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NOTES ON THE LIFE HISTORY TRAITS OF THE ROSETHORN ROCKFISH, *SEBASTES HELVOMACULATUS*

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The rosethorn rockfish, *Sebastes helvomaculatus*, inhabits the Northeast Pacific Ocean along the west coast of North America from the Coronado Islands, California to Cape Yakataga, Alaska in the north and the Shumagin Islands, Alaska to the west. Adults inhabit depths ranging from 22 to 507 m and are usually found resting solitary in crevices or caves on vertical wall habitat or in mud protected by boulders or cobble. The maximum observed size was found in a female specimen 420 mm fork length (FL) and 1200 g. Age composition and growth were estimated from sectioned sagittal otoliths of 194 fish collected in 1995. Ages ranged from 6 to 64 years. Growth was slow and was best described by the von Bertalanffy growth model. A total of 82 gonads was collected throughout 1995. Reproductive observations for rosethorn rockfish showed an annual cycle with group synchronous development producing only one brood per year. The gonadosomatic index (GSI) peaked in November for males and in May for females. Parturition occurs from May to June. The length at 50% maturity was 228 mm FL for males and 208 mm FL for females. The rate of natural mortality (*M*) was estimated to be 0.04 using the GSI method and 0.07 using the maximum age method.

The rosethorn rockfish, (*Sebastes helvomaculatus* Ayres 1859), is in the subfamily Sebastinae and family Scorpaenidae (Kendall 1991). William O. Ayres first described *Sebastes helvomaculatus* 17 October 1859 from specimens taken near San Francisco, California. At that time, it was brought to the San Francisco fish markets in considerable numbers with lengths rarely exceeding 10 inches (250 mm) (Ayres 1859). The rosethorn rockfish is small, with olive green mottling on its dorsal surface that gives way to yellow and coral coloration on its sides. There are four and sometimes five white spots on the dorsal surface above the lateral line. Its ventral surface is light-pink. The American Fisheries Society recognizes the common name rosethorn rockfish for *Sebastes helvomaculatus*. Other common names include rosethorn rockcod, swordspine, flyfish, deep-water scacciatale and deep-water scratch-tail (Hitz 1965). The purpose of this note is to present information on species longevity, growth rates, and maturation schedule.

Rosethorn rockfish range from near the Coronado Islands, California (32°34'N, 117°22'W)[1] to Cape Yakataga, Alaska (59°38'N, 142°34'W)[2] in the north and the Shumagin Islands, Alaska (54°22'N, 160°01'W)[2] to the west (Fig. 1). Adults inhabit depths from 22[1] to 507[2] m. Off southeastern Alaska, in a remotely operated vehicle (ROV) study, rosethorn rockfish were usually found alone on vertical wall habitat

