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Widow Rockfish

Proceedings of a workshop, Tiburon, California, December 11-12, 1980

William H. Lenarz
Donald R. Gunderson, *editors*

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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Sponsored by:

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U.S. DEPARTMENT OF COMMERCE
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WIDOW ROCKFISH WORKSHOP: Introduction

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INTRODUCTION

This workshop was organized because of the increase between 1978 and 1980 in coastwide landings of widow rockfish, from less than 1,000 mt to more than 20,000 mt, and because of scientists' concern with the lack of knowledge both of the fishery and biology of the species. Most scientists active in research on Pacific groundfish, as well as some members of the fishing industry and fishery managers, attended the workshop.

These proceedings contain the report of the workshop discussion panel, status reports on California, Oregon, and Washington fisheries through 1980, and a collection of seven papers presented at the workshop. The status reports provide an historical perspective of the development of an important fishery. The papers present a fairly complete survey of biological knowledge of widow rockfish, economic status of the fishery, and fishery-independent methods for estimation of abundance. The papers also contain some information developed after the workshop.

Since the workshop, the fishery has matured. Largest landings were made in 1981, when more than 28,000 mt were landed. Maximum sustainable yield (MSY) is estimated to be slightly less than 10,000 mt, and the stock appeared to be at about the MSY level in 1985. The Pacific Fishery Management Council and National Marine Fisheries Service have implemented regulations that have maintained landings since 1983 at approximately the maximum sustainable yield level. Fishery-dependent stock assessments are being made on an annual basis for the Pacific Fishery Management Council. While these assessments are considered to be the best possible with available data, scientists responsible for the assessment have chosen to delay their publication in the formal scientific literature until more data are obtained. However, the stock assessment reports are available from the Pacific Fishery Management Council.

In addition to the papers in this collection, three papers have been published on widow rockfish since 1980. Boehlert, Barss, and Lamberson (1982) estimate fecundity of the species off Oregon; Gunderson (1984) describes the fishery and management actions; and Laroche and Richardson (1981) describe the morphology and distribution of juvenile widow rockfish off Oregon.

During the past decade, the fishery for widow rockfish has developed from a minor fishery to one of the more important on the Pacific Coast. Our knowledge of the biology and dynamics of the species has progressed from minimal to relatively extensive for a groundfish species. It is our intention in preparing this collection of papers to make this knowledge readily available to the scientific community.

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Report of Discussion Panel

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Chairman William Lenarz convened a panel composed of members of the Groundfish Plan Development Team (Pacific Fishery Management Council), an economist, and fishing industry representatives to discuss the current status of the rockfish fishery, research needs, its relationship to other groundfish fisheries and research, and the outlook for its future. The panel first acknowledged the limited information and understanding of widow rockfish biology, stock distribution and abundance, and the fishery. The chair expressed the hope that the current workshop would provide some initial impetus and direction to information gathering efforts which bear on answering a variety of crucial questions.

STATUS OF THE FISHERY

Robert Francis presented an overview of the status of the fishery given the limited biological and fishery information available. He offered the opinion that the success fishermen have enjoyed in recent years may be short-lived, and that a dramatic collapse of the fishery is conceivable. This judgment was based on a general understanding of the biology of widow rockfish—a long-lived species with relatively low reproductive rates—and the fact that the Oregon fishery appears to depend primarily on one or two year-classes.

If the one or two year-classes that now support the Oregon catches are unusually strong, it is conceivable that fishing success would be greatly reduced when the year-class(es) diminish because of natural and fishing mortality. Another participant noted that the age structure of Oregon catches could also be explained in two other ways. The foreign hake fishery could have caused high fishing mortality before National Marine Fishery Service observers recorded incidental catches. This could account for the relative scarcity of older fish in Oregon catches. It was also noted that rockfish are often segregated by size or age. It is possible that the Oregon fishery has been exploiting only areas containing relatively large amounts of the two year-classes. It was observed that widow rockfish landed in Eureka have been larger and apparently older than those landed in Oregon.

Because rockfish are long-lived species with relatively low reproductive rates, they probably cannot support sustained high fishing mortality. It is not unusual for such species to have large standing stocks based on many year-classes before fishing is initiated. The standing stocks can support a large fishery for a short period of time as the stock is being decreased by fishing, and only a relatively small fishery thereafter. In the absence of a very large stock supporting fishable aggregations and/or another, yet to be recruited, large year-class, there is a marked potential for substantially reduced catches of widow rockfish in the near future.

Francis argued that such a collapse could happen before any rational management program could be implemented, and that intensive research may best be directed at alternative fisheries, perhaps shortbelly rockfish or Pacific whiting. He suggested that sustained production might be achieved soon only through voluntary industry control of fishing mortality. He concluded with the view that because traditional measures of catch-per-effort (CPUE), and its utilization in models designed to assess the effects of fishing on a stock, are likely not applicable in this instance because of the schooling behavior of the species, alternative methods of assessment will have to be applied.

Some participants felt that new innovative means of measuring fishing effort, such as was done for the tropical tuna fishery, should be explored with aggregating species. Others believed that if the schools, which are the subject of the fishery, are supported by a larger, underlying population, then assessment becomes a more complex matter; they are skeptical that CPUE would ever provide a meaningful measure for changes in stock size. The experience of some fishermen is that heavily fished widow rockfish modify their behavior and become more successful in avoiding trawls, which in itself could affect CPUE measurements. It was suggested that a possible key to assessing stock status might be the monitoring of rates at which aggregations are reconstituted after being reduced by fishing several times.

Hydroacoustic and midwater trawling surveys probably offer the best chance for fishery-independent monitoring of widow rockfish concentrations and changes in their distribution. It was pointed out that a reduction in the range occupied by widow rockfish (similar to the range reduction exhibited by Pacific sardines during their collapse) could occur, and this might provide an early warning of stock failure. It was emphasized that the study of widow rockfish behavior is critical to stock assessment efforts using hydroacoustics and trawling. Fishermen stated that any effort to assess on the basis of school encounters, for instance, might be confounded by the very dynamic nature of widow rockfish distributions. The absence of schools from an area where they are normally present may not reflect a reduction of population size, but simply represent a change in distribution in response to environmental factors. It was noted that an excellent opportunity to study fish behavior exists within the fishery industry. There was general agreement that hydroacoustic assessment should be supplemented with information obtained by experienced scientists, who have utilized commercial vessels as observation platforms and have drawn upon the expertise of knowledgeable captains, to obtain an understanding of behavior characteristics.

It was noted that continuation of catch sampling programs will provide data necessary for the cohort type analysis of stock assessment. However, several more years of data are necessary for other than a rudimentary analysis.

The feasibility of using larval abundance as an index to spawning stock size was discussed. While that approach was considered to have potential, as in the other approaches to stock assessment, it was acknowledged that a number of problems would first have to be resolved. These would include developing techniques for identification of larval widow rockfish, establishing larval growth and mortality rates, determining fecundity and associated variability, and determining the size of the survey area. The most difficult problem to resolve may be identification, as the larvae of several rockfish species, including widow rockfish, are very similar. It appears that solution of the identification problem will require the difficult task of rearing larvae of several of these species. In all probability, if the larval abundance approach does become useful, it would only be so after several years of investigation.

General concepts of the ecosystem dynamics approach to tracking and predicting stock abundance were briefly described. Difficulties in the method are associated mainly with establishing species relationships, trophic level interactions, and the rigidity of those relationships which is usually assumed by the model. In spite of these problems, recent work in the field has shown promise, and a number of participants expressed the view that further work is definitely warranted and should be encouraged. Additionally, such efforts could provide important building blocks in multispecies fisheries management models considered to be important. It is possible that this approach may provide some rough estimates in a relatively short time, but considerable effort would be necessary for more refined estimates.

The resource assessment discussion was concluded with consideration of the need and priority for such work, given other research needs. There were questions about the urgency of directing significant research effort toward the widow rockfish resource if, indeed, there is a high probability that the fishery will experience an abrupt failure soon. There was some opinion that perhaps the resource is presently unmanageable, given natural fluctuations in availability and abundance. It was also suggested that a ''biological'' problem may never exist if reductions in CPUE force vessel captains to discontinue seeking widow rockfish (low-value/high-volume fisheries may be particularly sensitive to changes in CPUE) and turn to alternative species. However, fishermen indicated that a predictive capability would be desirable and would have significant economic implications, especially for smaller vessels which usually lack the capital for response in converting to different fishing gear and moving to other markets. Most scientists agreed that widow rockfish research must be kept in perspective, but that it should be pursued at some reasonable level to bring the current small database to a point where it would provide a basis for management decisions.

