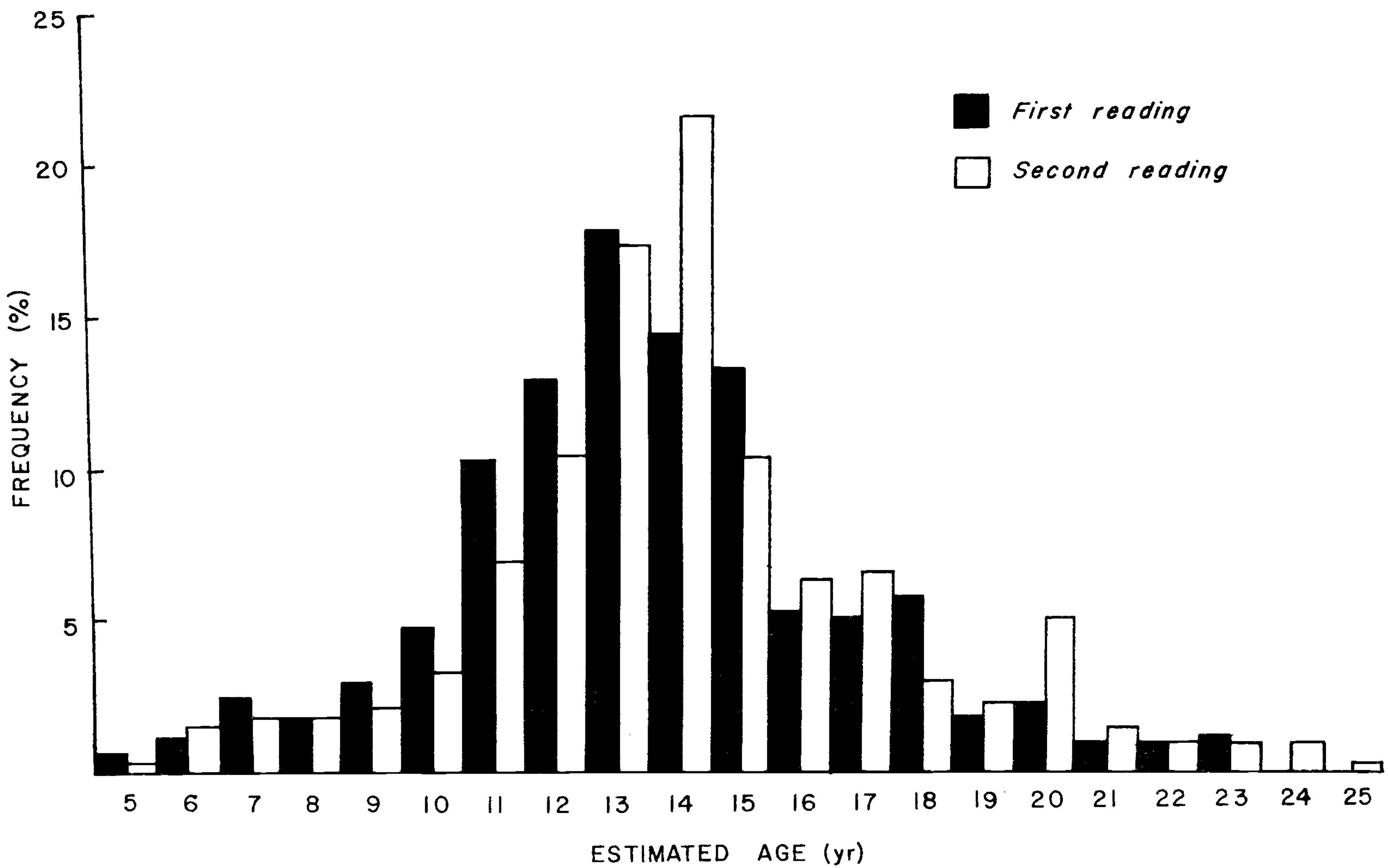

Figure 5. Age composition of 353 canary rockfish obtained by two independent readings of their otoliths; specimens were collected from fish processing plants in Astoria and Coos Bay, Oregon, 1974.

same person for black rockfish correspond for ages 9 to 12. There is less agreement for other ages (Figure 6). The distributions are approximately normal with means of 11.1 and 10.2 years, respectively, for first and second readings. Figure 4 shows the means to be significantly different at the 95% level. The standard deviations of the two distributions differ more for this species than for yellowtail and canary rockfish. Ranges of the two distributions are similar (Figure 4).