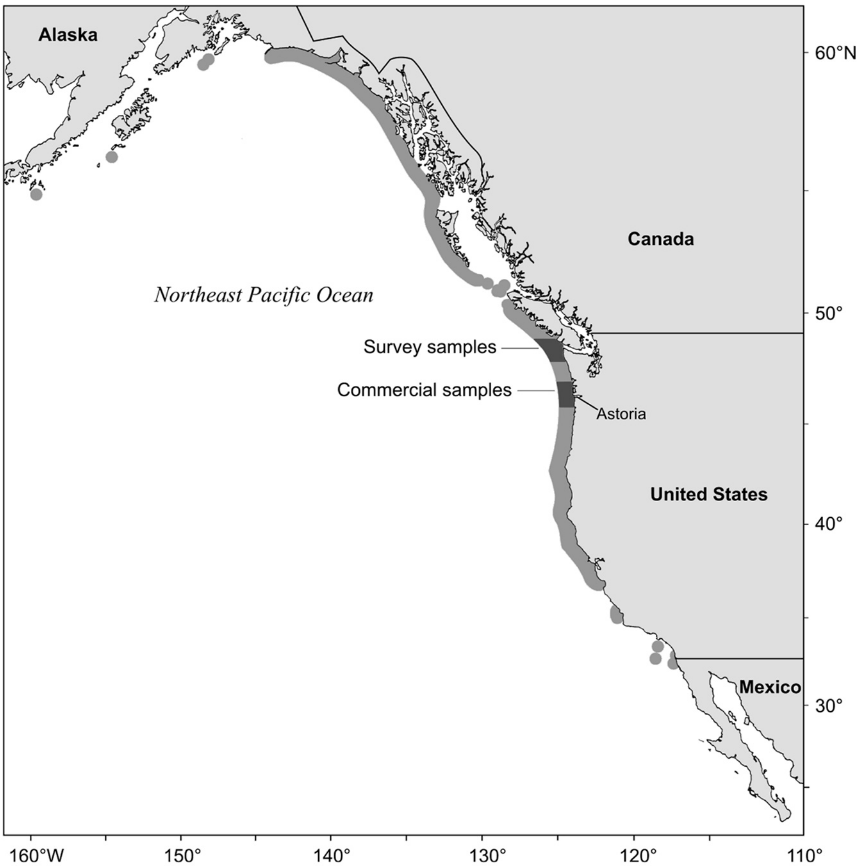

Figure 1. Distribution of rosethorn rockfish based on records in the National Marine Fisheries Service, Alaska Fisheries Science Center, Resource Assessment and Conservation Engineering survey database 1948-2005, and the Scripps Institution of Oceanography Marine Vertebrates Collection, University of California, San Diego. Locations of areas where specimens used in this study were captured are also shown.

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[1]Scripps Institution of Oceanography Marine Vertebrates Collection, University of California, San Diego.

[2]National Marine Fisheries Service, Alaska Fisheries Science Center, Resource Assessment and Conservation Engineering survey database 1948-2005.

(Johnson et al. 2003). Off the west coast they are often found solitary resting in crevices or caves, and in mud protected by boulders or cobble (Pearcy et al. 1989, Love et al. 2002). In a submersible study off northern Washington, they were found much more often in untrawlable areas, than in areas that could be trawled (Jagielo et al. 2003). Commercial catches of rosethorn rockfish are taken principally in bottom trawls from California to Washington and by longline gear in the eastern Gulf of Alaska at depths between 80 and 400 m.

Most of the specimens in this study were sampled from research trawl tows in the National Marine Fisheries Service (NMFS) 1995 West Coast triennial survey (Wilkins et al.[3]) which extended from Point Conception (34°27'N) to the middle of Vancouver Island (49°40'N). Since the research surveys do not cover all seasons of the year, additional monthly collections were taken from the commercial trawl landings in Astoria, Oregon (46°13'N) in 1995. Fork lengths (FL) were recorded for all rosethorn rockfish captured in the survey tows and collected from the commercial trawl landings. Existing data sets from bottom trawl surveys conducted by the Alaska Fisheries Science Center (AFSC) were analyzed to determine the geographic and depth distributions of this species.

On NMFS research cruises, sagittal otoliths were collected from stratified samples of five fish per sex per centimeter FL. Otoliths were taken from all fish sampled in the commercial trawl landings. Otoliths were stored in 50% ethanol and were aged using the "break and burn" method following the criteria of Chilton and Beamish (1982). Age readings were taken from the left otolith, unless there was a problem with clarity, in which case the right otolith was used. The broken otolith surface consisted of opaque and translucent (hyaline) zones. Each hyaline zone was considered an annulus. The sulcus region was the preferred area on the otolith for reading ages, but counts were made in at least two regions, if possible, wherever the clarity was best. The opaque nucleus and the first hyaline zone were considered the first year and each following year was represented by an opaque zone followed by a hyaline zone (Bratberg 1956, Westrheim 1973, Six and Horton 1977, Nedreaas[4] 1990). Only annuli that were continuous throughout the otolith were counted. Only completed annuli were counted (e.g., the newly forming opaque zone was not counted until a clearly defined hyaline zone was formed). All ages of fish were assumed to have a 1 January birth date; that is, the age in the first half of the year equaled the number of annuli plus 1 and later in the year when the hyaline zone was evident the age simply equaled the number of annuli. Annular deposition of opaque and translucent zones for rockfish species has been validated using marginal increment analysis (Kimura et al. 1979, Love et al. 1990, Pearson et al. 1991, Pearson 1996, Shaw and Gunderson

[3]Wilkins, M.E., M. Zimmermann, and K. L. Weinberg. 1998. The 1995 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U. S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-89, 138 p. plus Appendices.