THE MARKET

It was generally viewed that the market for widow rockfish is strong and could be further expanded. A critical factor in maintenance and expansion of the market is adequate quality control. Because of the nature of the flesh, product quality is dependent on extraordinary handling procedures from the time the fish is caught until the product is cooked for consumption. Individual trawl catches should be kept small, iced immediately, and delivered within 36 hours. Processing, distribution, and sale of the fresh product must be expedited so the product arrives at the market in good condition. Freezing widow rockfish products has not been very successful. Most processors report that fillets discolor when frozen and have an undesirable texture when thawed. Alternative freezing procedures are being investigated.

Other market problems relate to proper handling at the retail level, and some participants urged a program of education for retailers. It was pointed out that part of the handling problem is that most retailers cannot distinguish rockfish species because of the practice of applying generic nomenclature to a variety of species; therefore, they are not in a position to provide special treatment to species with a short shelf life. The result is that all rockfish products become more difficult to market because consumers avoid ''rockfish'' in general subsequent to a bad experience with one species in the group. It was agreed that marketing success can be significantly impacted by nomenclature and that there is need for considerable modification of marketing practices.

There was discussion concerning the influence of the relatively new widow rockfish market on the market for traditional rockfish species. Some believed that there was a negative impact on existing markets because the relatively inexpensive widow rockfish products were out-competing and replacing other groundfish products. Others claimed that replacement of traditional products was insignificant and cited increased landings of all rockfish within the last 2 years. It was suggested that processors prefer widow rockfish because they achieve generally higher recovery rates during the filleting process. It was speculated that if replacement is occurring, it may affect the sole market more than any other, because smaller vessels which traditionally have fished for sole are being replaced by large vessels with midwater trawling capability which are fishing instead for widow rockfish.

FUTURE OF THE FISHERY

The future of the rockfish fishery is uncertain. Present catches and markets are favorable, but how the resource will respond to current levels of fishing and environmental events is unknown. The marketplace is very dynamic and complex, and one can only speculate about its future, though current indicators are encouraging. The question was raised of potential alternative fisheries should the widow rockfish fishery become less successful or fail completely. It was stated that the whiting joint-venture fishery had provided good alternative employment, but is now less attractive because regulations preventing processing vessels from fishing require processors to depend on a larger number of catcher vessels, all making smaller deliveries than when one or two catcher vessels were used to supplement processor catches. The curtailment of large deliveries reduced profit margins in the whiting joint venture for some vessels. Groundfish resources off the Alaska coast may be a reasonable alternative for some of the larger vessels presently in the widow rockfish fishery.

Review of Data on Historical Catches of Widow Rockfish in Northern California

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ABSTRACT

The fishery for widow rockfish (*Sebastes entomelas*) off Northern California is reviewed. Landings between 1973 and 1978 were less than 600 mt. Landings increased to 1,862 mt in 1979 and 4,808 mt in 1980. Locations of catches, biological composition of landings and several other aspects of the fishery are described.

HISTORY OF EXPLOITATION

The widow rockfish (*Sebastes entomelas*) was an untargeted, underutilized species in the Eureka-Crescent City area prior to 1979. It had been taken primarily with bottom trawl from widely spaced aggregations, in 40-140 fathoms. These aggregations produced high catch rates during the fall and spring, which are the mating and spawning seasons for the species.

In 1979 a highly directed midwater trawl fishery developed for widow rockfish off the northern California coast. New technology, incorporating the use of electronic navigation, fish finding equipment, and midwater nets, extended fishing operations into previously unfished areas and enabled vessels to follow shifts in widow rockfish concentrations throughout the year.

Widow rockfish landings, by all gear, ranged from 0.3 mt in 1962 (Nitsos 1965) to 4,808 mt in 1980. For the years 1973-80, the fishery displayed rapid development from under 100 mt through 1975 to over 1,000 mt in 1979 and exceeding 4,000 mt in 1980 (Table 1). While the increased landings were due mostly to the new midwater trawl fishery, bottom trawl landings also increased (Table 1).

Historically, large widow rockfish concentrations have occurred off headlands such as Cape Blanco, Cape Mendocino, Point Reyes, and Point Sur (Fig. 1). Common characteristics of these areas include extended points of land, offshore canyons, and current circulation eddies inshore of main currents (Reid et al. 1958). These oceanographic characteristics appear to be associated in some manner with aggregations of widow rockfish during their reproductive cycle.

DATA BASE

Prior to 1973, species composition records for northern California rockfish landings are inadequate due to the lack of a market sampling program. Species composition reports based on landing receipt records were misleading for *S. entomelas* because the industry was often referring to the darkblotched rockfish *S. crameri* when reporting landings of "widow rockfish." Species composition data since 1973 are based on market samples.

There is a lack of an adequate widow rockfish data series for proper stock assessment. A continuation of the present rockfish sampling program will provide the data necessary for effective management decisions. Market samples taken since 1973 have shown that the size and sex composition of commercial landings of catches in the Eureka-Crescent City area has remained relatively unchanged. The average total length of sampled widow rockfish

Table 1—Landings (mt) of *Sebastes entomelas* in relation to other *Sebastes* species in the trawl fishery in the Eureka-Crescent City area, 1973-80.

	Sebastes entomelas			Other *Sebastes*		
Year	Bottom trawl	Midwater trawl	Total	Bottom trawl	Midwater trawl	Total
1973	30		30	1,004		1,004
1974	11		11	1,237		1,237
1975	81		81	918		918
1976	162		162	1,054		1,054
1977	568		568	600		600
1978	270		270	721		721
1979	1,005	857	1,862	400	12	412
1980	1,172	3,636	4,808	785	13	798

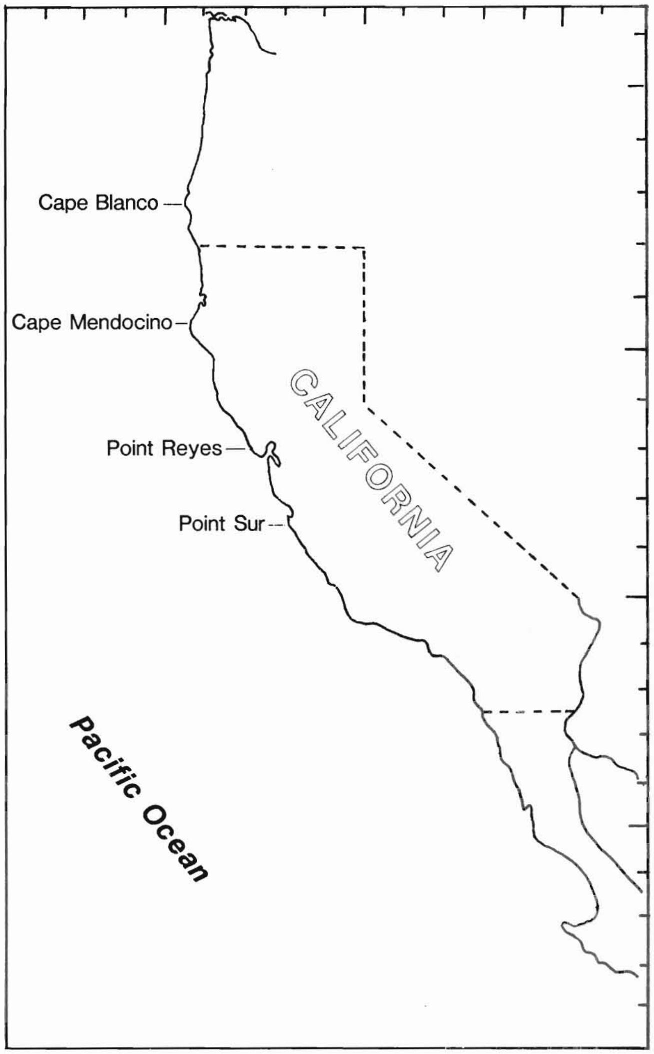

Figure 1—Geographic areas on the California coast associated with widow rockfish concentrations.

has been 458 mm (annual range average 440-477 mm). Female fish comprised about 65% of the samples. In 1980, the 1970 year-class comprised about 25% of the landings and appears to be stronger than the preceding year-classes.

FUTURE OF THE FISHERY

It is anticipated that the widow rockfish fishery will expand as harvesting, processing, and marketing techniques develop. From five vessels in 1980, midwater trawl participants are expected to double or even triple in the next year. Smaller vessels are expected to enter the midwater fishery using small-scale midwater nets or by pair trawling in order to offset low horsepower.

