NOTES

FECUNDITY OF THE WIDOW ROCKFISH, *SEBASTES ENTOMELAS,* OFF THE COAST OF OREGON

During the past several years a strong fishery has developed for the widow rockfish, *Sebastes entomelas.* Historical records and the trace amounts captured in early demersal fish surveys (Alverson et al. 1964) contrast sharply with recent catches. Between 1963 and 1977, for example, total catches from 16 to 666 metric tons (t) were landed in Washington, Oregon, and northern California as compared with 19,526 t in 1980 (Demory[1]). Traditional demersal fish surveys have undersampled this species because of both its level of aggregation and its midwater habits (Alverson et al. 1964; Gunderson and Sample 1980) and have therefore not recognized the value of the resource. The increased importance of *S. entomelas* in the west coast trawl fishery has resulted in increased effort to obtain biological information necessary for management of the fishery (Lenarz and Gunderson[2]).

This note is intended to describe the fecundity of *S. entomelas* off Oregon as a function of length and weight, adding to the limited information available from samples collected in 1957 through 1959 and described by Phillips (1964).

Materials and Methods

Sebastes entomelas ovaries were collected in December 1980 and January 1981 during port sampling in Newport, Oreg., by the Oregon Department of Fish and Wildlife. All samples were taken from commercial midwater trawling vessels which had fished off central Oregon (lat. 42°30' to 45°00'N). While the port sampling was random with respect to size, the samples selected for fecundity analysis were size stratified, and large and small samples were relatively overrepresented. Each specimen was measured to the nearest centimeter in fork length (FL) and

weighed to the nearest 10 g; otoliths were removed for subsequent age determination. Ovaries used for fecundity estimates in the present study were those with yolked oocytes corresponding to maturity stage 3 of Barss and Echeverria,[3] although eggs were counted in a few fertilized ovaries which, when collected, showed no signs of extrusion. Whole ovaries were preserved in Gilson's solution modified as described in Gunderson et al. (1980). The solution was changed after approximately 1 wk, and after two more weeks the ovaries were teased apart with forceps and shaken at regular intervals to facilitate separation of ovarian tissue from oocytes. Finally, after approximately 3 mo, the ovaries were put through a coarse strainer under running water, which aided in separating oocytes from ovarian tissue.

Oocyte counts were made by the wet subsampling method (Bagenal and Braum 1968). Oocytes were placed in a beaker and the contents were diluted to a final volume dependent upon the size of the ovary, but varying from 200 to 2,000 ml. The oocytes and water were placed on a magnetic stirrer and stirred until a homogeneous mixture was obtained. Six subsamples (2 ml each) were taken by pipette and placed in vials. Three to six subsamples were counted (depending upon variability of the first three counts) under a binocular microscope. Since all ovaries were mature and within a month of fertilization, there was no difficulty in discerning and counting maturing oocytes. Fecundity was estimated by multiplying the mean number of maturing oocytes per milliliter by the volume of water and oocytes from which the subsamples were drawn.

Results and Discussion

Sixty-eight ovaries from *S. entomelas* were collected, three in December 1980 and 65 in January 1981. Four of the ovaries showed signs of fertilization; although counts were taken on these four specimens, they were not included in the

fecundity estimates, which correspond to the "pre-fertilized" fecundity of Raitt and Hall (1967). The distribution of fish lengths for the fecundity samples is shown in Figure 1.

Mean diameter of the preserved, unfertilized oocytes was 0.814 mm and individual means ranged from 0.634 to 0.954 mm. The mean number of oocyte subsamples counted was 4.1 and ranged from 3 to 6. Coefficients of variation of the counts ranged from 0.6 to 10.2% with a mean of 4.6%. As expected, fecundity increased with increasing length, with estimates ranging from 95,375 oocytes at 33 cm FL to 1,113,000 oocytes at 52 cm FL (Fig. 2). Data were fit with linear regressions as used by Gunderson et al. (1980) and with power functions frequently used in fecundity-length relationships (Bagenal and Braum 1968; Raitt and Hall 1967). Although both equations were highly significant, the linear regression provided a slightly better fit to the data but may underestimate fecundity at lengths below about 36 cm FL. Only rarely, however, are females smaller than 35 cm FL sexually mature (Barss and Echeverria footnote 3). A linear relationship was also used to describe the weight-fecundity relationship (Fig. 3). The fitted equations are as follows:

Length
$$F = 59,182.4 \ L - 1,999,200$$
$$r^2 = 0.90 \qquad N = 64$$
    or
$$\log F = 5.431(\log L) - 3.19$$
$$r^2 = 0.89 \qquad N = 64$$

FIGURE 2.—Fecundity of *Sebastes entomelas* as a function of fork length (cm). Triangles represent mean values for fecundity from the present study and the line represents the fitted curve through these points. Squares represent mean values of fecundity from Phillips (1964) with lengths converted to the nearest cm FL. The relationship from the present study is significantly different from that of Phillips (analysis of covariance, $P<0.01$).

Weight
$$F = 605.71 \ W - 261,830.7$$
$$r^2 = 0.91 \qquad N = 64$$

where F = fecundity (maturing oocytes), L = fork length (cm), W = weight (g), r^2 = coefficient of determination, and N = number of specimens. Fecundity of *S. entomelas* is thus relatively high within the genus *Sebastes*, with values similar to
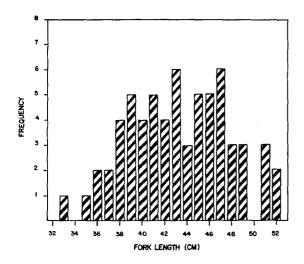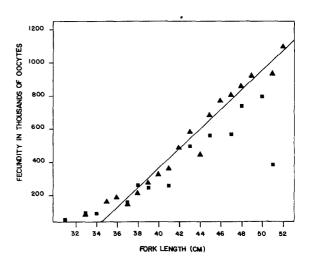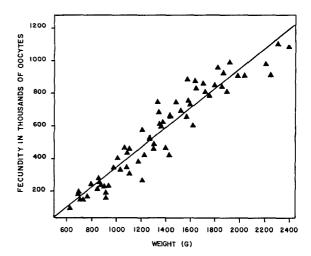

FIGURE 1.—Length-frequency of specimens of *Sebastes entomelas* used in estimating fecundity.

FIGURE 3.—Fecundity of *Sebastes entomelas* as a function of weight. Each point represents an individual specimen.

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those of *S. flavidus* and *S. pinniger* at equivalent lengths (Gunderson et al. 1980). The mean value of weight-specific fecundity (389 eggs/g body weight) is also relatively high for this genus, as summarized by MacGregor (1970); this value should be considered carefully, however, since weight-specific fecundity is dependent upon size and age (Table 1).

TABLE 1.—Weight-specific fecundity (eggs/g body weight) by age class of *Sebastes entomelas* from the present study. N = number of specimens, SE = standard error of the mean. The mean age of specimens >15 yr is 21.5 yr.

Age (yr)	N	Specific fecundity (eggs/g)	SE
5	1	151.4	—
6	3	254.0	37.0
7	6	272.9	31.4
8	3	273.3	6.7
9	5	355.3	26.9
10	12	374.7	27.9
11	14	444.9	22.6
12	6	423.4	38.2
13	5	476.8	22.5
14	1	516.1	—
≥15	8	447.4	7.8

The length-fecundity and weight-fecundity relationships described in the present study differ significantly from data presented by Phillips (1964; analysis of covariance, $P<0.01$). The 20 fish in his study were collected from 1957 to 1959 in California. We converted the total length measurements in Phillips to fork length using the total length-fork length relationship in Lenarz[4] and plotted mean values by 1 cm length intervals for comparison with data from the present study (Fig. 2). Values are similar through approximately 40 cm FL, but at greater lengths the values from Phillips are more variable and generally lower than fecundity determined in the present study. Similarly, data on mean weight-specific fecundity was lower; MacGregor (1970) calculated a value of 288 eggs/g from Phillips' (1964) data. As stated above, the mean from the present study was 389 eggs/g. The weight-fecundity regression from Phillips (1964) is characterized by a lower slope. The lines intersect near 1,000 g and Phillips' estimate at 2,000 g is