[4]Nedreaas, K.H. 1990. Genetic studies and age-determination of northeast Atlantic redfish (Genus *Sebastes*). Dr. Scient. Thesis, University of Bergen, Norway. 181 p.

2006). Radiometric aging has also been used to validate ages for rockfish (Bennett et al. 1982, Campana et al. 1990, Kastelle et al. 2000). The break-and-burn ageing method is now used in most cases (Beamish 1979, Archibald et al. 1981, Wilson[5] 1984, Nichol[6] 1990, Beckmann et al. 1997) and is accepted as valid for the aging of rockfish (MacLellan 1997).

Ages were estimated by an age reader from the AFSC experienced in reading *Sebastes* otoliths. An age reader from the Oregon Department of Fish and Wildlife re-read a sub-sample of 20% of the otoliths to test percent agreement. Bias was assessed visually using age-bias plots (Campana et al. 1995) and precision was measured with the coefficient of variation (CV) (Chang 1982). Results from the age determination were used to develop parameters for the von Bertalanffy growth equation. Other data recorded included length, somatic weight, gonad weight, and macroscopic maturity observations.

Gonad collections were made from commercial catches landed at Astoria, Oregon, during most months in 1995. Most fish were captured with bottom trawls at locations within a few hours travel from port (near the mouth of the Columbia River). A total of 82 gonads was excised from the fish and preserved in 10% formalin buffered with sodium acetate trihydrate. Other data collected included fork length to the nearest 1.0 mm, somatic weight (gonads and stomach contents removed) to the nearest 1.0 g, gonad weight to the nearest 0.1 g, and gross maturity stage observations. Sections of testes and ovary were taken from the middle portion of the preserved gonads. These sections were embedded in paraffin wax, thin-sectioned to a thickness of 5 mm, stained with Harris' haematoxylin and counter-stained with eosin (H & E). The slides were examined to determine developmental stages for both ovaries and testes. The results were used to determine the length and ages at 50% maturity and to develop a gonadosomatic index (GSI) to estimate natural mortality (Gunderson 2003, Shaw and Gunderson 2006).

The developmental stage descriptions for the rosethorn rockfish testes and ovaries followed the same criteria used for greenstriped rockfish, (*Sebastes elongatus*), (Shaw and Gunderson 2006) and are summarized in Table 1. The diameter of the fifth largest oocyte in a random cross-section from the middle portion of each ovary was used as a measure of ovary development (West 1990, Shaw and Gunderson 2006). Oocyte and embryo diameters were measured from histological cross-sections using an ocular micrometer and compound microscope. If embryos were present in the ovary and the eggs were no longer round, the longest axis was measured. If the embryos had

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[5]Wilson, C.D. 1984. The effects of different otolith aging techniques on estimates of growth and mortality for two species of rockfishes, *Sebastes pinniger* and *Sebastes diploproa*. M.S. Thesis, Oregon State University, Corvallis. 107 p.

[6]Nichol, D.G. 1990. Life history examination of darkblotched rockfish (*Sebastes crameri*) off the Oregon coast. M.S. Thesis, Oregon State University, Corvallis, 124 p.

Table 1. Summary of the gross and cellular classes and cell stages of rosethorn rockfish testes and ovaries (from Shaw and Gunderson 2006).

Gross testes class	Cellular testes class	Sperm stages present
Immature	I, II	Ga, Gb
Developing	III, IV, V, VI, VII, VIII, IX	Ga, Gb, Gc, Gd, PSc, SSc, ESd, LSd, ESz
Ripe	X	Ga, ESz, LSz
Spent / Resting	XI	RSz, Ga, Gb, Gc, Gd, PSc, SSc
Gross ovary class	**Cellular ovary class**	**Oocytes stages present**
Immature	I, II, III	Og, CN, EPN, LPN
Vitellogenesis	IV, V, VI, VII, VIII, IX	Og, CN, EPN, LPN, OV, PY, SY, TY, MN, PM
Clear egg	X, XI	Og, CN, EPN, LPN, Mat, Em
Eyed larvae	XI	Og, CN, EPN, LPN, Em
Spent / Resting	XII	REm, EF, Og, CN, EPN, LPN, OV