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The Widow Rockfish Fishery in Oregon, 1963-80

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ABSTRACT

The fishery for widow rockfish (*Sebastes entomelas*) off Oregon is reviewed. Landings between 1935 and 1978 were less than 500 mt. Landings increased to 1,960 mt in 1979 and 8,581 mt in 1980. Several other aspects of the fishery are described including age composition of the landings.

HISTORICAL PERSPECTIVE

Rockfish species composition sampling began in Oregon in 1963. From 1963 through 1977 landings of widow rockfish ranged from 1 to 665 mt and averaged 134 mt. During this period widow rockfish were most prominent during the years 1966-69 and may have been a substitute species for Pacific ocean perch which was heavily overfished by the U.S.S.R. and Japan (Table 1).

In December 1978 a Newport vessel was successful at catching widow rockfish in a midwater trawl. Landings in 1978 were modest at about 1,300 mt. Landings in 1979 were still modest at 1,960 mt, of which about 1,010 mt were caught by midwater trawl.

THE 1980 FISHERY

Landings of widow rockfish in 1980 were 8,581 mt—an increase of 383% over 1979 and 63 times greater than the 1963-77 average landing of 134 mt. Twenty-two vessels participated in the fishery, making 435 deliveries. The average trip was about 43,500 lbs (19.7 mt), and ranged from 21,774 lb (9.9 mt) to 68,495 lbs (31.1 mt). Of landings into Oregon, 62% went to Newport, 34% to Astoria, and 4% to Coos Bay.

AGE COMPOSITION

Age samples were routinely collected from landings made in 1979 and 1980. Age composition in both years was dominated by the 1970 year-class: 43% in 1979 and 32% in 1980. Age data showed that the 1971 year-class was also prominent, comprising 21% of the 1979 landings and 25% of the 1980 landings. Age data collected through 1980 show that recruitment to the fishery begins at age 5, and a cohort remains in the fishery at least 18 years.

Table 1—Widow rockfish landings in Oregon ports, 1963-80.

Year	Landing (mt)	Year	Landing (mt)
1963	142	1972	30
1964	341	1973	15
1965	34	1974	7
1966	377	1975	11
1967	665	1976	55
1968	160	1977	34
1969	117	1978	472
1970	1	1979	1,960
1971	25	1980	8,581

Table 2—Summary of widow rockfish landings in Oregon, 1980.

Month	Landings (mt)	Number of vessels	Number of trips	Average delivery
January	374	5	21	17.8
February	708	5	40	17.7
March	880	6	55	16.0
April	721	5	38	19.0
May	69	2	7	9.9
June	93	2	3	31.0
July	428	1	14	30.6
August	540	6	24	22.5
September	1,032	10	52	19.8
October	1,233	9	63	19.6
November	1,061	11	47	22.6
December	1,442	16	71	20.3
Total	8,581	22	435	19.7

Description of the Washington State Fishery for Widow Rockfish

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ABSTRACT

The fishery for widow rockfish (*Sebastes entomelas*) off the state of Washington is reviewed. Landings between, 1966 and 1978 were less than 500 mt. Landings increased to 1,697 mt in 1979 and more than 5,000 mt in 1980. Market conditions, gear, and other aspects of the fishery are described.

Washington's widow rockfish (*Sebastes entomelas*) fishery is currently in a state of rapid development. Although the genus *Sebastes* has been landed in Washington since at least 1943, records of landings by species are available only since 1966. Washington's processors are required to report all purchases of marine fish; however, rockfish landings are reported as either Pacific ocean perch (POP) or "other rockfish." Landings of various rockfish species are estimated by subsampling the nominal POP and "other rockfish" for species composition.

Estimates of annual landings of widow rockfish show a stable fishery from 1966 to 1976. Landings varied from zero to 81 metric tons (mt) and averaged approximately 0.6% of all "other rockfish" landings (Table 1, Fig. 1). During this time, widow rockfish were strictly harvested incidentally to other rockfish species.

In 1977, widow rockfish harvest began to increase; however, this increase was coincident primarily with the increased harvest of yellowtail rockfish (*S. flavidus*). A small directed fishery was centered off the Oregon coast. It became apparent that widow rockfish catches in excess of 90 mt/trip were possible. The quality of the landed widow rockfish presented a problem in the market; thus, market pressures temporarily constrained expansion of the fishery. Nevertheless, in 1979 widow rockfish landings increased 300% to nearly 1,700 mt.

Widow rockfish have replaced yellowtail rockfish as the single most abundant species among 1980 "other rockfish" landings. The previously mentioned market constraints are largely resolved and the widow rockfish fishery is becoming fully developed. We have estimated 1980 widow rockfish landings at 6,629 mt or 49% of the "other rockfish" landings. The fishery, primarily located on the Astoria canyon, has demonstrated a bimodal harvest pattern with peak landings in March and September.

Washington's widow rockfish fishermen are trawling with midwater nets, such as the Polish rope trawl, and using net sounders, sector scanning sonar, and conventional onboard hydroacoustics. Large landings are made with tows of extremely short duration. However, considerable search hours may be necessary to locate

Table 1—Estimated Washington state landings (metric tons) of widow rockfish, *Sebastes entomelas*, 1966-80.

	INPFC* area							
	Charlotte		Vancouver		Columbia		Total	
Year	mt	%	mt	%	mt	%	mt	%
1966	0		0		0		0	
1967	0		0.9	0.01	0		0.9	<0.01
1968	0.1	<0.01	23.3	0.98	0		23.4	0.50
1969	39.5	0.87	9.8	0.30	0		49.2	0.63
1970	15.3	0.49	0	0	0		15.3	0.28
1971	10.6	0.38	28.3	1.59	0		38.9	0.82
1972	33.4	1.03	6.5	0.46	0		39.9	0.83
1973	61.4	1.55	15.2	1.24	0		76.6	1.47
1974	11.4	0.54	0.1	<0.01	0		11.5	0.32
1975	9.6	0.76	7.5	0.54	0		17.1	0.58
1976	0	0	36.8	1.55	8.3	0.52	45.1	0.82
1977	76.9	3.43	177.6	4.54	27.5	1.31	282.0	3.42
1978	11.4	2.28	246.2	5.91	157.8	3.42	413.0	4.44
1979	9.8	1.48	338.7	8.45	1,306.5	21.28	1,654.9	15.31
1980	1.1	0.29	143.1	3.94	6,484.8	68.05	6,629.0	48.97

*Int. N. Pac. Fish. Comm.

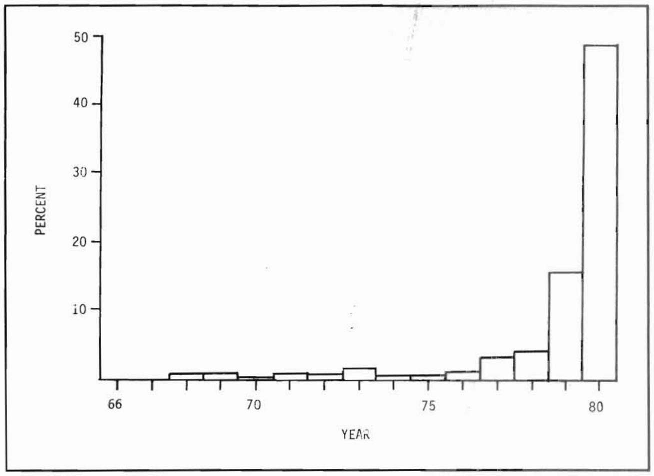

Figure 1—Washington state's annual landings of *S. entomelas* expressed as a percentage of "other rockfish" landings, 1966-80.

dense widow rockfish schools. It is apparently not uncommon to search for 6 plus hours, then make a 15-minute tow for a catch of 20 to 40 mt. Fishing is typically carried on at night. Average landing per trip is 16 mt.

Schooling behavior of widow rockfish allows them to be targeted easily by fishermen, and catches are often 100% *S. entomelas*. Species most commonly caught incidentally to widow rockfish include yellowtail rockfish and Pacific whiting (*Merluccius productus*). Other *Sebastes* landed with *S. entomelas* include Pacific ocean perch (*S. alutus*), bocaccio (*S. paucispinis*), canary rockfish (*S. pinniger*), and sharpchin rockfish (*S. zacentrus*).