Survival

Estimates of survival obtained by two methods generally correspond for all species and readings, although Chapman-Robson estimates were consistently lower than catch curve estimates (Table 13). At the 95% level none of the paired estimates from the two readings were significantly different, as shown by the overlap of confidence intervals. Differences between survival estimates calculated from readings of the same otoliths were greatest for yellowtail rockfish and smallest for canary rockfish by either the catch curve or the Chapman-Robson method; yet, on the average, differences between catch curve estimates for the two readings were greater than those obtained by the Chapman-Robson method (Table 13). The differences between catch curve estimates were 0.108, 0.015, and 0.093 for yellowtail, canary, and black rockfish, respectively, while differences between Chapman-Robson estimates were 0.051, 0.031, and 0.051, respectively. According to Ricker (1975), the catch

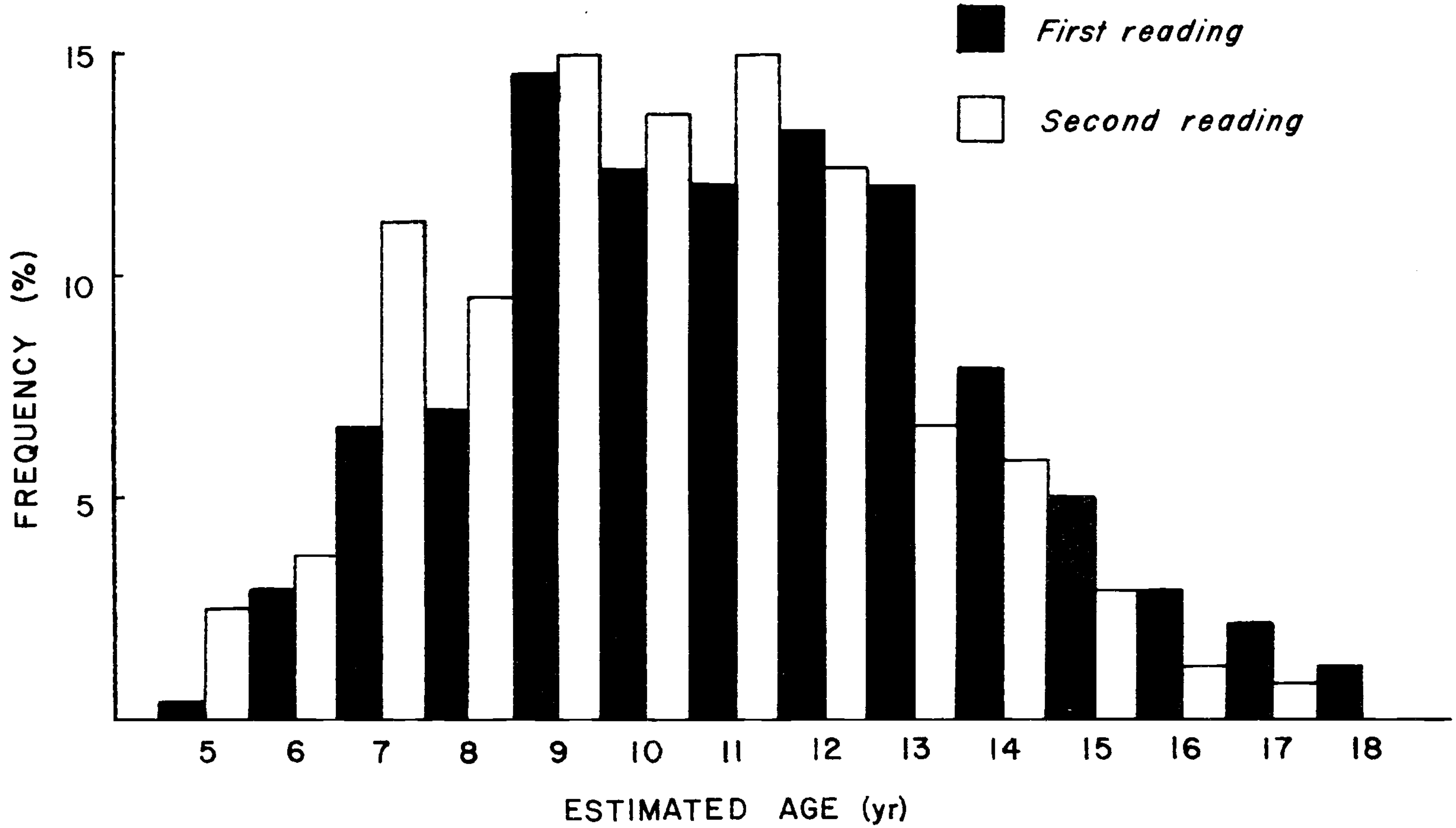

Figure 6. Age composition of 242 black rockfish obtained by two independent readings of their otoliths; specimens were collected from fish processing plants in Astoria and Coos Bay, Oregon, 1974.

Table 13. Survival estimates based on two independent readings of the otoliths of yellowtail, canary, and black rockfish landed in Oregon, 1973-74.