Abbreviations:
Ga 1° spermatogonia **LSd** late spermatid **Og** oogonia **TY** 3° yolk
Gb 2° spermatogonia **ESz** early spermatozoa **CN** chromatin nucleolus **MN** migratory nucleus **Gc** 3° spermatogonia **LSz** late spermatozoa **EPN** early perinucleus **PM** prematuration
Gd 4° spermatogonia **RSz** residual spermatozoa **LPN** late perinucleus **Mat** mature
PSc 1° spermatocyte **OV** oil vacuole **Em** embryo **SSc** 2° spermatocyte
PY 1° yolk **REm** residual embryo **ESd** early spermatid **SY** 2° yolk
EF Empty follicle

hatched, an estimated standard length of the larvae was used as a proxy.

The age-length relationship was established by fitting the von Bertalanffy growth model to the data using a weighted nonlinear regression. This model is expressed as:

$$l_t = L_\infty(1 - e^{-K(t-t_0)}) \qquad (1)$$

where l_t = length of fish at age t;
L_∞ = theoretical maximum length;
K = growth coefficient;
t = age of fish; and
t_0 = theoretical age at zero length.

To estimate the instantaneous rate of natural mortality (M), two methods were used and compared (Shaw and Gunderson 2006): a maximum age method (Hoenig 1983) and a GSI method, which uses the equation $M = 1.79\ GSI$ (Gunderson 1997, Gunderson 2003). The relationship between length and weight was represented by the power curve equation and the length at maturity was estimated by fitting a logistic model to the observed proportion mature as a function of length (Shaw and Gunderson 2006). The relationship between total body weight and total length was represented by the power curve equation: $W = aL^b$. The percentage occurrence of mature fish at length was estimated by fitting a logistic model to the observed proportion of mature fish. The logistic equation was:

$$P_x = \frac{1}{1 + e^{ax+b}} \tag{2}$$

where P_x = proportion mature at length x;
x = fork length;
a, b = constants estimated by the model.

Nonlinear regression was used to estimate the constants.

A total of 194 otoliths was collected and read. Of these, 112 came from research survey tows off Cape Flattery, Washington during August 1995 and 82 from commercial catches taken off Astoria, Oregon throughout 1995. Size and age compositions from the research and commercial samples were compared and no statistically significant differences were found. Ages ranged from 6 to 64 years (mean = 21.6 years). Lengths ranged from 170 to 313 mm FL (mean = 242 mm). Independent readings (tests) were performed on a subsample of 38 randomly selected otoliths. Agreement (+ or – 1 year) between readings was 28.9%. The coefficient of variation (CV) between the readings was 11.6%. Mean age was 22.0 years for males, and 21.2 years for females. The von Bertalanffy growth curves for male and female rosethorn rockfish were similar, with females showing only a slightly higher $L_{¥}$ (Figure 2). Estimates of natural mortality (*M*) ranged from .042 using the GSI method to .075 for the maximum age method (Table 2). The length-weight relationships for male and female rosethorn rockfish are based on a total of 99 males and 95 females. Although males and females reached similar maximum lengths (Fig. 2), males on average weighed slightly more than females at the same length.

Reproductive observations for rosethorn rockfish showed an annual cycle with group synchronous development producing only one brood per year. Mating probably occurs from December to April off Oregon and Washington, as evidenced by the GSI which peaked in November for males, and then declined through June during an extended mating season (Fig. 3). Mature spermatozoa were observed in gonad collections from November through June and residual spermatozoa were found from May through August. In August, spermatogenesis was initiated, giving a rise in GSI values. In females, the GSI peaked in May and declined through August (Fig. 4). During August through November, the GSI held steady at low levels and then began to increase in December. Ovarian development progressed to the clear egg ovary stage by March. Females were not sampled in July, October, or January. Embryos were found in the ovaries 20 April (early embryonic stages), 9 May (mid-to late embryonic stages), and 10 June (late embryonic stages). Parturition occurs in May and June.

