ANALYSIS OF AGE DETERMINATION METHODS FOR YELLOWTAIL ROCKFISH, CANARY ROCKFISH, AND BLACK ROCKFISH OFF OREGON[1]

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ABSTRACT

Age determination methods and their application are presented for yellowtail rockfish, *Sebastes flavidus;* canary rockfish, *S. pinniger;* and black rockfish, *S. melanops,* collected off Oregon during 1972-75. Of 25 anatomical structures examined, those compared for consistency of readings were the anal fin pterygiophore, opercle, otolith, scale, and vertebra. Various heating, staining, and microscopy techniques were applied to otoliths and scales with little success. The effect of deviation between otolith readings on survival estimates and age-length relationships is discussed. Consistency of otolith readings was generally superior to other structures for these three species. For yellowtail, canary, and black rockfishes, respectively, 71, 76, and 76% of two independent otolith readings deviated by no more than ±1 assumed annulus. Consistency of otolith readings for all three species decreased with age. Even though age estimates were not completely consistent, Chapman-Robson and catch curve estimates of survival, as well as age-length relationships, each derived from two readings of the same set of otoliths, were not significantly different at the 95% level for the three species. Age-length relationships are given for both male and female yellowtail, canary, and black rockfishes.

In 1973, yellowtail rockfish, *Sebastes flavidus* (Ayres); canary rockfish, *S. pinniger* (Gill); and black rockfish, *S. melanops* Girard, composed 41, 38, and 4%, respectively, of the total Oregon commercial trawl catch of rockfishes consisting of 19 species (Oregon Department of Fish and Wildlife[4] unpubl. data). Because little is known of the biology of these fishes, information on age, length, and weight are needed for estimates of mortality, growth, and ultimately sustainable 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 these species. Specific objectives were: 1) to determine if counts of 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.

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 100% agreement between independent readings of redfish otoliths with less than 10 annuli, but agreement between readings for fish from 7 to 20 + yr was only 31%. Sandeman (1961) used scales for juvenile redfish (<5 yr), but found otoliths to be superior for older fish.

In the North Pacific Ocean, the majority of research relative to our study has been conducted on the Pacific ocean perch, *S. alutus*. Alverson and Westrheim (1961) reported readability of scales for Pacific ocean perch was only fair, while Chikuni and Wakabayashi (1970) were satisfied with scales for the same species. Westrheim (1973) subsequently found that agreement between readings of Pacific ocean perch otoliths decreased from 100% for 0-zone otoliths to 26% for 19-zone otoliths. Phillips (1964) found both scales and otoliths could be used for valid age estimations for 10 species of California rockfish, includ-

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ing *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 of *S. melanops,* although Miller (1961) indicated that the ages of several specimens were estimated. Westrheim and Harling (1975) used otoliths to determine age-length relationships for 26 scorpaenids in the northeast Pacific.

TABLE 1.—Structures examined from yellowtail rockfish, canary rockfish, 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

METHODS AND MATERIALS

Most fish used in this study were sampled randomly from the commercial trawl landings in Astoria and Coos Bay, Oreg., 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. Twenty-five anatomical structures (Table 1), including the anal fin pterygiophores (largest), opercles, otoliths, scales, and several anterior vertebrae were sampled from carcasses obtained from fish processing plants in Newport, Oreg., from 1974 to 1975. Juvenile fish were collected on research cruises on the Oregon continental shelf from 1972 to 1974, and by scuba and 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 10×. Otolith sections 0.3 mm thick were obtained with a 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 a scale projector with a 48-mm objective. Other structures, including 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 and pterygiophores and vertebrae were examined by use of a binocular dissecting microscope at 10×.

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) 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 accessory (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 2 wk, 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 rockfishes were made by the same person.

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 the catch curve (Ricker 1975) methods. The age-length relationship of yellowtail rockfish was described by the equation $L = cA^b$, where L = length (centimeters), A = estimated age (years), 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, were 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 6 yr.

