Ageing and Growth of Widow Rockfish

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ABSTRACT

Surface examination of otoliths appears to be satisfactory for age determination of widow rockfish except for large specimens. The results indicate that one ring is laid down per year through age 10. Comparison of surface readings with sectioned readings from difficult-to-read otoliths indicates that surface readings are slightly lower than sectioned readings from such otoliths (3.0 years for males and 2.4 years for females). I recommend that surface readings not be used for males larger than 44 cm and females larger than 47 cm. Data from 2,003 females and 2,184 males were used to estimate the parameters of the von Bertalanffy growth curve.

INTRODUCTION

Previous to this study, a paper by Phillips (1964) is the only publication that develops a growth curve for widow rockfish, *Sebastes entomelas*. His work was based on scale readings and included only a few fish older than 13 years. He did not attempt to verify the accuracy of using scales to age widow rockfish and did not separate sexes. In this study I use otoliths for aging; estimate growth curves for each sex with data from numerous fish estimated to be older than 13 years; and evaluate the accuracy of using otoliths for age determinations.

MATERIALS AND METHODS

Otoliths from sized and sexed fish were made available by the Oregon Department of Fish and Wildlife from samples collected from the commercial fishery in Newport and Astoria; by the Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, from samples collected by observers onboard foreign and joint-venture vessels fishing for Pacific whiting, *Merluccius productus*; and by the California Department of Fish and Game and the Southwest Fisheries Center, Natl. Mar. Fish. Serv., NOAA, from samples collected from the recreational and commercial fisheries of California.

Otoliths were placed in alcohol or water over a black background and examined at 12× for age estimation. Whenever possible, I determined whether the outer edge of the otolith was opaque or hyaline. Such determinations were difficult beyond an age of about 10 years. The criteria used by Kimura et al. (1979) for yellowtail rockfish, *S. flavidus*, were followed for estimating age. However, in contrast to Kimura et al.'s experience with yellowtail rockfish, the anteriodorsal and posteriodorsal regions were usually more easily interpreted than the anterior region. Also, we have found it easier to count from the outer edge to the center of the otolith rather than the reverse, as was usually done by Kimura et al. (1979). Kimura et al. also counted from the outer edge when reading otoliths from older fish. Thick, difficult-to-read otoliths were sectioned using a Buehler Isomet triple-blade saw and read using transmitted light at 50×. Transparent nail mender was used for mounting the otoliths for sectioning and reading. Total lengths were measured for the California samples, while fork lengths were measured for the others. The relationship

$$\text{Fork length} = 6.1635 + 0.9341\ \text{Total length (mm)}$$

was used to estimate fork length from total length. The relationship was estimated by least squares from measurements made of fish captured off California.

The von Bertalanffy growth curve was used to describe growth:

$$\text{Fork length} = L_\infty[1 - e^{-k(\text{Age} - t_0)}]$$

where

L_∞ = theoretical average size at infinite age
k = instantaneous growth completion rate
t_0 = theoretical age when length is zero.

The computer program BGC3 (Abramson 1971) was used to estimate the parameters of the model. Most couplets of age and size used to estimate the parameters were averages of size at age by trimester and sampling area. If sample size from a given area

and trimester was less than 10, data from more than one area were combined. Averages for entire years were used for fish older than 13 years because growth is relatively slow at this age and sample sizes were small. If sample size was smaller than 10 for fish older than 15 years, data from adjacent years were combined.

RESULTS

Since geographical location did not appear to have an effect on seasonality of ring formation, samples from all sources were combined for Table 1. The results show that few otoliths have opaque edges during January through April, compared with a large majority during June through November. The marked seasonality of ring formation indicates that otoliths are valid for age estimation of widow rockfish up to about 10 years old. The results are similar to those of Kimura et al. (1979) for yellowtail rockfish, except that the opaque edge appears about a month later in the spring for widow rockfish. Kelly and Wolf (1959) obtained similar results for redfish, *S. marinus*, up to 7 years old from the Gulf of Maine. Westrheim (1973) found that juvenile Pacific ocean perch, *S. alutus*, form one ring per year off British Columbia.

Differences in age estimates between entire and sectioned otoliths are shown in Tables 2 and 3. On the average, age estimates are higher from sectioned otoliths than from entire otoliths of all sizes. There is a tendency for differences in age estimates to increase with size. However, most otoliths were selected for sectioning because they were relatively thick and difficult to interpret. Thus while the tendency is valid for age differences to increase with size, the data in Table 2 are not representative of the true relationship between size and difference. Differences tended to be greater for males than for females. Otoliths from males are thicker for a given size of fish than otoliths from females and are more difficult to interpret. The average difference was only 3.03 years for males and 2.45 years for females, but differences as great as 11 years for males and 14 years for females were observed (Table 3). While these differences seem large, they are small compared with some as great as 50 years found by Beamish (1979) for the relatively slow-growing Pacific ocean perch. In concordance with Beamish (1979), I found the first few annuli adjacent to the focus of sectioned otoliths difficult to interpret. I also agree with Beamish (1979) that structures that I interpreted to be older annuli on sectioned otoliths, and that account for the observations of large differences between estimates from some sectioned and entire otoliths, are often straightforward to interpret and give every indication of being valid annuli.