Table 2. Summary of life history parameters for rosethorn rockfish from this study unless otherwise noted. Standard errors are in parentheses.

	male	female
Max. Age (years)	64	61
Max. Length (mm)	400	420
Max. Weight (g)	910	1200
$W = aL^b$ (a)	0.00000712	0.00000445
$W = aL^b$ (b)	3.1278	3.2082
$L_{¥}$(mm, von Bertalanffy)	279.3	286.6
	(7.7)	(16.9)
K (von Bertalanffy)	0.113	0.101
	(0.016)	(0.018)
t_0 (years, von Bertalanffy)	-2.07	2.78
	(0.52)	(0.60)
$L_{0.5}$(mm, von Bertalanffy)	228	208
$A_{0.5}$(years, von Bertalanffy)	13	10
M (maximum age)	0.071	0.075
M (GSI)	0.042	(0.010)
GSI	0.6	2.3
Mating	Dec - Apr	
Parturition	May - Jun	
Gestation (days)	40 - 60	
Maximum Depth (m)[1]	507	
Mean Depth (m)[1]	219	
Range North[1]	59°38’	
Range South[2]	32°34’	

[1]National Marine Fisheries Service, Alaska Fisheries Science Center, Resource Assessment and Conservation Engineering survey database 1948-2005.
[2]Scripps Institution of Oceanography Marine Vertebrates Collection, University of California, San Diego.

Mean oocyte and fertilized egg diameter steadily increased from August to May (Fig. 4). A sharp increase occurs in June when larvae begin to hatch within the ovary.

The length at which 50% of male rosethorn rockfish reached sexual maturity ($L_{0.5}$) was 228 mm FL (Fig. 5) and the corresponding age ($A_{0.5}$) was 13 years based on the von Bertalanffy growth model. Some males matured at 210 mm FL and all males matured by 280 mm FL. For females, the $L_{0.5}$ was 208 mm FL and corresponding $A_{0.5}$ was 10 years. Some females matured by 190 mm FL and all females matured by 260 mm FL.

In general, this species is fairly small compared to other *Sebastes* species. They are found near the boundary of the outer continental shelf and upper continental slope (150 to 400 m), over a wide geographic range (Baja California to Alaska), and in habitats ranging from mud bottom protected by boulders and cobble to rocky