Maturity of Widow Rockfish *Sebastes entomelas* from the Northeastern Pacific, 1977-82

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ABSTRACT

Gonad development, size, age, calculated weight at maturity, and fecundity for the widow rockfish (*Sebastes entomelas*) are reported. In 1977-82, a total of 3,636 specimens were examined from commercial trawl and partyboat sport catches off Oregon and California. Gonad development was earlier in southern latitudes. The principal months of parturition were February-March off Oregon and January-February off California. Mean size, age, and calculated mean weight at 50% maturity were 33 cm fork length (FL), 4 years of age, and 534 g for Oregon males, compared with 32 cm FL and 5 years for California males. Oregon females were 50% mature at 38 cm FL, 7 years of age, and 937 g, as compared with 33 cm FL and 5 years for California females. Over 99% of the males and 92% of the females randomly sampled from Oregon landings were mature, compared with 93% males and 94% females from California landings. Fecundity increased with increasing length and ranged from 95,000 to 1,113,000 eggs in Oregon samples.

INTRODUCTION

Research on the life history of the rockfishes has focused primarily on commercially important species (Sorokin 1958, 1967; Shiokawa 1962; Moser 1967; Gunderson 1977) or species in a nearshore habitat (Berge and Schultz 1973; Miller and Geibel 1973; Hallacher 1976; Hobson and Chess 1976; Larson 1977). Some life history information on the widow rockfish (*Sebastes entomelas*) occurs incidentally in studies using market samples (DeLacy and Dryfoos 1962; DeLacy et al. 1964; Phillips 1964) and in trawl surveys (Harling et al. 1971; Hitz 1962; Westrheim 1975; Westrheim and Harling 1975). The species has only recently been focused upon, due to a new and rapidly expanding fishery. In 1979 a target fishery began on widow rockfish off Oregon and California by large domestic trawlers using pelagic trawls. Life history information on these populations is being investigated while the fishery is still young.

The reproductive biology of widow rockfish was investigated to determine months of spawning (parturition) and age and size of sexual maturity for each sex. This information provides a baseline for examination of possible changes in the populations, such as sexual maturity at younger ages as fishing reduces the density of fish. Field studies were conducted to determine age, length, and weight at sexual maturity by sex for widow rockfish landed by the commercial fleet in Oregon during 1979-80. Life history information on *Sebastes* spp. was collected from the sport and commercial fleets in California beginning in 1977, and the program was expanded in 1980 to include reproductive biology. This information has been used to examine reproductive biology of widow rockfish and to make comparisons between the Oregon and California populations.

METHODS

Life history and maturity data were acquired by sampling rockfish in the Oregon commercial fishery and in the California commercial and sport fisheries. The Oregon phase of the sampling began in 1979 on commercial trawl catches made from Cape Blanco to the Columbia River. Since 1979, data collected included fork length, sex, otolith and gonad stage, and descriptions of gonads of individual fish. Individual weight to the nearest 10 g was added to the data collected in December 1979. Information on stomach contents was taken frequently in 1980. Sixty-eight ovaries were collected in December 1980 and January 1981 and processed as described by Boehlert et al. (1982). Samples of approximately 30 fish were taken from commercial landings at least once a month when available. In 1979, 14 random samples were taken, comprised of 195 females and 209 males. In 1980, 31 random samples were taken, comprised of 446 females and 475 males. An additional 49 females and 81 males were selectively sampled because they were either very small or large specimens, and they were were needed to supplement the random samples. Sampling began in 1977 on sport catches made in California. Data were collected on morphometrics, meristics, sex, gonad stage, and age (otoliths) for all rockfish species and included 42 male and 80 female widow rockfish. California maturity data collection was expanded in March 1980 on catches made from Eureka to Morro Bay. Random samples of the sport and commercial fisheries contained 15-20 fish per sample for all *Sebastes* spp. landed. Data collected included total length, sex, otoliths, gonad stage, interstitial fat, and stomach contents from 832 male and 1,227 female widow rockfish. Total length (TL) was converted to fork length (FL) by the equation FL = 6.1635 + 0.9341(TL) for comparing Oregon and California data (Lenarz 1987).

The Oregon maturity criteria used to describe gonad condition were modified from Westrheim (1975) and Gunderson (1977) and are shown in Table 1. California maturity stages were determined in the laboratory after the gonads were preserved in 10% formalin. The criteria (Table 2) were similar to those used in Oregon.

RESULTS

Timing of gonad development

The reproductive biology of the genus *Sebastes* is similar in all species that have been investigated (Eigenmann 1892; Sorokin 1967; Moser 1967; Westrheim 1975). *Sebastes entomelas* is ovoviviparous; that is, ova are retained within the ovaries after internal fertilization and contain enough yolk so that no additional nutritive material is supplied to the embryos by the female parent (Hickman 1961; DeLacy et al. 1964; MacGregor 1970). Gestation usually lasts from 1-3 months. Gaseous embryonic wastes are eliminated through the highly vascularized gonad (Moser 1967). While Moser (1967) and MacGregor (1970) reported that some members of the genus have two broods per season, most *Sebastes* species spawn once annually (Westrheim 1975). Widow rockfish have a well defined period of egg development and spawn once a year, as shown by our data and by the absence of secondary oocytes as reported by Boehlert et al. (1982).

Samples of Oregon catches indicated that copulation occurred primarily in December. Eggs were fertilized about a month following copulation. Embryos developed at nearly the same rate, and parturition occurred about 1 month following fertilization. Widow rockfish are live bearers, and we observed fish containing large numbers of tiny free larvae.

Gonad development of widow rockfish occurred earlier in southern latitudes as indicated by the principal months of parturition (Table 3). Mature Oregon widow rockfish testes were noticeably swollen in June and contained some noticeable milt in August (Fig. 1). Mature females off Oregon began to display enlarged grey ovaries with opaque white eggs in September. In October as the ovaries enlarged, they become pinky-white in color. By January many females contained colorless, translucent fertilized eggs. Eyed eggs and larvae appeared in February and spawning (parturition) was completed in March.

Gonad development in California fishes begins about a month earlier than in Oregon, with mating during September, fertilized eggs occurring in November, and spawning completed during February (Fig. 1). The trend of later parturition in northern latitudes is confirmed with data from British Columbia where spawning occurs during April (Westrheim 1975). There is a time lag of 1 to 2 months between copulation and fertilization. Hence there is the possibility of sperm storage by the female.

Sexual maturity by age, length, and weight

Fifty percent sexual maturity for female widow rockfish occurred at an earlier age and smaller length in southern fishing areas (Table 4). Males appeared to mature sexually at a smaller length and younger age than females off Oregon.

First sexual maturity for males occurred at age 3 yr in Oregon samples (Table 5) and age 3 in California samples (Table 6). Mature females were first seen at age 5 in Oregon samples and age 3 in

Table 1—Gonad condition criteria applied to *Sebastes entomelas* from Oregon landings, 1979-80.

	Code	Condition	Description
Males	1	Immature	String-like, colorless, translucent, very small
	2	Maturing	Slight swelling, translucent, white, small
	3	Mature	Ribbon-like, swolen, brown to white
	4	Developing	Large, swollen, easily broken, milt in sperm duct
	5	Spawning	Swollen, flowing milt when pressure applied to testes
	6	Spent	Swollen, milt in sperm duct
	7	Resting	Ribbon-like, flat, tan or brown
Females	1	Immature	String-like, very small, firm, translucent
	2	Maturing	Small, greyish white, translucent or opaque
	3	Mature	Large, opaque, granular, grey to pink-white, ova held in follicle
	4	Developing	Fertilized, large, translucent (cleared) eggs with pink cast or colorless, ova usually not held in follicle
	5	Spawning	Eyed eggs and/or larvae, ova not held in follicle, large, contains much fluid
	6	Spent	Flaccid, purple to pink ovary, flattened elliptical in cross section
	7	Resting	Moderate size, firm, red-grey ovary

Table 2—Gonad condition codes applied to *Sebastes entomelas* from California landings.

Code	Males	Code	Females
1	Immature	1	Immature
2	Maturing	2	Maturing
3	Mature	3	Mature
		4	Fertilized (developing)
		5	Eyed larvae (spawning)
		6	Spent
7	Resting	7	Resting

Table 3—Principal months of parturition by area for *Sebastes entomelas*.

Area	Month
California	January-February
Oregon	February-March
British Columbia[1]	April

[1]from Westrheim (1975)

Table 4—Percent maturity for Oregon, California, and British Columbia *Sebastes entomelas* by age, size, and weight.