Species	Chapman-Robson			Catch curve				Ages util.
	Est.	S. E.	95% Conf. limits	Est.	S. E.	95% Conf. limits	R^2	
S. flavidus								
R_1 *	0.535	0.037	0.461-0.609	0.597	0.042	0.494-0.699	0.95	14-18
R_2 **	0.586	0.032	0.522-0.650	0.705	0.048	0.588-0.823	0.90	14-18
S. pinniger								
R_1	0.669	0.025	0.619-0.719	0.725	0.036	0.648-0.802	0.86	15-23
R_2	0.700	0.023	0.654-0.746	0.740	0.036	0.663-0.817	0.85	15-23
S. melanops								
R_1	0.602	0.031	0.540-0.664	0.670	0.022	0.619-0.721	0.98	12-17
R_2	0.551	0.040	0.471-0.631	0.577	0.027	0.515-0.639	0.97	12-17

* R_1 = First reading.

** R_2 = Second reading.

curve method is superior if variability in year-class strength exists. The high values of R^2 and the relatively low standard errors of the catch curve procedure indicate that such variability is minor.

Age-length Relationship

The age-length relationships derived from two otolith readings for both sexes of yellowtail rockfish and described by the equation $L = cA^b$ are similar (Figure 7). However, fitted lengths-at-age for the first reading are slightly higher than those for the second reading (Tables 14 and 15). This result is consistent with the fact that the first reading was generally lower than the second. Nevertheless, 95% confidence limits of the estimates of constants c and b overlap considerably for the first and second readings (Table 16), indicating no significant differences in the age-length relationships derived from the two independent readings. Little or no overlap of confidence limits for constants c and b exists for males and females for either the first or second readings (Table 16), indicating a significant difference between the age-length relationships by sex for yellowtail rockfish. Age-length data for yellowtail rockfish were initially applied to the von Bertalanffy growth-in-length equation, but due to the lack of young fish in the samples the constant t_0 in the equation was not biologically sound.