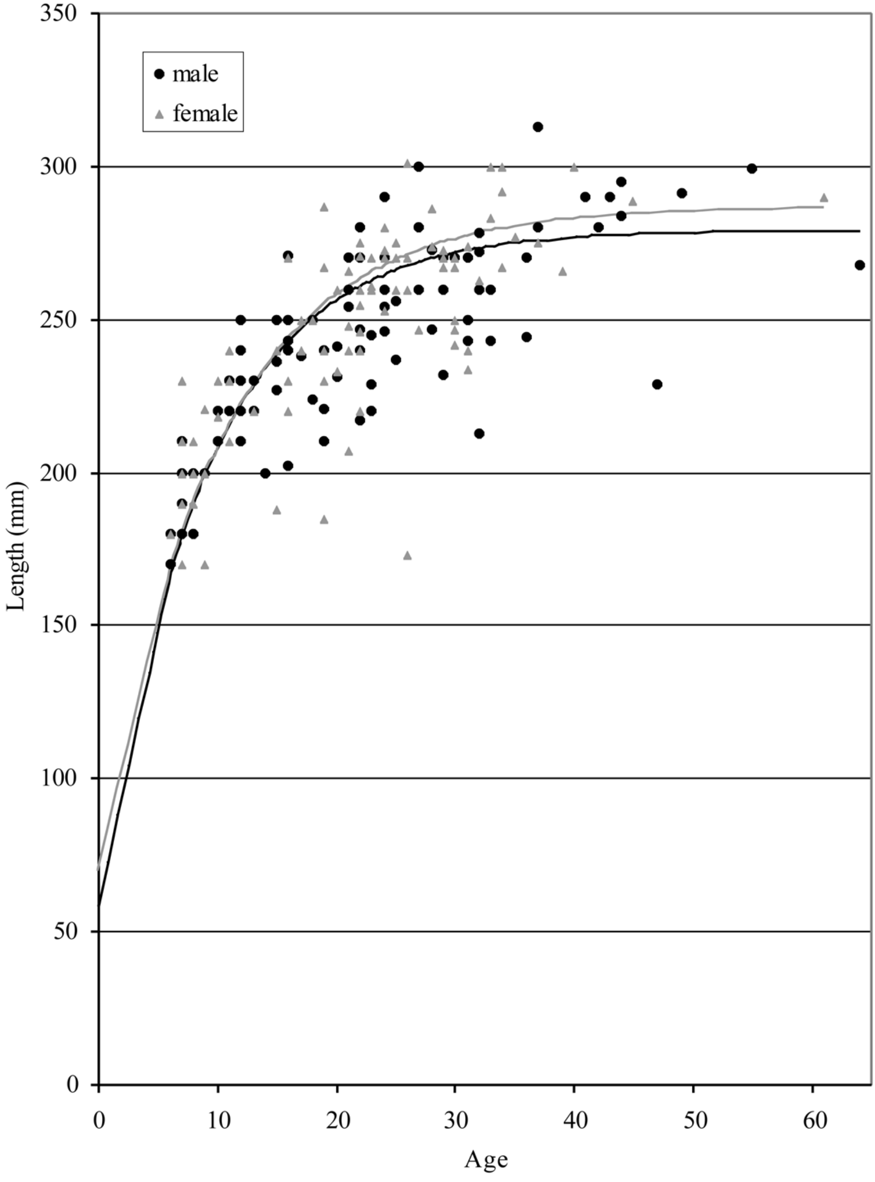

Figure 2. Male and female von Bertalanffy growth curves for rosethorn rockfish taken in 1995 from Oregon market samples and survey collections taken off Washington, Oregon, and California.