RESULTS AND DISCUSSION

Suitability of Structures for Age Determination

Only 5 of 25 anatomical structures sampled were suitable for estimation of age. These were the anal fin pterygiophore, opercle, otolith, scale, and vertebra. The criterion used to determine suitability for aging was the presence of enumerable growth zones. Based on examination of a limited sample, most structures 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 Table 2. Exact agreement ±1 assumed annulus is also given. Agreement was low for all structures and species except otoliths of canary rockfish. Agreement between otolith readings for yellowtail and canary rockfishes was superior to agreement between 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 rockfishes.

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. Throughout the entire study at least one of the two otoliths was partially or completely crystallized in 23 of 1,116 (2.1%) yellowtail rockfish, 27 of 666 (4.1%) canary rockfish, and 29 of 302 (9.6%) black rockfish. There were more readable vertebral centra and otoliths than any of the other structures. Many

TABLE 2.—Estimations of age, number of readable structures, and percent agreement of two independent readings of five structures sampled from 35 yellowtail rockfish, canary rockfish, and black rockfish landed off Newport, Oreg., 1974-75.

Structure	Estimated age (yr) Min-max	Mean	No. readable	Agreement (%) Exact	±1 yr
		Yellowtail rockfish			
Anal pterygiophore	9-18	12.5	29	24	59
Opercle	—	—	3	—	—
Otolith	10-18	15.2	34	24	71
Scale	8-15	11.2	32	16	59
Vertebral centrum	8-18	12.9	35	11	49
		Canary rockfish			
Anal pterygiophore	7-20	9.5	33	33	76
Opercle	4-18	7.8	31	10	48
Otolith	5-22	8.9	35	77	97
Scale	7-23	10.7	32	31	69
Vertebral centrum	5-18	8.9	35	31	60
		Black rockfish			
Anal pterygiophore	5-18	9.6	32	19	66
Opercle	5-18	9.2	28	39	75
Otolith	6-15	10.7	35	40	74
Scale	7-16	10.7	31	23	61
Vertebral centrum	6-18	10.3	35	14	54

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 subsequently was compared in a larger sample. 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 ($P<0.05$)[5] and black ($P<0.005$) rockfishes (Table 3). No significant difference occurred between readings of otoliths and scales for canary rockfish ($P>0.90$). Percent agreement between first readings of both structures for all three species was low.

TABLE 3.—Percent agreement in estimates of age between first and second readings of the same structure and between first readings of different structures (otoliths and scales) sampled from the same yellowtail rockfish, canary rockfish, or black rockfish caught off Oregon, 1974-75.

Species	Within structures: Otolith Exact	Otolith ±1	Scale Exact	Scale ±1	Between structures Exact	±1	*N*
Yellowtail rockfish	42	80	26	60	14	53	89
Canary rockfish	37	73	36	70	15	39	91
Black rockfish	48	81	26	54	11	43	98

In terms of consistency of readings, the otolith is the best structure of those examined for age determination of yellowtail, canary, and black rockfishes; yet, even this method is questionable. Deviations of readings of yellowtail rockfish otoliths by two readers generally increased with age of the fish (Figure 1). For canary rockfish otoliths read twice by the same person, deviations of readings initially increased and then stabilized with increasing age (Figure 2). Deviations of readings of black rockfish otoliths read twice by the same person also increased with age of the fish (Figure 3). The distribution of deviations is skewed considerably in the positive direction, indicating that the second reading was substantially lower than the first. For our largest sample of 322 yellowtail rockfish, 481 canary rockfish, and 357 black rockfish, respectively, 71, 76, and 76% of the two readings deviated by no more than ±1 assumed annulus. In a study on Pacific ocean perch by Westrheim (1973), 85% of two otolith readings by different people deviated by no more

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

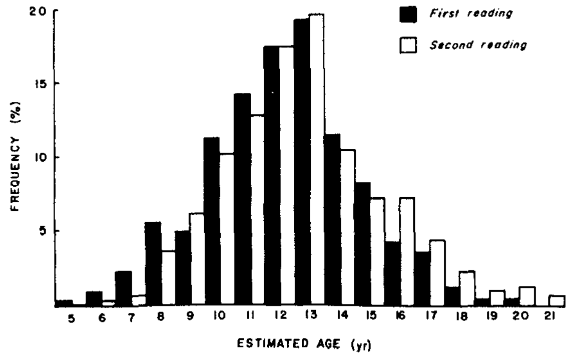

FIGURE 1.—Age composition of 322 yellowtail rockfish obtained by two independent readings of their otoliths; specimens were collected from fish processing plants in Astoria and Coos Bay, Oreg., 1973-74.