Age-length relationships for male canary rockfish based on

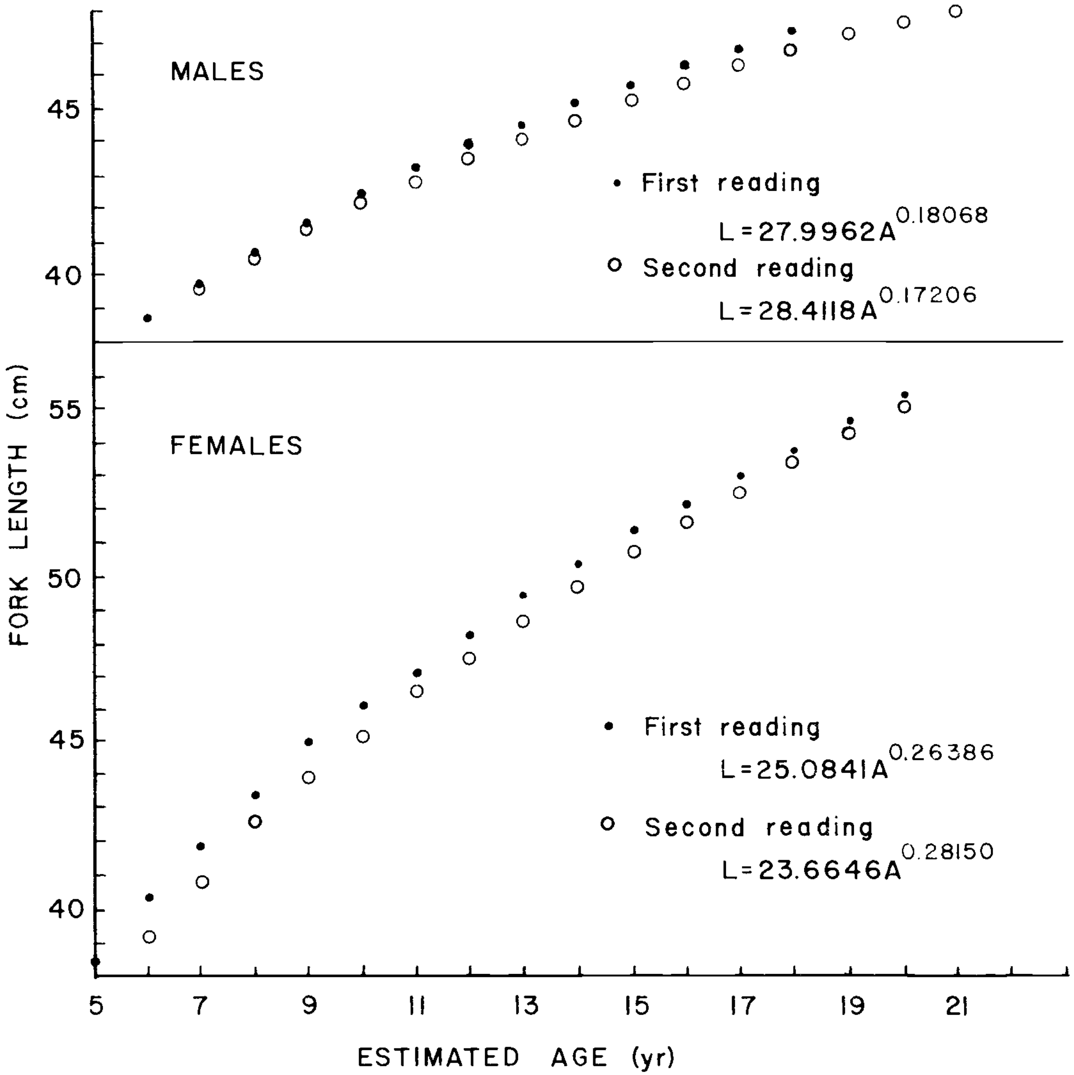

Figure 7. Age-length relationships for yellowtail rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-74.

Table 14. Lengths-at-age of male yellowtail rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-74.

	Fitted length (cm)		Sample Mean length (cm)		Sample size	
Age	R_1*	R_2**	R_1	R_2	R_1	R_2
6	38.7	--	37.0	--	3	0
7	39.8	39.7	39.7	35.5	3	2
8	40.8	40.6	41.6	40.6	7	5
9	41.6	41.5	41.2	41.3	5	11
10	42.4	42.2	42.9	42.8	15	12
11	43.2	42.9	43.7	42.9	16	17
12	43.9	43.6	43.8	43.6	28	21
13	44.5	44.2	43.9	44.8	23	28
14	45.1	44.7	45.5	45.2	23	15
15	45.7	45.3	46.1	45.8	17	12
16	46.2	45.8	45.0	45.5	4	15
17	46.7	46.3	46.6	45.7	5	7
18	47.2	46.7	45.5	45.3	2	3
19	--	47.2	--	44.0	0	1
20	--	47.6	--	--	0	0
21	--	48.0	--	45.0	0	2

*R_1 = First reading

**R_2 = Second reading

Table 15. Lengths-at-age of female yellowtail rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-74.

	Fitted length (cm)		Sample Mean length (cm)		Sample size	
Age	R_1*	R_2**	R_1	R_2	R_1	R_2
5	38.4	--	30.0	--	1	0
6	40.3	39.2	--	30.0	0	1
7	41.9	40.9	41.3	--	4	0
8	43.4	42.5	43.6	41.7	10	6
9	44.8	43.9	45.3	43.5	10	8
10	46.1	45.2	46.6	45.8	19	19
11	47.2	46.5	47.9	47.0	27	22
12	48.3	47.6	48.6	48.4	23	30
13	49.4	48.7	49.4	48.8	34	30
14	50.3	49.7	49.3	49.5	12	17
15	51.3	50.7	50.4	50.8	8	10
16	52.1	51.6	52.6	52.7	9	7
17	53.0	52.5	52.2	52.3	6	7
18	53.8	53.4	53.0	51.3	2	4
19	54.6	54.2	52.0	52.0	1	2
20	55.3	55.0	53.0	52.0	1	4

*R_1 = First reading

**R_1 = Second reading

Table 16. Constants of the age-length relationship $L = cA^b$ for yellowtail rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-74.

	Constants	
	c	b
Males-Reading 1	27.9962	0.18068
Std. error	1.0374	0.01469
95% conf. limits	25.9629-30.0295	0.15189-0.20947
Males-Reading 2	28.4118	0.17206
Std. error	1.0409	0.01579
95% conf. limits	26.3716-30.4520	0.14111-0.20301
Females-Reading 1	25.0841	0.26386
Std. error	1.0403	0.01595
95% conf. limits	23.0451-27.1231	0.23262-0.29510
Females-Reading 2	23.6646	0.28500
Std. error	1.0429	0.01662
95% conf. limits	21.6205-25.7087	0.25242-0.31758

two independent readings are nearly identical (Figure 8, Table 17). Growth curves for females are similar (Figure 8), but discrepancies exist at older ages where fitted lengths for the first reading are higher than those for the second (Table 18). This difference exists because the first reading was generally lower than the second, and readability decreases with age. Interval estimates of the von Bertalanffy constants L_∞, k, and t_0 for first and second readings for males are comparable (Table 19). Greater differences occur between estimates of the parameters for first and second readings for females, although interval estimates still overlap. The greatest discrepancy exists between values of L_∞, a difference of 3. 52 cm; however, the above results indicate no significant differences between the age-length relationships derived from the two readings. For males and females for the first reading, there is no overlap of interval estimates for L_∞, slight overlap for k, and considerable overlap for t_0 (Table 19). Similarly, for males and females for the second reading, there is no overlap of interval estimates for L_∞, and considerable overlap of interval estimates for k and t_0. This indicates that differences in growth exist between the sexes for canary rockfish.