67.5% of that predicted by the regression from the present study. Gunderson et al. (1980) noted a similar pattern of generally lower fecundity at greater lengths when comparing their data for *S. goodei* and *S. flavidus* with that of Phillips (1964). Since the methods in the present study are most similar to those of Gunderson et al. (1980), methodological differences could explain the different results. Geographic differences, however, may also be involved. Gunderson et al. (1980) noted increased fecundity at length for *S. goodei* in northern as compared with southern geographic regions. Clear differences are also apparent in the length at 50% maturity for several species of *Sebastes*, with maturity occurring earlier in southern areas. Barss and Echeverria (footnote 3), for example, noted that the length and age at 50% maturity for *S. entomelas* females are 38 cm FL and 7 yr off Oregon and 32 cm FL and 5 yr off California. Thus reproductive characteristics within species may differ between areas.

It is probable that *S. entomelas* spawns only once per year. While MacGregor (1970) noted evidence of multiple spawning in three species of *Sebastes*, these species were generally characterized by lower weight-specific fecundity than observed for *S. entomelas*. Furthermore, the lack of a secondary mode of oocytes and the distinct, relatively short spawning season noted by Barss and Echeverria (footnote 3) in both Oregon and California samples indicate a single spawning per year for this species.

Estimates of fecundity from the four samples of *S. entomelas* with fertilized ovaries were below values predicted from the weight-fecundity relationship; the percent of expected fecundity decreased with increasing developmental stage of embryo (Table 2). These specimens had no signs of extrusion of embryos during capture, but it cannot be ruled out. Raitt and Hall (1967), however, noted that egg counts from fertilized

TABLE 2.—Percentage of nonviable eggs and reduction in fecundity in the ovaries of four specimens of fertilized *Sebastes entomelas*. The percent nonviable eggs was determined in four subsamples of 300 eggs. Expected fecundity was determined from the weight-fecundity relationship.

Ovarian stage	% nonviable eggs (±2 SE)	Fecundity (% expected)
Newly fertilized	0.4 (0.17)	87
Late high blastula	1.0 (0.81)	62
Late high blastula	3.2 (0.79)	56
Eyed embryos	0.4 (0.17)	38

specimens of *S. marinus* were below those of non-fertilized specimens and suggested that the difference was related either to incomplete fertilization or to presence of nonviable eggs which are subsequently resorbed after fertilization. MacGregor (1970) observed undeveloped or unfertilized oocytes from the same batch as developing embryos in all species of *Sebastes* examined, but these accounted for only 0.06% of the egg count in *S. paucispinis*. In *S. entomelas*, this percentage was higher (Table 2). Moreover, since the percentage of expected fecundity decreases with later developmental stage, resorption of nonviable embryos may occur throughout the gestation period. Because estimated and realized fecundity may differ, Gunderson (1977) suggested that fecundity estimates of *S. alutus* be considered tentative. Foucher and Beamish (1980) have made similar suggestions concerning fecundity of the oviparous Pacific hake, noting that nonviable oocytes could contribute to overestimates of fecundity. In the genus *Sebastes* it would thus be interesting to determine fecundity in various stages of developing and fertilized ovaries in a shallow living species which could be captured with no fear of extrusion-related reductions in counts of fertilized eggs or embryos.

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A COMPARATIVE STUDY OF AUTOCHTHONOUS BACTERIAL FLORA ON THE GILLS OF THE BLUE CRAB, *CALLINECTES SAPIDUS*, AND ITS ENVIRONMENT[1]

The bacterial flora of blue crabs, *Callinectes sapidus*, has been previously enumerated and identified by examining blue crab hemolymph (Tubiash et al. 1975; Sizemore et al. 1975; Colwell et al. 1975). Other studies on live blue crabs

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