AN ABSTRACT OF THE THESIS OF

Daniel G. Nichol for the degree of Master of Science in Fisheries and Wildlife presented on March 15, 1990.

Title: Life History Examination of Darkblotched Rockfish (*Sebastes crameri*) off the Oregon Coast

Abstract approved: Signature redacted for privacy.

The growth, size and age composition, mortality and reproduction of darkblotched rockfish (*Sebastes crameri*) were examined using fishery data and analysis of fish characteristics for samples collected off the Oregon coast. A total of 1060 fish, caught by commercial groundfish and shrimp trawlers operating out of Newport, Coos Bay and Astoria, were collected between July 1986 and July 1987.

S. crameri were found to be slow growing and long-lived reaching ages in excess of 100 years. The composition of fish captured with commercial groundfish trawl gear (excluding shrimp gear) was dominated by recent recruits ranging from 6 to 9 years of age. The age at full recruitment to commercial groundfish gear was 7 years. Assuming constant recruitment and mortality after 1978, total instantaneous mortality (Z) for recent recruits may have been as high as 0.42. This estimate may be inflated,

however, if the 1978-1980 yearclasses were strong relative to earlier yearclasses.

The timing of major reproductive events was protracted. Insemination occurred from September to December, fertilization from December to February, and parturition from December to March. Fifty percent of the females were mature at an age of 8 years and a total length (TL) of 36.7 cm, whereas males attained 50% maturity at an age of 5 years and 29.7 cm TL. Fecundity increased nonlinearly with fish size and ranged from 19,815 to 489,064 oocytes/ovary pair.

Based on its longevity, its relatively young age at full recruitment, and its age at maturity, *S. crameri* appears vulnerable to overexploitation.

Life History Examination of Darkblotched Rockfish (*Sebastes crameri*) off the Oregon Coast

by

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GENERAL INTRODUCTION

Despite the commercial importance and abundance of many of the rockfish (*Sebastes* spp.) found off the Oregon coast, a considerable gap in life history information exists, particularly for those species currently managed as a group called the *Sebastes* complex. This life history investigation concentrates on one of the most commercially important species within this complex, darkblotched rockfish (*Sebastes crameri*).

Since the implementation of the Magnuson Fisheries Conservation and Management Act in 1976, growth of the domestic trawl fleet off Oregon has led to increased landings of most rockfish (Golden, 1989), including *S. crameri*. Since 1979, the commercial trawl catch of *S. crameri* averaged 630 metric tons annually. Prior to 1976, *S. crameri* was an important component of the foreign trawl landings off Oregon (Niska, 1976; Fraidenburg, 1977). Research surveys conducted off the Oregon coast have indicated a high abundance of darkblotched rockfish, particularly over the continental slope (Demory et al., 1976; Richardson and Laroche, 1979; Gunderson and Sample, 1980; Weinberg, 1984; Coleman, 1986; Coleman, 1988).

Despite their abundance and high utilization, only limited research has been conducted on the life history of darkblotched rockfish. Knowledge of this species' life history and current status may assist in the implementation of new management plans on the commercial trawl fishery. This study examines the growth, size and age composition, mortality, maturity and fecundity of S. crameri based on fishery data and analysis of fish characteristics for samples collected off the Oregon coast.

REVIEW OF LITERATURE

Occurrence

The range of darkblotched rockfish extends from Santa Catalina Island off southern California to the Bering Sea (Miller and Lea, 1972). Research surveys have found abundant concentrations of *S. crameri* from Monterey, California to Vancouver Island, British Columbia (Snytko and Fadeev, 1974; Demory et al., 1976, Barss et al., 1977; Gunderson and Sample, 1980; Weinberg, 1984; Coleman, 1986; Coleman, 1988). Adult darkblotched rockfish inhabit the upper continental slope (Demory et al., 1976) in areas with complex bottom profiles, high productivity and steady gyres (Snytko and Fadeev, 1974). They are associated with other slope species such as Pacific ocean perch (*Sebastes alutus*), splitnose rockfish (*Sebastes diploproa*), yellowmouth rockfish (*Sebastes reedi*), stripetail rockfish (*Sebastes saxitola*), sharpchin rockfish (*Sebastes zacentrus*) and shortspine thornyheads (*Sebastolobus alascanus*) (Snytko and Fadeev, 1974; Niska, 1976; Fraidenburg et al., 1977). Off Oregon, *S. crameri* ranked second in terms of biomass among *Sebastes* spp. on the continental slope (Demory et al. 1976).

Darkblotched rockfish were commonly caught during triennial Pacific West coast bottom trawl surveys conducted from 1977 to 1986 by the National Marine Fisheries Service (NMFS)(Gunderson and Sample, 1980; Weinberg, 1984; Coleman, 1986; Coleman, 1988). The species was relatively more abundant in the deep water stratum (101-200 fm; 184-366 m) of the Columbia (43°00′ to 47°30′N), Eureka (40°30′ to 43°00′N) and Monterey (35°30′ to 40°30′N) INPFC[1] areas. In the 1986 survey, *S. crameri* ranked highest among all species sampled (23.3%) in terms of catch per unit effort (kg/km trawled) in the Columbia area deep water stratum (184-366 m) and ranked second (24.5%) in the deep stratum off Eureka. Although these surveys used gear which was more selective for rockfish than flatfish, the high frequency of occurrence in trawl catches suggests that *S. crameri* were highly abundant in the areas sampled.

Larval and juvenile darkblotched rockfish have been shown to be abundant off the Oregon coast. Richardson and Laroche (1979) found that *S. crameri* larvae and pelagic juveniles were most abundant between 83 and 93 km offshore (700 - 1,300 m depth), although they ranged from 23 km (95 m depth) to 194 km offshore. Shenker (1988), similarly, found highest concentrations of rockfish larvae (including *S. crameri*) to occur beyond 50 km offshore.

Catch History

Darkblotched rockfish was one of the 3 major species contributing to the Pacific ocean perch (POP) assemblage fishery off Oregon and Washington during the 1960′s. Beginning in 1966, concentrated fishing on the POP

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[1] International North Pacific Fisheries Commission.

assemblage by Russian trawlers off Oregon and Washington led to the depletion of POP by 1967. By 1971, landings of *S. crameri* by domestic trawlers surpassed those of POP (Niska, 1976).

Darkblotched rockfish was also a major species contributing to "other rockfish"[2] landings by foreign trawlers. Substantial removals of "other rockfish" by foreign trawlers (Soviet, Japanese and Polish) occurred from 1967 to 1975 off the U.S. West Coast, although estimates of total quantities removed are tenuous. Fraidenburg et al. (1977) estimated that a minimum of 33,113 metric tons of rockfish were taken by foreign trawlers from 1967 to 1975 in the Columbia INPFC area alone. Substantially greater removals were estimated for areas off British Columbia. Based on species composition data from the domestic fleet during this period, *S. crameri* was probably an important component of the foreign catch, particularly in the slope regions. Exploitation by foreign vessels off the U.S West Coast ceased with the implementation of the Magnuson Fisheries Conservation and Management Act in 1976.

Prior to 1978, total landings of darkblotched rockfish by domestic bottomfish trawlers off Oregon never exceeded 340 metric tons per year, and averaged 138 metric tons annually. After 1978, growth of the domestic trawl fleet

[2] Market category and fishery. Landings of rockfish were historically categorized into two groups: "Pacific ocean perch" and "other rockfish" (Niska, 1976).

off Oregon led to increased landings of most rockfish, including *S. crameri*. High catches of rockfish in 1981 and 1982 prompted managers to impose trip limit regulations for rockfish in 1983. All rockfish except for POP, widow rockfish (*Sebastes entomelas*), shortbelly rockfish (*Sebastes jordani*) and *Sebastolobus* spp. have since been managed as a group called the *Sebastes* complex. Since the implementation of trip limit regulations, annual landings of *S. crameri* have been relatively constant, and somewhat below the peak of 920 metric tons that occurred in 1982 (Fig. 1).

Darkblotched rockfish are currently caught by Oregon trawlers using several types of fishing strategies as defined by Pikitch (1987). Marketable fish are captured by fisherman employing both bottom rockfish (BRF) and deepwater Dover sole (DWD) fishing strategies, and juveniles are commonly caught by shrimp trawlers.

Life History

Darkblotched rockfish, like all species of the genus *Sebastes*, are viviparous, and extrude their larvae in one batch during winter. Larvae are pelagic when released and individuals as small as 8 mm in standard length (SL) have been observed (Richardson and Laroche, 1979). The transition from pelagic to benthic habitat is thought to occur when fish are approximately 40 to 60 mm SL (Richardson and Laroche, 1979). This corresponds with information reported by Phillips (1964) who collected

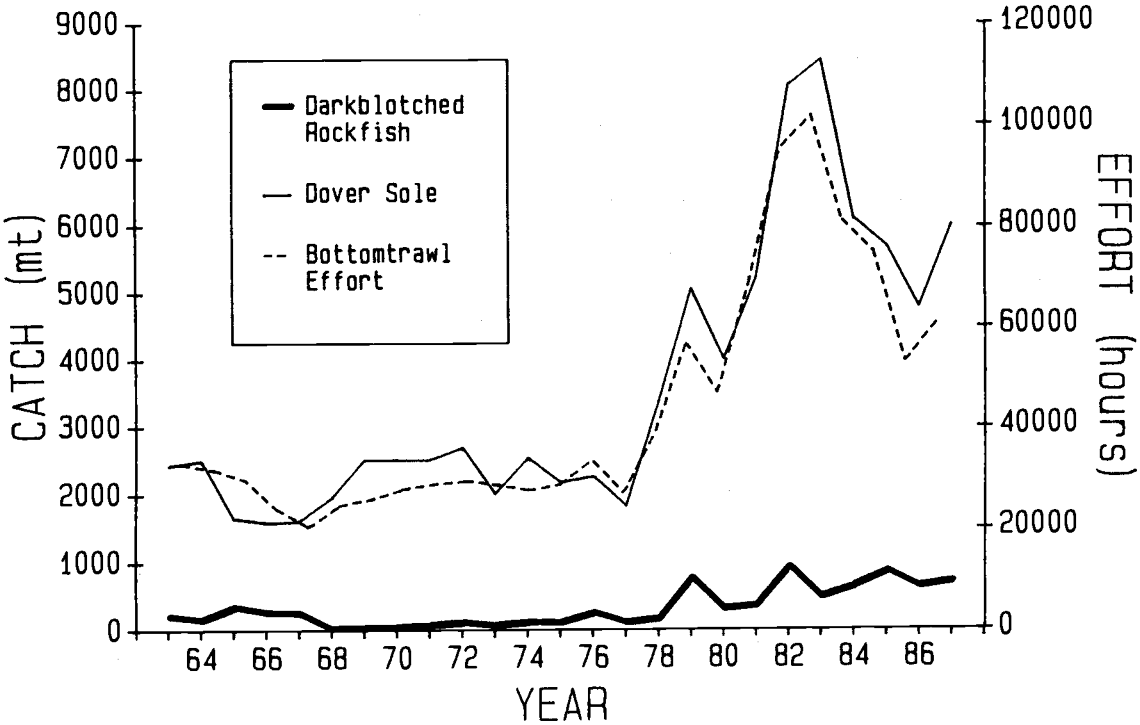


Figure I-1. Landings (metric tons) of darkblotched rockfish and Dover sole, and total effort by Oregon commercial groundfish trawlers, from 1963 to 1987.[1]

[1] Data was compiled from three sources: The Pacific Coast Fishery Information Network (PacFin), report #35, Pacific Marine Fisheries Commission, Northwest & Alaska Fisheries Center, 7600 Sand Point Way NE, Seattle, WA 98115; the Oregon Department of Fish and Wildlife annual technical sub-committee reports, 1979-85; and Barss and Niska (1978).

young-of-the-year specimens of *S. crameri*, 65-91 mm in total length (TL), on bottom habitat between 40 and 70 fathoms (fm) depth off Point Reyes and Fort Bragg, California. These specimens were approaching the end of their first year of growth (Phillips, 1964).

There has been some limited life history research conducted on *S. crameri* including studies of age-length-weight relationships, growth, maturity, fecundity, biomass and larval fecundity. Phillips (1964) presented information on maximum size (22.5 inches), distinguishing meristic features, size and age at maturity, fecundity and food habits of darkblotched rockfish caught off California. He also published information on the relationships between age, length, and weight, length-frequency distributions, and von Bertalanffy growth parameters for both sexes combined. According to Phillips (1964), *S. crameri* reached 50% maturity at an approximate length of 30.5 cm TL and an age of six years. The primary months of parturition were November through March, and fecundity (# eggs/female) ranged from 45,000 to 600,000.

Westrheim and Harling (1975) described the age-length relationships for 26 species of *Sebastes* (including *S. crameri*) off British Columbia and compared the results with Phillip's (1964) data. Phillips (1964) used scales as aging structures and Westrheim and Harling (1975) interpreted ages from whole otolith surfaces, both of which have been found to underestimate actual ages of rockfish, particularly for older fish (Beamish, 1979; Archibald et al., 1981; Bennett et al., 1982; Boehlert and Yoklavich, 1984; Wilson, 1984). Phillips (1964) and Westrheim and Harling (1975) derived maximum age estimates of 16 and 23 respectively for *S. crameri*. A subsequent study that used otolith sections for age determination, observed ages up to 47 years for *S. crameri* caught off British Columbia (Archibald et al., 1981; Leaman and Beamish, 1984; Shaw and Archibald, 1981).

Westrheim (1975) sampled over 30 species of rockfish (including *S. crameri*), primarily off British Columbia and the Gulf of Alaska, and obtained information on maturity and larval identification. In addition, Echeverria (1987) investigated the maturity and reproductive seasonality of 34 California rockfish species (including *S. crameri*) and defined maturity stage criteria for the genus *Sebastes* using histological techniques. Most recently, Barss (1989) provided data on length at maturity and reproductive cycling for 35 rockfish species captured off Central Oregon.

Westrheim (1975) calculated fork length (FL) at 50% maturity for *S. crameri* off West Vancouver Island (British Columbia) to be 34 cm for males and 37 cm for females, considerably larger than the length calculated by Phillips (1964) for *S. crameri* off California. The principal month of parturition was estimated to be February. Echeverria (1987) found 50% maturity, for *S. crameri* collected from central to northern California, to occur at a length of 27 cm TL and an age of four years for both males and females, both smaller and younger than the results obtained by Phillips (1964). The primary months of fertilization and parturition were estimated to be December and January, respectively. Barss (1989) estimated the length at 50% maturity for *S. crameri* to occur at 30 cm FL and 35 cm FL for males and females, respectively.

S. crameri has not been sampled in significant numbers, and the maturity data presented by Westrheim (1975), Echeverria (1987), and Barss (1989) should be viewed as preliminary. Westrheim (1975) examined 2288 adult *S. crameri* for gonad condition over a span of ten years (1963-73) and Echeverria (1987) did not sample *S. crameri* in numbers great enough (407 sampled from 1977 to 1982) to allow statistical treatment of maturity data. Barss (1989) provided maturity data for 346 specimens of *S. crameri* captured off Central Oregon from 1985 to 1986, but did not provide ages.

CHAPTER I

Growth, Size and Age Composition, and Mortality of Darkblotched Rockfish (*Sebastes crameri*) off the Oregon Coast

ABSTRACT

Although darkblotched rockfish (*Sebastes crameri*) has been one of the most abundant and commercially important rockfish (*Sebastes* spp.) in the Northeast Pacific Ocean, little research has been conducted on their life history, particularly off the Oregon coast.

Darkblotched rockfish were collected monthly at sea aboard commercial groundfish and shrimp trawlers operating out of Newport and Coos Bay, Oregon. Samples were supplemented by collections of fish carcasses from fish processing plants in Newport. A total of 1060 fish were collected between July 1986 and July 1987. Additional length-frequency and catch per unit effort (CPUE) data were collected aboard bottomfish trawlers operating out of Coos Bay, Newport and Astoria between June of 1985 and December, 1987.

Darkblotched rockfish were found to be slow growing and longlived, reaching ages in excess of 100 years. Larger, older fish were found to occur most frequently in deep water. A large percentage of the stock consisted of 6, 7 and 8 year olds. Assuming constant recruitment and mortality for all year-classes collected, total instantaneous mortality (Z) for recent recruits may be as high as 0.42.

Considering this species life history characteristics, its longevity and slow growth, and the fact that their age

at full recruitment is less than their age at 50% maturity, it seems unlikely that it can withstand intensive fishing pressure for a prolonged period.

INTRODUCTION

Darkblotched rockfish (*Sebastes crameri*) is one of the most abundant and commercially important rockfish off the Oregon coast. Approximately 50% of all bottomfish trawl landings conducted off Oregon since 1978 have consisted of rockfish (genus *Sebastes* and *Sebastolobus*). Since 1963, darkblotched rockfish has averaged 5th in rank of importance in terms of utilized fish weight among some 30 rockfish species caught by Oregon commercial bottomfish trawlers. Increased fishing effort by trawlers off Oregon in the past decade has resulted in greater catches of *S. crameri* in recent years, averaging 630 metric tons annually since 1979 (Fig. 1). Despite their high abundance and commercial importance, little research has been conducted on the life history of this species, particularly off Oregon.

Evidence suggests that techniques previously used to age *Sebastes* species, including scale and surface otolith analysis, underestimated age, particularly for older fish (Beamish, 1979; Archibald et al., 1981; Bennett et al., 1982; Boehlert and Yoklavich, 1984; Wilson, 1984). Although life history characteristics of many species of rockfish have been described in the literature, few studies have obtained sample sizes large enough to adequately describe the life history characteristics of all the species they mentioned. Thus, due to small sample size and inaccurate aging techniques used in the past, there remains a significant gap of life history information for many of the rockfish species, including such commercially important and abundant ones as *S. crameri*.

This report describes the growth, size and age composition and mortality of *S. crameri* based on fishery data and analysis of fish characteristics for samples collected off the Oregon coast.

MATERIALS AND METHODS

Data Collection

A total of 1,060 fish, caught by commercial groundfish and shrimp trawlers operating out of Newport, Coos Bay and Astoria, Oregon, were collected between July 1986 and July 1987. Catch locations ranged from 43°10'N to 47°17'N latitude (Fig. 2). At-sea collections numbered 513 individuals caught aboard groundfish trawlers and 222 caught aboard shrimp trawlers. Marketable fish were purchased from the skippers. In addition, 325 filleted fish were collected from fish processing plants in Newport.

Date and time of capture, depth, and capture location were recorded at sea. For fish collected at fish processors, fishermen's logbook data was used to approximate this information.

Information recorded included sex, total length (TL) and fork length (FL) measured to the nearest millimeter, fish weight in grams, and gonad weight measured to the nearest 0.01 gram. Sagittal otoliths were removed and stored in 50 percent ethanol for subsequent aging. Gonads from 286 males and 255 females were stored in 10 percent phosphate-buffered formalin for later histological analysis and fecundity estimations. Fish weights were the only data not retrieved from specimens collected at fish processing plants.

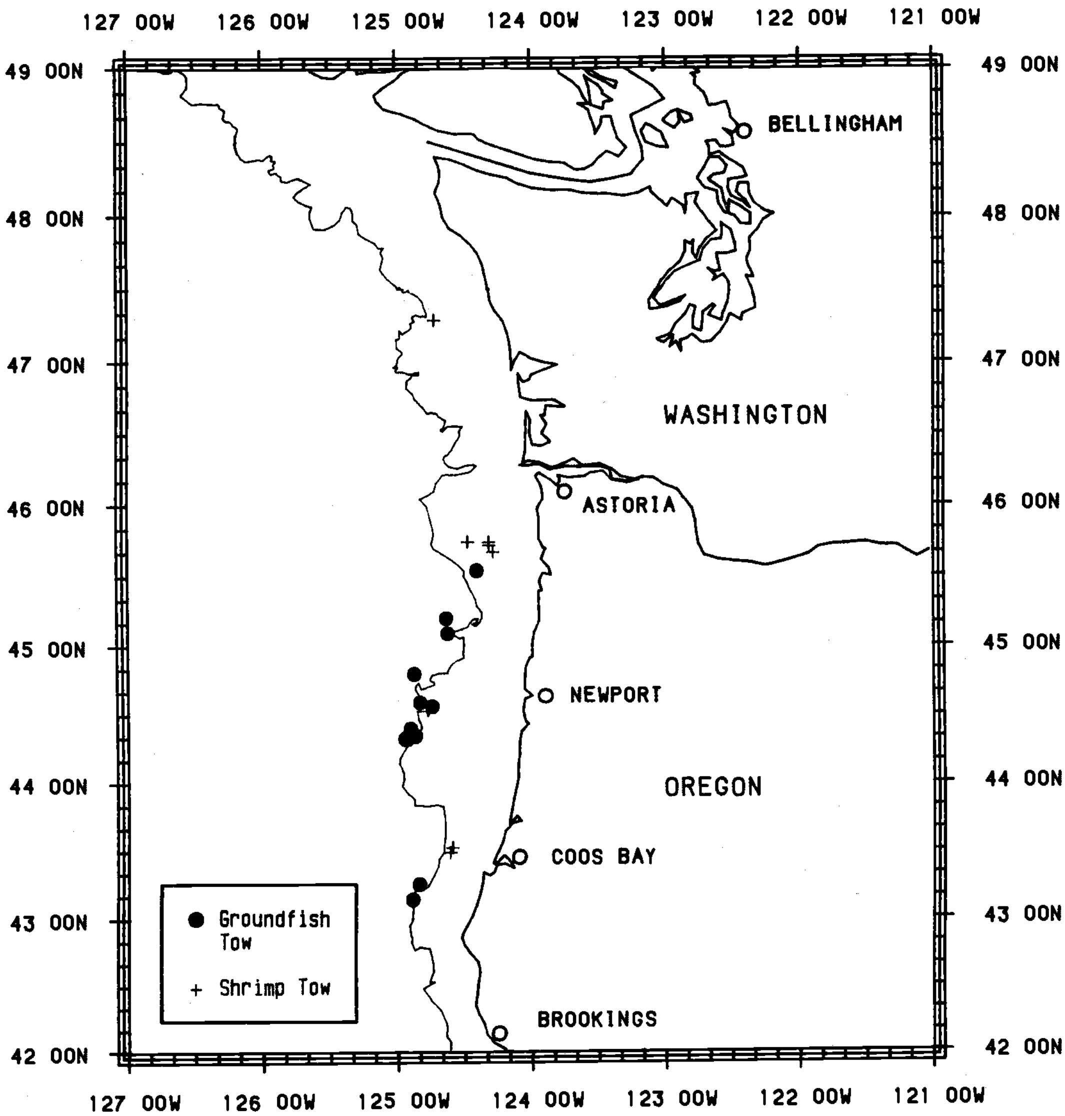


Figure I-2. Locations of commercial groundfish and shrimp trawl tows, where specimens of Sebastes crameri were collected at sea between July 1986 and July 1987. The 200 fathom depth contour line is included.

Length frequency data (Pikitch et al., 1988) were recorded for 1256 darkblotched rockfish (in addition to fish collected) caught between January 1986 and December 1987 aboard trawlers operating out of Coos Bay, Newport and Astoria (latitude 42°50′ to 47°20′N, Fig. 3).

At sea observations of catch and effort, recorded aboard commercial bottomfish trawlers off Oregon between June 1985 and December 1987 (Pikitch et al., 1988), were used to derive indices of catch per unit effort (CPUE) for *S. crameri*. For every tow, the total weight of the catch was estimated by the skipper and/or samplers. A random sample of the catch was then taken and species were sorted, counted and weighed. An expansion coefficient was derived by dividing the total catch weight in a tow by the total sample weight (all species). The total weight and number for each species in a tow were then estimated by multiplying the species sample weight and number respectively by the expansion coefficient. The tow time (hrs) was used as an index of effort.

The total catch of *S. crameri*, and effort for tows that included some catch of *S. crameri* (Fig. 4), were summarized for various depth intervals. CPUE was then computed in terms of fish weight (kg/hrs towed) and numbers (no./hrs towed). This database contained 458 hauls and 1683.63 trawl hours for tows that included some catch of *S. crameri*.

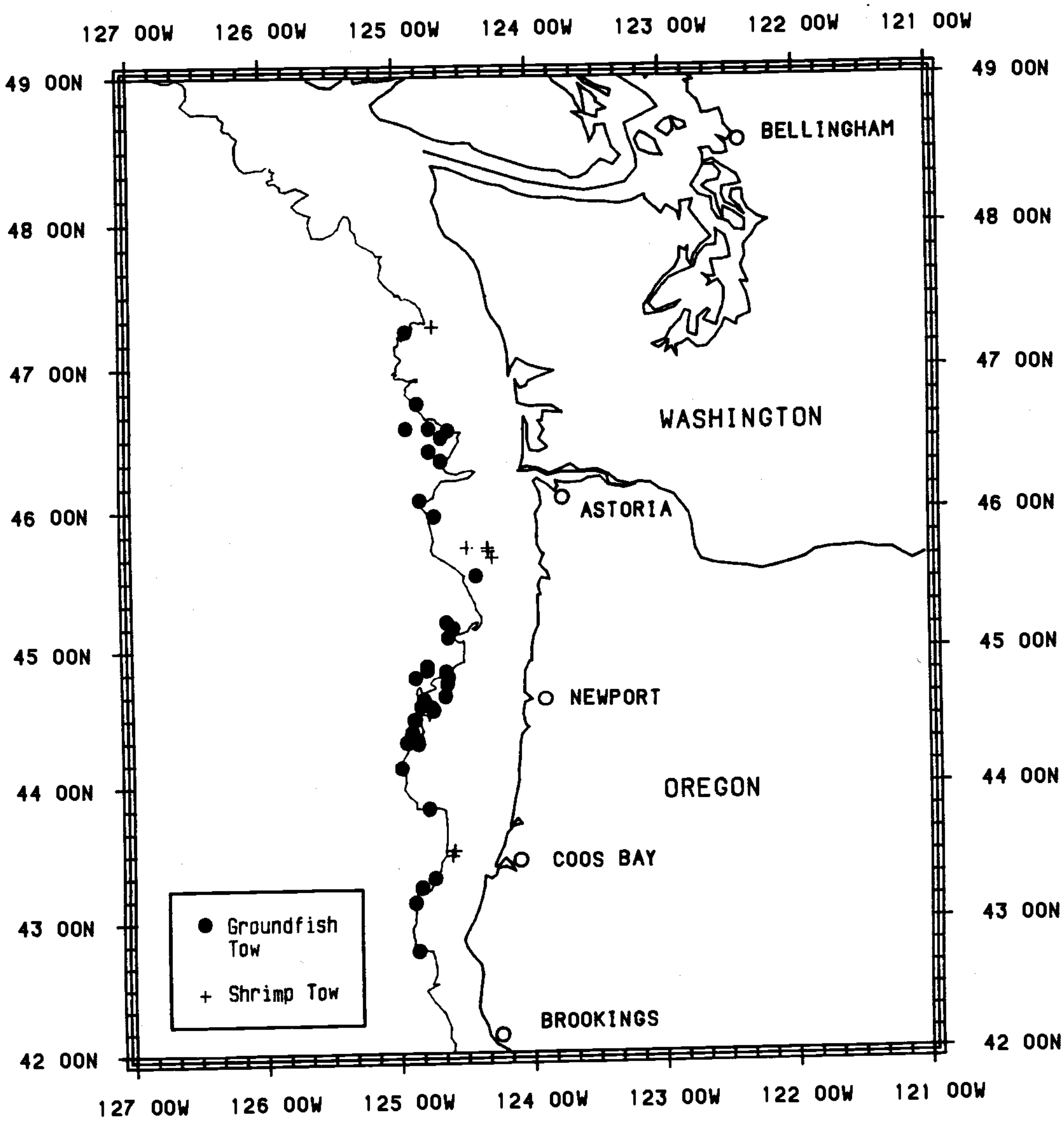


Figure I-3. Locations of commercial groundfish and shrimp trawl tows where length measurements of <u>Sebastes crameri</u> were recorded during research surveys conducted between January 1986 and December 1987. The 200 fathom depth contour line is included.