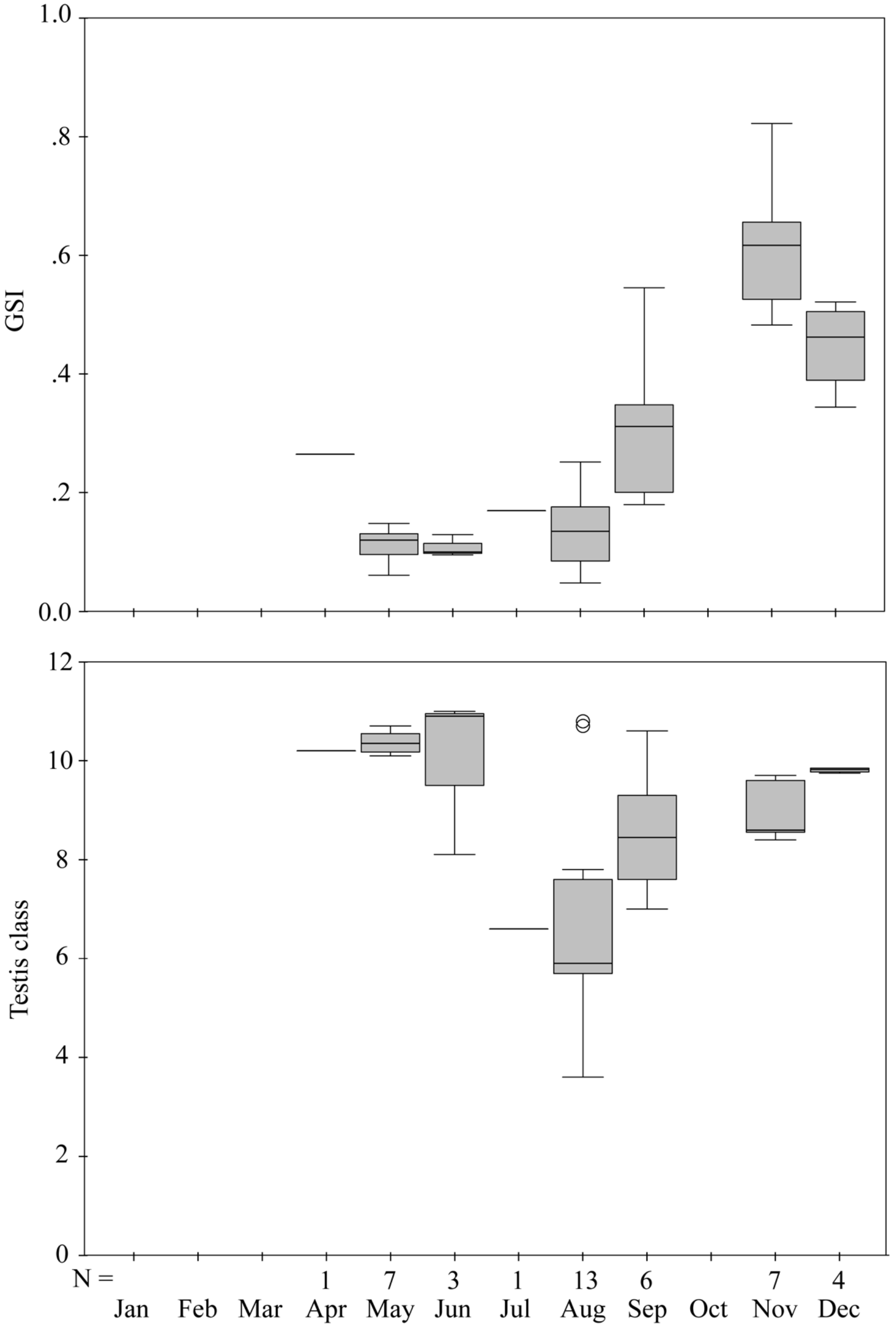

Figure 3. Box plots of the gonadosomatic index (GSI) and testes class by month for male rosethorn rockfish. The box is the interquartile range. The whiskers are the high and low values excluding outliers (o). The line across the box is the median.

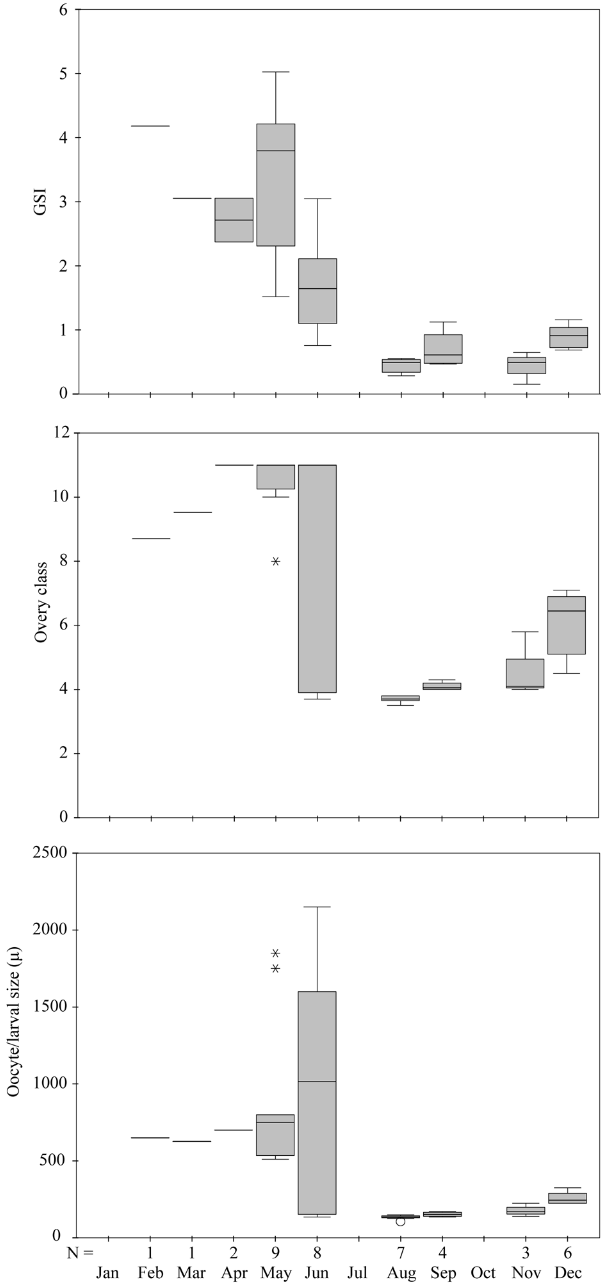

Figure 4. Box plots of the gonadosomatic index (GSI), ovary class, and oocyte/larval size (m) by month for female rosethorn rockfish. The box is the interquartile range. The whiskers are the high and low values excluding outliers (o) and extreme values (*). The line across the box is the median.