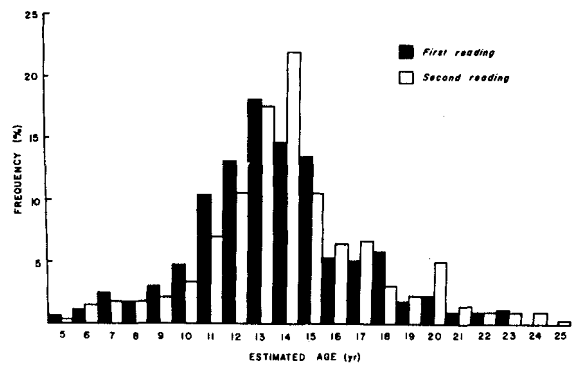

FIGURE 2.—Age composition of 353 canary rockfish obtained by two independent readings of their otoliths; specimens were collected from fish processing plants in Astoria and Coos Bay, Oreg., 1974.

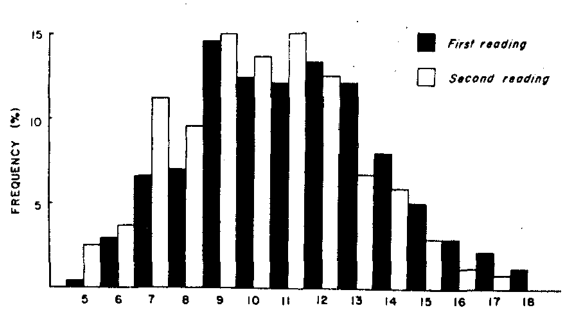

FIGURE 3.—Age composition of 242 black rockfish obtained by two independent readings of their otoliths; specimens were collected from fish processing plants in Astoria and Coos Bay, Oreg., 1974.

than ±1 zone. Kelly and Wolf (1959) reported 59.7% agreement ±1 yr for otoliths of 7–20+ yr-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 on otoliths that can be used in age determination (Figure 4); two or three generally give superior results depending on the species in question. 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 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 showed 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 1 yr could exist between independent readings of the same area of a particular otolith.

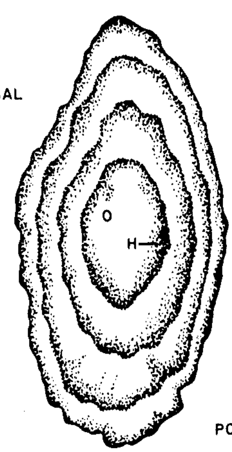

FIGURE 4.—Drawing of the right otolith (sagitta) from a 4-yr-old black rockfish as seen under reflected light on a dark background showing the marginal areas used in age determination (O-opaque zone; H-hyaline zone).

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.

Because one could question the use of only two readings to assess the consistency of otolith readings, 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 agreement statistics ($P > 0.75$). In this case, consistency of readings was not changed by the addition of a third reading.

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 rockfishes 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 *Sebastes 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*.

Unfortunately, similar tests could not be conducted in this study owing to the absence of any obviously dominant year classes in the fish sampled and to the 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. 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, because of the irregular growth of otoliths of older rockfish, different marginal areas provide different results.

Otolith Sections

Results indicate that consistency of otolith readings is superior to that of scales or other structures for the three species of rockfishes studied, but agreement of otolith readings still may be unsatisfactory. Otoliths were sectioned to try to improve consistency of readings. 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, *Sebastes* sp.; and horse mackerel, *Trachurus trachurus*. These annuli are not seen when the distal surface of the otolith is used for age determination and the investigator underestimates the age of the fish.

Exact agreement between readings of whole and sectioned otoliths of canary rockfish (37 vs. 21%) differed by 16 percentage points (Table 4). 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. The similarity of the mean estimated ages 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.

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 5).

TABLE 4.—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.