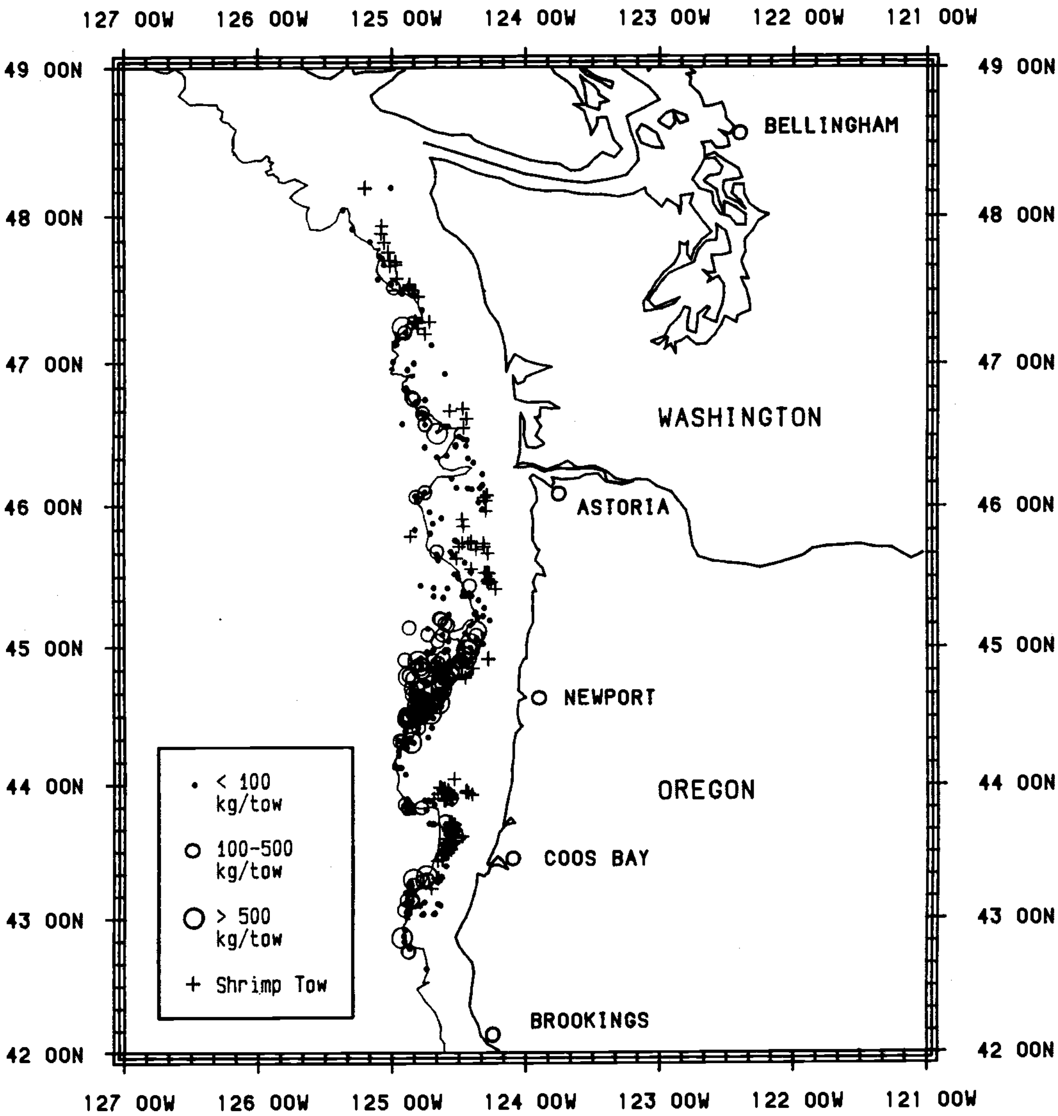


Figure I-4. Locations of commercial groundfish (dot and circles) and shrimp (+) trawl tows where at least some darkblotched rockfish were captured during research surveys conducted between June 1985 and December 1987. The 200 fathom depth contour line is included.

Otolith Fixing

Sections of the left otolith of each fish were prepared according to methods described by Boehlert (1985). First, otoliths were embedded onto cardboard tags with polyester casting resin. A dorso-ventral slice, perpendicular to the sulcus was then made using a Buehler low-speed Isomet saw with two diamond blades separated by 0.45 to 0.55 mm spacers. Sections were mounted on slides with histological mounting medium, then were ground to a desirable thickness using a Buehler Ecomet III grinder with 600 grit Carbimet paper discs.

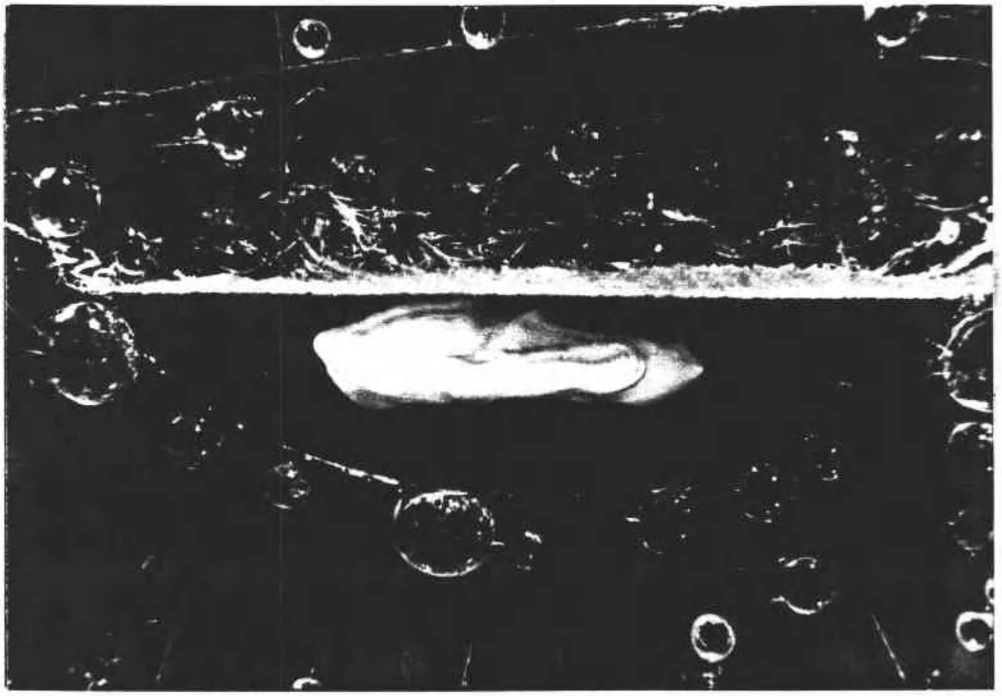
Age Determination

Otolith sections were viewed under a dissecting microscope using reflected light and a black background at 10-50X magnification (Figs. 5, 6, 7, 8). Thick otolith sections were viewed under a compound microscope using transmitted light and magnifications up to 100X (Figs. 9A, 9B; 10A, 10B). A cover slip and 2-3 drops of water were placed on sections to reduce glare.

Fish were assigned ages based on the aging criteria of Chilton and Beamish (1982). By convention, all fish were assigned a birth date of January 1. The translucent hyaline zones were considered annuli. Hyaline zones, which appeared dark when reflected light was used, and clear when transmitted light was used, were counted in two directions where possible: 1) from the focus to the dorsal edge, and 2) from the focus to the ventral. For older individuals,

Figure I-5. Otolith section of a 1+ year old male darkblotched rockfish, captured 28 July, 1986. Viewed with a dissecting microscope with reflected light and a black background, 20X.

Figure I-6. Otolith section of a 2+ year old male darkblotched rockfish captured 28 July, 1986. Viewed with a dissecting microscope with reflected light and a black background, 20X.



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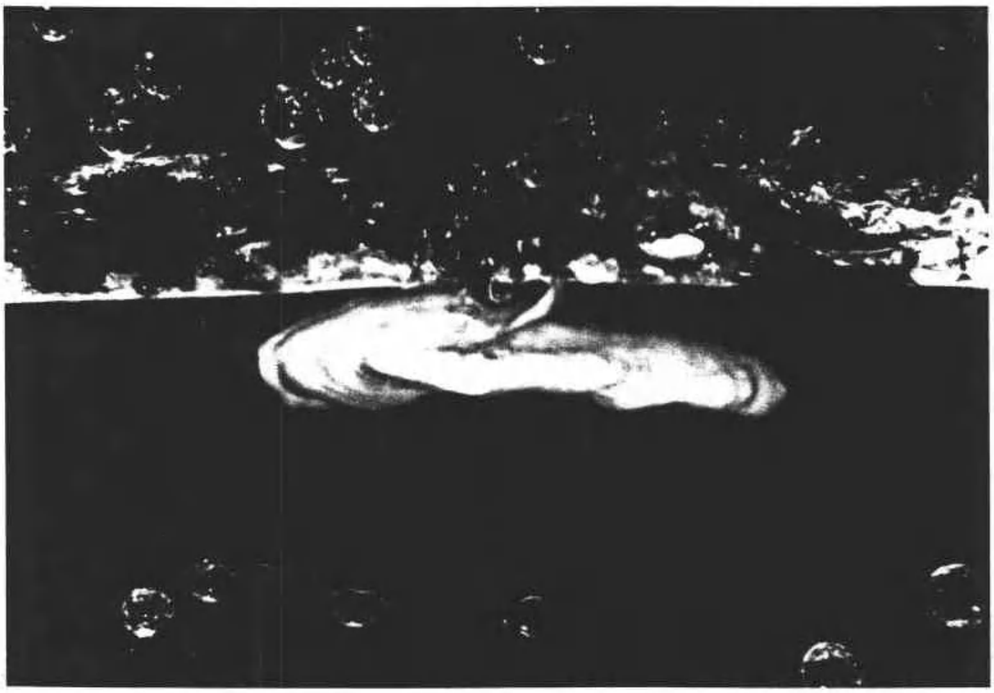
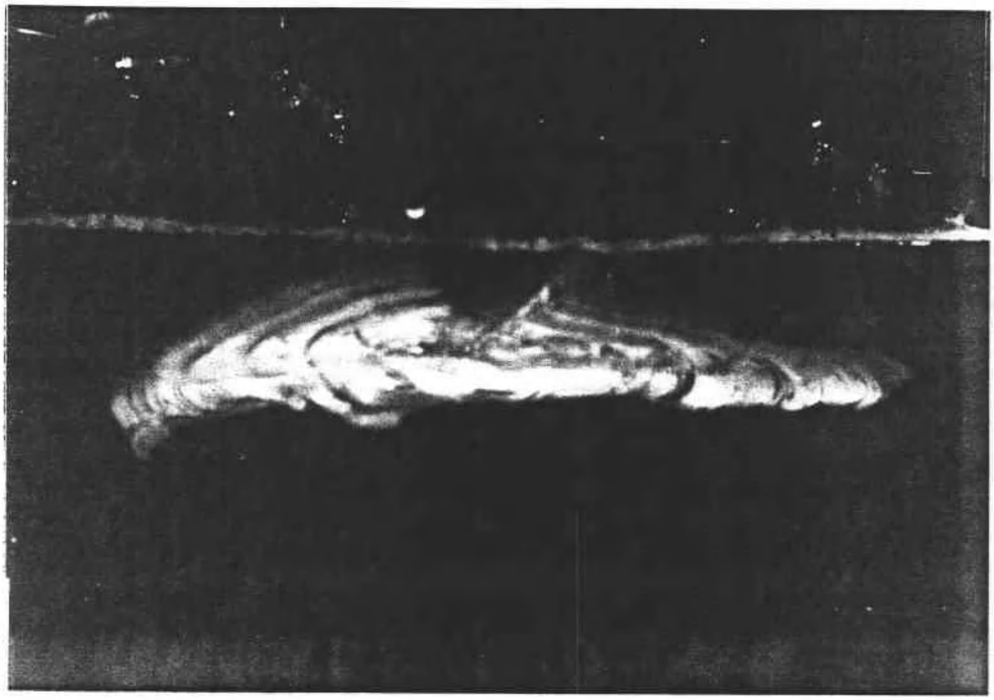


Figure I-6.

Figure I-7. Otolith section of a 4+ year old female darkblotched rockfish captured 8 November, 1986. Viewed with a dissecting microscope with reflected light and a black background, 20X.

Figure I-8. Otolith section of a 6+ year old female darkblotched rockfish captured 14 December, 1986. The 7th annular band (hyaline zone) is nearly completed on the edge of the otolith. Viewed with a dissecting microscope with reflected light and a black background, 20X.



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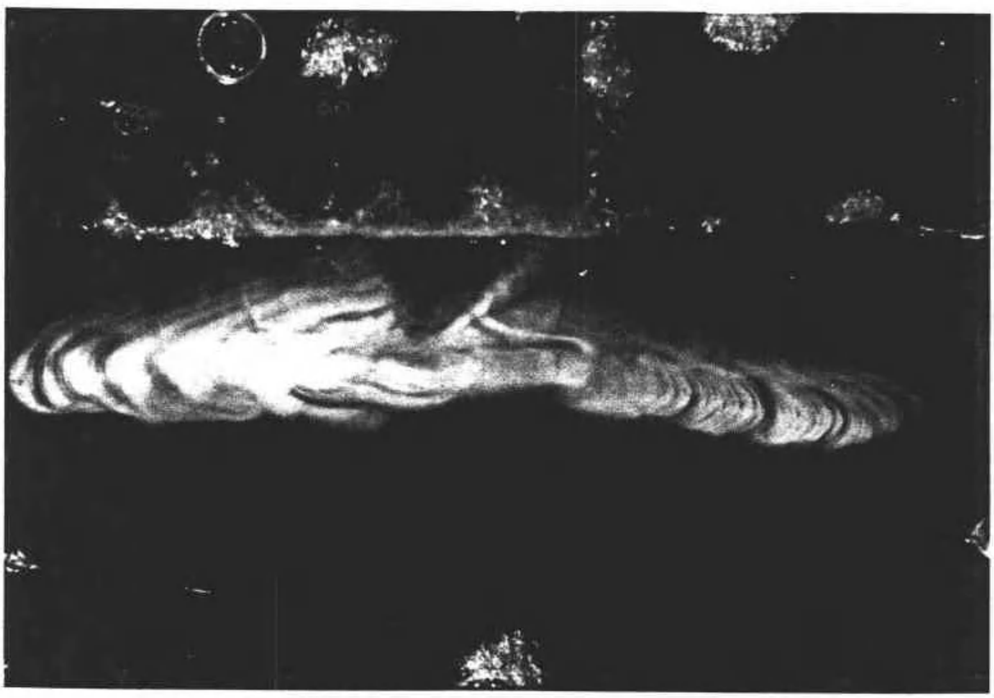
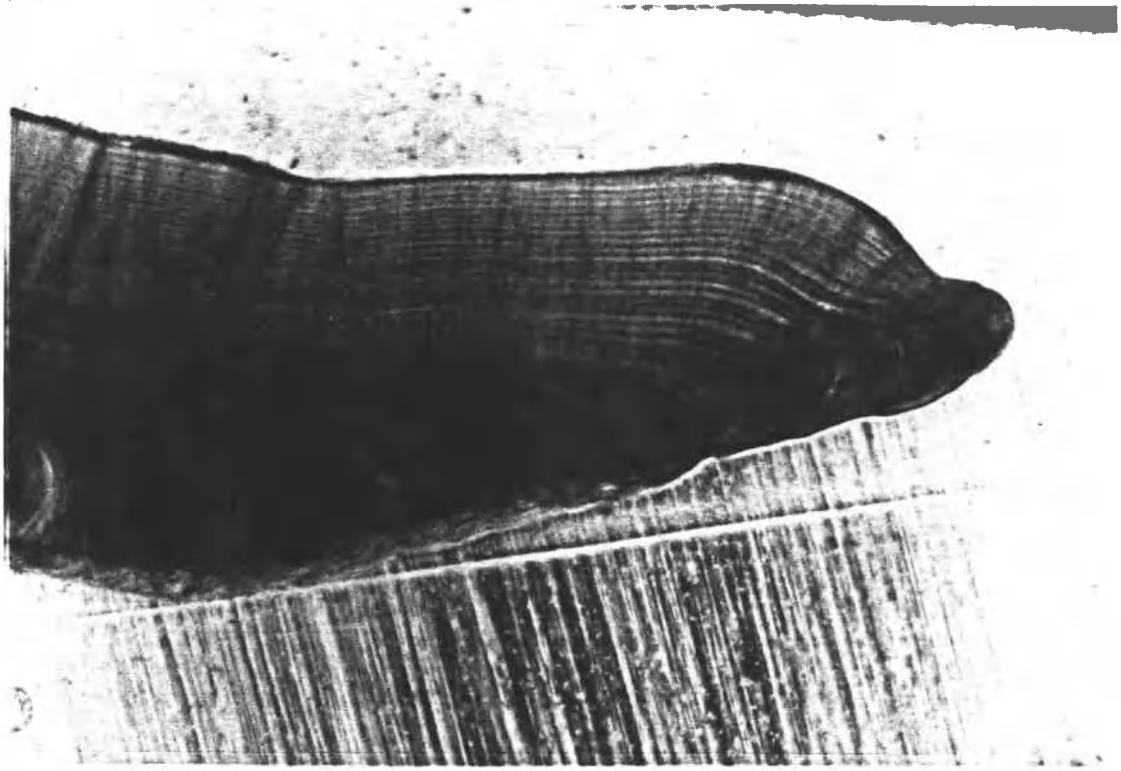


Figure I-8.

Figure I-9. (a) The dorsal side of an otolith section from a 29 year old male darkblotched rockfish captured 29 March, 1987. Viewed with a compound microscope and transmitted light, 40X.
(b) A dorsal-interior view of the same otolith section, viewed with a compound microscope and transmitted light at 100X. The pointer indicates the 10th hyaline zone (appears clear) counted from the focus.

(a)



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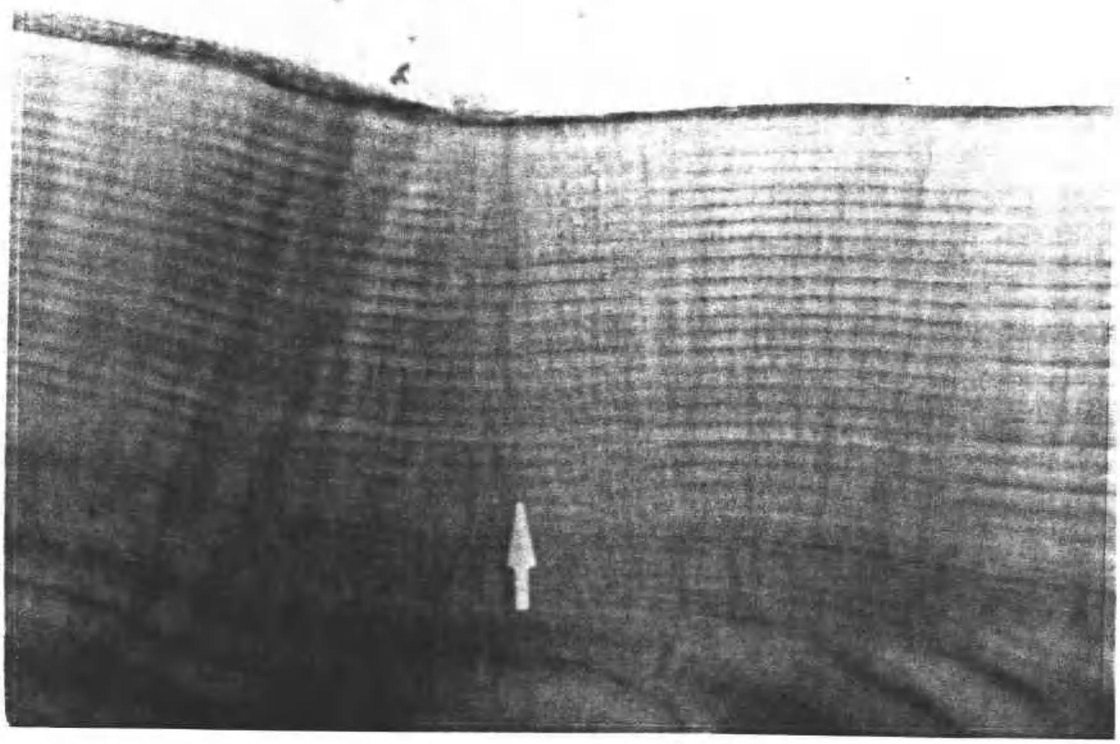
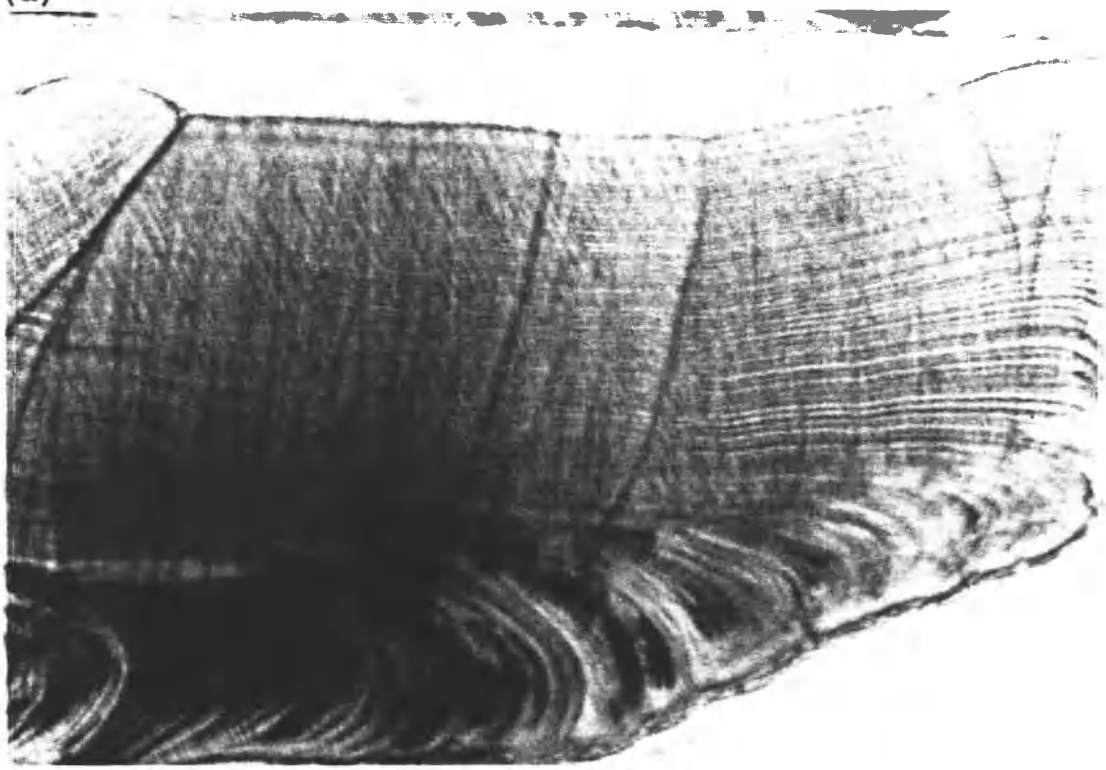


Figure I-9.

Figure I-10. (a) The dorsal side of an otolith section from a 59 year old male darkblotched rockfish captured 2 November, 1986. Viewed with a compound microscope and transmitted light, 40X.
(b) A dorsal-interior view of the same section, viewed with a compound microscope and transmitted light at 100X. The pointer indicates the 25th hyaline zone (appears clear) counted from the focus.