Growth curves for male black rockfish derived from two otolith readings are similar (Figure 9), although discrepancies exist between fitted lengths at older ages (Table 20). The same is true for the age-length relationship for females (Figure 9, Table 21); yet,

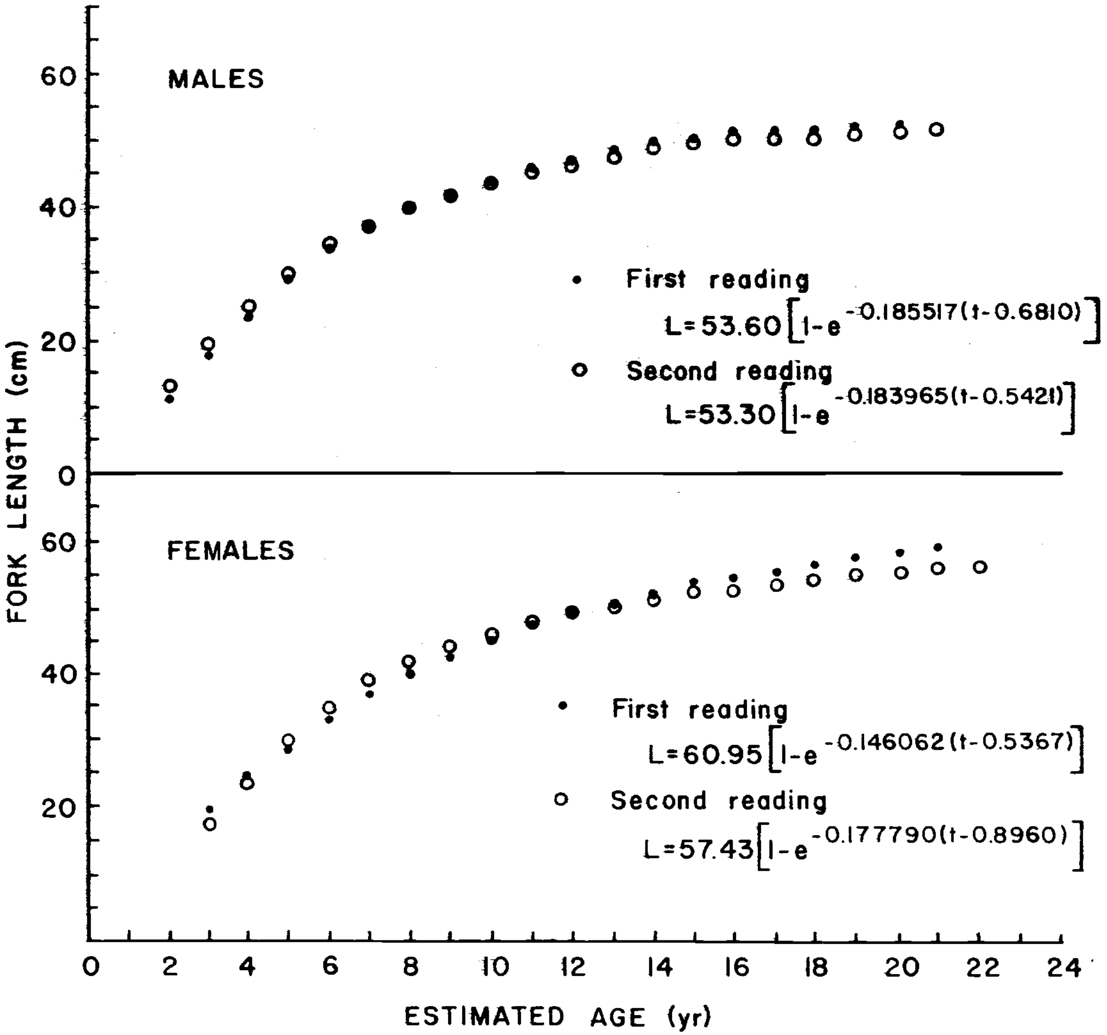

Figure 8. Age-length relationships for canary rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1972-74.

Table 17. Lengths-at-age for male canary rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1972 and 1974.