		Males			Females		
	Maturity %	Age (yr)	Length (cm)	Weight (g)	Age (yr)	Length (cm)	Weight (g)
Oregon	>0	3	31	444	5	35	662
	50	4	33	534	7	38	937
	100	8	38	870	9	43	1150
California	>0	4	25	—	4	25	—
	50	5	32	—	5	33	—
	100	8	46	—	8	46	—
British Columbia[1]	50	—	37	—	—	38	—

[1]from Westrheim (1975)

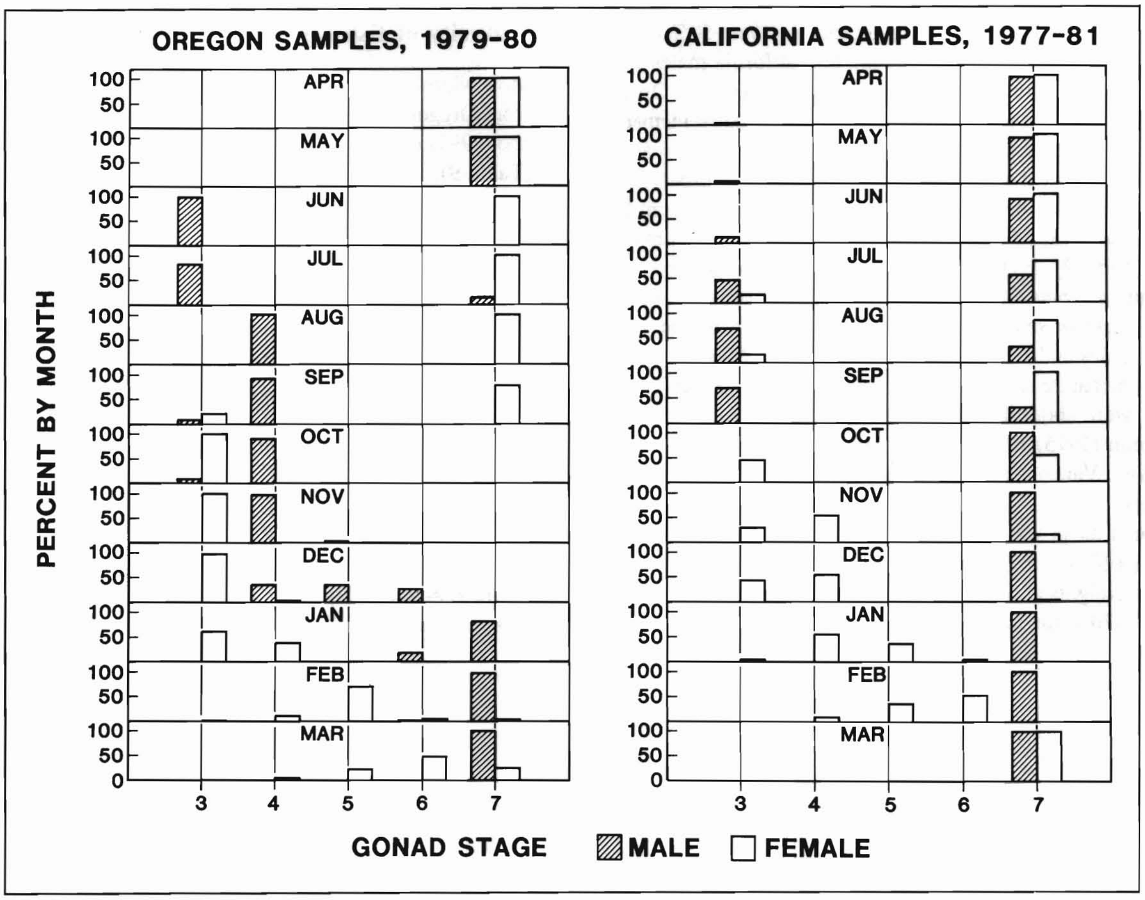

Figure 1—Gonad condition of *Sebastes entomelas* by month from Oregon samples, 1979-80, and from California samples, 1977-81. See Appendix for actual percent distribution of Oregon random samples.

Table 5—Maturity by age and sex for *Sebastes entomelas* for Oregon samples, 1979-80 (includes random and nonrandom age samples).

Age	Number				%	
	Immature		Mature		Mature	
(yr)	M	F	M	F	M	F
3	0	—	1	—	100	—
4	6	4	5	0	46	0
5	10	23	29	4	74	15
6	1	10	21	2	96	17
7	2	3	16	7	89	70
8	0	6	59	23	100	79
9	2	8	196	150	99	95
10	0	6	187	217	100	97
11	0	2	74	73	100	97
12	0	0	41	36	100	100
13	0	0	15	19	100	100
14	0	0	7	15	100	100
15	0	0	8	10	100	100
16	0	0	4	8	100	100
17	0	0	3	3	100	100
18	0	0	1	4	100	100
19	—	0	—	4	—	100
20	—	0	—	4	—	100
21	—	0	—	1	—	100
22	—	0	—	2	—	100
23	—	0	—	2	—	100
Total no.	21	62	667	584		

Table 6—Maturity by age and sex for *Sebastes entomelas* from samples off California, 1977-82.

Age	Number				%	
	Immature		Mature		Mature	
(yr)	M	F	M	F	M	F
2	1	1	—	—	—	—
3	9	13	3	2	25	13
4	17	23	4	6	19	21
5	9	14	24	25	73	64
6	9	5	36	44	80	90
7	5	5	40	45	90	90
8	1	—	38	41	97	100
9	—	1	55	62	100	98
10	4	—	96	124	96	100
11	2	2	139	160	99	99
12	2	3	120	152	98	98
13	—	4	65	122	100	97
14	—	—	54	97	100	100
15	—	1	28	78	100	99
16	—	—	37	73	100	100
17	—	—	17	46	100	100
18	—	—	10	41	100	100
19	—	—	8	19	100	100
20	—	—	6	10	100	100
21	—	—	2	8	100	100
22	—	—	1	10	100	100
Total no.	59	72	783	1165		

California samples. Males from Oregon samples were 50% mature at about age 4 and 100% mature at age 8. California males were 50% and 100% mature at about age 5 and 8, respectively. Oregon female widow rockfish were 50% and 100% sexually mature at about age 7 and 9, respectively. Off California, females reached 50% and 100% sexual maturity at about age 5 and 8, respectively.

Off Oregon, males began to mature sexually at about 31 cm FL, with 50% mature at 33 cm, most mature at 36 cm, and all mature at 38 cm (Table 7). Females began to mature at 35 cm, and were 50% mature at about 38 cm and almost 100% mature at 42 cm.

Widow rockfish sexual maturity off California began at about 25 cm for males and 26 cm for females (Table 8). Most males and females were mature at 38 cm, but all fish may not have been mature until they were about 46 cm.

Westrheim (1975) reported that length at 50% maturity in the area of West Vancouver Island was 37 cm for males and 38 cm for females.

Calculated mean weight at first sexual maturity was 444 g for males and 662 g for females from Oregon samples (Table 4). Respective weights at 50% and 100% maturity were calculated at 534 g and 870 g for males and 937 g and 1,150 g for females.

Maturity of fish taken by Oregon trawl fishery

Most widow rockfish were sexually mature in the random samples from Oregon commercial trawl landings in 1979-80. By number, about 99% of the males and over 92% of the females were mature (Table 9).

Fecundity

Boehlert et al. (1982) reported on the fecundity of widow rockfish from Oregon samples taken in December 1980 and January 1981. Fecundity increased with increasing length, weight, and usually age. Estimates of fecundity ranged from 95,375 oocytes at 33 cm FL to 1,113,000 oocytes at 52 cm FL. The fecundity-length and fecundity-weight relationships were as follows.

Length $F = 59{,}182.4\ L - 1{,}999{,}200;\ r^2 = 0.90;\ N = 64$

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

where F = fecundity, L = fork length (cm); W = weight (gm), r^2 = coefficient of determination, and N = number of specimens.

Table 7—Maturity by fork length and sex for *Sebastes entomelas* from Oregon trawl catches, 1979-80. Selected fish included.

Length (cm)	Number: Immature M	Immature F	Mature M	Mature F	% Mature M	% Mature F
29	—	1	—	0	—	0
30	—	—	—	—	—	—
31	0	—	2	—	100	—
32	3	1	1	0	25	0
33	6	6	6	0	50	0
34	3	10	6	0	67	0
35	5	14	26	1	84	7
36	2	11	51	1	96	9
37	2	14	56	8	97	36
38	0	6	87	15	100	71
39	0	3	123	26	100	90
40	1	4	119	52	99	93
41	0	5	100	83	100	94
42	0	1	65	83	100	99
43	0	0	39	101	100	100
44	0	0	18	70	100	100
45	0	0	10	61	100	100
46	0	0	6	32	100	100
47	0	0	1	21	100	100
48	0	0	1	16	100	100
49	—	0	—	17	—	100
50	—	0	—	12	—	100
51	0	0	1	7	100	100
52	—	0	—	3	—	100
53	—	0	—	1	—	100
54	—	0	—	1	—	100
Total no.	22	76	718	611		

Table 8—Maturity by fork length and sex for *Sebastes entomelas* from California, 1977-82.