(a)



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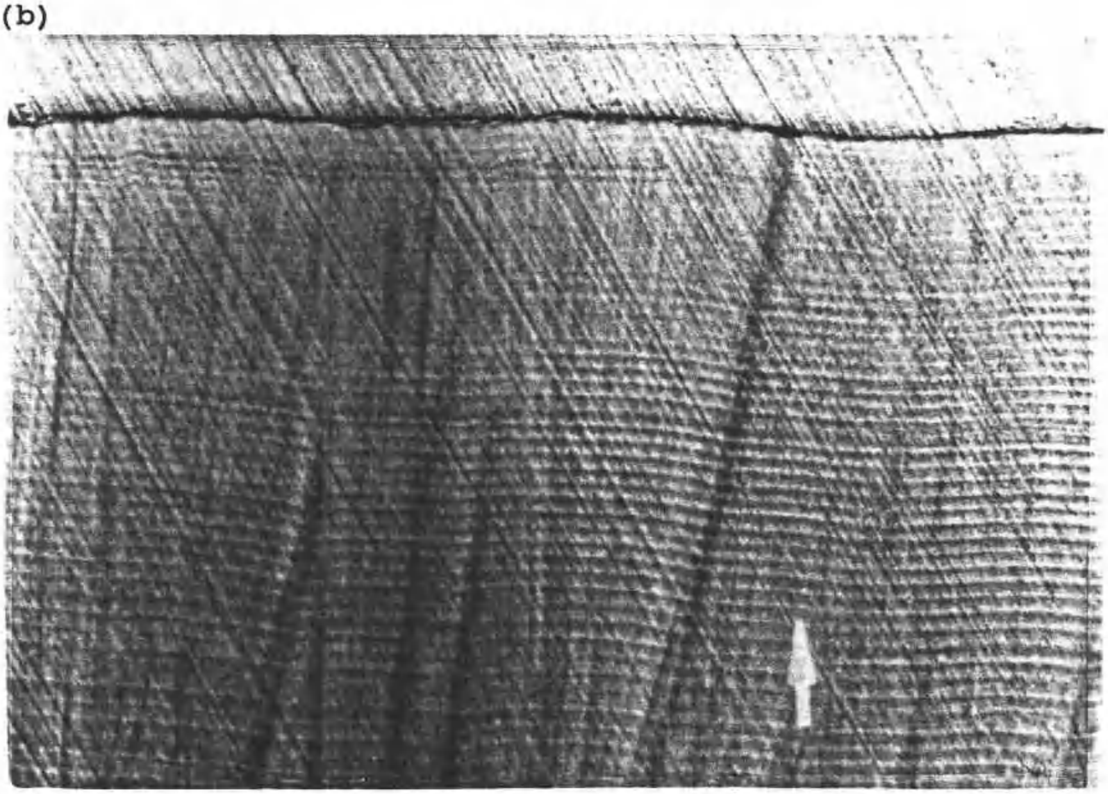

Figure I-10.

whose otoliths grew significantly in thickness, the last hyaline zone on the dorsal edge was followed to the interior-dorsal quadrant of the otolith section. The same was done for the ventral side. In cases where counts differed between the two regions, the age determined from the region with the clearest growth pattern was chosen as the final age. For older fish (>15 years), growth patterns in the ventral interior region of the otolith were often inconsistent and blurred and final ages were determined from the dorsal side only.

To corroborate the aging technique, a sample of 50 right otoliths were sent to the Pacific Biological Station's (PBS)[3] aging lab for examination. The PBS prepared the right otoliths using the "break and burn technique" (Chilton and Beamish, 1982), then aged them. The corresponding left otoliths were sectioned and aged by the author. Age reading differences were compared using a paired t-test. Growth pattern differences between right and left otoliths were assumed negligible.

If only one hyaline zone is formed during a single year, then one can deduce that the number of such zones corresponds to the age of an individual fish. To examine whether hyaline growth zones were formed annually, the preponderance of various "edge types" by month, as described by Kimura et al. (1979), was examined. Edge

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[3] Department of Fisheries and Oceans, Resource Services Branch, Pacific Biological Station, Nanaimo, B.C. V9R 5K6.

types were defined as follows: 1) hyaline zone is present on the otolith edge; 2) an opaque zone is visible beyond the last hyaline zone; and 3) a wide band of opaque zone is visible on the otolith edge. Edge types were recorded at the dorsal and the ventral edge of the otolith section. However, only dorsal edge types that were discernible were used in the subsequent analysis.

Growth

Length and age data for males and females were fitted to a von Bertalanffy growth model of the form:

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

where L_t= fish length at time t

L_∞= theoretical maximum length at infinite age

t = age of fish

t_0= theoretical age at length 0

K = growth coefficient

using the Gauss-Newton nonlinear least squares procedure (SAS Institute Inc., 1987). Linear regression was used to describe growth of male fish greater than 30 years of age.

Length-Weight Relationship

The length-weight relationship for *S. crameri* was described using the equation:

$$W = aL^b$$

where W= weight of fish (g)

L= total length of fish (mm)

and a & b = linear constants

The constants a and b were estimated using linear regression on log(W) and log(L).

Total Length - Fork Length Conversion

Equations for total length (mm) as a function of fork length (mm) and vise-versa were estimated using standard linear regression.

Size and Age Composition

Size and age-frequency samples from each groundfish tow were expanded to total catch in each tow by multiplying the sample number of *S. crameri* at each length or age, respectively, by the ratio of the total weight of *S. crameri* in the tow to the weight sampled.

Length-frequency data (expanded) were plotted by sex, latitude and depth. Data were grouped by latitude corresponding to approximate areas of operation of trawlers fishing out of the 3 major Oregon ports (Astoria, lat. 45° 50′ to lat. 47°20′N; Newport, lat. 44°10′ to 45°30′N; and Coos Bay, lat. 42°50′ to lat 43°50′N) (Fig. 2), and by depth (101-150 fm; 151-200 fm; and greater than 200 fm).

Age composition data (expanded) were summarized for Newport and Coos Bay areas based on groundfish tows conducted in the 151-200 fm, and greater than 200 fm depth strata. Data for fish collected at fish processing plants were not included in size or age compositions analysis.

Length and age-frequency data taken at shallower depths (<150 fm) were compiled from specimens collected aboard commercial shrimp vessels. One collection consisted of a single tow conducted in 74 fm off the Washington coast (lat. 47°17′N); the other consisted of 2 tows conducted in 108 fm off Coos Bay, OR (lat. 43°30′N).

Mortality

Total instantaneous mortality (Z) of *S. crameri* was estimated from data obtained from the Newport area at depths greater than 150 fm, by use of catch curve analyses. Following Ricker (1975), Z was approximated by the slope of the descending right hand limb of the age-ln(frequency) relationship. Slopes were calculated using standard linear regression on age-frequency data for males, females and sexes combined. Because it was apparent that groundfish trawl effort and landings of *S. crameri* varied among years, mortality rate (Z) was calculated for 3 age groupings, representing periods of different fishing intensity. Mortality rate was assumed constant within each age group range. Constant recruitment and the absence of age specific differences in Z for the entire age range were also assumed in this analysis.

RESULTS

Corroboration of Aging Technique

Comparison of ages obtained by the present study with those obtained by the Pacific Biological Station's aging lab revealed only slight differences, except for older fish (Fig. 11). No significant differences were found between ages obtained by the two examinations for fish aged less than 60 years by the author ($P>0.085$). For older otoliths, the PBS was unable to obtain confident age readings due to uneven breaking of the otoliths. It was suggested that the storage medium (50% ethanol) may have made the thicker otoliths too dry and therefore unsuitable for breaking. The PBS typically stores otoliths in a 50% glycerin and water mixture plus thymol.

Edge Type Analysis

Edge types from 619 fish were used to define the phase of annular growth (Kimura et al., 1979). Hyaline zones were most prominent on the otolith edge during winter months and opaque growth most prominent in the remaining months (Fig. 12). It appears that only one hyaline zone is formed during a year, corroborating the existence of annular bands.

Growth

Mean size at age was similar among areas for younger fish (Tables 1-4). It was not possible to compare size at

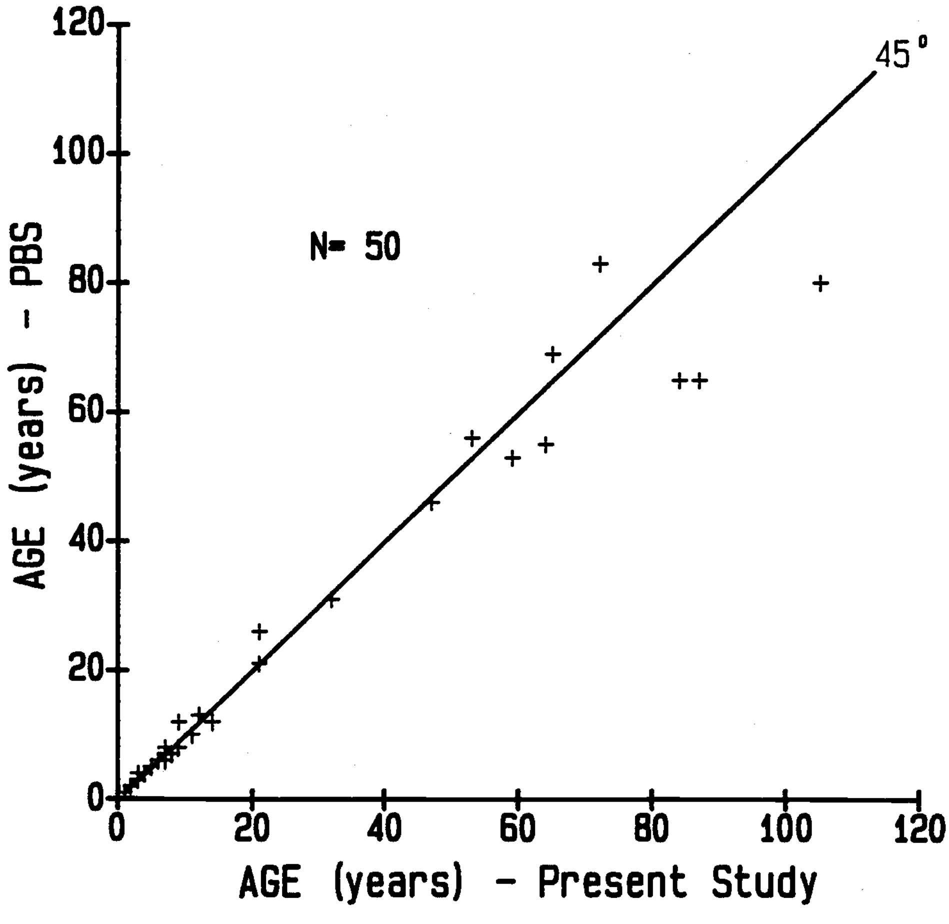


Figure I-11. Comparison of ages obtained by the present study using otolith sections with those obtained by the Pacific Biological Station (PBS) using the "break and burn technique". A 1:1 ratio line is included.

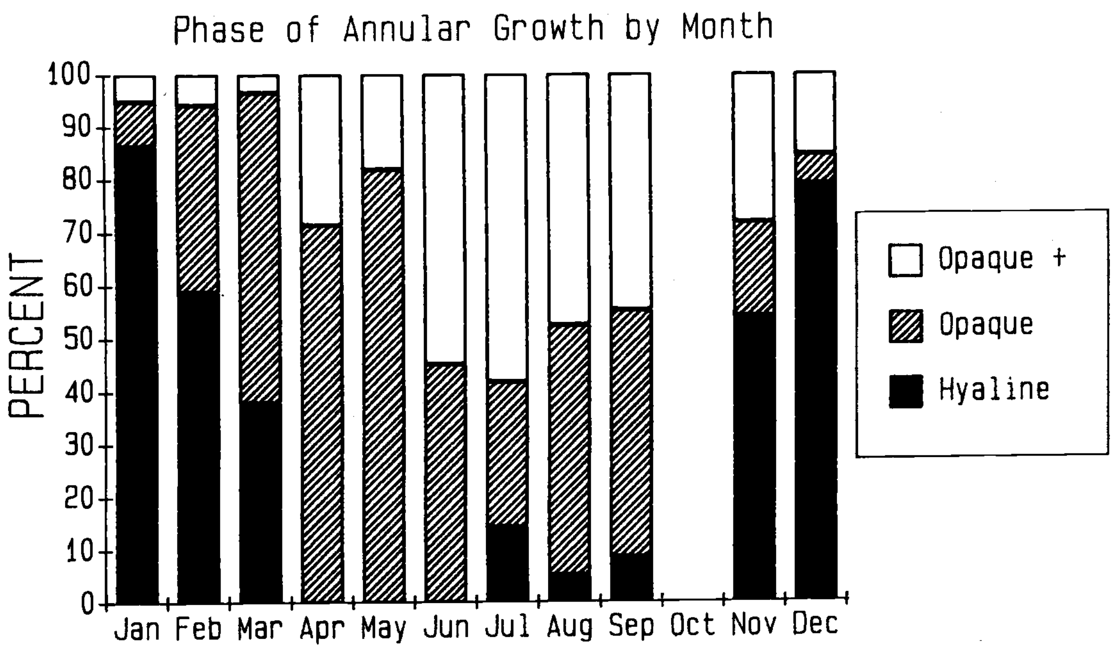


Figure I-12. Percentage of fish with otoliths possessing the following edge types: 1) hyaline; 2) opaque; 3) opaque+, by month.

Table I-1. Mean total length (L) at age in mm for male <u>Sebastes crameri</u> by area. Groundfish and shrimp trawl samples combined. N=number in sample; Std=standard deviation.

	NEWPORT			COOS BAY			ASTORIA		
Age	N	L	Std	N	L	Std	N	L	Std
1	4	122	17.1	-	-	-	16	140	6.1
2	2	172	12.0	2	185	10.6	10	197	11.0
3	3	213	13.7	24	234	12.3	3	214	19.3
4	8	241	24.0	12	270	19.3	1	227	-
5	9	294	20.3	15	293	15.5	-	-	-
6	36	323	14.0	13	316	11.0	-	-	-
7	84	331	13.4	11	328	9.6	-	-	-
8	50	341	12.9	3	326	2.0	-	-	-
9	25	349	11.7	3	330	21.4	-	-	-
10	3	353	4.9	-	-	-	-	-	-
11	9	368	9.8	1	350	-	-	-	-
12	8	369	9.5	-	-	-	-	-	-
13	8	369	15.1	1	336	-	-	-	-
14	4	374	17.9	-	-	-	-	-	-
15	8	382	14.0	-	-	-	-	-	-
16	14	379	18.5	-	-	-	-	-	-
17	5	372	14.1	-	-	-	-	-	-
18	6	377	9.8	-	-	-	-	-	-
19	4	386	7.7	1	375	-	-	-	-
20	6	376	21.0	-	-	-	-	-	-
21	4	390	12.7	-	-	-	-	-	-
22	3	367	17.9	-	-	-	-	-	-
23	3	385	6.8	-	-	-	-	-	-
24	5	383	15.7	-	-	-	-	-	-
25	3	391	13.7	-	-	-	-	-	-
26	2	372	17.0	-	-	-	-	-	-
27	1	408	-	-	-	-	-	-	-
28	4	381	26.0	-	-	-	-	-	-
29	1	394	-	-	-	-	-	-	-
30	2	387	1.4	-	-	-	-	-	-
32	-	-	-	1	402	-	-	-	-
33	4	409	4.7	-	-	-	-	-	-
34	2	384	6.4	-	-	-	-	-	-
35	3	405	10.3	-	-	-	-	-	-
36	1	400	-	-	-	-	-	-	-
37	2	403	3.5	-	-	-	-	-	-
39	2	412	2.8	-	-	-	-	-	-
41	3	396	8.5	-	-	-	-	-	-
42	4	403	17.8	1	408	-	-	-	-
43	1	395	-	-	-	-	-	-	-
44	3	394	6.7	-	-	-	-	-	-
45	2	409	36.8	-	-	-	-	-	-
46	1	402	-	-	-	-	-	-	-
47	1	391	-	-	-	-	-	-	-
48	1	402	-	-	-	-	-	-	-

Table I-1. Continued.

	NEWPORT			COOS BAY			ASTORIA		
Age	N	L	Std	N	L	Std	N	L	Std
49	2	419	5.0	-	-	-	-	-	-
51	2	408	7.8	-	-	-	-	-	-
52	2	421	1.4	-	-	-	-	-	-
53	1	400	-	-	-	-	-	-	-
54	1	438	-	-	-	-	-	-	-
55	1	387	-	-	-	-	-	-	-
57	2	415	28.3	-	-	-	-	-	-
58	1	425	-	-	-	-	-	-	-
59	3	418	7.6	-	-	-	-	-	-
60	1	391	-	-	-	-	-	-	-
62	1	428	-	-	-	-	-	-	-
65	1	413	-	-	-	-	-	-	-
66	1	425	-	-	-	-	-	-	-
68	3	428	14.8	-	-	-	-	-	-
70	3	417	20.0	-	-	-	-	-	-
72	1	400	-	-	-	-	-	-	-
74	1	413	-	-	-	-	-	-	-
84	1	395	-	-	-	-	-	-	-
88	1	445	-	-	-	-	-	-	-

Table I-2. Mean total length (L) at age in mm for female Sebastes crameri by area. Groundfish and shrimp trawl samples combined. N=number in sample; Std=standard deviation.

	NEWPORT			COOS BAY			ASTORIA		
Age	N	L	Std	N	L	Std	N	L	Std
1	3	119	17.1	-	-	-	17	137	5.3
2	4	184	12.0	3	188	2.9	2	185	7.1
3	-	-	-	37	236	14.5	4	227	11.5
4	11	248	24.0	17	274	15.0	1	252	-
5	10	282	20.3	23	304	13.9	-	-	-
6	58	334	14.0	20	331	11.8	-	-	-
7	107	346	15.4	11	347	8.7	-	-	-
8	68	361	16.1	4	352	16.0	-	-	-
9	19	374	10.9	1	366	-	-	-	-
10	5	382	7.6	-	-	-	-	-	-
11	11	387	22.2	-	-	-	-	-	-
12	4	406	18.3	-	-	-	-	-	-
13	5	409	11.4	1	363	-	-	-	-
14	5	433	14.7	-	-	-	-	-	-
15	1	423	-	-	-	-	-	-	-
16	6	425	12.6	-	-	-	-	-	-
17	7	428	18.3	-	-	-	-	-	-
18	12	424	17.5	-	-	-	-	-	-
19	3	428	20.4	-	-	-	-	-	-
20	2	424	26.2	-	-	-	-	-	-
22	2	432	10.6	-	-	-	-	-	-
23	2	414	38.2	-	-	-	-	-	-
24	3	437	12.4	-	-	-	-	-	-
25	2	454	9.2	-	-	-	-	-	-
26	1	473	-	-	-	-	-	-	-
27	1	454	-	-	-	-	-	-	-
29	1	448	-	-	-	-	-	-	-
30	1	443	-	-	-	-	-	-	-
32	2	438	2.8	-	-	-	-	-	-
34	1	450	-	-	-	-	-	-	-
35	1	460	-	-	-	-	-	-	-
36	2	462	24.7	-	-	-	-	-	-
39	2	476	27.6	-	-	-	-	-	-
40	1	449	-	-	-	-	-	-	-
41	2	456	1.4	-	-	-	-	-	-
42	3	450	10.0	-	-	-	-	-	-
44	2	457	12.7	-	-	-	-	-	-
45	1	465	-	-	-	-	-	-	-
47	1	480	-	-	-	-	-	-	-
48	2	452	7.1	-	-	-	-	-	-
50	1	483	-	-	-	-	-	-	-
53	2	474	37.5	-	-	-	-	-	-
54	1	484	-	-	-	-	-	-	-
55	1	450	-	-	-	-	-	-	-
57	3	465	15.6	-	-	-	-	-	-

Table I-2. Continued.

	NEWPORT			COOS BAY			ASTORIA		
Age	N	L	Std	N	L	Std	N	L	Std
58	3	463	7.5	-	-	-	-	-	-
59	1	472	-	-	-	-	-	-	-
60	1	441	-	-	-	-	-	-	-
61	3	449	15.5	-	-	-	-	-	-
62	1	448	-	-	-	-	-	-	-
64	3	472	9.9	-	-	-	-	-	-
65	2	456	20.5	-	-	-	-	-	-
66	3	460	11.9	-	-	-	-	-	-
70	-	463	-	-	-	-	-	-	-
71	3	471	16.0	-	-	-	-	-	-
72	1	479	-	-	-	-	-	-	-
73	1	470	-	-	-	-	-	-	-
74	1	471	-	-	-	-	-	-	-
75	1	473	-	-	-	-	-	-	-
78	1	477	-	-	-	-	-	-	-
80	1	453	-	-	-	-	-	-	-
82	3	473	28.4	-	-	-	-	-	-
86	1	440	-	-	-	-	-	-	-
87	1	450	-	-	-	-	-	-	-
88	1	445	-	-	-	-	-	-	-
95	1	475	-	-	-	-	-	-	-
105	1	476	-	-	-	-	-	-	-

Table I-3. Mean weight (g) at age for male *Sebastes crameri* by area. Groundfish and shrimp trawl samples combined. N=number in sample; Wt=mean weight; Std=standard deviation.

	NEWPORT			COOS BAY			ASTORIA		
Age	N	Wt	Std	N	Wt	Std	N	Wt	Std
1	4	26	14.0	-	-	-	16	42	6.2
2	2	81	17.0	2	94	17.0	10	132	25.9
3	3	158	27.0	24	213	33.3	3	187	59.2
4	8	252	82.0	12	361	78.2	1	217	-
5	7	436	101.9	15	448	68.0	-	-	-
6	17	559	87.3	13	560	77.6	-	-	-
7	48	593	79.2	11	593	49.7	-	-	-
8	32	643	64.2	3	531	52.0	-	-	-
9	15	700	89.6	3	652	107.8	-	-	-
10	1	638	-	1	-	-	-	-	-
11	5	788	118.2	1	642	-	-	-	-
12	7	781	52.5	-	-	-	-	-	-
13	4	816	96.8	1	620	-	-	-	-
14	3	718	43.7	-	-	-	-	-	-
15	4	804	45.8	-	-	-	-	-	-
16	9	824	134.0	-	-	-	-	-	-
17	3	823	53.7	-	-	-	-	-	-
18	6	830	75.0	-	-	-	-	-	-
19	2	910	14.1	1	865	-	-	-	-
20	4	802	233.8	-	-	-	-	-	-
21	4	948	50.8	-	-	-	-	-	-
22	3	803	71.6	-	-	-	-	-	-
23	3	873	81.4	-	-	-	-	-	-
24	2	974	20.5	-	-	-	-	-	-
25	2	950	126.6	-	-	-	-	-	-
26	1	714	-	-	-	-	-	-	-
28	3	871	100.6	-	-	-	-	-	-
30	1	870	-	-	-	-	-	-	-
32	-	-	-	1	1039	-	-	-	-
33	3	1079	28.6	-	-	-	-	-	-
34	2	922	10.6	-	-	-	-	-	-
35	1	919	-	-	-	-	-	-	-
36	1	930	-	-	-	-	-	-	-
37	2	1054	47.4	-	-	-	-	-	-
39	1	1155	-	-	-	-	-	-	-
41	2	924	2.8	-	-	-	-	-	-
42	3	1001	42.7	1	1100	-	-	-	-
43	1	981	-	-	-	-	-	-	-
44	2	950	29.0	-	-	-	-	-	-
45	1	918	-	-	-	-	-	-	-
46	1	999	-	-	-	-	-	-	-
48	1	1054	-	-	-	-	-	-	-
49	2	1042	38.9	-	-	-	-	-	-
51	2	1108	41.7	-	-	-	-	-	-
52	2	1196	5.6	-	-	-	-	-	-

Table I-3. Continued.

	NEWPORT			COOS BAY			ASTORIA		
Age	N	Wt	Std	N	Wt	Std	N	Wt	Std
53	1	970	-	-	-	-	-	-	-
54	1	1375	-	-	-	-	-	-	-
55	1	927	-	-	-	-	-	-	-
57	1	1036	-	-	-	-	-	-	-
58	1	1101	-	-	-	-	-	-	-
59	2	1055	79.2	-	-	-	-	-	-
60	1	969	-	-	-	-	-	-	-
65	1	1185	-	-	-	-	-	-	-
66	1	1247	-	-	-	-	-	-	-
68	3	1248	70.5	-	-	-	-	-	-
70	2	1176	197.3	-	-	-	-	-	-
72	1	1099	-	-	-	-	-	-	-
84	1	1021	-	-	-	-	-	-	-

Table I-4. Mean weight (g) at age for female *Sebastes crameri* by area. Groundfish and shrimp trawl samples combined. N=number in sample; Wt=mean weight; Std=standard deviation.

	NEWPORT			COOS BAY			ASTORIA		
Age	N	Wt	Std	N	Wt	Std	N	Wt	Std
1	3	26	16.5	-	-	-	17	39	5.1
2	4	99	19.3	3	103	3.0	2	114	26.9
3	-	-	-	37	219	43.0	4	233	35.3
4	11	274	73.8	17	380	75.6	1	278	-
5	9	403	100.4	23	502	66.8	-	-	-
6	28	630	83.8	20	656	80.0	-	-	-
7	62	683	83.1	11	769	95.1	-	-	-
8	37	792	113.3	4	780	103.9	-	-	-
9	19	838	92.5	1	982	-	-	-	-
10	2	936	87.0	1	-	-	-	-	-
11	6	907	149.7	-	-	-	-	-	-
12	2	1168	10.6	-	-	-	-	-	-
13	3	1196	153.5	1	777	-	-	-	-
14	4	1441	112.0	-	-	-	-	-	-
16	4	1346	122.7	-	-	-	-	-	-
17	3	1328	18.9	-	-	-	-	-	-
18	5	1310	206.4	-	-	-	-	-	-
19	1	1070	-	-	-	-	-	-	-
20	2	1279	93.3	-	-	-	-	-	-
22	1	1225	-	-	-	-	-	-	-
23	1	1065	-	-	-	-	-	-	-
24	1	1402	-	-	-	-	-	-	-
25	1	1360	-	-	-	-	-	-	-
27	1	1599	-	-	-	-	-	-	-
29	1	1580	-	-	-	-	-	-	-
32	2	1462	12.0	-	-	-	-	-	-
36	1	1882	-	-	-	-	-	-	-
39	2	1930	223.4	-	-	-	-	-	-
40	1	1493	-	-	-	-	-	-	-
42	1	1542	-	-	-	-	-	-	-
44	1	1629	-	-	-	-	-	-	-
45	1	1927	-	-	-	-	-	-	-
47	1	1695	-	-	-	-	-	-	-
48	1	1492	-	-	-	-	-	-	-
50	1	1782	-	-	-	-	-	-	-
53	1	1380	-	-	-	-	-	-	-
55	1	1445	-	-	-	-	-	-	-
57	2	1725	76.4	-	-	-	-	-	-
58	2	1851	217.8	-	-	-	-	-	-
59	1	1852	-	-	-	-	-	-	-
60	1	1590	-	-	-	-	-	-	-
61	3	1381	228.3	-	-	-	-	-	-
62	1	1632	-	-	-	-	-	-	-
64	3	1696	63.4	-	-	-	-	-	-
65	2	1611	358.8	-	-	-	-	-	-

Table I-4. Continued.