Age	Fitted length (cm)		Sample Mean length (cm)		Sample size	
	R_1*	R_2**	R_1	R_2	R_1	R_2
2	11.6	12.5	14.0	15.5	6	6
3	18.7	19.4	18.0	16.6	4	7
4	24.6	25.1	24.0	25.8	12	8
5	29.6	29.8	29.0	29.2	8	14
6	33.6	33.8	30.8	32.3	10	6
7	37.0	37.1	36.0	36.0	3	2
8	39.8	39.8	36.5	36.0	2	1
9	42.2	42.1	45.3	42.6	8	5
10	44.1	44.0	44.7	43.9	11	8
11	45.7	45.5	46.4	46.5	23	17
12	47.0	46.8	47.5	48.2	25	22
13	48.2	47.9	48.9	48.4	32	38
14	49.1	48.8	49.1	48.5	27	48
15	49.8	49.6	49.2	49.5	32	22
16	50.5	50.2	50.1	49.5	12	12
17	51.0	50.7	50.1	50.7	12	10
18	51.5	51.2	51.4	49.4	13	5
19	51.8	51.5	51.0	50.7	4	6
20	52.1	51.8	51.0	51.2	2	9
21	--	52.1	--	54.0	0	2

*R_1 = First reading

**R_2 = Second reading

Table 18. Lengths-at-age for female canary rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1972 and 1974.

Age	Fitted length (cm)		Sample Mean length (cm)		Sample size	
	R_1*	R_2**	R_1	R_2	R_1	R_2
3	18.4	17.9	23.5	19.0	2	2
4	24.2	24.4	24.7	24.7	17	21
5	29.2	29.7	29.2	29.5	26	32
6	33.5	34.3	31.4	33.0	13	13
7	37.2	38.0	35.9	40.7	15	6
8	40.5	41.2	40.1	38.7	7	7
9	43.3	43.8	39.3	44.5	3	2
10	45.7	46.1	48.0	50.3	6	4
11	47.7	47.9	50.5	48.3	11	6
12	49.5	49.5	50.4	50.3	18	13
13	51.1	50.8	51.4	51.1	27	20
14	52.4	51.8	53.0	50.9	21	24
15	53.6	52.8	52.4	52.9	12	13
16	54.6	53.5	54.8	54.0	6	9
17	55.5	54.2	53.6	53.3	5	12
18	56.2	54.7	55.3	54.2	6	5
19	56.9	55.1	55.5	55.5	2	2
20	57.4	55.5	56.0	55.3	6	8
21	57.9	55.8	59.5	57.3	3	2
22	--	56.1	--	57.0	0	2

*R_1 = First reading

**R_2 = Second reading

Table 19. Constants of the von Bertalanffy equation for canary rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1972 and 1974.

	Constants		
	L_∞	k	t_0
Males-Reading 1	53.60	0.185517	0.6810
Std. error	0.62	0.009977	0.1483
95% conf. limits	52.38-54.82	0.165962-0.205072	0.3903-0.9717
Males-Reading 2	53.30	0.183965	0.5421
Std. error	0.59	0.009796	0.1481
95% conf. limits	52.14-54.46	0.164765-0.203165	0.2518-0.8324
Females-Reading 1	60.95	0.146062	0.5367
Std. error	1.46	0.013350	0.2900
95% conf. limits	58.09-63.81	0.119896-0.172228	(-0.0317)-(1.1051)
Females-Reading 2	57.43	0.177790	0.8960
Std. error	0.78	0.011937	0.2059
95% conf. limits	55.90-58.96	0.154393-0.201187	0.4924- 1.2996