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

TABLE 5.—Treatments applied to otoliths and scales of yellowtail, canary, and black rockfishes 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 absorbed
Methyl violet stain	Albrechtsen (1968)	Stain absorbed, but zones indistinct
Silver nitrate stain	1% aqueous solution	Stain not absorbed
	Scales	
Polarized light microscopy	Kosswig (1971)	Zones near focus indistinct

Effect of Deviations of Otolith Readings on Biological Information

Age Composition

The frequencies of two independent readings of yellowtail rockfish otoliths made by different readers generally correspond for ages 9-15 (Figure 1). Correspondence is lower for younger and older age-groups. The two distributions are approximately normal with means of 12.2 and 12.8 yr, respectively. Figure 5 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 1 yr (Figure 3).

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 2). Greatest discrepancies occurred at ages 11, 14, and 20. Again the distributions are approximately normal with means of 13.6 and 14.2 yr for first and second readings, respectively. The means are not significantly different at the 95% level (Figure 5). The standard deviations are similar, while the maximum ages disagree by 2 yr.

Otolith reading frequencies for two independent readings by the same person for black rockfish correspond closely for ages 9-12. There is less agreement for other ages (Figure 3). The

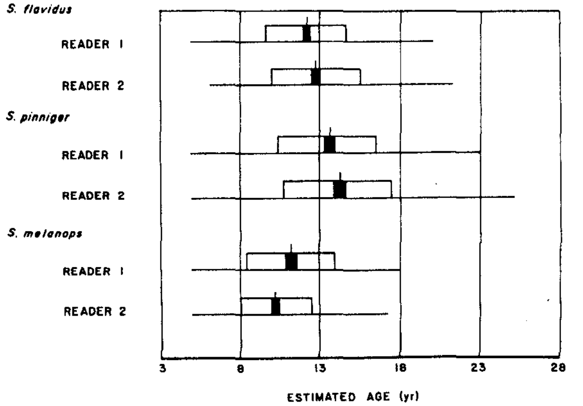

FIGURE 5.—Mean (vertical line), range (horizontal line), standard deviation of the mean (white bar), and 95% confidence intervals about the mean (black bar) for two otolith age readings of yellowtail rockfish, canary rockfish, and black rockfish landed in Oregon, 1973-74.

distributions are approximately normal with means of 11.1 and 10.2 yr, respectively, for first and second readings. Figure 3 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 rockfishes. Ranges of the two distributions are similar (Figure 5).

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 6). 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 6). The differences between catch curve estimates were 0.11, 0.015, and 0.093 for yellowtail, canary, and black rockfishes, respectively, while differences between Chapman-Robson estimates were 0.051, 0.031, and 0.051, respectively.

Age-Length Relationship

The age-length relationships derived from two otolith readings for yellowtail rockfish were described by the equation $L = cA^b$ (Figure 6). Fitted lengths-at-age for the first reading were slightly higher than those for the second reading, but 95% confidence limits of the estimates of constants c and b overlap considerably for the first and second readings (Table 7). 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 7), 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 were not well described by this equation due to the lack of young fish in the samples.[6]

Age-length relationships for male canary rockfish based on two independent readings are nearly identical (Figure 7). Growth curves for females are similar (Figure 7), but discrepancies exist at older ages where fitted lengths for the first reading were higher than those for the second.

[6]The von Bertalanffy equations derived from two readings of yellowtail rockfish otoliths were:

Males—Reading 1: $l_t = 47.96[1 - \exp(-0.16(t + 4.01))]$
Reading 2: $l_t = 46.34\,[1 - \exp(-0.27(t - 1.03))]$

Females—Reading 1: $l_t = 55.47\ [1 - \exp(-0.14(t + 3.19))]$
Reading 2: $l_t = 53.81\ [1 - \exp(-0.19(t - 0.24))]$.

TABLE 6.—Survival estimates based on two independent readings of the otoliths of yellowtail rockfish, canary rockfish, and black rockfish landed in Oregon, 1973-74.