	NEWPORT			COOS BAY			ASTORIA		
Age	N	Wt	Std	N	Wt	Std	N	Wt	Std
66	2	1548	335.9	-	-	-	-	-	-
70	1	1714	-	-	-	-	-	-	-
71	3	1762	158.1	-	-	-	-	-	-
72	1	1410	-	-	-	-	-	-	-
73	1	1500	-	-	-	-	-	-	-
74	1	1780	-	-	-	-	-	-	-
75	1	1632	-	-	-	-	-	-	-
78	1	1733	-	-	-	-	-	-	-
80	1	1779	-	-	-	-	-	-	-
82	2	1417	403.0	-	-	-	-	-	-
86	1	1360	-	-	-	-	-	-	-
87	1	1551	-	-	-	-	-	-	-
105	1	1850	-	-	-	-	-	-	-

age among areas for older fish due to the lack of older age groups in Coos Bay and Astoria samples.

Age-length relationships are described for the Newport area only. Females tend to grow faster and reach larger sizes than males (Tables 1-4, Fig. 13). Growth is fast from age 0 to 10, then slows significantly. Length at age of males and females slowly increases with increasing age and does not completely cease, even after age 30, suggesting that either fish continue to grow throughout their lifetime and/or this increasing trend is due to differences in growth patterns among different year classes. *S. crameri* is longlived, like other species of the genus *Sebastes*. The maximum age observed was approximately 105 years.

Age-length data from Newport area collections were fit with von Bertalanffy growth equations for males, females and sexes combined (Table 5). The growth relationship described the age-length data well for females (Fig. 13), however, for males it tended to underestimate size for ages groups greater than 30 (Fig 12B). The linear equation

$$TL= 0.495(age) + 383.5 \qquad R^2= 0.18$$

was used to describe size at age for age groups greater than 30.

Length-Weight Relationship

Total Length (mm) was highly correlated with weight (kg) (P<0.001) and is described for both sexes by:

$$W= (1.35 \times 10^{-5})\, L^{3.0359} \qquad R^2= 0.99 \qquad N= 754$$

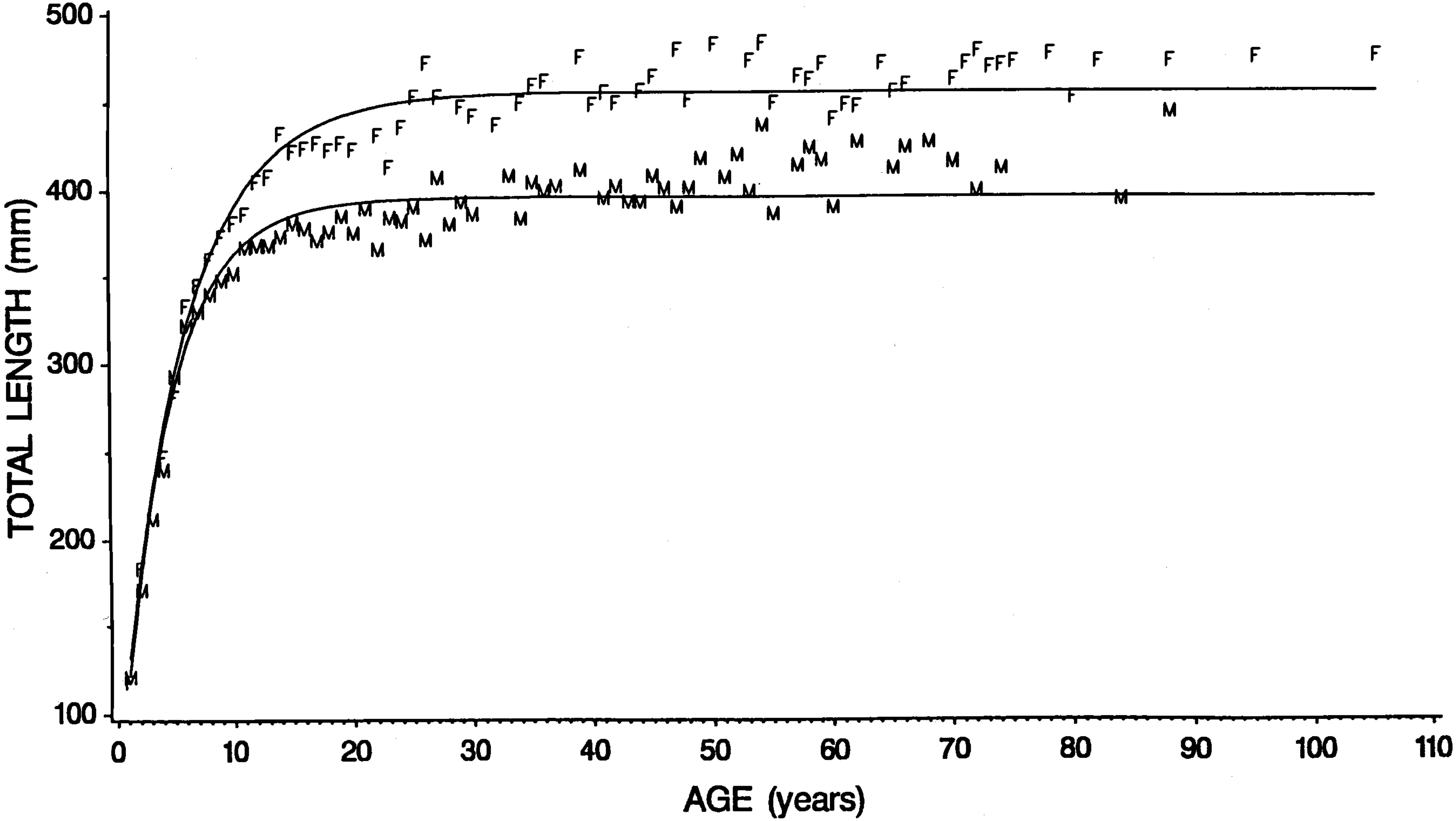


Figure I-13. Mean lengths (mm) at age and von Bertalanffy growth curves for male and female darkblotched rockfish collected off Newport, Oregon.

Table I-5. Von Bertalanffy growth parameter estimates for darkblotched rockfish captured off Newport, Oregon by commercial groundfish and shrimp trawlers. N=number in sample; SE=standard error.

Sex	Parameter	Estimate	SE	95% C-I
Males	L_∞	395.5[1]	1.56	392.4 - 398.6
N= 383	K	0.2352	0.0066	0.2222 - 0.2481
	t_0	-0.58	0.14	-0.86 - -0.31
Females	L_∞	455.7[1]	1.90	452.0 - 459.4
N= 417	K	0.1779	0.0046	0.1688 - 0.1871
	t_0	-0.92	0.16	-1.23 - -0.61
Sexes	L_∞	423.0[1]	1.72	419.6 - 426.3
Combined	K	0.2053	0.0055	0.1944 - 0.2162
N= 800	t_0	-0.78	0.15	-1.07 - -0.48

[1] Total Length (mm).

Total Length - Fork Length Conversion

Total length (mm) and fork length (mm) conversion equations are as follow:

TL= 0.846 + 1.046 (FL) R^2= 0.99, N= 1058, SE= 2.0095

FL= -0.564 + 0.956 (TL) R^2= 0.99, N= 1058, SE= 1.9219

Size and Age Composition

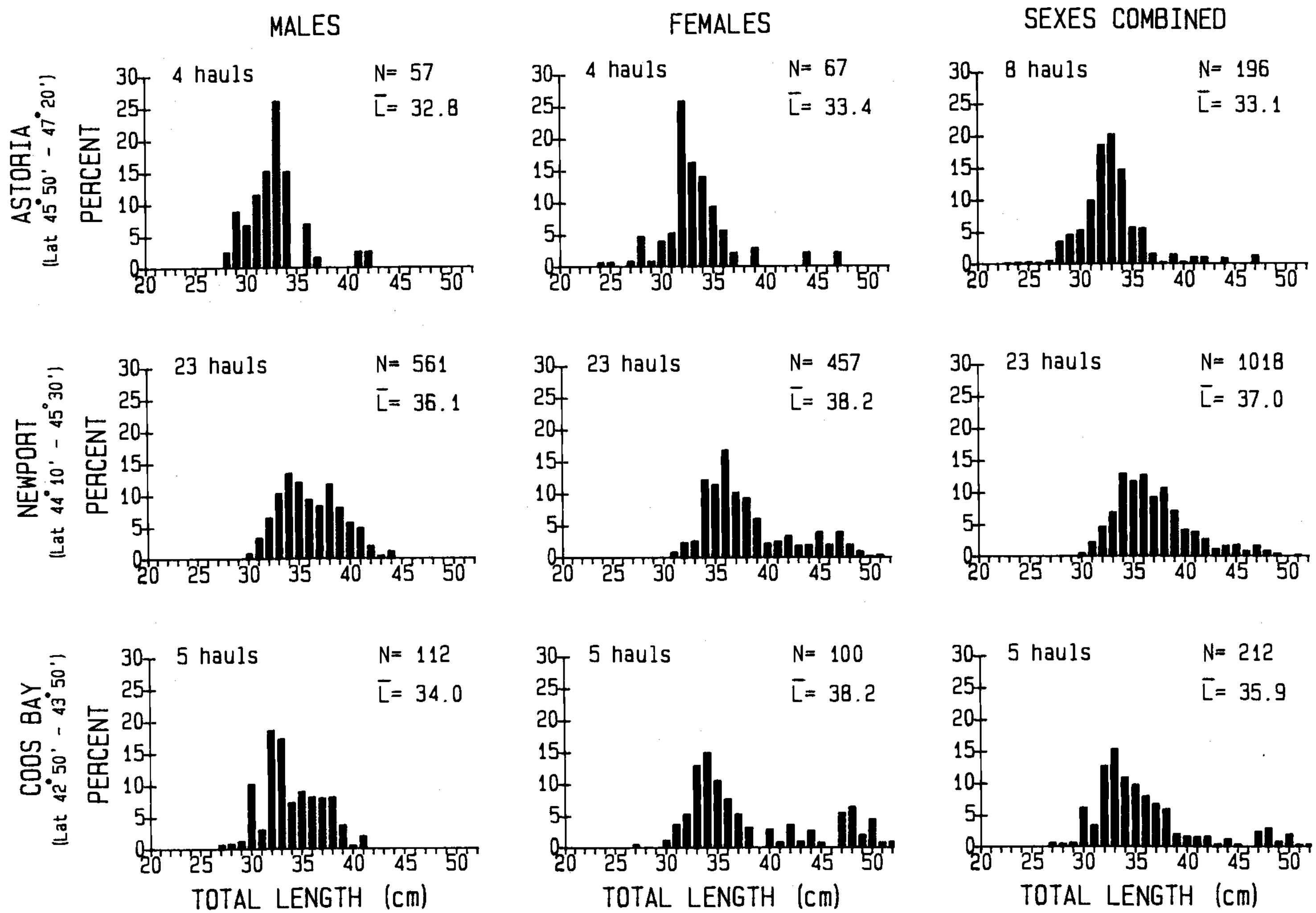
Length compositions of fish caught by bottomfish trawlers were plotted by sex for bottom depths greater than 150 fm at the three sample areas (Figs. 14, 15, 16).

Females had a larger mean size than males in all areas and depth strata. Females also had a bimodal size distribution, most evident in Coos Bay and Newport samples.

Size compositions varied among areas. Astoria length compositions were considerably smaller for both sexes than Newport and Coos Bay samples (Figs. 14, 16). Males caught in the Coos Bay area were smaller in size than males caught in the Newport area, whereas females showed similar distributions (Figs. 14, 15).

Larger fish tended to occur more frequently in deeper water as mean size increased with increasing depth. In the Astoria area, the mean size of *S. crameri* caught in groundfish tows increased from 28.7 cm TL inside of 150 fm to 33.1 cm TL below 150 fm (Fig. 16). Out of the Newport area, where length samples were collected predominantly outside of 150 fm, the length/depth correlation was less evident. Higher percentages of large fish (>40 cm), however, were found outside 200 fm than inside 200 fm

Figure I-14. Length compositions of *Sebastes crameri* by sex and area, at depths ≥ 150 fathoms. The number of hauls, the number of fish measured (N) and mean lengths ($\bar{L}$) are included. Percentages and mean lengths are based on length-frequency samples that were expanded by the ratio of the total weight of *S. crameri* in a tow to the weight of the fish that were measured.



MALES
FEMALES
SEXES COMBINED
ASTORIA (Lat 45°50' - 47°20')
NEWPORT (Lat 44°10' - 45°30')
COOS BAY (Lat 42°50' - 43°50')
PERCENT
4 hauls
N= 57
L= 32.8
4 hauls
N= 67
L= 33.4
8 hauls
N= 196
L= 33.1
23 hauls
N= 561
L= 36.1
23 hauls
N= 457
L= 38.2
23 hauls
N= 1018
L= 37.0
5 hauls
N= 112
L= 34.0
5 hauls
N= 100
L= 38.2
5 hauls
N= 212
L= 35.9
TOTAL LENGTH (cm)

Figure I-14.

Figure I-15. Length compositions of *Sebastes crameri* by sex, area and depth. The number of hauls, the number of fish measured (N) and mean lengths ($\bar{L}$) are included. Percentages and mean lengths are based on length-frequency samples that were expanded by the ratio of the total weight of *S. crameri* in a tow to the weight of the fish that were measured.

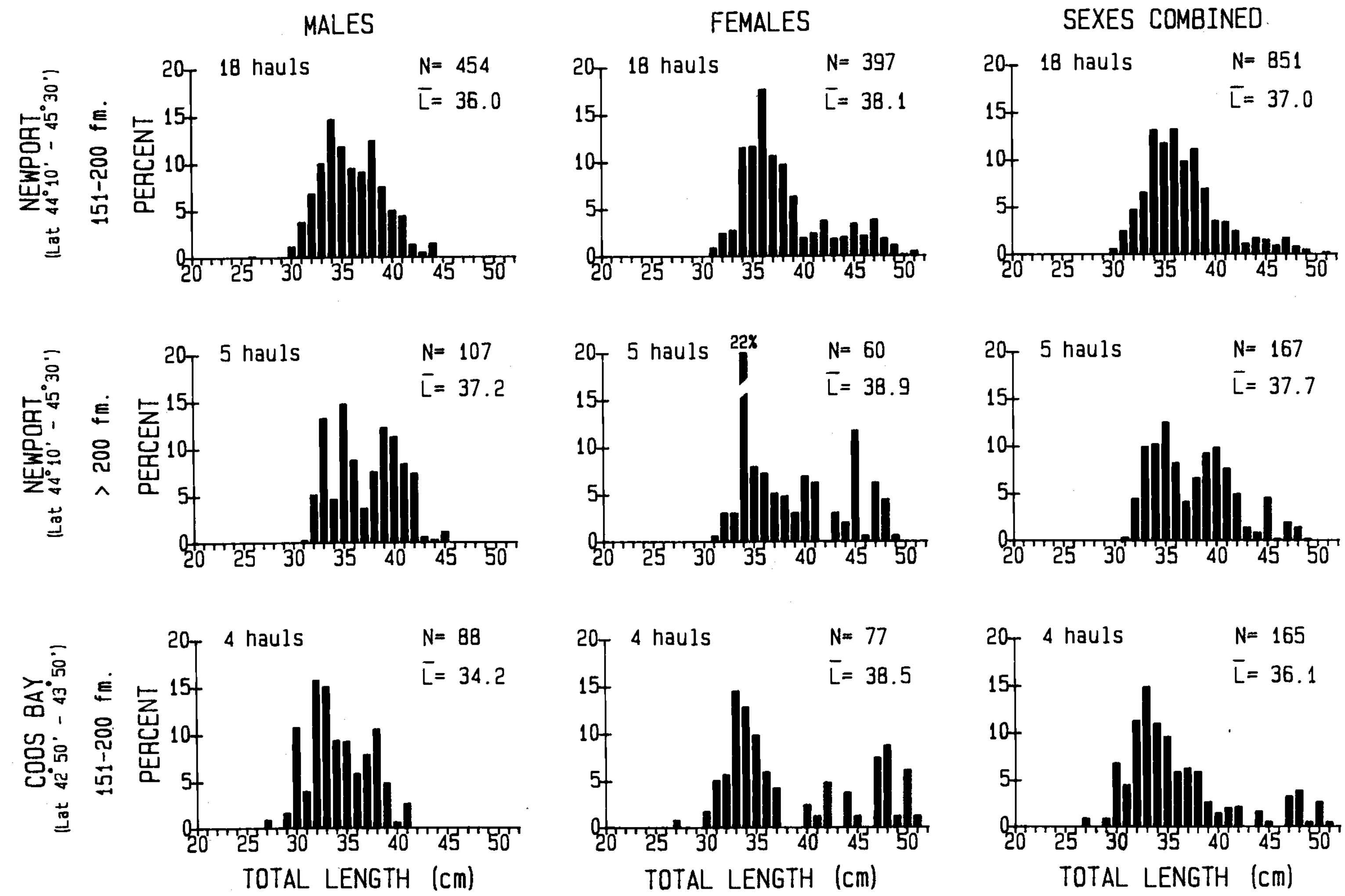

MALES
FEMALES
SEXES COMBINED
NEWPORT (Lat 44°10' - 45°30')
151-200 fm.
PERCENT
18 hauls
N= 454
L̄= 36.0
18 hauls
N= 397
L̄= 38.1
18 hauls
N= 851
L̄= 37.0
NEWPORT (Lat 44°10' - 45°30')
> 200 fm.
5 hauls
N= 107
L̄= 37.2
5 hauls
22%
N= 60
L̄= 38.9
5 hauls
N= 167
L̄= 37.7
COOS BAY (Lat 42°50' - 43°50')
151-200 fm.
4 hauls
N= 88
L̄= 34.2
4 hauls
N= 77
L̄= 38.5
4 hauls
N= 165
L̄= 36.1
TOTAL LENGTH (cm)
TOTAL LENGTH (cm)
TOTAL LENGTH (cm)

Figure I-15.

Figure I-16. Length compositions of Sebastes crameri (sexes combined) by area and depth. The number of hauls, the number of fish measured (N) and mean lengths ($\bar{L}$) are included. Percentages and mean lengths are based on length-frequency samples that were expanded by the ratio of the total weight of S. crameri in a tow to the weight of fish that were measured.

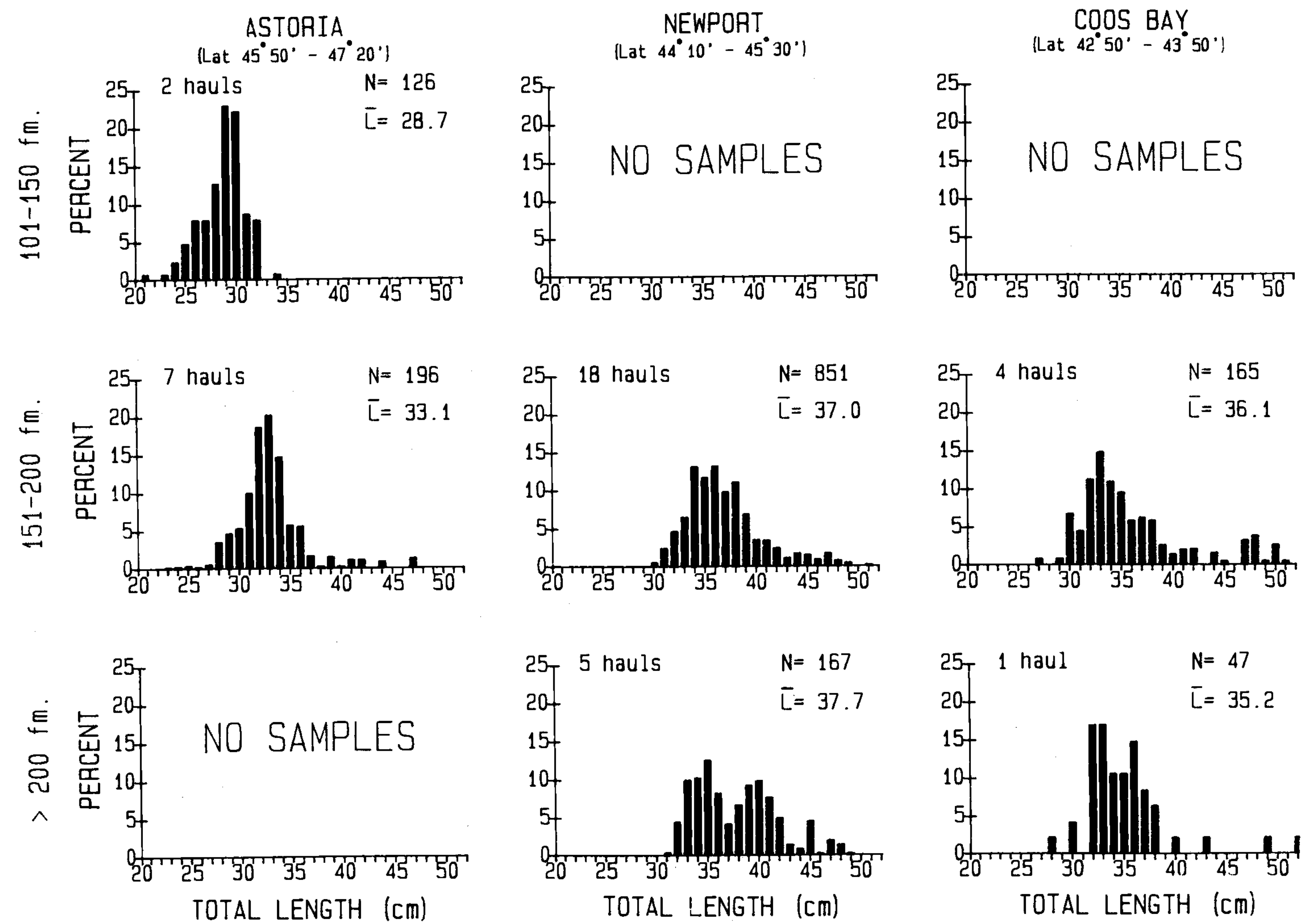

ASTORIA
(Lat 45°50' - 47°20')
NEWPORT
(Lat 44°10' - 45°30')
COOS BAY
(Lat 42°50' - 43°50')
101-150 fm.
151-200 fm.
> 200 fm.
PERCENT
2 hauls
N= 126
L̄= 28.7
NO SAMPLES
NO SAMPLES
7 hauls
N= 196
L̄= 33.1
18 hauls
N= 851
L̄= 37.0
4 hauls
N= 165
L̄= 36.1
NO SAMPLES
5 hauls
N= 167
L̄= 37.7
1 haul
N= 47
L̄= 35.2
TOTAL LENGTH (cm)

Figure I-16.

(Figs. 15, 16). Using a 2 X 2 G-test of independence (Sokal and Rohlf, 1969), it was confirmed that length distributions were dependent on depth for males ($P<0.005$), females ($P<0.05$) and sexes combined ($P<0.001$).

Age compositions of *S. crameri* collected by bottomfish trawlers are presented for the Newport and Coos Bay areas (Figs. 17, 18).

Age compositions at bottom depths greater than 150 fm were dominated by 6, 7, 8, and 9 year old fish, with a peak at 7 years of age off Newport and 6 years of age off Coos Bay. In the Newport area, ages of some fish exceeded 80 years, although 81% of the fish sampled were less than 30 years of age (Fig. 17). Off Coos Bay there was a younger age composition and a scarcity of older fish (Fig. 18).

Higher percentages of older fish were found outside 200 fm (Figs. 17, 19). Using a 2 X 2 G-test of independence (Sokal and Rohlf, 1969), age distribution was found to be dependent on depth ($P<0.005$).

Considerable differences in size and age composition were found among samples collected aboard shrimp trawlers. Collections taken off Pt. Grenville, WA (lat. 47°17′N) at 74 fm were dominated by immature fish averaging 16.6 cm TL, 60% of which were 1 year olds (Figs. 20a, 20b). Collections off Coos Bay (lat. 43°30′N) in 108 fm contained a wider range of fish lengths averaging 25.8 cm TL (Fig. 21a). Ages ranged from 2 to 9 but consisted primarily of 3, 4 and 5 year olds (Fig. 21b).

Figure I-17. Age composition of Sebastes crameri (sexes combined) off Newport, Oregon, by depth. The number of hauls and the number of fish aged (N) are included. Percentages are based on age-frequency samples that were expanded by the ratio of the total weight of S. crameri in a tow to the weight of fish that were aged.