Data from 2,003 female and 2,184 male fish were used to estimate the parameters of the von Bertalanffy growth curve. When otoliths were sectioned, age estimates from the sections were used. Females and males were treated separately because growth often exhibits sexual differences for rockfish (Beamish 1979; Boehlert and Kappenman 1980; Fraidenburg 1980; Golden et al. 1980; Kelly and Wolf 1959; Kimura et al. 1979; Lenarz 1980; Six and Horton 1977; Westrheim 1973; and Wilkins 1980).

Since Boehlert and Kappenman (1980) found latitudinal differences in growth for *S. diploproa*, growth curves were estimated separately for fish sampled from California and Oregon (Fig. 1). The greatest differences were found for fish less than 7 years old; very few of these fish were caught by the commercial fisheries of Oregon and California, but a significant portion of the California recreational catch is less than 7 years old (Cooperrider 1987). There is a good possibility that the younger age groups that appear in low numbers in the Oregon fishery are relatively fast-growing members

Table 1—Seasonality of ring formation on otoliths of widow rockfish collected off California, Oregon, and Washington, 1978-80.

Month	Number with opaque edge	Number with hyaline edge	Percent with opaque edge
January	4	30	12
February	4	54	7
March	6	33	15
April	3	30	9
May	7	16	30
June	67	9	88
July	215	22	91
August	57	11	84
September	220	1	100
October	230	17	93
November	32	1	97
December	26	11	70

Table 2—Average differences in age estimates between sectioned and entire otoliths of widow rockfish by size and sex.

Fork length (cm)	Male		Female	
	Avg. difference (yr)	No.	Avg. difference (yr)	No.
41	2.5	2		
42	2.4	9	1.3	3
43	3.4	16		
44	3.1	35	1.3	3
45	2.9	33	1.6	7
46	4.0	19	1.1	15
47	2.6	7	1.6	23
48	0.8	4	2.4	43
49	3.0	1	2.9	33
50	0.5	2	2.8	36
51			3.7	20
52			2.5	8
53			2.5	2
			4.0	2

Table 3—Frequency distributions of differences in age estimates between sectioned and entire otoliths of widow rockfish by sex.

Difference (yr)	No. males	No. females
−4	6	1
−3	4	1
−2	2	3
−1	7	12
0	10	25
1	14	30
2	20	39
3	18	34
4	15	17
5	14	9
6	12	11
7	6	6
8	1	2
9	1	1
10	2	2
11	2	1
12		
13		
14		1
Average	3.03	2.45

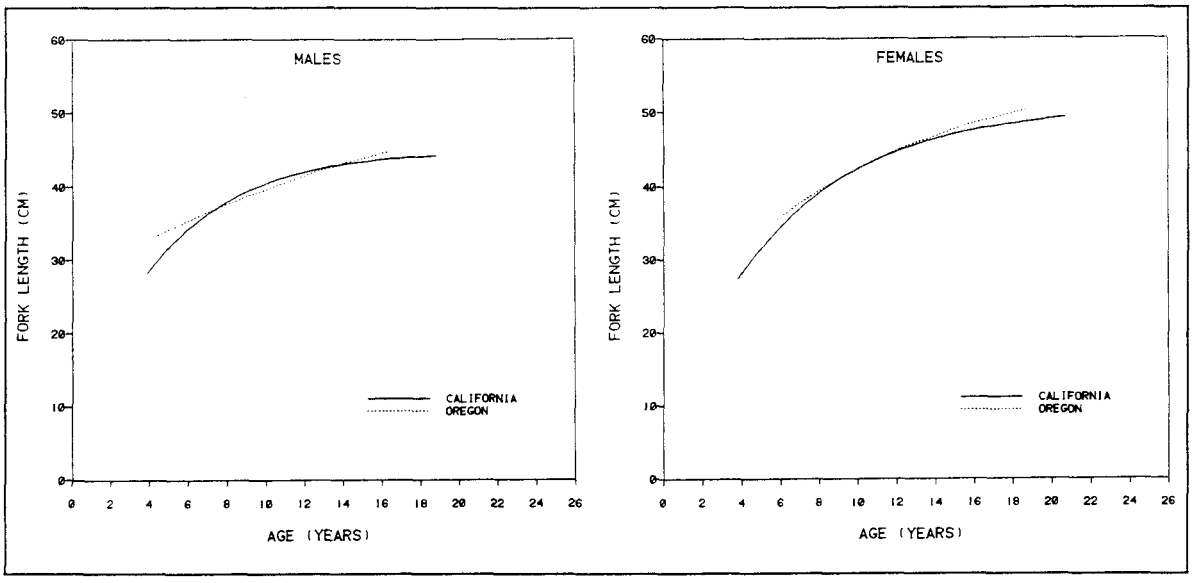

Figure 1—Estimated von Bertalanffy growth curves for male and female widow rockfish caught off Oregon and California.

of their cohorts. Thus, the difference observed in the growth curves could be due to sampling artifacts and not have an underlying biological basis. Consequently, it was decided to combine fish from all areas.