Length (cm)	Number: Immature M	Immature F	Mature M	Mature F	% Mature M	% Mature F
23	2	1	—	—	0	0
24	1	—	—	—	0	0
25	1	1	1	—	50	0
26	1	1	4	1	80	50
27	2	4	1	3	33	43
28	6	7	1	1	14	13
29	3	7	1	—	25	0
30	5	8	4	3	44	27
31	6	8	2	4	25	33
32	4	3	5	2	56	40
33	1	4	3	6	75	60
34	2	2	6	6	75	75
35	5	1	6	7	55	88
36	3	6	13	9	81	60
37	6	4	10	16	63	80
38	2	2	23	10	92	83
39	4	1	35	19	90	90
40	2	—	59	21	97	100
41	2	1	81	28	98	97
42	1	1	121	35	99	97
43	5	2	158	47	97	96
44	1	2	122	75	99	97
45	2	1	87	133	98	99
46	—	—	40	145	100	100
47	—	—	19	137	100	100
48	—	—	3	140	100	100
49	—	—	2	164	100	100
50	—	—	—	116	—	100
51	—	—	—	67	—	100
52	—	—	—	28	—	100
53	—	—	—	10	—	100
54	—	—	—	2	—	100
Total no.	67	67	807	1235		

Table 9—Sexual maturity by number in random samples of *Sebastes entomelas* from Oregon trawl landings, 1979-80.

	1979		1980	
	Male	Female	Male	Female
No. immature	1	14	4	25
No. mature	208	181	475	421
% mature	99.5	92.8	99.2	94.4

The length-fecundity and weight-fecundity relationships described by Boehlert et al. (1982) differed significantly from data presented by Phillips (1964) on California widow rockfish. Fecundity of California fish was generally lower with respect to length and weight. The smallest number of developing eggs that Phillips found in the 1957-59 samples was 55,600 in a 324 mm TL fish (~30.5 cm FL). The largest number of developing eggs (915,200) was found in a 478 mm TL (~45 cm FL) female.

Table 10—Mean fork length and weight by sex at age for *Sebastes entomelas* from catches off Oregon and California.

	Mean length (cm)				Mean weight[1] (g)	
Age	Male		Female		Male	Female
(yr)	Ore.	Cal.	Ore.	Cal.	Ore.	
3	31.0	25.3	29.0	24.7	444	350
4	32.0	29.1	33.3	28.7	534	549
5	35.0	32.0	35.2	33.2	642	662
6	36.4	34.6	37.0	34.9	727	780
7	37.6	36.6	39.1	37.3	800	936
8	38.6	38.2	40.2	39.3	870	1,025
9	39.5	39.5	41.6	41.0	932	1,150
10	39.8	40.5	42.8	42.5	958	1,255
11	41.0	41.4	44.2	43.7	1,050	1,400
12	42.2	42.1	45.4	44.8	1,141	1,427
13	43.6	42.6	46.0	45.6	1,261	1,596
14	43.3	43.1	47.7	46.4	1,233	1,798
15	44.2	43.4	48.5	47.0	1,316	1,899
16	46.7	43.7	49.0	47.6	1,558	1,965
17	44.7	44.0	49.0	48.0	1,362	1,965
18	45.0	44.1	49.3	48.4	1,393	2,008
19	46.0	44.3	50.0	48.7	1,490	2,099
20	46.0	44.4	49.5	49.0	1,490	2,031
21	—	—	54.0	49.2	—	2,704
22	—	—	51.4	49.4	—	2,299
23	—	—	52.0	—	—	2,388

[1]Calculated mean weight, $w = a L^b$
Female: $a = 0.00545$; $b = 3.28781$; $r^2 = 0.99384$
Male: $a = 0.01188$; $b = 3.06631$; $r^2 = 0.99599$

DISCUSSION

Geographical variation in age at maturity

Size at 50% maturity is apparently smaller in southern latitudes (Table 4); however, this may be due to factors other than geographic variation. Oregon and California fish differ only slightly in size after age 8 (Table 10) and the divergence in the growth rate only in younger fish is suspicious. Many fish sampled in California, especially the smaller fish, were sampled from the hook-and-line sport fishery, with 43 of the 134 immature fish landed commercially. The age-length discrepancy may be due to geographical variation, but possibly the larger of the immature fish move offshore where they are available to trawlers, the only catches sampled in Oregon. This possible movement of fish could cause the apparent increase in size at 50% maturity observed in Oregon.

Management implications (biological) based on maturity

The Oregon commercial fishery on widow rockfish in 1979-80 was almost entirely on mature fish. Therefore, the management question is how to best utilize mature fish. During this time there was no biological problem related to the catch of juvenile widow rockfish.

As long as there is not a fishery on juveniles, and as long as juveniles and adult stocks are separate, as apparently they are now, restrictions on size retained would seem to be inappropriate. Oregon female widow rockfish are 50% sexually mature at 38 cm FL, which could be used as a biological point of concern for Oregon fish. With the same reasoning, 33 cm could be the point of concern for California fish. However, since fecundity of small but mature females appears to be relatively low, a larger size may be more appropriate.

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Appendix

Distribution (%) of mature widow rockfish by gonad condition and month in Oregon random market samples, 1979-80.

	Gonad Stage									
	Male					Female				
Month	3	4	5	6	7	3	4	5	6	7
January	0	0	0	19	81	61	39	0	0	0
February	0	0	0	2	98	1	11	70	5	3
March	0	0	0	0	100	0	3	22	48	27
April	0	0	0	0	100	0	0	0	0	100
May	0	0	0	0	100	0	0	0	0	100
June	100	0	0	0	0	0	0	0	0	100
July	83	0	0	0	17	0	0	0	0	100
August	0	100	0	0	0	0	0	0	0	100
September	9	91	0	0	0	21	0	0	0	79
October	10	90	0	0	0	100	0	0	0	0
November	0	98	2	0	0	100	0	0	0	0
December	0	36	37	27	0	98	2	0	0	0

Descriptions of Reared Larvae of Six Species of *Sebastes*

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ABSTRACT

This paper describes techniques used in rearing larvae obtained from field-caught females of six species of rockfishes (*Sebastes*). The early larval stages are described for three of these species (*S. entomelas*, *S. serranoides*, and *S. rubrivinctus*) and more complete larval series are described for three other species (*S. rufus*, *S. ovalis*, and *S. constellatus*). The larval taxonomic characters of these species are compared with those of other rockfish species. Experiments on yolk-sac larvae of *S. rubrivinctus* showed that sinking rates decrease with decreasing yolk volume and point to the precise timing of ontogeny and birth in *Sebastes*.

INTRODUCTION

Estimation of spawning biomass by sampling eggs and larvae has been accomplished for important fish stocks off California (Ahlstrom 1954, 1966, 1968; Smith 1972). Rockfishes are highly fecund live-bearers whose newborn young are at a developmental stage similar to the first-feeding larvae of typical pelagic spawners (Moser 1967). Since their larvae are abundant and widesparead over the CalCOFI (Calif. Coop. Oceanic Fish. Invest.) sampling area (Ahlstrom 1961; Ahlstrom et al. 1978), there is a potential for spawning biomass estimation from ichthyoplankton samples. This potential is confounded by the large number of species (62 off California; Hubbs et al. 1979) and the relative paucity of larval characters.

Identification of larvae of eastern Pacific rockfishes has proceeded slowly. Complete developmental series, from newborn individuals to the juvenile stage, are known for eight species: *S. aurora*, *S. cortezi*, *S. dallii*, *S. jordani*, *S. levis*, *S. macdonaldi*, *S. melanostomus*, and *S. paucispinis* (Moser et al. 1977; Moser and Ahlstrom 1978; Moser et al. 1985). These identifications have been accomplished by comparing the full-term larvae from identified females with the smallest larvae of distinct series obtained from plankton hauls. Also, newly transformed identifiable juveniles with remnants of larval pigmentation and morphological features were used, along with meristic characters, to identify larval series. Using the latter technique, Richardson and Laroche (1979) and Laroche and Richardson (1980, 1981) have described postflexion larvae and early juveniles of the widow rockfish (*S. entomelas*) and nine other species. This opens the possibility for estimation of recruitment, providing these stages can be sampled adequately. Our plankton samples are dominated by early larval stages (Fig. 1) and may allow estimation of spawning biomass when critical information on fecundity, mortality, and duration of the early pelagic phase becomes available.