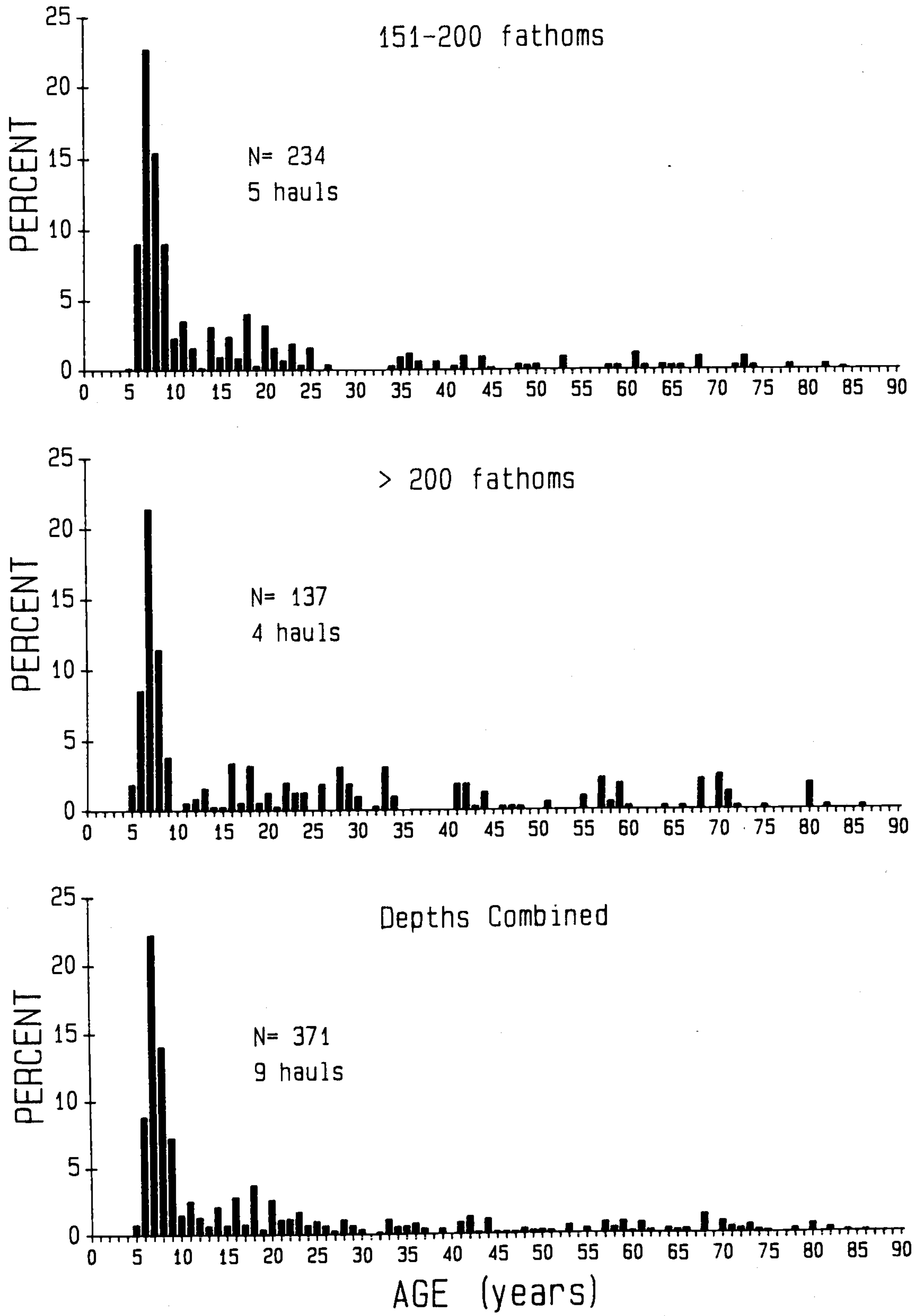

151-200 fathoms
N= 234
5 hauls
PERCENT
0
5
10
15
20
25
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
> 200 fathoms
N= 137
4 hauls
PERCENT
Depths Combined
N= 371
9 hauls
PERCENT
AGE (years)

Figure I-17.

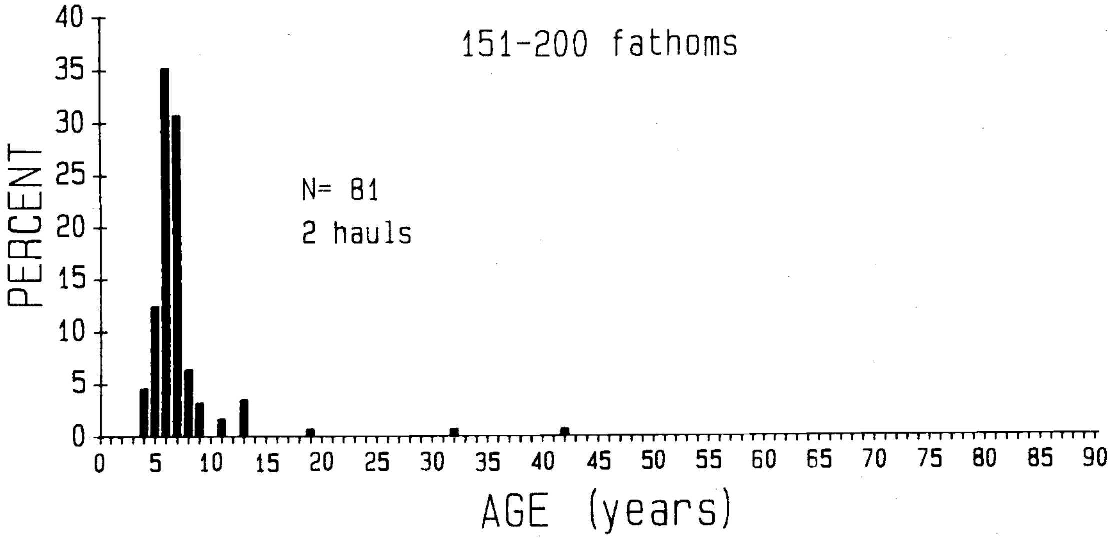


Figure I-18. Age composition of <u>Sebastes</u> <u>crameri</u> (sexes combined) off Coos Bay, Oregon, at depths from 150 to 200 fathoms. The number of hauls and the number of fish aged (N) are included. Percentages are based on age-frequency samples that were expanded by the ratio of the total weight of <u>S</u>. <u>crameri</u> in a tow to the weight of fish that were aged.

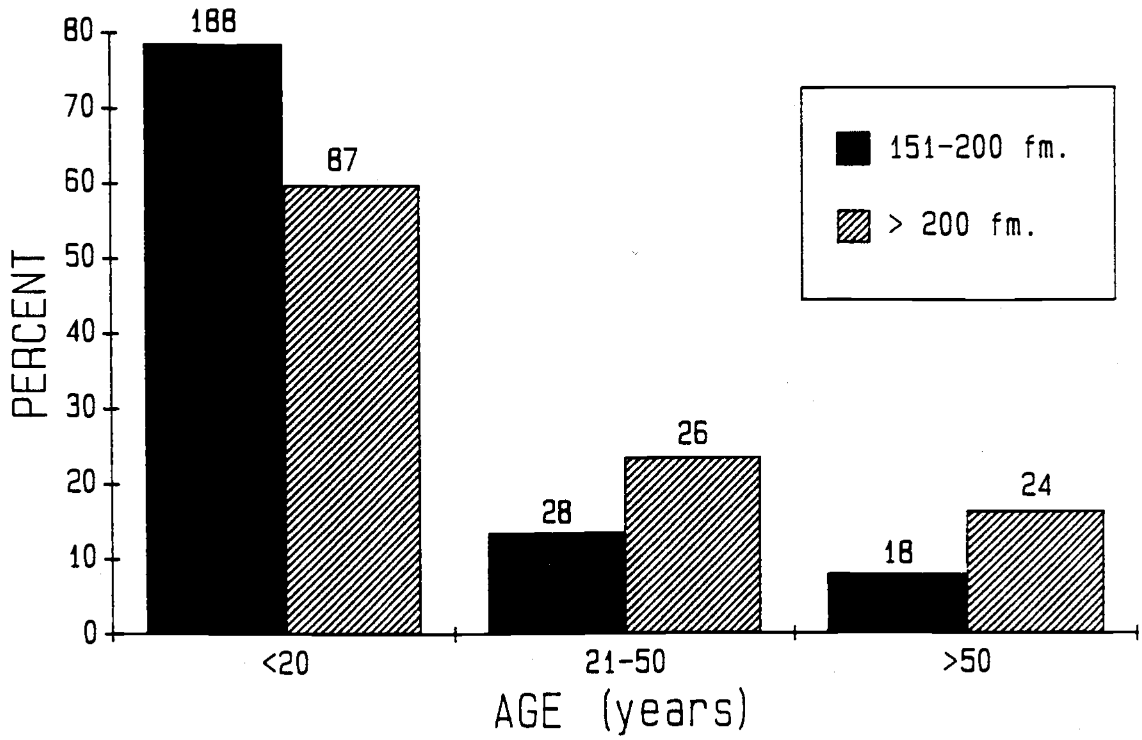


Figure I-19. Percent composition of Sebastes crameri (sexes combined) among 3 age groupings for specimens collected off Newport, Oregon at depths between 150 and 200 fathoms and at depths greater than 200 fathoms. Column numbers indicate the number of fish aged. Percentages are based on age-frequency samples that were expanded by the ratio of the total weight of S. crameri in a tow to the weight of fish that were aged.

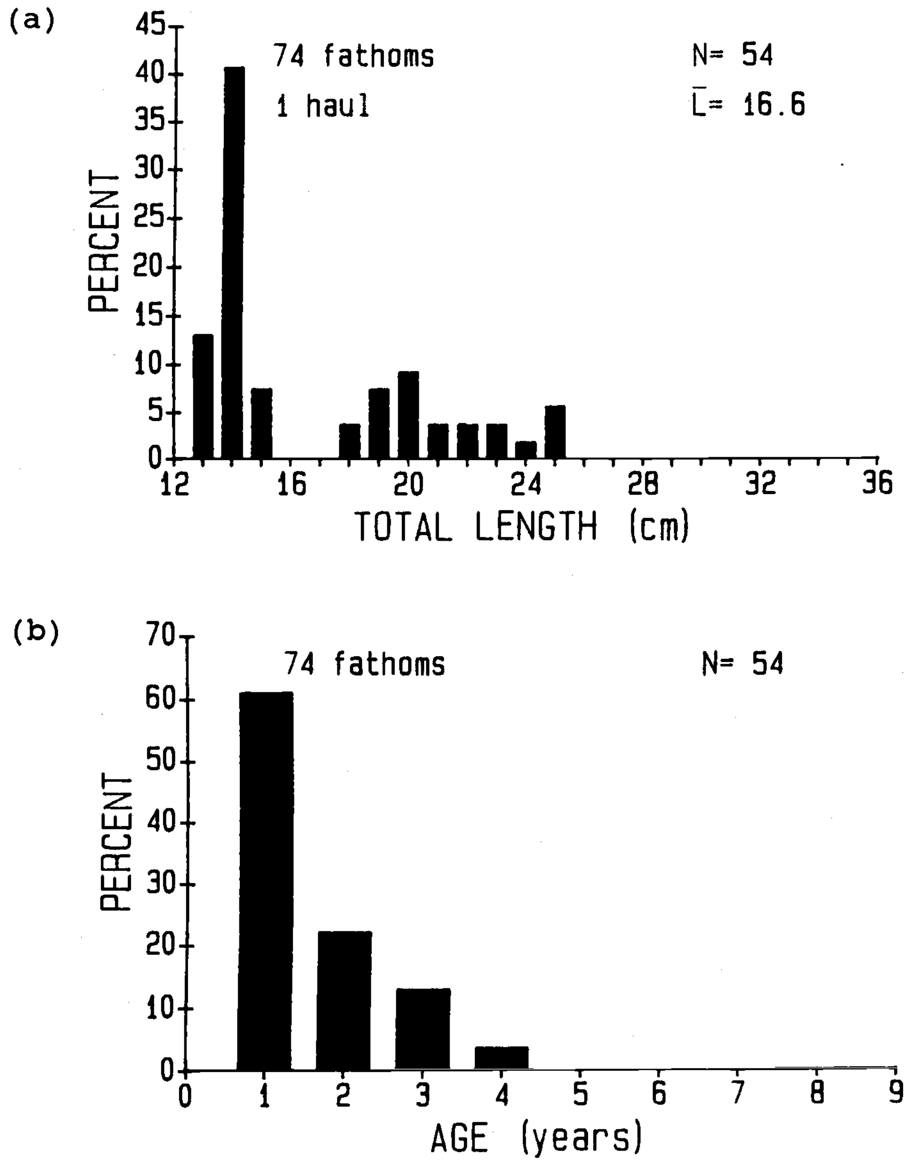


Figure I-20. Length composition (a) and age composition (b) of Sebastes crameri caught by commercial shrimp trawlers off Washington (lat. 47°17') at a depth of 74 fathoms. Mean lengths (L̄) and sample sizes (N) are included.

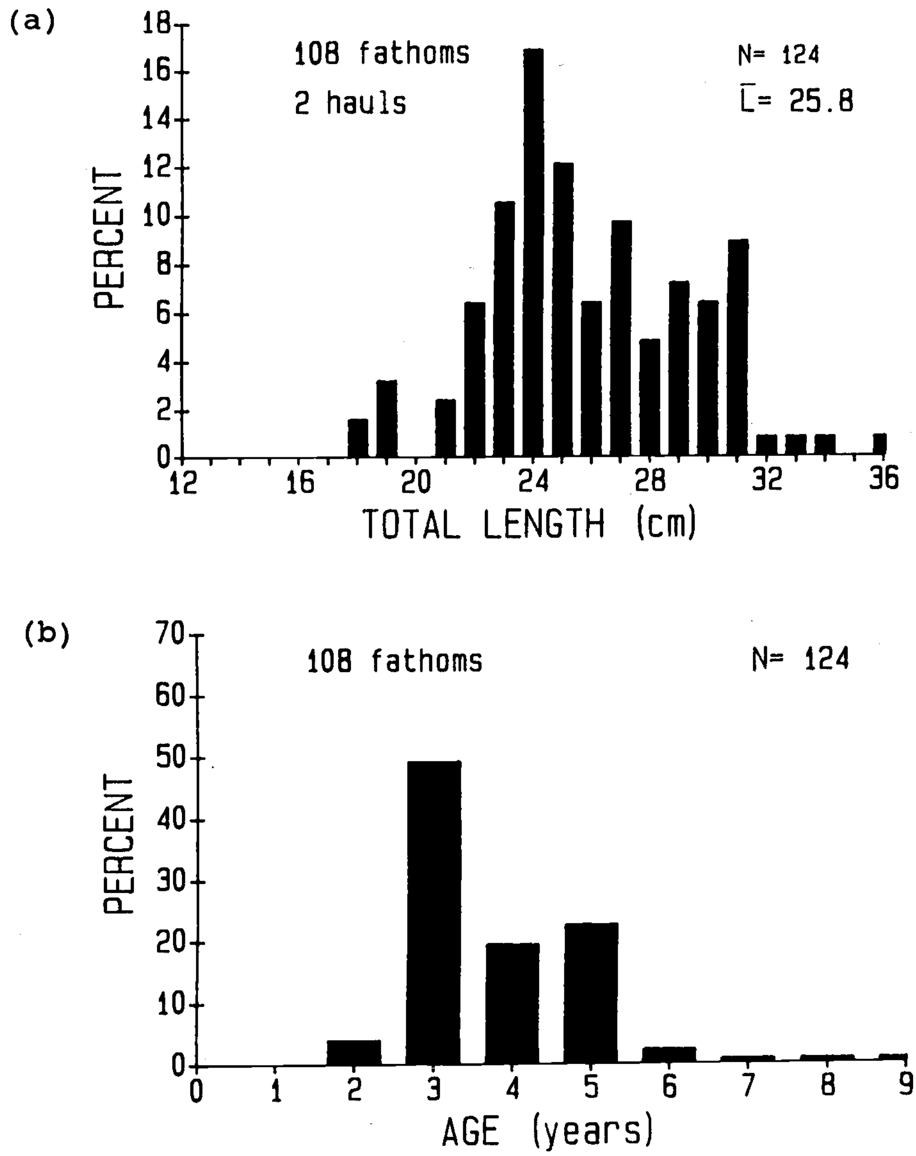


Figure I-21. Length composition (a) and age composition (b) of Sebastes crameri caught by commercial shrimp trawlers off Coos Bay, Oregon (lat. 43°30') at a depth of 108 fathoms. Mean lengths ($\bar{L}$) and sample sizes are included.

Mortality

Comparison of catch curve slopes revealed no significant difference in mortality (Z) between males and females for the age ranges used (analysis of covariance, $P>0.2357$). Catch curves for males and females were therefore combined.

Catch curves were generated for the following 3 age groupings: 7 to 14; 15 to 30; and >30. Estimates of Z generated by this procedure corresponded to mortality during the years 1979-1987, 1963-1978, and prior to 1962, respectively. With catch rates of *S. crameri* highest after 1978, the current mortality rate (Z_1) could be as high as 0.42 (Fig. 22; Table 6). The validity of these results should be viewed with caution, as variable recruitment and differences in age-specific mortality could have skewed the slope of the catch curves.

Catch Per Unit Effort (CPUE)

Using CPUE (catch in no./hrs towed) as a relative measure of fish density, abundance was found to decline with increasing depth (Fig. 23). Few fish were found outside of 300 fm. Given the observed trend of increased mean size with increased depth, the low CPUE in the 51-100 fm range was most likely an artifact of gear selectivity. Based on the length composition of *S. crameri* captured with shrimp trawl gear (3.5 cm codend mesh) in 74 fm (Fig. 20a), fish inhabiting water shallower than 100 fm were likely too

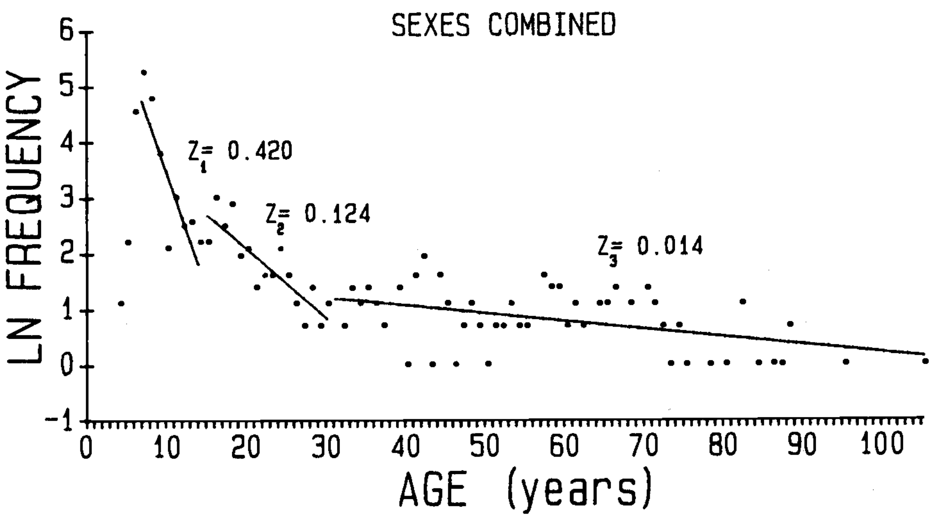


Figure I-22. Catch curves and estimates of total instantaneous mortality (Z) for specimens of <u>Sebastes crameri</u> collected at depths greater than 150 fathoms off Newport, Oregon. Catch curves were generated for the following age groupings: 7-14; 15-30; and >30.

Table I-6. Estimates of total instantaneous mortality (Z), for darkblotched rockfish collected at depths greater than 150 fathoms off Newport, Oregon. Estimates are based on catch curve analysis generated for various age groupings. N=number in sample; SE=standard error.

	Age Range	Year-Classes	Z	R^2	P-Value	SE	N
Z_1	7-14	1972-1980	0.420	0.73	0.0068	0.1042	413
Z_2	15-30	1956-1971	0.124	0.72	0.0001	0.0205	115
Z_3	31-105	1881-1955	0.014	0.21	0.0011	0.0041	122

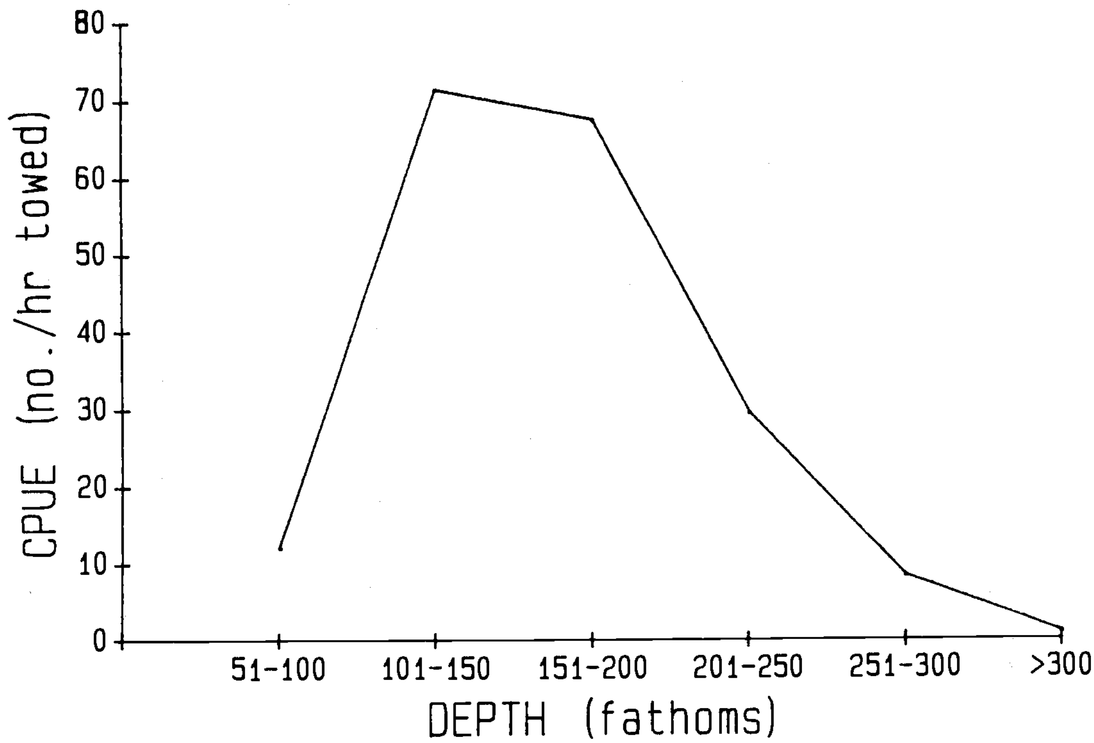


Figure I-23. Catch per unit effort (CPUE, no./hr towed) by Oregon commercial groundfish trawlers, by depth, for tows in which Sebastes crameri were caught during at-sea research surveys conducted between June 1985 and December 1987.

small to be retained with groundfish trawl gear (9.5-11.4 cm codend mesh).

In terms of weight, CPUE (kg/hrs towed) was highest between 150 and 200 fm, and again, few fish were found outside of 300 fm (Fig. 24). Both effort (hours) and catch (kg) were highest between 150 and 200 fm (Figs. 25, 26).

Figure I-24. Catch per unit effort (CPUE, kg/hr towed) by Oregon commercial groundfish trawlers, by depth, for tows in which Sebastes crameri were caught during at-sea research surveys conducted between June 1985 and December 1987.

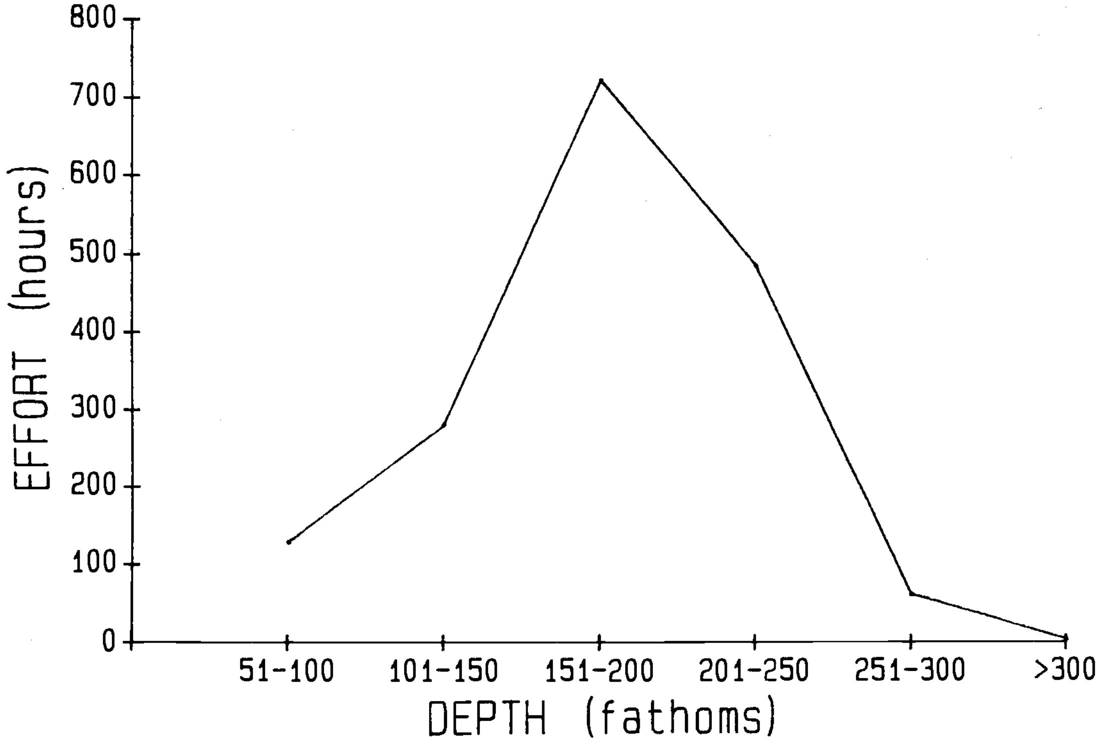


Figure I-25. Effort (hrs towed) by Oregon commercial groundfish trawlers, by depth, for tows in which Sebastes crameri were caught during at- sea research surveys conducted between June 1985 and December 1987.