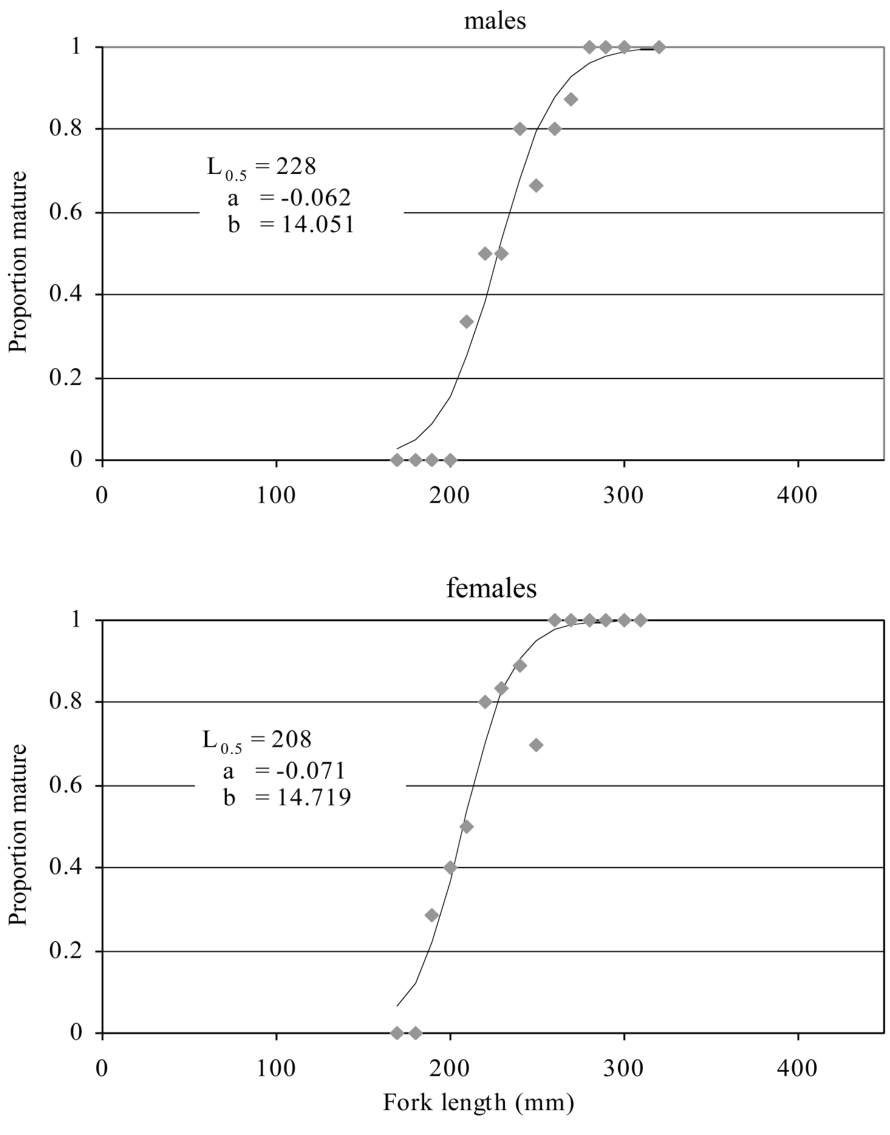

Figure 5. Maturity distributions and logistic curves for male and female rosethorn rockfish taken in 1995 from Oregon market samples and survey collections taken off Washington, Oregon, and California.

outcroppings.

Rosethorn rockfish are long-lived (to 64 years), slow-growing, and late in maturing. Growth slowed considerably after maturity, but the growth rates of males and females were similar at all ages. The length at 50% maturity estimated in this study was similar to that estimated for fish sampled off British Columbia (220-230 mm FL for males and 190-230 mm FL for females) (Harling et al.[7]). Both the British Columbia study and this study estimate a larger $L_{0.5}$ for males. The species is viviparous like all *Sebastes* species. Gonadal development of this species was similar to the greenstriped rockfish (Shaw and Gunderson 2006). Development is group-synchronous, the reproductive cycle lasts 1 year, and only one brood of embryos is produced. Copulation takes place in the winter to early spring and the spermatozoa are stored from 1 to 5 months within the ovary until fertilization takes place in the spring. Gestation lasts from 40-60 days and embryos are retained within lumen of the ovary until the yolk sack is mostly absorbed. Parturition occurs May and June.

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