	Chapman-Robson			Catch curve				
Species	Estimate	SE	95% conf. limits	Estimate	SE	95% conf. limits	R^2	Ages used
Yellowtail rockfish:								
Reading 1	0.54	0.04	0.46-0.61	0.60	0.04	0.49-0.70	0.95	14-18
Reading 2	0.59	0.03	0.52-0.65	0.71	0.05	0.59-0.82	0.90	14-18
Canary rockfish:								
Reading 1	0.67	0.03	0.62-0.72	0.73	0.04	0.65-0.80	0.86	15-23
Reading 2	0.70	0.02	0.65-0.75	0.74	0.04	0.66-0.82	0.85	15-23
Black rockfish:								
Reading 1	0.60	0.03	0.54-0.66	0.67	0.02	0.62-0.72	0.98	12-17
Reading 2	0.55	0.04	0.47-0.63	0.58	0.03	0.52-0.64	0.97	12-17

TABLE 7.—Estimates of parameters describing the age-length relationship for yellowtail rockfish, canary rockfish, and black rockfish based on two independent readings of their otoliths. The 95% confidence limits for the estimates are in parentheses.

Parameters	First reading	Second reading
♂ yellowtail rockfish:		
c	28.00	28.41
	(25.96-30.03)	(26.37-30.45)
b	0.18	0.17
	(0.15-0.21)	(0.14-0.20)
♀ yellowtail rockfish:		
c	25.08	23.66
	(23.05-27.12)	(21.62-25.71)
b	0.26	0.29
	(0.23-0.30)	(0.25-0.32)
♂ canary rockfish:		
L_∞	53.60	53.30
	(52.38-54.82)	(52.14-54.46)
k	0.19	0.18
	(0.17-0.21)	(0.16-0.20)
t_0	0.68	0.54
	(0.39-0.97)	(0.25-0.83)
♀ canary rockfish:		
L_∞	60.95	57.43
	(58.09-63.81)	(55.90-58.96)
k	0.15	0.18
	(0.12-0.17)	(0.15-0.20)
t_0	0.54	0.90
	(−0.03-1.11)	(0.49-1.30)
♂ black rockfish:		
L_∞	50.30	52.03
	(49.07-51.53)	(50.48-53.58)
k	0.23	0.22
	(0.21-0.26)	(0.19-0.25)
t_0	−0.46	−0.44
	(−0.65)-(−0.28)	(−0.62)-(−0.26)
♀ black rockfish:		
L_∞	57.83	58.78
	(55.30-60.36)	(56.43-61.13)
k	0.17	0.18
	(0.14-0.19)	(0.15-0.20)
t_0	−0.74	−0.56
	(−0.99)-(−0.49)	(−0.77)-(−0.35)

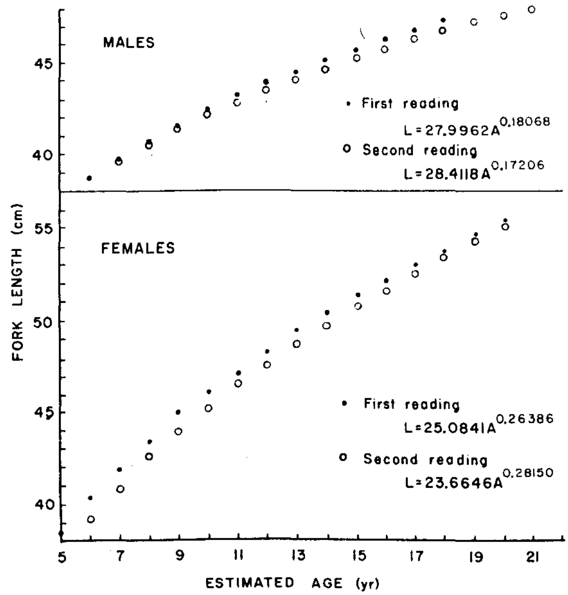

FIGURE 6—Age-length relationships for yellowtail rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-74.

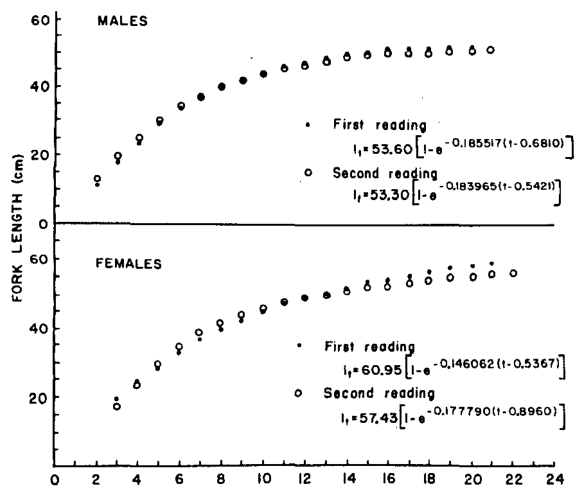

FIGURE 7.—Age-length relationships for canary rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1972 and 1974.