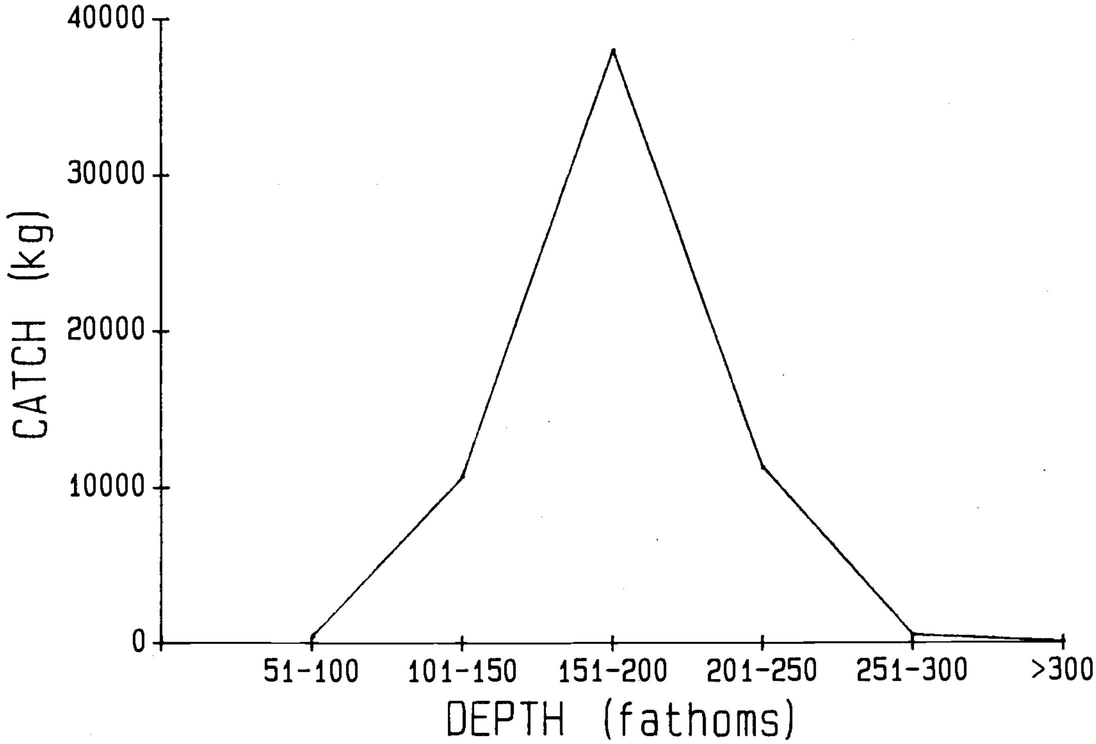


Figure I-26. Catch (kg fish) of <u>Sebastes</u> <u>crameri</u> by Oregon commercial groundfish trawlers, by depth, for tows in which Sebastes crameri were caught during at-sea research surveys conducted between June 1985 and December 1987.

DISCUSSION

Corroboration of Ages

The aging methodology used to age specimens of *S. crameri* in this study has been shown to yield ages consistent with those determined using the methodologies employed by the Pacific Biological Station (PBS) for rockfish (*Sebastes*) species. Although the few oldest otoliths (>60 years) in the sample provided to the PBS could not be aged with confidence, because the aging criteria was demonstrated to be the same, ages determined for old fish by this study were considered precise. The maximum ages observed for *S. crameri* in this study are consistent with maximum ages that have been observed for other species of the genus *Sebastes* (Chilton and Beamish, 1982; Leaman and Beamish, 1984).

Edge type analysis supported the hypothesis that bands are formed annually in *S. crameri* otoliths. The majority of fish used in edge type analysis, however, were less than 10 years of age (92%) because edge types in older fish were rarely discernable. This analysis, therefore, corroborates the formation of annular bands in younger fish (<10 years) only. On the other hand, the majority of fish collected were young, as 71% were less than 10 years of age.

Although the formation of annular bands and the method of age determination used in this study have only been corroborated, not validated, they have been validated for a number of other species in the genus *Sebastes*. Leaman and Nagtegaal (1987) validated the formation of annular bands and the aging technique employed by the PBS for yellowtail rockfish (*Sebastes flavidus*) attaining ages up to 34 years, and Bennett et al. (1982) validated the longevity of *Sebastes diploproa* to 80 years. It is believed that the same annular growth patterns validated in the otoliths of other rockfish (*Sebastes* spp.), also exist for *S. crameri*.

Growth

Growth for both males and females begins with a "rapid growth phase" followed by a period of extremely slow growth. Females attain larger maximum lengths but approach their maximum length (L_∞) at a slower rate (K) than males. Divergence in growth between sexes occurs at approximately age 6 and 30 cm TL (Fig. 13).

Comparisons with growth estimates for *S. crameri* collected off British Columbia revealed significant differences. Shaw and Archibald (1981) and Archibald et al. (1981) reported lower mean sizes at age and a lower maximum age for darkblotched rockfish collected off British Columbia in 1979 (Fig. 27; Table 7). Von Bertalanffy parameters, K and L_∞ were significantly smaller than for the present study (Fig. 28; Table 8).

Phillips (1964) and Westrheim and Harling (1975) reported higher maximum sizes (L_∞) and lower maximum ages than the present study (Fig. 28; Table 8). Phillips (1964) and Westrheim and Harling (1975), however, used scales and

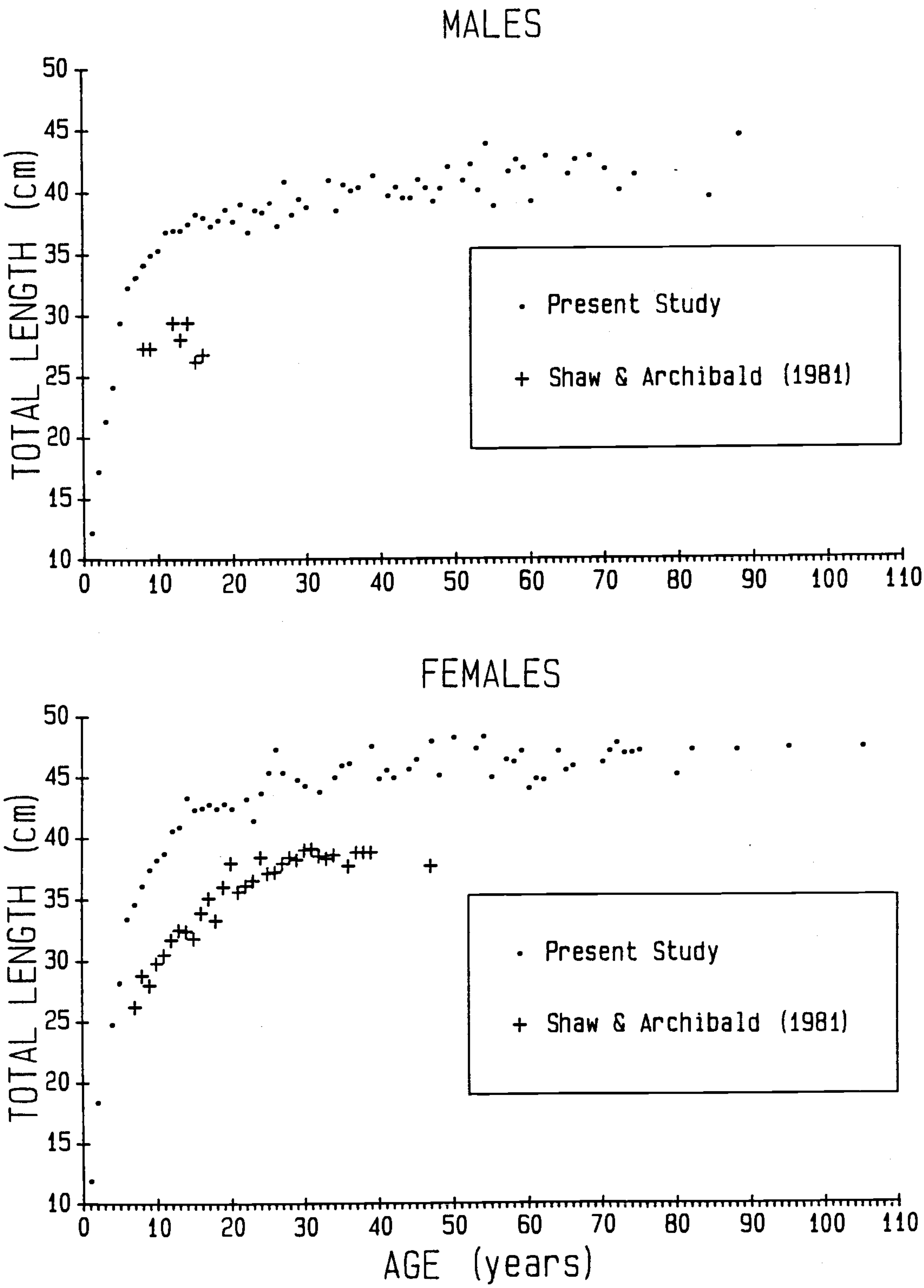


Figure I-27. Comparison of mean lengths at age for male and female darkblotched rockfish, between specimens collected off British Columbia (Shaw and Archibald, 1981) and those collected off Oregon (present study).

Table I-7. Comparison of mean lengths (cm) at age, estimated for <u>Sebastes</u> <u>crameri</u> by different authors. M=males; F=females; T=sexes combined.

	Phillips (1964)	Westrheim & Harling (1975)[1]		Shaw & Archibald (1981)[1]		Present study[2]	
Age	T	M	F	M	F	M	F
0	8.5	-	-	-	-	-	-
1	8.2	13.6	13.6	-	-	12.2	11.9
2	14.0	19.5	18.7	-	-	17.2	18.4
3	19.2	20.8	22.4	-	-	21.3	-
4	23.8	24.2	22.2	-	-	24.1	24.8
5	27.7	27.1	28.5	-	-	29.4	28.2
6	31.2	28.0	28.6	-	-	32.3	33.4
7	34.2	30.1	31.9	-	26.2	33.1	34.6
8	36.1	32.4	32.9	27.3	28.8	34.1	36.1
9	37.8	32.6	32.0	27.3	28.0	34.9	37.4
10	39.4	36.1	37.2	-	29.8	35.3	38.2
11	40.9	36.2	35.1	-	30.5	36.8	38.7
12	42.4	35.1	38.3	29.4	31.7	36.9	40.6
13	43.7	38.8	40.4	28.0	32.5	36.9	40.9
14	45.6	39.3	-	29.4	32.4	37.4	43.3
15	46.4	-	44.3	26.2	31.8	38.2	42.3
16	47.0	40.8	44.5	26.8	33.9	37.9	42.5
17	-	43.5	46.3	-	35.1	37.2	42.8
18	-	42.4	46.4	-	33.3	37.7	42.4
19	-	42.4	45.8	-	36.0	38.6	42.8
20	-	-	48.5	-	37.9	37.6	42.4
21	-	43.0	47.7	-	35.6	39.0	-
22	-	-	48.0	-	36.1	36.7	43.2
23	-	-	48.7	-	36.5	38.5	41.4
24	-	43.5	-	-	38.4	38.3	43.7
25	-	-	-	-	37.1	39.1	45.4
26	-	48.7	50.8	-	37.2	37.2	47.3
27	-	-	-	-	37.9	40.8	45.4
28	-	-	48.7	-	38.4	38.1	-
29	-	-	-	-	38.2	39.4	44.8
30	-	-	-	-	39.0	38.7	44.3
31	-	-	-	-	39.1	-	-
32	-	-	-	-	38.5	-	43.8
33	-	-	-	-	38.3	40.9	-
34	-	-	-	-	38.6	38.4	45.0
35	-	-	-	-	-	40.5	46.0
36	-	-	-	-	37.7	40.0	46.2
37	-	-	-	-	38.8	40.3	-
38	-	-	-	-	38.8	-	-
39	-	-	-	-	38.8	41.2	47.6
40	-	-	-	-	-	-	44.9
41	-	-	-	-	-	39.6	45.6
42	-	-	-	-	-	40.3	45.0
43	-	-	-	-	-	39.4	-

Table I-7. Continued.

Age	Phillips (1964)	Westrheim & Harling (1975)[1]		Shaw & Archibald (1981)[1]		Present study[2]	
	T	M	F	M	F	M	F
44	-	-	-	-	-	39.4	45.7
45	-	-	-	-	-	40.9	46.5
46	-	-	-	-	-	40.2	-
47	-	-	-	-	37.7	39.1	48.0
48	-	-	-	-	-	40.2	45.2
49	-	-	-	-	-	41.9	-
50	-	-	-	-	-	-	48.3
51	-	-	-	-	-	40.8	-
52	-	-	-	-	-	42.1	-
53	-	-	-	-	-	40.0	47.4
54	-	-	-	-	-	43.8	48.4
55	-	-	-	-	-	38.7	45.0
57	-	-	-	-	-	41.5	46.5
58	-	-	-	-	-	42.5	46.3
59	-	-	-	-	-	41.8	47.2
60	-	-	-	-	-	39.1	44.1
61	-	-	-	-	-	-	44.9
62	-	-	-	-	-	42.8	44.8
64	-	-	-	-	-	-	47.2
65	-	-	-	-	-	41.3	45.6
66	-	-	-	-	-	42.5	46.0
68	-	-	-	-	-	42.8	-
70	-	-	-	-	-	41.7	46.3
71	-	-	-	-	-	-	47.2
72	-	-	-	-	-	40.0	47.9
73	-	-	-	-	-	-	47.0
74	-	-	-	-	-	41.3	47.1
75	-	-	-	-	-	-	47.3
78	-	-	-	-	-	-	47.7
80	-	-	-	-	-	-	45.3
82	-	-	-	-	-	-	47.3
84	-	-	-	-	-	39.5	-
88	-	-	-	-	-	44.5	47.3
95	-	-	-	-	-	-	47.5
105	-	-	-	-	-	-	47.6

[1] Lengths converted from FL (mm) to TL (mm) by equation: TL= 0.846 + 1.046(FL).

[2] Newport area fish only. Groundfish trawl (N=757) and shrimp trawl (N=44) samples combined.

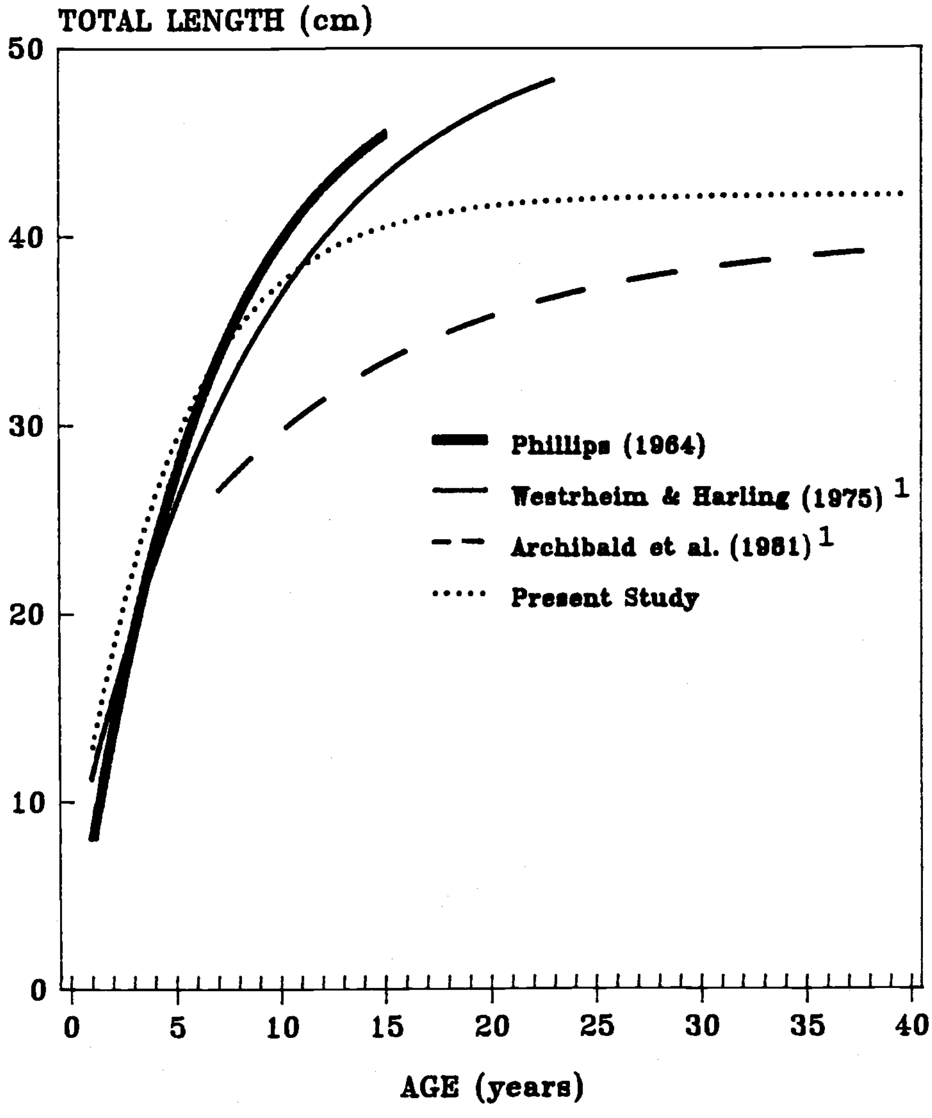


Figure I-28. Comparison of von Bertalanffy growth curves (sexes combined), estimated for Sebastes crameri by different authors.

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[1] Predicted lengths (mm) at age were converted from FL to TL by: TL= 0.846 + 1.046(FL).

Table I-8. Comparison of Von Bertalanffy growth parameters (L_∞, K, t_0), estimated for Sebastes crameri by different authors. N=number in sample; M=males; F=females; T=sexes combined.

Source	Sex	N	L_∞	K	t_0	Age Range	Aging Structure
Phillips (1964)	T	683	50.2	0.156	-0.12	1-16	Scales
Westrheim & Harling (1975)[1]	M	108	42.7 (44.7)	0.12	-2.2	0-21	Otolith Surface
	F	103	51.6 (54.0)	0.094	-2.5	1-23	Otolith Surface
	T	258	49.7 (52.1)	0.11	-1.2	1-23	Otolith Surface
Archibald et al. (1981)[1]	F	185	38.3 (40.1)	0.087	-5.4	7-39	Ototith Section
Present Study[2]	M	383	39.6	0.235	-0.58	1-88	Otolith Section
	F	417	45.6	0.178	-0.92	1-105	Otolith Section
	T	800	42.3	0.205	-0.78	1-105	Otolith Section

[1] Results in fork length (cm). Total length (cm) estimated in parenthesis using TL(mm)= 0.846 + 1.046*FL(mm).

[2] Newport area fish only.

whole otolith surfaces, respectively, to age fish, both of which have been found to underestimate actual ages of rockfish (Beamish, 1979; Archibald et al., 1981; Bennett et al., 1982; Boehlert and Yoklavich, 1984; Wilson, 1984). Consequently, these comparisons may serve only to illustrate how differences in aging technique can change the perception of growth. If growth continues for older fish, even slightly, growth relationships computed with underestimated ages may result in an inflation of the mean size at age (Wilson, 1984) and an inflated value of L_∞. The growth curves of Phillips (1964) and Westrheim and Harling (1975) diverge from the present study's curve at approximately age 7 and 11, respectively. The origin of these divergences may indicate the points above which ages were underestimated.

Size and Age Composition

Length and age distributions of rockfish have previously been shown to be correlated with depth (Archibald et al. 1983; Archibald et al., 1981; Boehlert, 1980). The migration of *S. crameri* to deeper water with increasing age is indicated by the higher percentage of larger, older fish found outside 200 fm (Figs. 17, 19). In shrimp collections, although latitudes differed, depth was believed to be the major factor correlated with size and age distribution (Figs. 20a, 20b, 21a, 21b). Fish caught in 74 fm (135 m) were considerably smaller and younger than fish caught in 108 fm (197 m).

Examination of the age distribution of *S. crameri* off Newport and Coos Bay revealed high percentages of 6, 7 and 8 year old fish followed by rather low percentages of older fish. Several factors may have contributed to this skewed distribution. First, it is possible that fishing exploitation effectively truncated the older age groups as has been shown for other rockfish species such as *S. alutus* (Leaman and Beamish, 1984). Secondly, if the 1978-1980 years-classes were strong enough, they may have obscured the abundance of older fish. Length-frequency (L/F) data presented by Barss (1989) appears to confirm the latter. Barss (1989) provided L/F data for specimens of *S. crameri* captured off Central Oregon by commercial groundfish trawlers just prior to the collection dates of the present study. Interestingly, the data presented by Barss (1989) did not reflect the abundance of small fish (32-35 cm FL) observed in the present study (Fig. 29). If these samples were representative of the stock available to the fishery, a plausible explanation for the sudden increase in catch of small fish after June of 1986, would be the recruitment of strong yearclasses. Conversely, if the addition of new recruits obscured the abundance of older fish, then the standing stock of older fish must have been relatively low.

Given that *S. crameri* is not a highly targeted species and has received increased fishing effort off the Oregon coast only since 1979 (Fig. 1), it seems reasonable to observe fish of extremely old age. Even if fishing

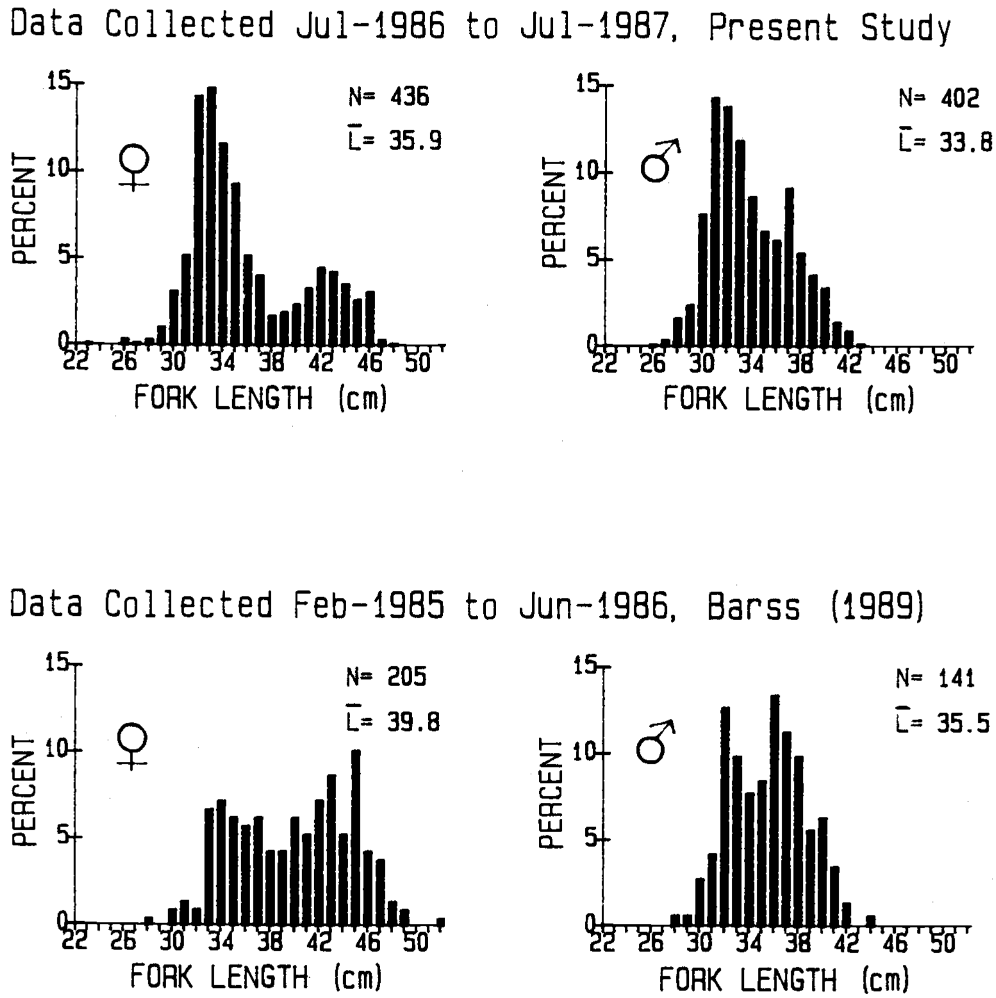


Figure I-29. Length compositions of *S. crameri* captured by commercial groundfish trawlers operating off Central Oregon from a) July 1986 to July 1987 (collected specimens from present study); and b) Feb. 1985 to June 1986 (Barss, 1989). Percentages and mean lengths ($\bar{L}$) are based on sample data, depths combined. N=number in sample mortality is high, older fish might be expected to persist for some time because fishing effort is directed in water shallower than 200 fm (Fig. 25). Although there has been a trend in recent years toward fishing in deeper water by Oregon bottomfish trawlers, effort is still concentrated inside of 200 fm (Golden, 1989).

Mortality

Estimation of total instantaneous mortality (Z) by use of a catch curve is dependent on the assumptions of constant mortality and constant recruitment. If fishing mortality is a large component of the total mortality, then the age range chosen for the catch curve must reflect a period of constant fishing mortality. Because fishing mortality has not been constant over all the age groups collected, three different limbs of catch curves were fitted in an effort to describe possible changes in overall mortality.

Assuming fishing mortality has been significantly higher after 1978, only age groups less than or equal to 14 should exhibit a decline in frequency commensurate with mortality after 1978. Examining the decline in frequency of these age groups (7-14), Z was estimated to be relatively high (0.420) (Fig. 22).

From 1963 to 1978, catch of *S. crameri* was moderate and constant (Fig. 1). Estimated mortality for this time period was much lower (0.124) (Fig. 22).

Mortality prior to 1963, estimated with age groups greater than 30, was low (0.014). Although fish were not abundant above age 30 and the correlation of the catch curve low (R^2= 0.21), this estimate may seem realistic for natural mortality considering the species longevity.

The catch curve analyses attempted to account for differences in fishing mortality encountered by fish during different periods of the fishery. It did not, however, account for the possibility of variable recruitment and changes in age-specific mortality, both of which can bias the slope of the catch curve (Ricker, 1975; Gulland, 1983). It's possible that the preponderance of 6, 7 and 8 year olds in the collections were, at least in part, due to the recruitment of 3 strong year-classes, rather than the depletion of older fish through fishing exploitation. In this case the most recent estimate of mortality rate (0.42) would be an overestimate. The analyses also did not account for the possibility that fishing and/or natural mortality might be different for different year-classes. Archibald et al. (1981) suggested that mortality might decrease for older rockfish prior to senescent mortality. Additionally, because older rockfish tend to inhabit deeper water, fishing mortality for older ones might be less than for younger ones. In light of these considerations, the mortality results presented in this paper should be viewed with caution.

Although no statistical differences in mortality between sexes were found after the modal age, differential fishing mortality may have occurred prior to the age at full recruitment. More females (277) than males (208) less than 9 years of age were captured (Table 9). If fishing mortality was higher on the faster growing females prior to the age at full recruitment, due to the size-selective nature of trawl mesh, then a higher percentage of males might be expected to survive during the course of a trawl fishery. This hypothesis is supported by the fact that more males (133) than females (95) in the 9-30 year age range, were captured (Table 9). Assuming that fish greater than 30 years of age were exposed to little or no fishery at the time they attained a "recruitable" size, they should exhibit a sex ratio commensurate with the stock when it was unexploited. The sex ratio for fish greater than 30 years of age was nearly 1:1 (Table 9).