Progress in the identification of rockfish larvae is dependent on rearing developmental species. Although Japanese workers have been successful in rearing *Sebastes* larvae (Table 1), the rearing of an eastern Pacific species to the juvenile stage has been accomplished only recently (Moser and Butler 1981). More recently Stahl-Johnson 1985) has reared the larvae of *S. caurinus* and *S. auriculatus*

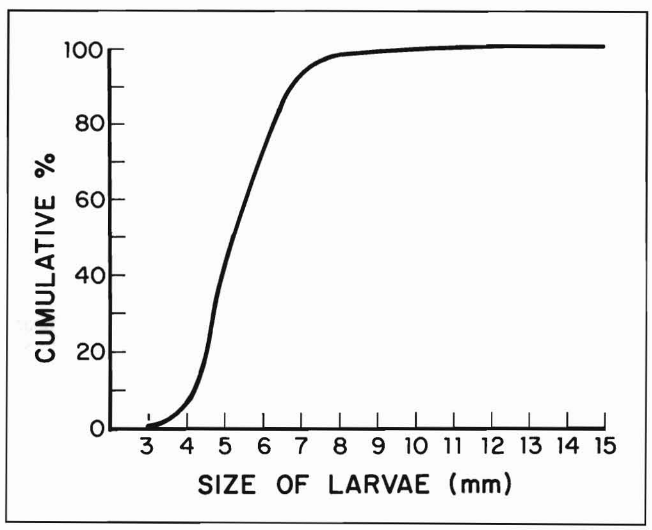

Figure 1.—Size composition of rockfish larvae in CalCOFI samples expressed in cumulative percent (N = 11,633).

Table 1—Summary of *Sebastes* rearing experiments.

Authors	Fujita	Fujita	Siokawa and Tsukahara	Tsukahara	Kusakari et al.	Moser and Butler
Date	1957	1958	1961	1962	1977	1981
Species	*S. pachycephalus*	*S. oblongus*	*S. pachycephalus*	*S. marmoratus*	*S. schlegeli*	*S. dallii*
Gestation period (days)	23	—	20	—	—	—
Rearing duration (days)	28	30	25	10	83	60
Food	*Artemia* nauplii	*Artemia* nauplii	*Artemia* nauplii	*Artemia* nauplii	*Brachionus* *Artemia* *Tigriopus*	Wild plankton
Feeding	yes	yes	yes	no	yes	yes
Source of larvae	Female spawned in aquarium	Female spawned in aquarium	Female spawned in aquarium	Female spawned in aquarium	Female spawned in aquarium	Female spawned in field
Initial size (mm)	6.9-7.0	7.25-7.50	6-7	3.5-4.5	5.3-7.9	5.4
Final size (mm)	9.75	14	13	5	50	24.3

Table 2—Dates and locality of capture and rearing information for *Sebastes* species.

Species	Date	Locality	Method of capture	Rearing temperature (°C)	Days reared	Diet
constellatus	4/16/78	60 Mile Bank	Hook-and-line	14.5-16.5	38	Wild plankton
entomelas[1]	3/06/81	Nelson Island Oregon	Midwater trawl	10	26	*Brachionus*, wild plankton
ovalis	1/27/78	60 Mile Bank	Hook-and-line	13.4-16.1	29	*Brachionus* and *Artemia* nauplii to day 13; wild plankton days 13-29
rubrivinctus	9/15/76	Tanner Bank	Bottom trawl	9.2-14.7	Cultured for 14 days	Not fed
rufus	2/01/78	60 Mile Bank	Hook-and-line	13.8-16.1	46	*Brachionus* and *Artemia* nauplii to day 5; *Tisbe* nauplii days 6-8; wild plankton days 8-46
rufus	1/20/79	60 Mile Bank	Hook-and-line	15.6-16.0	12	Wild plankton
serranoides	1/18/79	Tanner Bank	Hook-and-line	16.2-17.0	16	Wild plankton

[1]Information from G. W. Boehlert, Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, pers. commun.

through caudal fin formation, and G. W. Boehlert (NMFS Honolulu Lab., pers. comm.) has reared a partial series of *S. melanops*. This paper describes reared early larval stages of widow rockfish (*S. entomelas*), flag rockfish (*S. rubrivinctus*), and olive rockfish (*S. serranoides*) and more complete reared series of bank rockfish (*S. rufus*), speckled rockfish (*S. ovalis*), and starry rockfish (*S. constellatus*). Rearing was carried out at the Southwest Fisheries Center, La Jolla, California, except for the brood of *S. entomelas*, which was reared by G. W. Boehlert at the Marine Science Center, Newport, Oregon.

METHODS AND MATERIALS

Intraovarian rockfish larvae were obtained at sea by collecting near-term females with hook-and-line or by bottom trawling (Table 2). Rockfishes brought from depth often have expanded gas bladders which exert pressure on other internal organs and cause pregnant females to extrude their brood. Larvae from near-term females were collected in containers of seawater and brought back to the laboratory within one or two days for rearing. Free-swimming larvae were separated from dead ones and from those which were unable to swim off the bottom of the transport container and introduced into 100-L round black fiberglass rearing containers filled with filtered seawater. The containers were immersed in a water bath which maintained temperatures; an airstone was used to reduce stratification.

Larvae were fed cultured rotifers (*Brachionus plicatilis*), copepods (*Tisbe* sp.), wild plankton, or a combination of these (Table 2). Wild plankton was obtained by towing a 70-μm mesh net in Mission Bay, San Diego, Calif. The plankton was passed through a series of screens, and the 104-254 μm fraction, dominated by copepod nauplii, was used as food. Plankton densities in the rearing containers were maintained at 2-4 nauplii/mL, and a liter of dense algal culture, *Tetraselmis suesica* or *Duneliella* sp., was added daily as food for the plankton.

Larvae were removed from the culture tank and preserved in 3% buffered formalin to establish life history series for analysis of morphology and pigmentation. Terminology and methods of description follow those of Moser et al. (1977) and Moser and Ahlstrom (1978).

RESULTS AND DESCRIPTIONS

Sebastes entomelas

Rearing—According to G. W. Boehlert (NMFS Honolulu Lab., pers. comm.), extruded larvae were obtained on 6 March 1981 from females collected on the FV *Centurion* at Nelson Island, Oregon. Larvae were immediately placed in jars and buckets of filtered seawater and transported to the laboratory. Those swimming were pipetted into circular black plastic pots (10-L capacity) of UV-filtered seawater with salinity >30‰; all larvae were held in a constant temperature room at 10°C. Within 24 hours, moribund larvae were siphoned from remaining jars and buckets and swimming larvae were transferred into a dark green circular tank (120-L capacity). After three to five days in the laboratory, rotifers were introduced at densities from 2 to 4/mL along with a dense algal culture. Subject to availability, wild zooplankton was added to the rearing tanks. Mortality was minimal to day 11, increased rapidly from day 12 to 15, with 25% of the larvae surviving on day 13, and only one larva was left on day 26.

Morphology—Six preserved samples, from day 1 to day 10, were provided by G. W. Boehlert. Extruded larvae were 4.5-4.6 mm long; a yolk sac (0.55-0.60 mm in length) and oil globule were present. Prey items were present in the stomachs of specimens preserved on day 4, even though considerable yolk remained. The yolk sac and oil globule were absent in larvae sampled after day 7. Larvae did not show appreciable growth during the 10-day period (Table 3) and reached a state of development typical of full-term broods (Fig. 2).

Pigmentation—Larvae at day 10 had melanophores along the dorsal region of the gut, below the posterior gut region, and a series on the ventral midline of the tail. The tail series extended from the third or fourth postanal myomere to the 17th-19th postanal myomere, and contained 13-16 melanophores ($\bar{x}$ = 14.0±0.94 SD for 10 larvae counted). Pigment was present on the lower jaw in all specimens and melanophores were present on the brain, typically on each side of the cerebellum and optic lobes. A few specimens had 1-2 melanophores on the nape and scattered melanophores on the pectoral fin blade.