The von Bertalanffy curve provides an excellent description of the growth of females (Fig. 2, Table 4). The relationship was estimated to be

$$\text{Fork length (cm)} = 51.5690(1 - e^{-0.1501(\text{Age(yr)} + 1.4109)}).$$

The estimated growth curve for males is also satisfactory (Fig. 2, Table 5). The relationship is estimated to be

$$\text{Fork length (cm)} = 46.7394(1 - e^{-0.1650(\text{Age(yr)} + 1.9355)}).$$

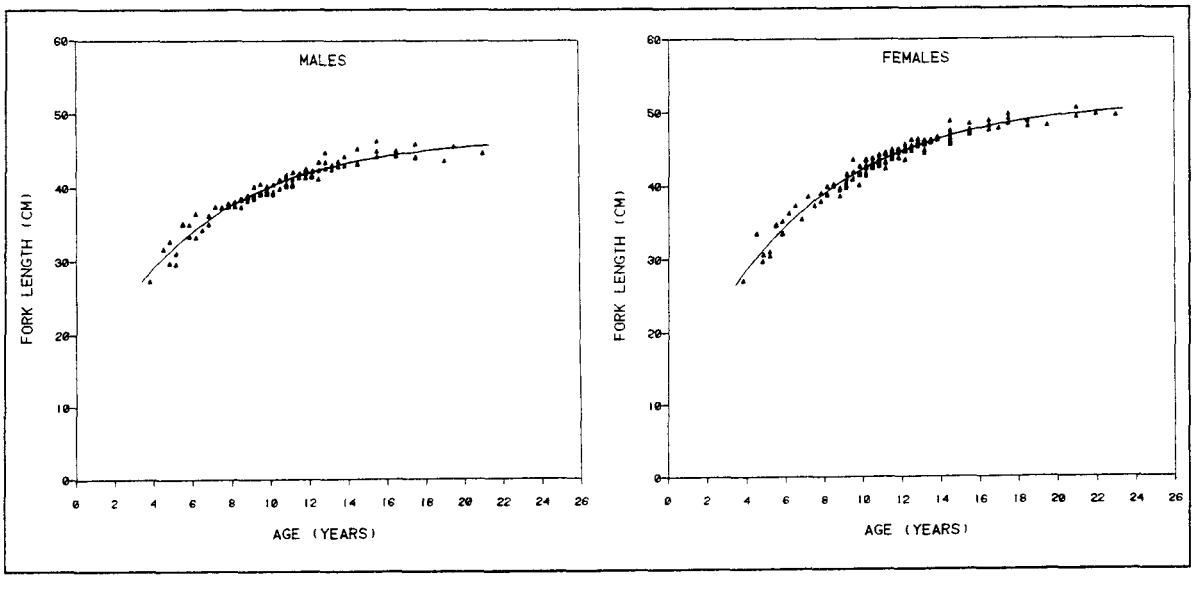

Figure 2—Estimated von Bertalanffy growth curves for male and female widow rockfish caught off California and Oregon, and observations of average size at age.

Table 4—Variables of the von Bertalanffy growth curve for female widow rockfish.

Age (yr)	Number of averages	Estimated average (mm)	Average of averages (mm)	Range of averages Minimum (mm)	Range of averages Maximum (mm)
3.83	1	281	272		
4.50	1	303	336		
4.83	2	314	303	298	307
5.17	2	324	309	306	312
5.50	2	333	348	347	348
5.83	3	342	341	335	353
6.17	1	350	364		
6.50	1	358	374		
6.83	1	366	356		
7.17	1	373	386		
7.50	1	380	374		
7.83	2	387	386	380	391
8.17	3	393	393	383	400
8.50	2	399	402	400	403
8.83	3	405	393	387	398
9.17	5	410	406	398	417
9.50	4	415	419	409	436
9.83	5	420	416	402	427
10.17	6	425	426	415	436
10.50	5	429	429	424	438
10.83	6	434	434	428	442
11.17	6	438	437	424	445
11.50	5	441	442	436	449
11.83	6	445	447	438	450
12.17	5	449	448	436	457
12.50	4	452	454	448	463
12.83	4	455	459	454	464
13.17	6	458	455	445	462
13.50	3	461	462	459	463
13.83	3	463	465	463	467
14.50	6	468	470	457	489
15.50	5	475	476	470	485
16.50	3	481	482	476	489
17.00	1	483	479		
17.50	3	486	492	485	498
18.50	2	490	485	481	488
19.00	1	492	496		
19.50	1	493	482		
20.50	1	496	496		
21.00	1	498	506		
22.00	1	500	497		
23.00	1	502	496		

Table 5—Variables of the von Bertalanffy growth curve for male widow rockfish.