Mortality (Z) of *S. crameri* off British Columbia was estimated at 0.07 (Archibald et al., 1981). Examination of the age composition presented by Archibald et al. (1981) suggests there may have been lighter fishing exploitation off British Columbia. The absence of fish over 50 years of age off B.C. might indicate a higher natural mortality than for the stock off Newport. On the other hand, if *S. crameri* was not collected over it full bathymetric range off British Columbia, as was suggested by Archibald et al.

Table I-9. Comparison, by age, of the number (N) of male and female darkblotched rockfish collected at sea aboard commercial groundfish trawlers operating off Oregon from July 1986 to July 1987.

Age (years)	Females (N)	Males (N)	Total (N)
4	6	2	8
5	8	11	19
6	76	48	124
7	116	94	210
8	71	53	124
9	20	27	47
10-30	75	106	181
>30	64	63	127

(1981), older fish might not have been represented in their samples.

Influence of Fishing

To best understand how fishing pressure might affect this stock, it's necessary to understand the species strategy for survival. Darkblotched rockfish, like most other species of the genus *Sebastes*, are typical of K-strategists (Adams, 1980) in that they are slow growing, long-lived, and are believed to spawn annually after a relatively long period of immaturity.

These characteristics offer distinct advantages for a population's survival. Individuals that spawn annually for many years ensure that some successful reproduction will occur even when conditions for larval survival are unfavorable for extended periods. In addition, a wide range in age-groups may, in any given year, give the population the capacity to produce offspring that are diverse in genetic makeup. This diversity may enhance the chances that at least some larvae will survive under a variety of different environmental conditions. Leaman and Beamish (1984) suggest that because rockfish allocate much of their energy to reproduction and maintenance rather than somatic growth for the majority of their life span, it may allow them to persist in environments of low productivity where competition and predation are reduced. Furthermore, because fecundity increases for larger, older fish (Chapter II), their reproductive contribution cannot be overlooked.

Survival of the population is linked to the species longevity.

Fish with these life history characteristics, however, are vulnerable to fishing overexploitation (Adams, 1980; Leaman and Beamish, 1984; Francis, 1985). Fisheries tend to remove the larger, older fish first. This might be illustrated for *S. crameri* by the truncation of older age groups. As Leaman and Beamish (1984) point out, fishery management has condoned the removal of the older less productive portion of virgin stocks because they contribute little to the overall biomass of the population. The species ability to thrive in the long term, unfortunately, may depend on the reproductive contribution of these older fish.

Rockfish, such as *S. crameri*, are also susceptible to overfishing because of their longevity and low production to biomass ratio. In unexploited rockfish stocks, rockfish maintain a relatively large standing stock with a very low "turnover" rate. Francis (1985) pointed out that maximum equilibrium surplus production is only a small portion of the unexploited biomass of a rockfish stock. Using simulation models to describe a species' capacity to support and maintain a fishery, given its' life history characteristics, Francis (1985) concluded that fisheries which develop on rockfish, can easily reach a harvesting potential that exceeds the productive capacity of the stock. As observed for POP in the 1960's, once stocks were depleted, they did not have the capacity to regenerate during an ongoing fishery. Additionally, if a stock of rockfish was fished to a point where recruitment was reduced, the recovery period, even in the absence of a fishery, would be slow (Francis, 1985).

Darkblotched rockfish may be particularly susceptible to overfishing because their age at full recruitment is less than their age at 50% maturity (Chapter II). The majority of females collected were not mature. Continued fishing near the age at maturity and removal of older fish may result in a reduction of recruitment.

The association of darkblotched rockfish with the Dover sole fishery may also be a detriment. Because S. crameri is part of a mixed stock fishery and often is a "by-catch" of fishing targeted at species such as Dover sole (Microstomus pacificus) and sablefish (Anoplopoma fimbria), management at the single species level would be difficult. A management plan geared towards maximizing the yield of more productive species of the complex such as Dover sole and sablefish, may occur at the expense of species such as darkblotched rockfish.

Darkblotched rockfish has been relatively abundant off the Oregon coast. Although there has not been a directed fishery for this species, it has been caught with regularity off Oregon since 1979. The high percentage of young fish observed in collections off Newport may indicate a truncation of the age distribution, and current mortality

(Z) appears high for recent recruits. Considering the species life history characteristics; its longevity, its relatively young age at full recruitment, and its age at maturity, it seems unlikely that it can withstand intensive fishing pressure for a prolonged period.

CHAPTER II

Reproduction of Darkblotched Rockfish, *Sebastes crameri*, off the Oregon Coast

ABSTRACT

The reproductive development, size and age at sexual maturity, and fecundity were described for darkblotched rockfish (*Sebastes crameri*) found off the Oregon coast.

A total of 1060 fish captured off Oregon by commercial groundfish and shrimp trawlers between July 1986 and July 1987, were examined. Observations on the gross and cellular morphology of gonads were used to describe the seasonal reproductive development and state of maturity for both males and females. Fecundity was estimated using gravimetric subsampling (Phillips, 1964; Bagenal and Braum, 1978; Hunter et al., 1985; Yoklavich and Pikitch, 1989).

A large percentage of females observed throughout the year, predominantly 6, 7 and 8 year olds, possessed ovaries in an intermediate "maturing" condition. Histological analysis revealed that these females were immature. Their ovaries showed no evidence of previous spawning and oocytes were unyolked.

Insemination of females occurred from September to December, fertilization from December to February, and parturition from December to March. Size and age at 50% maturity for females occurred at an older age (8.3 years) and an larger size (36.7 cm total length) than males (5.2 years; 29.7 cm total length). Fecundity ranged from 19,815 to 489,064 oocytes/ovary pair and increased with increasing fish size.

Given that the age at full recruitment of females (7 years) was less than their age at 50% maturity (8.3 years), and the largest most fecund individuals appeared reduced in abundance, further exploitation of this species may compromise future recruitment.

INTRODUCTION

Darkblotched rockfish, *Sebastes crameri*, have been shown to be an important component of the Oregon commercial groundfish trawl fishery (Chapter I). Research surveys conducted off Oregon aboard commercial bottomfish trawlers between 1985 and 1987 (Pikitch et al., 1988), offered the opportunity to collect and examine the biology of this species in detail. This investigation examines the reproductive biology of *S. crameri*.

Previous investigations have reported the reproductive characteristics of a variety of rockfish (*Sebastes* spp.) off California (Phillips, 1964; Echeverria, 1987), Oregon (Barss, 1989) and British Columbia (Westrheim, 1975). These investigations provided some reproductive data on *S. crameri*, however, none examined this species in detail.

This report provides detailed information on reproductive cycling (based on gross and cellular morphology of ovaries and testes), the size and age at sexual maturity, and fecundity for specimens of *S. crameri* found off the Oregon coast.

MATERIALS AND METHODS

Data Collection

Most specimens of *Sebastes crameri* were collected at sea aboard commercial bottomfish trawlers. Supplemental samples were collected at fish processing plants in Newport, Oregon (see Chapter I). In the laboratory, fish were weighed (nearest gm) and measured (nearest mm TL and FL). Sagittal otoliths were removed for aging (see Chapter I). Gonads were removed and weighed to the nearest 0.01 gram. In order to outline gonadal development, maturity stages based on criteria set by Echeverria (1987), were assigned to all gonads. Brief written descriptions based on gonad color, size and morphology were recorded for each specimen so that discrepancies in assigned maturity stages could be resolved after familiarization with the species maturation process. Additional macroscopic observations recorded included: the presence of milt and swelling of the sperm duct in testes; the presence of fertilized eggs, eyed larvae and residual larvae in ovaries.

Gonads were collected from 286 males and 255 females captured from July 1986 to July 1987. Gonads were preserved in 10% phosphate-buffered formalin for later histological analysis and fecundity estimations. Age and length data were recorded for all specimens (Chapter I).

Histological Preparation

Histological cross sections from 248 testes and 146 ovaries were taken from the middle portion of either the left or right gonad. Testes and ovary samples were embedded in paraffin, then sectioned at 7μ and 8μ, respectively. Sections were stained with Myer's haematoxylin and counterstained with eosin.

Histological Evaluation

Brief microscopic descriptions were recorded for each gonad section. Descriptions of the cellular morphology of ovaries and testes were based on terms presented by Moser (1967b), Lisovenko (1972) and Echeverria (1987).

For ovary sections, the presence of vesicles, yolk globules, developed follicles, eyed larvae, atretic oocytes, and stored sperm were noted. Maximum oocyte diameters were measured with an ocular micrometer.

For teste sections, the presence of germ cells, primary spermatogonia (PG), secondary spermatogonial cysts (SGC), primary spermatocyte cysts (PSC), secondary spermatocyte cysts (SSC), spermatid cysts (STC), and spermatozoa (SZ) was noted. The presence of SZ in the teste lumen, and signs of SZ resorption were also noted.

The macroscopic gonad maturity stages applied following criteria set by Echeverria (1987), were reevaluated following the microscopic assessments. New gonadal maturity stages, specific to *S. crameri*, were developed for testes and ovaries, and specific criteria were tabulated. The resulting tables represent modifications of the maturity stage criteria presented by Echeverria (1987) and Lisovenko (1970).

Length and Age at Maturity

Length and age at 50% maturity were predicted for males and females separately by fitting data to the logistic equation (Gunderson, 1980):

$$P_x = 1/(1+e^{ax+b})$$

where P_x= proportion mature at length or age x and a & b = constants. Constants were calculated using nonlinear regression (DUD procedure; SAS Institute, 1987).

Fecundity

Gravimetric subsampling (Phillips, 1964; Bagenal and Braum, 1978; Hunter et al., 1985; Yoklavich and Pikitch, In Press) was used to estimate fecundity, the number of viable oocytes produced per female. Ovaries were blotted dry and weighed to the nearest 0.1 mg. Subsamples, averaging 82.8 mg and 304 oocytes, were taken from the anterior, medial, and posterior regions of the left or right ovary and then weighed to the nearest 0.1 mg. The ovarian sacs were removed from each pair of ovaries. Ovaries were then broken apart and most of the internal connective tissue was removed. Ovarian sacs and internal connective tissue were weighed to the nearest 0.1 mg and subtracted from the total paired ovary weight.

Each subsample was placed on a slide with 3-4 drops of 33% glycerin (Hunter et al., 1975; Yoklavich and Pikitch, In Press). Oocytes were teased apart and then transferred to a plexiglass grid; vitellogenic oocytes were counted with aid of a dissecting microscope. Small, partially yolked oocytes were assumed to be unviable and were not counted.

Estimates of total fecundity were calculated for each sample region (anterior, middle, and posterior) by multiplying the sample number of oocytes by the ratio of the total paired ovary weight (less the ovarian sac and internal connective tissue) to the sample weight. Final estimates of fecundity for paired ovaries were derived by averaging the regional estimates.

Differences in oocyte densities among the three sample regions were tested using a two-way ANOVA with region and fish as independent factors (SAS Institute Inc., 1987).

RESULTS

Maturity Stage Criteria

Gonad maturity stages, based on gross and cellular morphology of gonads, were used to outline the seasonal development of *S. crameri* ovaries and testes (Tables 1, 2). Gonad maturity stages presented by Echeverria (1987) for *Sebastes* species did not in all cases describe the gonadal traits observed in *S. crameri*. As such, I modified her tables using gonad descriptions recorded in this investigation.

Contrary to Echeverrias' (1987) findings, no distinguishing gonad traits (gross or cellular) were observed that could accurately predict if a fish was in its first year of maturity. For females, Echeverria's (1987) maturity stage-2 (1st year maturity) was changed to "maturing" (Table 1) for reasons that will be discussed later. For males, Echeverria's (1987) first-year maturity stage was replaced by a stage presented by Lisovenko (1970) for *S. alutus*: the development of new spermatogenic cycles (stage 2; Table 2). Mature testes of *S. crameri* were commonly observed in this stage (Fig. 1b).

Seasonal Development of Ovaries

All mature females collected in July 1986 exhibited ovaries containing vitellogenic oocytes (stage 3; Fig. 1a). Yolk formation continued in mature females through November. Ovaries (paired) increased in weight (Fig 2a) as

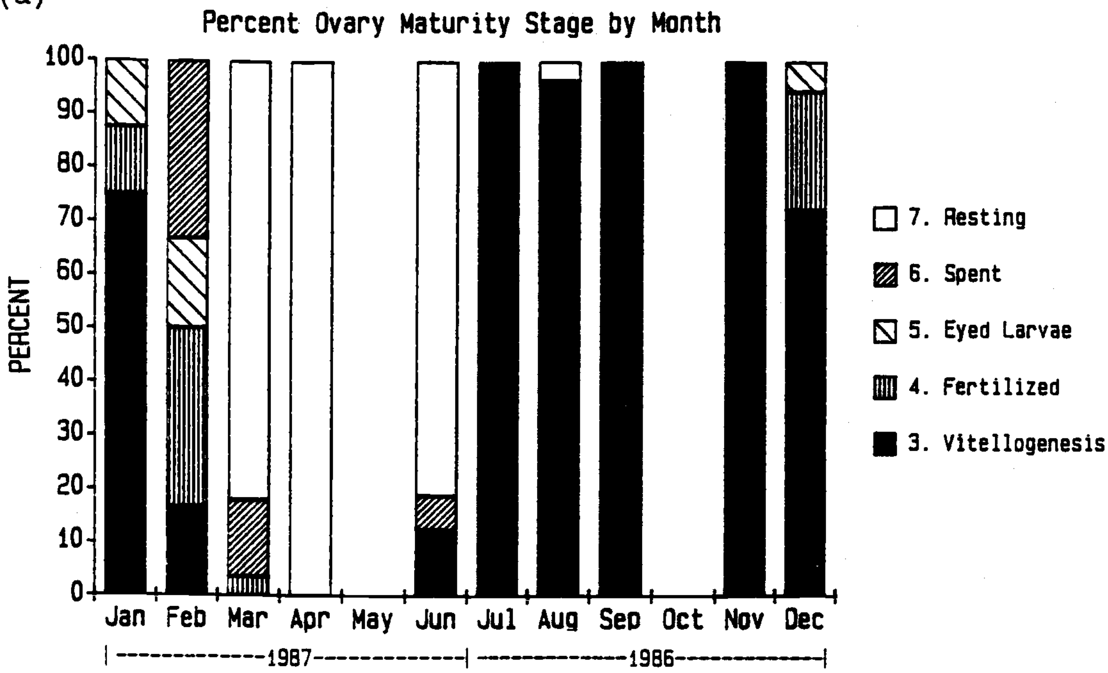
Table II-1. Maturity stage criteria for ovaries of Sebastes crameri, based on macroscopic and cellular observations.

Maturity stage	Macroscopic description	Cellular description
1. **Immature**	Pink and translucent. Oocytes not visible. Ovarian sac thin and <1.5 cm long. Paired ovary weight <1 g.	Oogonial nests with oocytes <0.15 mm in diameter.
2. **Maturing**	Pink, often appears bloodshot. Oocytes small, pink to cream color. Ovarian sac thin, taut and 1.5 to 3 cm long. Paired ovary weight from 1 to 4.5 g.	Maximum oocyte diameter from 0.15 to 0.26 mm. Follicles not differentiated into theca and granulosa cells. Atretic oocytes common from December to March. Yolk globules rare.
3. **Vitello-genesis**	Cream to cream-pink color. Oocytes large, cream color. Large ovaries have black pigmentation on ovarian sac. Ovarian sac >3 cm long. Paired ovary weight >4.5 g.	Yolk globules and oil vesicles present. Follicles differentiated into theca and granulosa cells. Maximum oocyte diameter from 0.26 to 0.60 mm. No atresia. Spermatozoa sometimes found outside follicles.
4. **Fertilized**	Pink cast. Large clear spherical eggs (embryos). Ovary flaccid.	Egg ovulated. Yolk coalesced. Oil vesicles coalesced into single vesicle. Pre-blastula to blastula embryo stage. Maximum embryo diameter from 0.67 to 0.80 mm. No atresia.
5. **Eyed Larvae**	Embryos with black pigmented eyes. Translucent, grey. Ovary flaccid, fluid-filled.	Embryos with black pigmented eyes.
6. **Spent**	Reddish-purple-grey. Ovarian sac thick, loose from interior. Residual larvae present.	Collapsed follicles and atretic oocytes, throughout. Residual larvae. Resorption of undeveloped oocytes. Oogonial nests present.
7. **Resting**	Grey-pink. Ovarian sac thick, loose from interior. Some with undefined black dots (residual larvae).	Oogonial nests throughout. Resorption of atretic oocytes, follicles, and residual larvae.

Table II-2. Maturity stage criteria for testes of <u>Sebastes</u> <u>crameri</u>, based on macroscopic and cellular observations. The presence of primary spermatogonia (PG), secondary spermatogonial cysts (SGC), primary spermatocyte cysts (PSC), secondary spermatocyte cysts (SSC), spermatid cysts (STC), and spermatozoa (SZ) are noted.

Maturity stage	Macroscopic description	Cellular description
1. **Immature**	Translucent, threadlike, often bloodshot. No milt, sharp edges. Paired testes weight <0.6 g.	GC's, PG's, and SGC's are the predominant stages of spermatogenesis. More advanced stages may occur in individuals nearing maturity.
2. **Development of spermatogenic cycles**	Dull to milk-white in color. Swollen. No milt. Color of x-section uniform. Sperm duct not swollen. Paired testes weight from 0.60 to 16 g.	PSC's are usually predominant. GC's, SGC's, SSC's, STC's and a few SZ cysts are also present. No SZ in lumen. Residual sperm in lumen rare.
3. **Maturation**	Dull to milk-white in color. Swollen. Slight to no milt in sperm duct. Color of x-section uniform. Sperm duct not swollen.	SZ are predominant. SZ cysts broken open. SZ in efferent ducts and sperm duct. GC's, PSC's, SSC's, and STC's also present. Spermatogonia rare.
4. **Spawning (Copulation)**	Milk-white to white-brown in color. Sperm duct swollen with milt. Periphery translucent and center white in x-section.	SZ are predominant, mostly present in lumen. Periphery cleared. Germ cell development at periphery. Phagocytosis at periphery.
6. **Spent**	Light-brown or mottled white in color, translucent. Slight milt. Periphery translucent.	GC's are predominant. Phagocytosis of SZ in sperm duct. No SZ in efferent ducts. PSC's, SSC's, STC's rare.
7. **Resting**	Brown, tan, or brown-grey in color. Triangular, sharp edges, firm, short in length. Small testes translucent. No milt. Paired testes weight from 0.4 to 3.9 g.	GC's, PG's, and SGC's predominate. Sperm duct empty. Residual sperm present early in this stage.

(a)



(b)

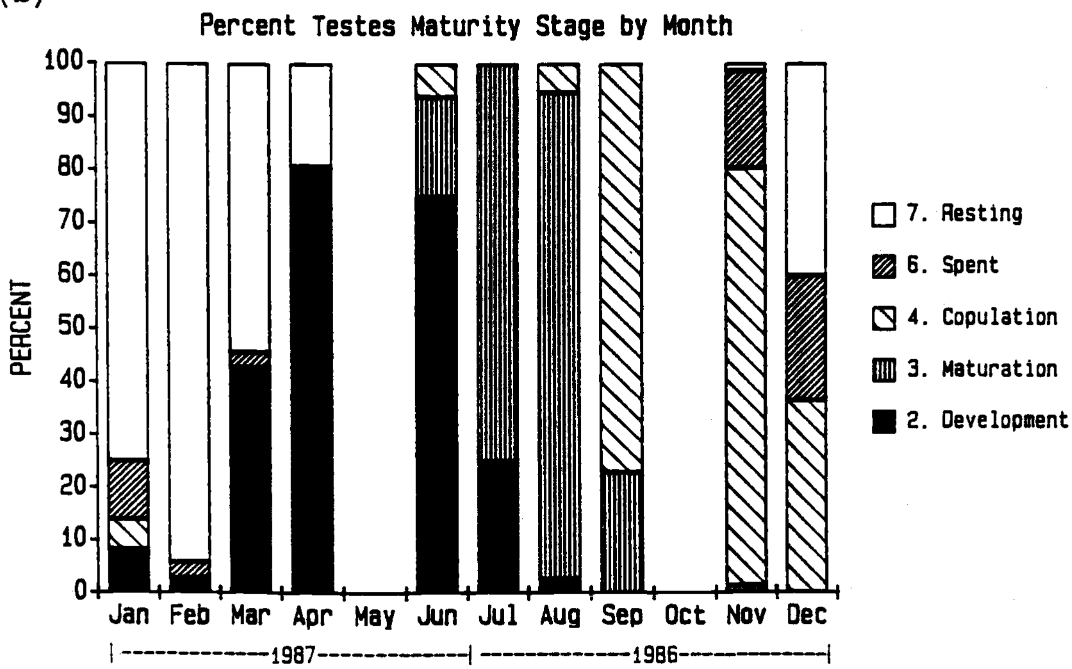


Figure II-1. Seasonal change in gonad condition for mature ovaries (a) and testes (b) of Sebastes crameri, based on maturity stage criteria (Tables II-1,2). Months of May and October were omitted due to small sample size.

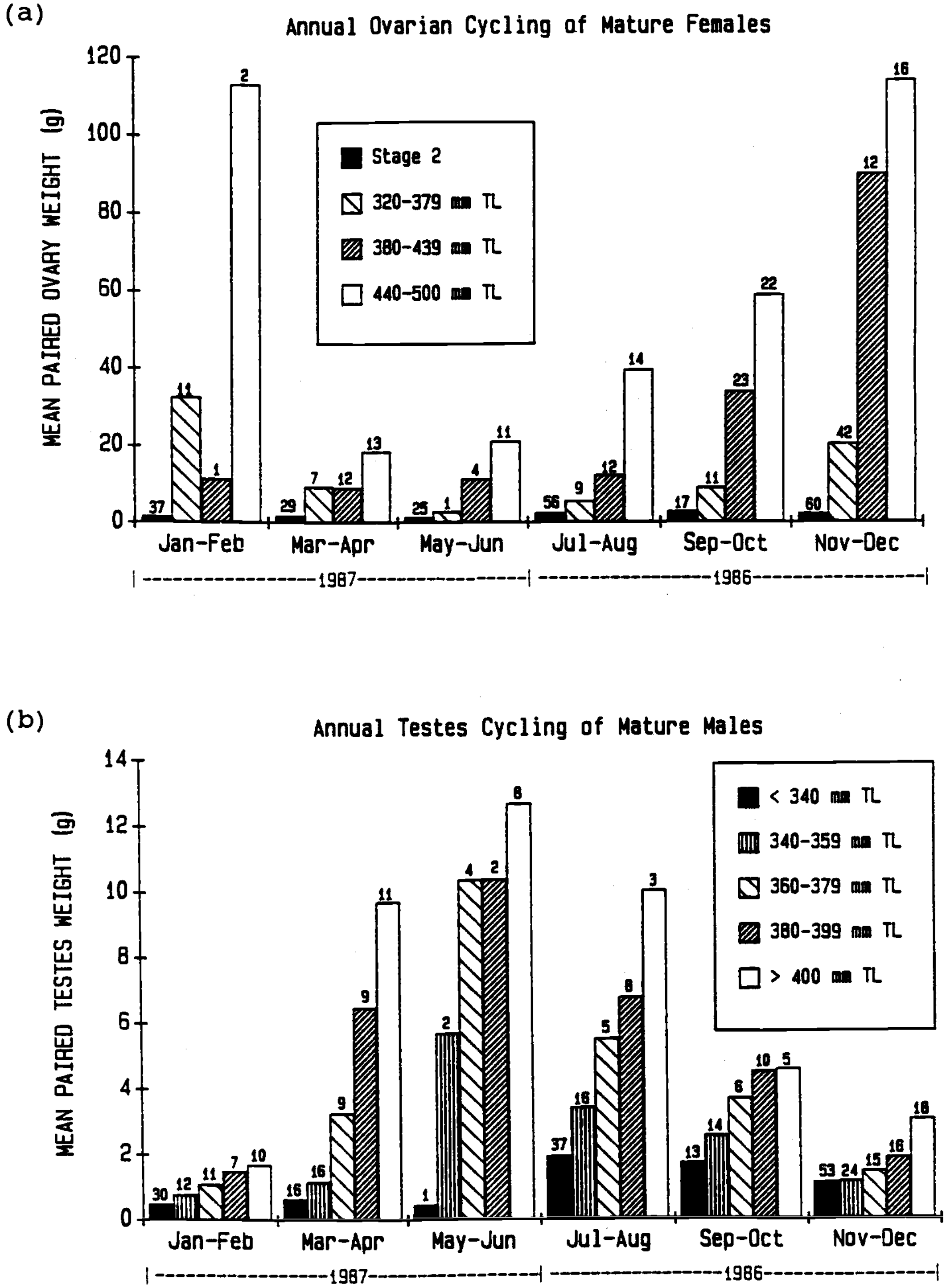


Figure II-2. Seasonal change in mean gonad weight for mature ovaries (a) and testes (b) of Sebastes crameri, presented for different fish length groupings. Mean weights of "maturing" (stage 2) ovaries are included. Column numbers indicate the sample size upon which mean weights were calculated.

oocytes enlarged. Sperm were sometimes observed outside follicles or within the ovarian stroma in histological sections of ovaries from females collected during this period.

Fertilized ovaries (stage 4) first appeared in December and specimens with eyed larvae were found between December and February. One specimen collected in March had fertilized eggs, so although no specimens with eyed larvae were observed past February 1987, parturition in some individuals occurred through March. The principal months of parturition were January and February. By March the majority of mature females were either spent (stage 6) or in a resting condition (stage 7) and by April all ovaries examined were in a resting condition (Fig. 1a). Ovaries remained in a resting condition for two to three months. In June of 1987, larger individuals were developing vitellogenic oocytes for the next season.

Maximum ovarian weights were observed from November to February 1987 as ovaries approached parturition (Fig. 2a). Ovary weights were lowest from March to June 1987 (Fig. 2a) when the majority were in a resting condition. Maturing (stage 2) ovaries varied little in weight from month to month (Fig. 2a).

The reproductive cycle of small females appeared to be delayed relative to the cycle of larger individuals. Small females exhibited a spent ovarian condition (stage 6) later in the season than did larger females, indicating that larger females probably spawn before smaller females.