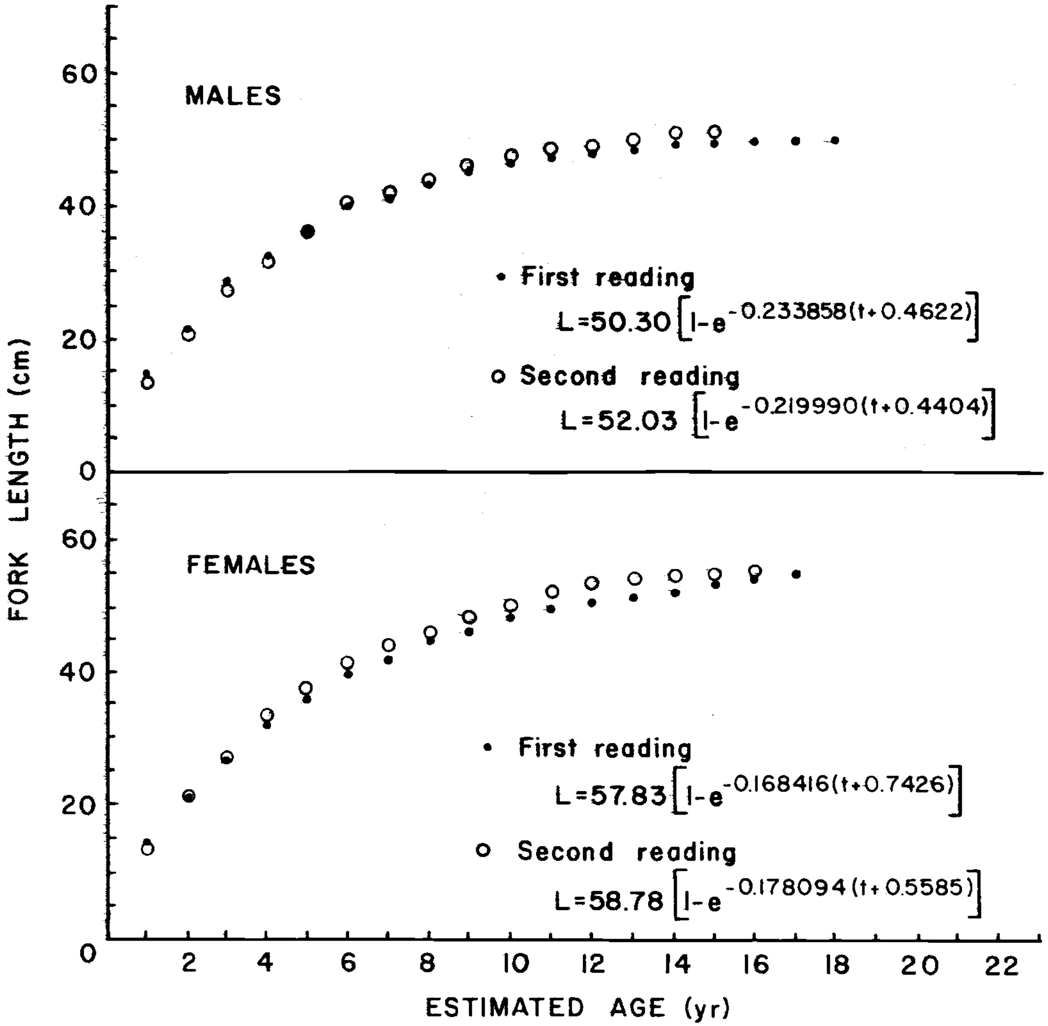

Figure 9. Age-length relationships for black rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-75.

Table 20. Lengths-at-age for male black rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-75.

	Fitted length (cm)		Sample Mean length (cm)		Sample size	
Age	R_1*	R_2**	R_1	R_2	R_1	R_2
1	14.6	14.1	14.8	14.7	47	43
2	22.0	21.6	21.0	18.8	4	6
3	27.9	27.6	27.0	24.8	4	8
4	32.6	32.4	28.0	29.0	6	6
5	36.3	36.3	30.7	39.0	3	3
6	39.2	39.4	42.3	42.0	6	6
7	41.5	41.9	45.9	43.6	7	16
8	43.4	43.9	42.4	43.7	11	9
9	44.8	45.5	45.2	46.0	16	16
10	45.9	46.8	46.5	46.9	14	15
11	46.9	47.8	47.6	47.4	9	18
12	47.6	48.7	48.2	49.0	19	13
13	48.1	49.3	47.1	48.6	10	9
14	48.6	49.9	48.3	48.9	9	7
15	49.0	50.3	48.2	48.0	5	2
16	49.2	--	48.0	--	5	0
17	49.5	--	48.0	--	3	0
18	49.6	--	47.5	--	2	0

*R_1 = First reading

**R_2 = Second reading

Table 21. Lengths-at-age for female black rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-75.

	Fitted length (cm)		Sample Mean length (cm)		Sample size	
Age	R_1*	R_2**	R_1	R_2	R_1	R_2
1	14.7	14.3	14.9	14.7	48	44
2	21.4	21.5	21.7	19.2	3	6
3	27.0	27.6	27.3	25.3	3	7
4	31.8	32.7	28.0	29.3	7	6
5	35.9	36.9	32.5	38.2	4	5
6	39.3	40.5	41.0	40.3	4	6
7	42.1	43.5	44.1	46.0	9	11
8	44.6	46.0	44.7	46.4	6	14
9	46.6	48.1	46.7	47.9	19	20
10	48.4	49.8	49.3	51.0	16	18
11	49.8	51.3	50.3	51.1	20	18
12	51.1	52.5	50.9	52.0	13	17
13	52.1	53.5	51.6	51.7	19	7
14	53.0	54.4	53.0	53.3	10	7
15	53.8	55.1	53.0	54.8	7	5
16	54.4	55.7	50.5	58.5	2	2
17	54.9	--	56.0	--	2	0

*R_1 = First reading

**R_2 = Second reading

interval estimates of all three von Bertalanffy constants overlap (Table 22), indicating no significant differences between growth curves obtained from the two readings. For males and females for the first reading, there is no overlap of interval estimates for L_∞ and k, and considerable overlap for t_0. For males and females for the second reading, there is no overlap of interval estimates for L_∞, slight overlap for k, and considerable overlap for t_0. As was found for yellowtail and canary rockfish, sexual differences in growth of black rockfish are apparent.