Age (yr)	Number of averages	Estimated average (mm)	Average of averages (mm)	Range of averages Minimum (mm)	Range of averages Maximum (mm)
3.83	1	287	274		
4.50	1	306	318		
4.83	2	314	313	298	328
5.17	2	323	305	297	312
5.50	2	330	352	351	352
5.83	2	338	343	335	351
6.17	2	345	350	333	366
6.50	1	351	343		
6.83	2	357	357	351	363
7.17	1	363	375		
7.50	1	369	374		
7.83	2	374	377	375	379
8.17	3	379	379	375	381
8.50	3	384	381	374	386
8.83	3	388	387	383	390
9.17	4	393	391	385	402
9.50	3	397	398	392	406
9.83	5	400	397	392	402
10.17	4	404	397	392	405
10.50	4	407	408	399	411
10.83	4	411	410	402	418
11.17	5	414	410	403	422
11.50	3	416	418	414	420
11.83	4	419	421	413	426
12.17	4	422	418	415	423
12.50	3	424	424	412	435
12.83	3	426	436	426	448
13.17	2	429	428	425	431
13.50	2	431	433	429	436
13.83	2	433	437	430	443
14.50	3	436	439	432	453
15.50	3	441	452	442	463
16.50	3	445	447	443	450
17.50	3	448	447	440	459
19.00	1	453	436		
19.50	1	454	456		
21.00	1	457	446		

DISCUSSION

A comparison of the growth curves of this study with that of Phillips (1964) (Fig. 3) reveals that Phillips estimated size at age to be larger. The difference may be explained by Phillips' use of scales which are unreliable for age estimates of relatively old rockfish (Kimura et al. 1979; Six and Horton 1977; Westrheim 1973). There is a tendency to underestimate age using scales, and Phillips used back-calculated size at age. An underestimated terminal age could result in size at age being overestimated for some of the subterminal ages of the specimen.

The results for fish 10 years and younger indicate that only one ring per year is laid down. Beyond age 10, the rings appear similar to rings verified as young annuli in younger fish. Otoliths from large fish become thick and difficult to interpret unless sectioned. The first few annuli of sectioned otoliths are difficult to interpret, but interpretation of older rings is often straightforward, since they appear similar to the valid annuli verified through seasonality of ring formation. If accurate estimates of the age of older fish are desired, otoliths should be sectioned in females larger than ~47 cm and males larger than ~ 44 cm. Otolith thickness in fish of a given size varies considerably. Thus it is sometimes desirable to section otoliths from fish smaller than the above guidelines, and sometimes it is not necessary to section otoliths from larger fish.

The estimated values of k, 0.1501 for females and 0.1650 for males, are mid-range for rockfish. Values of <0.1 have been reported for Pacific ocean perch (Golden et al. 1980) and splitnose rockfish, *S. diploproa* (Boehlert and Kappenman 1980); and >0.2 for shortbelly rockfish, *S. jordani* (Lenarz 1980), and black rockfish, *S. melanops* (Six and Horton 1977). Since k for widow rockfish is well within the range for other rockfish, the population responses to fishing are likely to be about average for rockfish (Adams 1980).

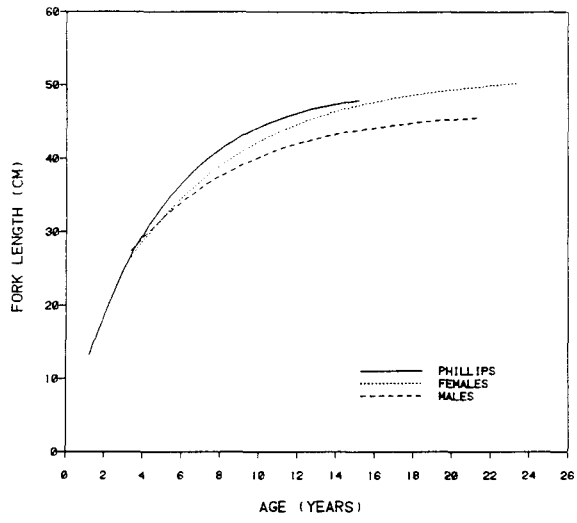

Figure 3—Comparison of growth curves estimated for widow rockfish by Phillips (1964) and this study. Phillips' data were converted from total length to fork length.

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