Forty-eight percent of the females collected aboard groundfish trawlers possessed ovaries in a stage-2 condition (Table 1), defined as the first year of maturity by Echeverria (1987). Stage-2 ovaries were observed throughout the collection period. Ovaries were pink to cream in color and were enveloped tightly by a thin ovarian sac that ranged from 1.5 to 3 cm in length. Paired ovaries rarely exceeded 4.5 g in weight and maximum oocyte diameters, measured from histological sections, ranged from 0.15 mm to 0.26 mm. These ovaries rarely developed yolked oocytes.

Stage-2 ovaries from females collected from December to March were found in a state of resorption. Extensive oolysis (oocyte degeneration) was observed in 32 of 39 of these ovaries examined with histology. Because stage-2 ovaries were unyolked and found in a state of degeneration during months when mature females were spawning, it was evident that the majority of these fish were not in their first year of maturity. Based on this evidence, and the premise that these "maturing" fish had never previously spawned, females with stage-2 ovaries were considered immature.

Seasonal Development of Testes

The majority of adult males were near spawning condition in July 1986, the start of the sampling period

(Fig. 1b). Spermatozoa were present in the sperm duct and efferent ducts, although sperm ducts were not swollen (Stage 3). The majority of adult males remained in this condition through August 1986. A few large males collected in August were in a spawning condition (stage 4), although testes at this stage were observed more frequently in males collected between September and November (Fig. 1b). Most testes were either spent (stage 6) or in a resting condition (stage 7) by the end of December. From January to March 1987, most testes were in a resting condition (stage 7) and from April to June testes were developing new spermatogenic series (stage 2). Testes in the stage-2 condition were easily identified in histological sections by the abundance of spermatogenic cysts in various stages of development prior to formation of mature spermatozoa (Table 2). Using gross morphology alone, however, it would be difficult to distinguish stage-2 testes from stage-3 testes.

Testes attained their maximum weight by June as testes approached maturation (stage 3; Fig. 2b). Testes in fish greater than 340 mm TL appeared to decrease in weight from June to August, however, this result may have been an artifact of small sample size during those months. Paired teste weights decreased further for males in a spawning condition and were at a minimum between December and February when the majority were in a resting condition.

As observed for females, the reproductive cycle in smaller individuals lagged behind the cycle of larger ones. Larger males were observed in spawning, as well as spent, conditions earlier in the season than smaller males.

Immature males were sampled throughout the season. Their testes were translucent and threadlike, and weighed less than 0.6 g. Histological sections revealed no spermatogenic development beyond secondary spermatogonia. Paired testes identified as resting (stage 7) sometimes weighed less than 0.6 g but were distinguished from immature testes (stage 1) by their tan coloration and by the presence of residual spermatozoa observed in histological sections.

Length and Age at Maturity

Estimated lengths at 50% maturity were 36.7 cm TL and 29.6 cm TL for females and males, respectively (Figs. 3a, 3b). The length-maturity relation for females is described by:

$$P_L = 1/(1-e^{-0.6165(L)+22.5995})$$

and for males by:

$$P_L = 1/(1-e^{-3.4631(L)+17.9228})$$

where L= total length in cm. Convergence criteria for the nonlinear regression analysis (DUD procedure; SAS Institute, 1987) were met for both relationships. Parameter estimates are presented in Table 3.

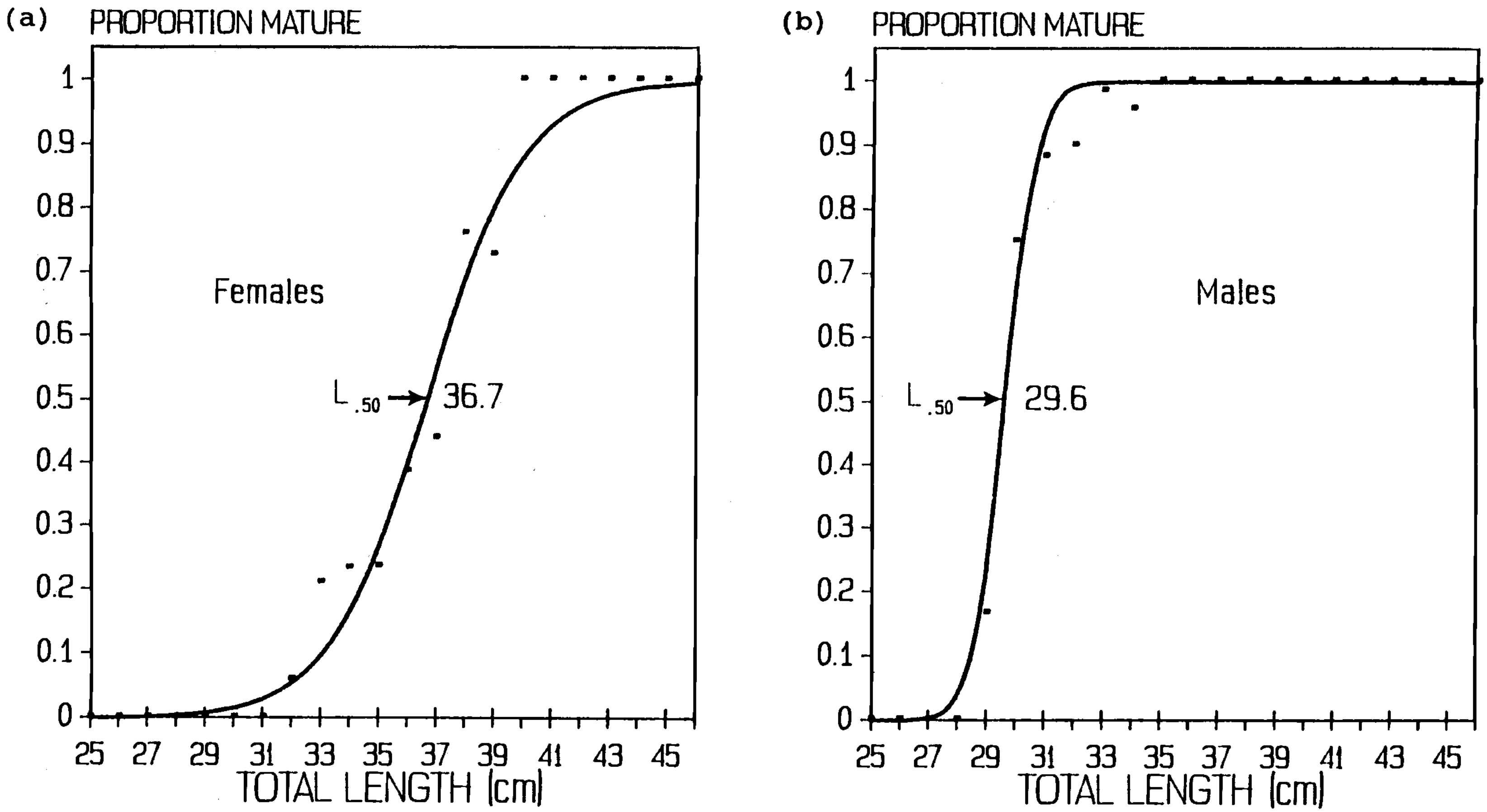


Figure II-3. Observed (points) and predicted (solid line) proportions of mature female (a) and male (b) darkblotched rockfish, by cm length intervals. Lengths at 50% maturity ($L_{.50}$) are also included.

Table II-3. Parameter estimates for the logistic equation relating the proportion of mature fish to total length (cm) for darkblotched rockfish captured off the Oregon coast by commercial groundfish and shrimp trawlers. $L_{.50}$= predicted length at 50% maturity; SE=standard error.

Sex	Parameter	Estimate	SE	95% C-I
Females	a	-0.6164	0.0584	-0.7383 - -0.4947
$L_{.50}$=36.7	b	22.5995	2.1428	18.1297 - 27.0693
Males	a	-2.4407	0.2016	-2.8529 - -2.0285
$L_{.50}$=29.6	b	72.2730	5.9782	60.0464 - 84.4996

Age at 50% maturity was estimated to be 8.3 years for females and 5.2 years for males (Figs. 4a, 4b). Equations relating age and maturity are as follow:

$$P_A = 1/(1-e^{-0.7464(A)+6.2289}) \quad \text{(Females)}$$

$$P_A = 1/(1-e^{-3.4631(A)+17.9228}) \quad \text{(Males)}$$

where A= age (years). Convergence criteria were also met for these relationships. Parameter estimates are presented in Table 4.

Fecundity

Fecundity was estimated for 58 ovary pairs, however, only 40 were used in the analysis. Ovaries containing fully yolked advanced oocytes (maturity stage 3), corresponding to Raitt and Halls (1967) "prefertilized fecundity", were included in the fecundity analysis. Five ovaries with fertilized oocytes and 13 with pre-vitellogenic oocytes were removed from the analysis.

Significant differences were found among regional estimates of fecundity (Two-way ANOVA, F=6.60, d.f.=2,78, P<0.0022). Fishers least-significant difference multiple comparison test (P<0.05) indicated that fecundities estimated from posterior subsampling were significantly lower than those estimated using either anterior or middle region subsampling. Anterior estimations were not significantly different from middle estimations. Posterior subsamples appeared to contain a higher percentage of connective tissue, which would account for the lower fecundity estimations. Coefficients of variation for

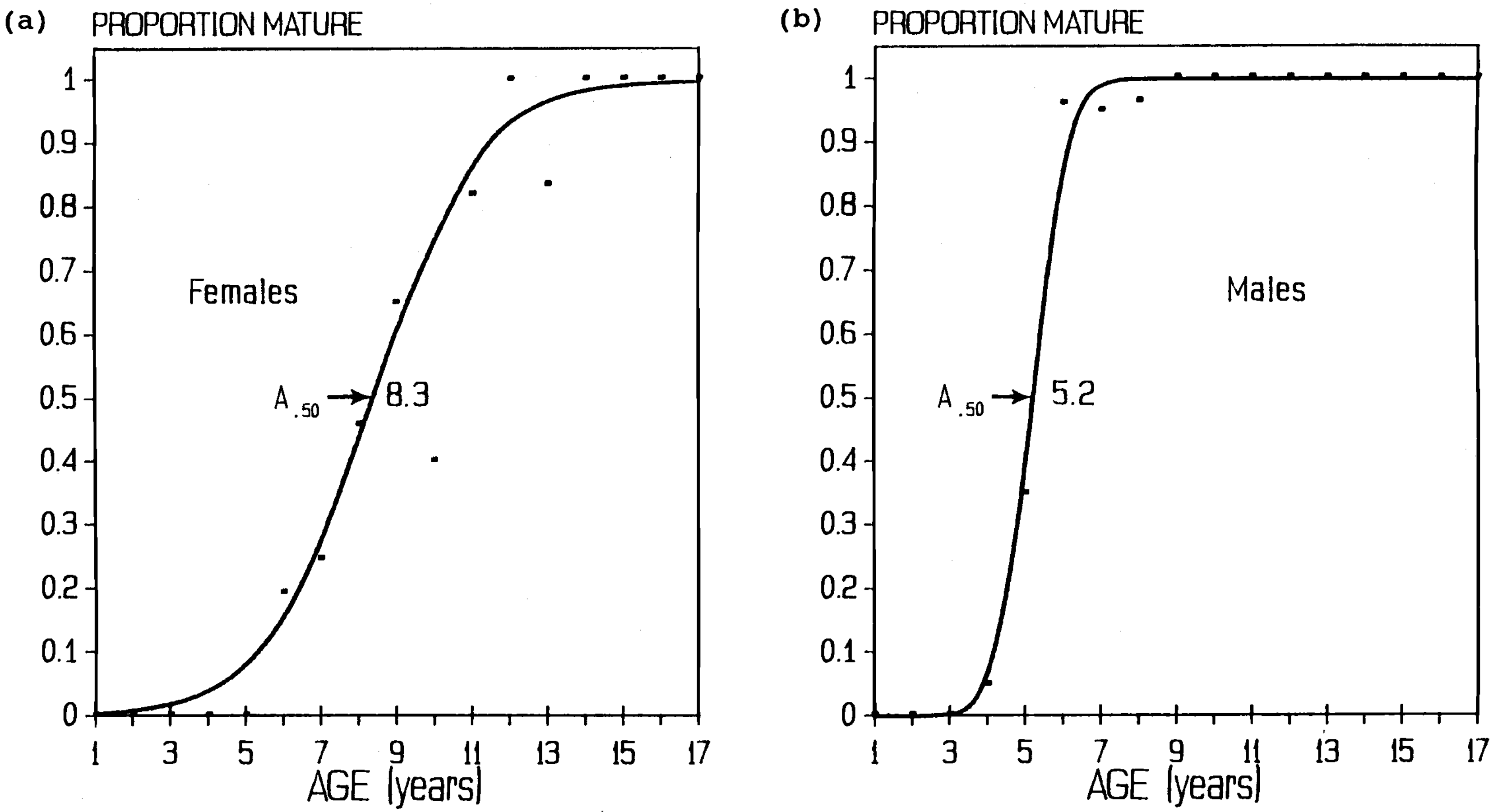


Figure II-4. Observed (points) and predicted (solid line) proportions of mature female (a) and male (b) darkblotched rockfish, by age (years). Ages at 50% maturity ($A_{.50}$) are also included.

Table II-4. Parameter estimates for the logistic equation relating the proportion of mature fish to fish age for darkblotched rockfish captured off the Oregon coast by commercial groundfish and shrimp trawlers. $A_{.50}$= predicted age at 50% maturity; SE=standard error.

Sex	Parameter	Estimate	SE	95% C-I
Females	a	-0.7464	0.0800	-0.9180 - -0.5747
$A_{.50}$=8.3	b	6.2289	0.6577	4.8183 - 7.6396
Males	a	-3.4631	0.3489	-4.2067 - -2.7195
$A_{.50}$=5.2	b	17.9228	1.7612	14.1689 - 21.6766

estimates of fecundity averaged across regions ranged from 0.58% to 13.71% with a mean of 4.63%.

The length-fecundity and weight-fecundity relationship were best fit using the power functions:

$$F=(4.3459 \times 10^{-10})L^{5.6049}, \qquad R^2= 0.905$$

and

$$F= 0.2727\ W^{1.923}, \qquad R^2= 0.916$$

where F is fecundity, L is total length of the fish (mm), W is the ovary-free fish weight (g), and R^2 is the coefficient of determination. Constants were estimated using the Gauss-Newton method of nonlinear least squares regression (SAS Institute Inc., 1987). Fish weights for filleted fish were estimated from the length-weight relationship (Chapter I).

Fecundity ranged from 19,815 to 489,064 and increased with increasing fish length and weight (Fig. 5a, 5b).

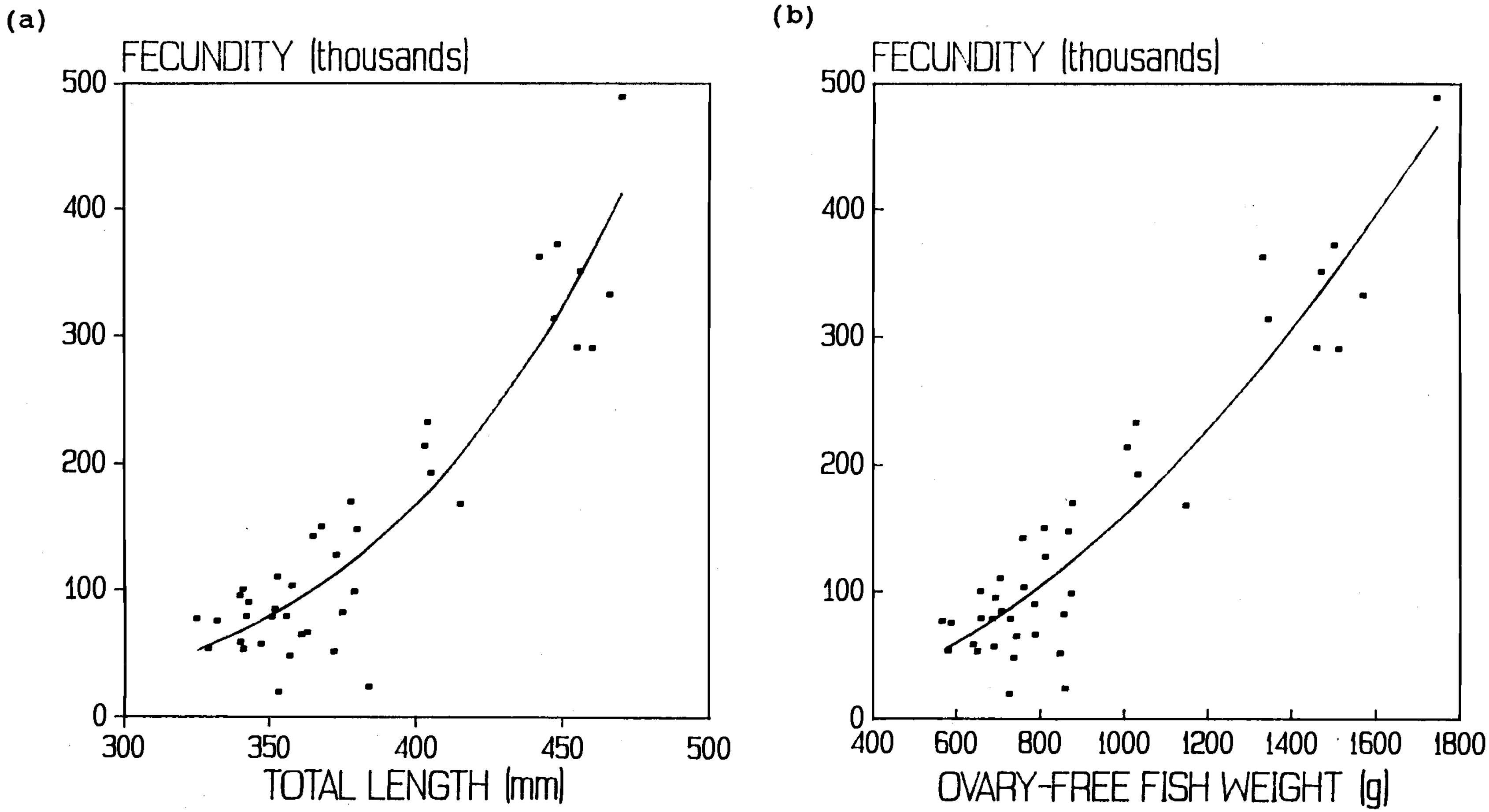


Figure II-5. Estimated fecundity of darkblotched rockfish, as a function of total length (a) and ovary-free fish weight (b). Curves represent the fitted equation.

DISCUSSION

Timing of Reproductive Events

The timing of reproductive events, observed for *S. crameri* off Oregon, was protracted. Insemination occurred from September to December, fertilization from December to February, and parturition from December to March. Individual males may have been in a spawning condition for more than one month. Males likely mated more than once during this period (Lisovenko, 1972; Echeverria, 1987). Based on the timing of insemination and fertilization, some females were estimated to store sperm in their ovaries for up to 3 months. Gestation (the time between fertilization and parturition), was estimated to be approximately one month, similar to other species of the genus *Sebastes* (Moser, 1967a; Echeverria, 1987).

Differences in timing of reproductive events among individual fish contributed to the protraction and overlap of reproductive events. One factor related to these differences was fish size. The timing of major reproductive events occurred earlier for larger individuals.

The flexibility in the timing of reproductive events in rockfish (*Sebastes* spp.) may serve to ensure reproductive success (Echeverria, 1987). Lisovenko (1970) suggested that the prolonged copulation period in rockfish (*Sebastes* spp.) may increase the probability that each female will be fertilized. Following the same logic, a protracted parturition period may increase the probability that some larvae will be released when conditions are favorable for their survival. The protraction of reproductive events for *S. crameri*, therefore, may play a role in the population's survival.

Previous investigations have indicated that parturition in some *Sebastes* species occurs earlier in the southern range of the species (Westrheim, 1975; Echeverria, 1987; Barss, 1989). Barss (1989) suggested that such a trend exists for *S. crameri*. Contrary to their findings, the timing of reproductive events for *S. crameri* does not appear to vary with latitude, at least from Central California to British Columbia. The estimated months of fertilization, insemination and parturition for *S. crameri* captured off central to northern California (Phillips, 1964; Echeverria, 1987), central Oregon (Barss, 1989; present study) and British Columbia (Westrheim, 1975), were similar (Table 5). Echeverria (1987) and Barss (1989) stated that parturition for *S. crameri* occurs in June off Alaska, however, no literature could be found that would confirm this.

Length and Age at Maturity

Males matured at a smaller size and younger age than females (Figs. 3, 4). Because groundfish trawlers use gear that is size selective, it was not surprising to observe a higher percentage of mature males than mature females.

Table II-5. Estimated months of insemination, fertilization, and parturition for <u>Sebastes</u> <u>crameri</u>. Brackets indicate capture locations.

Author	Insemination	Fertilization	Parturition
Phillips (1964) [Central-North CA]	--	--	Nov-Mar
Echeverria (1987) [Central-North CA]	--	December*	--
Barss (1989) [Central Oregon]	October	Dec-Jan	Jan-Apr
Present Study [Central Oregon]	**Sept-Dec**	**Dec-Feb**	**Dec-Mar**
Westrheim (1975) [British Columbia]	October*	--	February*

* Principal month.

Ninety-seven percent of all the males captured with groundfish gear (excludes shrimp gear) were mature. In contrast, only 51% of the females captured with groundfish gear were mature.

Lengths at 50% maturity ($L_{.50}$) estimated in this study were similar to values presented by Barss (1989), who also examined fish caught off central Oregon (Table 6). Westrheim (1975), who examined fish off British Columbia, reported significantly larger values of $L_{.50}$ for both males (38.9 cm TL) and females (35.6 cm TL) (Table 6). Phillips (1964) presented $L_{.50}$ (30.5 cm TL) and age at 50% maturity (6 years) for darkblotched rockfish captured from central to northern California. Although sexes were combined in Phillip's (1964) analysis, it appears that estimates of $L_{.50}$ sizes were lower than those found in the present study (Table 6). Echeverria (1987) presented considerably lower values of $L_{.50}$ and age at 50% maturity ($A_{.50}$) for *S. crameri* collected off Central to Northern California for both males and females (Table 6). These comparisons may suggest a trend toward smaller sizes at maturity from north to south. This interpretation, however, is difficult to assume because the aforementioned investigations were conducted during different years and the assessment of maturity may not have been the same.

Differences in maturity assessment rather than differences in life-history characteristics are likely responsible for the disparity between maturity estimates

Table II-6. Comparison of lengths ($L_{.50}$) and ages ($A_{.50}$) at 50% maturity, estimated for darkblotched rockfish by different authors. Lengths are presented in cm TL; ages in years.

Author	Capture Location	Females		Males	
		$L_{.50}$	$A_{.50}$	$L_{.50}$	$A_{.50}$
Phillips (1964)[1]	California	30.5	6	30.5	6
Echeverria (1987)	California	27	4	27	4
Barss (1989)[2]	Central OR	36.7	-	31.5	-
Present Study	**Central OR**	**36.7**	**8.3**	**29.6**	**5.2**
Westrheim (1975)[2]	B.C.	38.9	-	35.6	-

[1] Data estimated with sexes combined.

[2] Lengths (mm) converted from FL to TL by TL= 0.846 + 1.046(FL).

presented by Echeverria (1987) and those presented in this study (Table 6). In estimating $L_{.50}$ and $A_{.50}$, Echeverria (1987) considered stage-2 ovaries (Table 1) to be in their first reproductive year, and therefore mature. The majority of 6, 7 and 8 year old females in the present study possessed ovaries in a stage-2 condition. Histological analysis revealed these ovaries to be unyolked and immature. Females probably remain in a "maturing" state for up to 3 years before transforming to a mature vitellogenic (stage 3) condition. If Echeverria's (1987) *S. crameri* samples included these stage-2 females, $A_{.50}$ could have been underestimated by as many as 3 years. Had stage-2 ovaries in the present study been considered mature, estimates of $L_{.50}$ and $A_{.50}$ for females would have been 29 cm TL and 5 years, respectively, much closer to Echeverrias' (1987) estimates.

Fecundity

Phillips (1964), who also used the gravimetric technique, estimated fecundity for 12 darkblotched rockfish ranging from 335 to 575 mm TL. His estimates ranged from 36,600 to 609,800 oocytes/ovary pair.

Although maximum fish length and maximum fecundity for *S. crameri* were higher in Phillip's (1964) study, comparison of the two length-fecundity relationships revealed no significant differences. Comparisons of the linear relationships of log(fecundity) and log(length) between Phillips (1964) and the present study revealed no significant differences in either slopes (ANCOVA, $F=0.24$, $P>0.63$, $df=1,48$) or intercepts (ANCOVA, $F=1.80$, $P>0.10$, $df=1,49$).

Influence of Fishing

Fishing exploitation of long-lived species, such as *S. crameri*, may alter the mechanisms that have evolved to ensure their reproductive success. Their long reproductive life-spans reduce the risk of stock depletion when environmental conditions are unfavorable for extended periods (Leaman and Beamish, 1984). As fishing exploitation reduces the number of age groups in a population, the potential for population collapse increases. It has been suggested that the protraction of reproductive events (i.e. copulation and parturition) may increase the probability for reproductive success in a given season (Lisovenko, 1970; Echeverria, 1987). Because the timing of reproductive events appears related to fish size, the removal of larger individuals through fishing exploitation may reduce the duration of these events. Loss of this flexibility may also increase the chances for population collapse.

Two additional reproductive factors suggest that *S. crameri* is vulnerable to fishing pressure. First, females are fully recruited to the fishery by age 7, yet 50% maturity does not occur until age 8. All the spawners, therefore, are available to the fishery. Second, because the reproductive contribution (fecundity) is highest among the largest individuals, removal of such individuals without replacement may lead to a reduction in recruitment.

As mentioned earlier (Chapter I), a large percentage of the females captured with groundfish gear were 6, 7, and 8 years of age. More than 70% of these females were in a stage-2 condition, and therefore had never spawned. Forty-nine percent of the female darkblotched rockfish collected aboard groundfish trawlers were immature. This result could be due to the possibility that strong year-classes of fish were recently recruited to the fishery, and/or the possibility that older mature fish have been depleted and the fishery is now utilizing the younger portion of the stock. If the latter is true, continued capture of fish below the age at 50% maturity, may lead to a reduction in recruitment.

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