In summary, the observed deviations between otolith readings produced slightly different estimates of survival and of age-length relationships, although these differences were not statistically significant. The otolith method is the most reliable of those analyzed and I believe, with some reservations, that it can be used reliably for management purposes. The reader should be cautioned that contrary to the results of the statistical test, some of the survival estimates appear to be substantially different (Table 13). Possibly a Type II error exists (Snedecor and Cochran, 1967), i. e., the statistical test shows no significant difference when, in fact, one exists. I believe that, for the most part, the observed deviations between readings are minor; moreover, with the collaboration of two or more trained readers, consistency of age determinations can be improved.

Further studies establishing the validity of the technique are

Table 22. Constants of the von Bertalanffy equation for black rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-75.

	Constants		
	L_∞	k	t_0
Males-Reading 1	50.30	0.233858	-0.4622
Std. error	0.63	0.014197	0.0949
95% conf. limits	49.07-51.53	0.206032-0.261684	(-0.6482)-(-0.2762)
Males-Reading 2	52.03	0.219990	-0.4404
Std. error	0.79	0.013363	0.0919
95% conf. limits	50.48-53.58	0.193799-0.246181	(-0.6205)-(-0.2603)
Females-Reading 1	57.83	0.168416	-0.7426
Std. error	1.29	0.012919	0.1285
95% conf. limits	55.30-60.36	0.143095-0.193737	(-0.9945)-(-0.4907)
Females-Reading 2	58.78	0.178094	-0.5585
Std. error	1.20	0.011997	0.1065
95% conf. limits	56.43-61.13	0.154580-0.201608	(-0.7672)-(-0.3498)

warranted. This may be made possible by analysis of the marginal growth of the otoliths of juvenile rockfish. By providing evidence that an opaque and an adjacent hyaline zone truly constitute an annulus, accuracy of otolith age determinations will be ensured.

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APPENDICES

Appendix Table 1. Sex, length, age, and depth of capture of 23 yellowtail rockfish with crystallized otoliths caught off Oregon, 1972-74.

No.	Sex[1/]	Length (cm)	Age (yr)	Depth (fm)
1	F	45	9	*
2	F	55	*	*
3	*	*	*	*
4	M	47	*	50-70
5	F	52	19	50
6	M	39	*	50
7	M	49	16	50
8	M	36	8	50
9	M	44	*	*
10	F	53	16	40-80
11	M	45	*	40-80
12	M	43	12	40-80
13	F	53	*	*
14	M	46	*	*
15	F	36	6	48-53
16	F	37	*	48-53
17	M	45	7	48-53
18	M	44	15	80
19	F	49	14	80
20	M	45	14	80
21	F	51	16	66-82
22	F	52	15	66-82
23	F	50	15	66-82

[1/] Symbols: M = male; F = female.

*Data unavailable

Appendix Table 2. Sex, length, age, and depth of capture of 27 canary rockfish with crystallized otoliths caught off Oregon, 1972-74.

No.	Sex[1/]	Length (cm)	Age (yr)	Depth (fm)
1	F	54	*	*
2	M	52	*	*
3	M	47	*	*
4	*	*	8	*
5	F	54	*	80
6	F	53	14	80
7	M	45	10	80
8	M	50	20	80
9	F	56	20	80
10	M	50	12	80
11	F	52	*	80
12	F	55	*	80
13	F	26	4	*
14	M	30	5	*
15	M	19	2	*
16	M	29	6	*
17	F	31	5	*
18	F	58	15	70-82
19	M	48	13	70-82
20	M	48	10	70-82
21	F	46	13	50-52
22	M	53	20	50-52
23	M	48	15	50-52
24	F	38	7	50-52
25	M	41	8	50-52
26	F	38	6	50-52
27	F	34	7	50-52

[1/]Symbols: M = male; F = female.

*Data unavailable.

Appendix Table 3. Sex, length, age, and depth of capture of 29 black rockfish with crystallized otoliths caught off Oregon, 1973-75.

No.	Sex[1/]	Length (cm)	Age (yr)	Depth (fm)
1	*	*	*	*
2	*	*	*	*
3	*	*	*	*
4	*	*	*	*
5	*	*	*	*
6	*	*	*	*
7	*	*	*	*
8	*	*	*	*
9	*	*	*	*
10	*	*	*	*
11	*	14	*	*
12	M	12	*	*
13	M	46	*	30
14	M	47	*	30
15	M	52	*	30
16	M	52	*	30
17	M	49	*	30
18	F	50	9	40
19	M	45	10	40
20	F	42	5	40
21	M	45	9	40
22	M	48	14	40
23	M	46	11	40
24	M	45	10	40
25	F	55	11	40
26	F	46	9	40
27	F	45	8	40
28	F	52	9	40
29	M	43	10	40

[1/] Symbols: M = male; F = female.

* Data unavailable.