This difference exists because the first reading was generally lower than the second, and readability decreased with age. Interval estimates of the von Bertalanffy constants L_∞, k, and t_0 for first and second readings for males are comparable (Table 7). Greater differences occur between estimates of the parameters for first and second readings for females, although interval estimates still overlap. 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 7). 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.

Growth curves for male black rockfish derived from two otolith readings are similar (Figure 8), although discrepancies existed between fitted lengths at older ages. The same is true for the age-length relationship for females (Figure 8). Interval estimates of all three von Bertalanffy constants overlap considerably (Table 7), 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

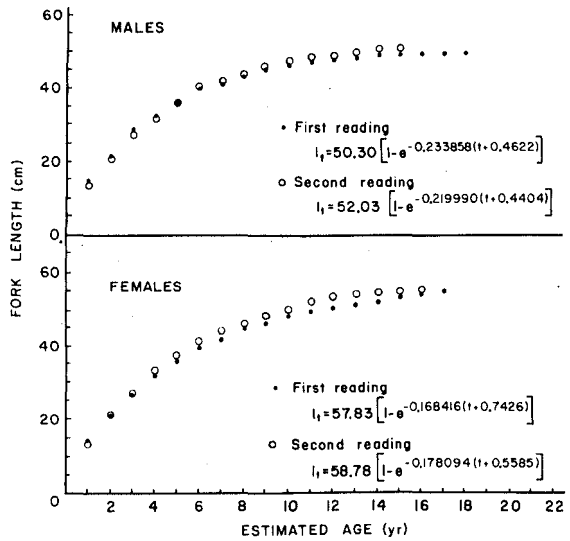

FIGURE 8.—Age-length relationships for black rockfish derived from two independent readings of their otoliths collected from Oregon samples, 1973-75.

estimates for L_∞, slight overlap for k, and considerable overlap for t_0. As was found for yellowtail and canary rockfishes, sexual differences in growth of black rockfish are apparent.

Further support of the otolith method may be evidenced by a comparison of mean lengths-at-age obtained in this study with those of other investigators. Phillips (1964) and Westrheim and Harling (1975) reported mean lengths similar to those obtained in this study for yellowtail rockfish (Table 8). A similar correspondence of canary rockfish lengths does not exist, where an increase of values from north to south is noted. This analysis is limited by small sample sizes and could further be complicated by geographical differences in growth reported to exist for other species of rockfishes in the Northeast Pacific (Westrheim and Harling 1975).

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 we 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 6). Possibly a Type II error exists (Snedecor and Cochran 1967), i.e., the statistical test shows no significant difference when, in fact, one exists. We 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 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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TABLE 8.—Mean length (centimeters) at selected ages of yellowtail rockfish and canary rockfish from British Columbia, Oregon, and California. Numbers of fish are shown in parentheses.

		British Columbia (Westrheim and Harling 1975)		Oregon (This study—reading 1)		California (Phillips 1964)
Species	Age	Male	Female	Male	Female	Sexes combined
Yellowtail rockfish	5	27.1 (16)	27.6 (10)	—	30.0 (1)	31.9 (116)
	10	42.3 (4)	41.0 (2)	42.9 (15)	46.6 (19)	43.0 (48)
	15	46.6 (18)	49.2 (7)	46.1 (17)	50.4 (8)	50.4 (6)
	20	47.6 (8)	—	—	53.0 (1)	—
Canary rockfish	5	22.5 (1)	23.5 (1)	29.0 (8)	29.2 (26)	31.9 (128)
	10	—	38.5 (1)	44.7 (11)	48.0 (6)	46.8 (57)
	15	—	—	49.2 (32)	52.4 (12)	56.5 (7)
	20	50.5 (1)	—	51.0 (2)	56.0 (6)	—

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