Sebastes rufus

Rearing—Larvae collected on 1 Feb. 1978 were 4.6-4.8 mm in length when stocked. The oil globule and a small yolk remnant were invested in the liver tissue. The yolk was utilized within four days; however, the oil globule persisted to the end of the first week. Larvae did not feed on *Brachionus* or *Artemia* nauplii provided through day 5. They began feeding when nauplii and copepodites of a laboratory culture of *Tisbe* were added to the tank on day 6. Within a day the *Tisbe* moved to the sides and bottom of the container and were unavailable to the larva. Beginning on day 8, wild plankton was provided and elicited feeding activity immediately. Larvae survived until day 46.

Larvae collected on 20 Jan. 1979 were 4.3-4.7 mm in length and had a conspicuous yolk mass about 0.6 mm in diameter. They began feeding on wild copepod nauplii added that day even though the yolk mass was about 0.5 mm in diameter and occupied the anterior half of the gut region. By day 5, the yolk mass and oil globule were confined to the liver tissue. Yolk utilization was complete by the end of one week; however, the oil globule persisted one or two days more. Larvae survived until day 12.

Morphology—Larvae of *S. rufus* lack distinctive morphological features (Tables 4, 5; Fig. 2). The 6.1-mm specimen (Fig. 2D) had developing caudal rays and hypural elements and a straight notochord; the largest specimen (7.6 mm) had a completely flexed notochord (Fig. 2E). The supporting elements of the dorsal and anal fins were forming in the 7.6-mm specimen. Head spine development is similar to that observed in other species (Moser and Ahlstrom 1978). At about 6.0 mm, the following spines were forming: third posterior preopercular, second and fourth anterior preopercular, pterotic, and parietal. In the 7.6-mm specimen, the second and fourth posterior preopercular spines were also present. The postocular spine was just beginning to form above the eye. The parietal spines were relatively short and flat against the head.

Pigmentation—Newborn larvae had one or two melanophores above the brain, one at the nape, a dorsal melanistic shield above the gut, and a short postanal series along the ventral midline (Fig. 2). The ventral midline series extended from the fifth and sixth postanal myomere to the 14th-18th postanal myomere and contained 8-13 melanophores ($\bar{x}$ = 10.3±1.54 SD for all specimens in growth series). Dorsal midline melanophores appeared soon after extrusion and increased in number in two stanzas up to the notochord flexion stage ($\bar{x}$ = 2.0±1.24 SD for specimens in 4.4 mm-5.2 mm range, and $\bar{x}$ = 9.4 ± 2.67 SD for specimens in the 5.5 mm-7.6 mm range).

The symphysis of the lower jaw was pigmented at 4.7-4.8 mm; the dorsal surface of the brain was solidly pigmented by 4.7 mm, except for the olfactory lobe region which was pigmented at 5.6 mm. Melanophores were added to the nape to produce a solid blotch by 4.7 mm, the 7.6 mm specimen had a melanistic streak on each side of the snout along the maxillaries, and the upper opercular region was pigmented.

At 4.7 mm, a melanophore was present on the medial surface of each pectoral fin base and small melanophores were scattered over the fin blade. The medial surface of the fin base was solidly

Table 3—Measurements (mm) of larvae of *Sebastes entomelas*.

Body length (age in days)	Yolk sac (length × width)	Snout-anus distance	Head length	Snout length	Eye diameter	Body depth	Pectoral fin Length	Pectoral fin Base depth
4.6 (1)	0.60 × 0.45	1.6	0.89	0.22	0.32	0.68	0.21	0.20
4.4 (2)	0.55 × 0.43	1.5	0.90	0.26	0.31	0.63	0.20	0.20
4.5 (4)	0.45 × 0.31	1.5	0.92	0.30	0.30	0.62	0.23	0.24
4.5 (7)	0.18 × 0.18	1.4	0.90	0.26	0.31	0.64	0.25	0.26
4.8 (10)	—	1.6	0.98	0.27	0.33	0.61	0.23	0.24
4.3 (10)	—	1.4	0.85	0.25	0.30	0.59	0.21	0.23

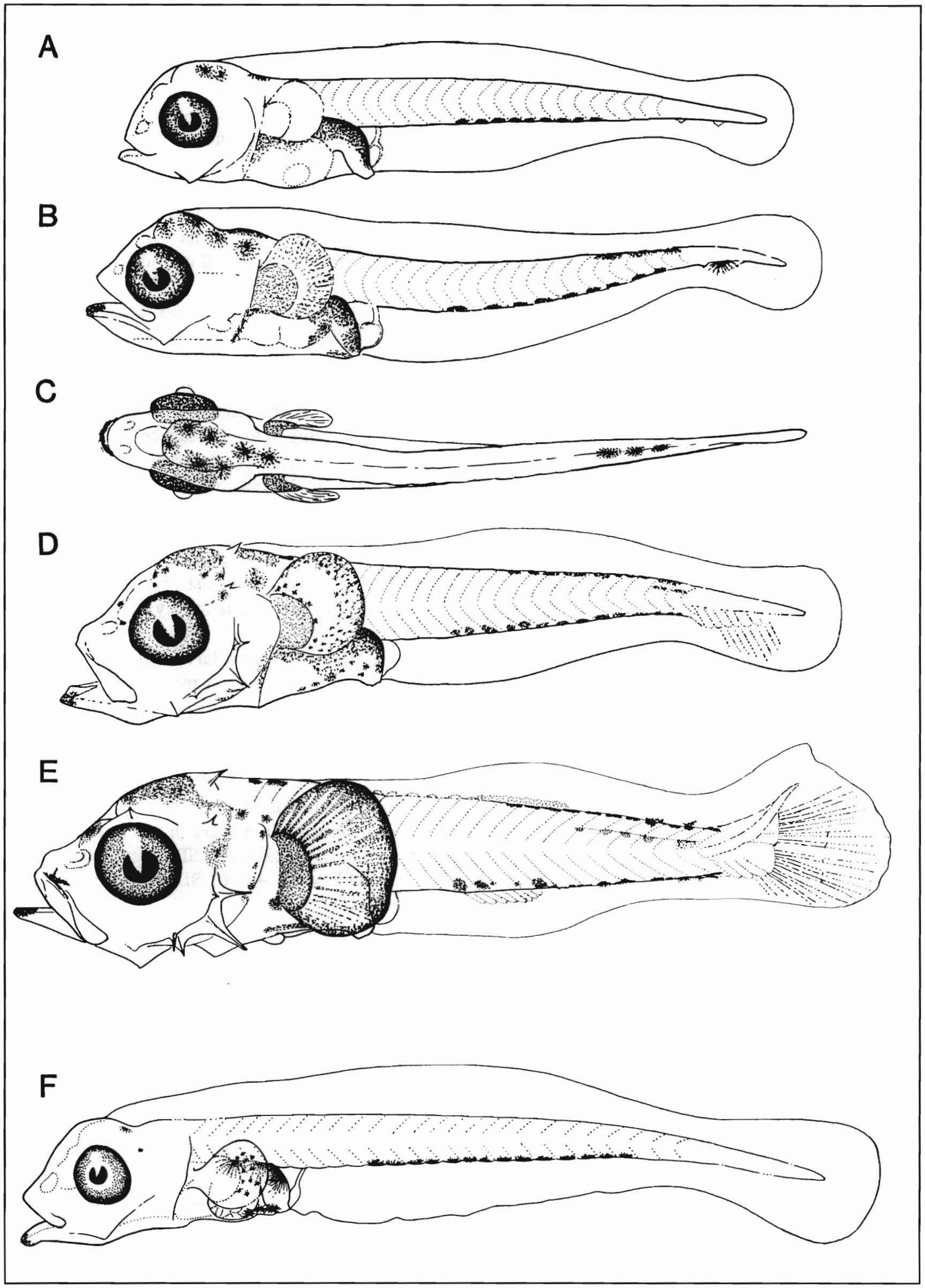

Figure 2—Larvae of *Sebastes rufus* (A-E) and *S. entomelas* (F). A. 4.8 mm, day 3; B. 4.9 mm, day 9; C. 4.9 mm, day 9 (dorsal view); D. 6.1 mm, day 22; E. 7.6 mm, day 35; F. 4.8 mm, day 10.

Table 4—Measurements (mm) of larvae of *Sebastes rufus*.

Body length (age in days)	Snout-anus distance	Head length	Snout length	Eye diameter	Body depth	Pectoral fin Length	Pectoral fin Base depth	Pelvic fin length
4.8 (3)	1.8	1.1	0.29	0.38	0.68	0.25	0.20	
4.8 (4)	1.9	1.2	0.26	0.43	0.81	0.26	0.26	
4.7 (6)	1.8	1.1	0.26	0.42	0.70	0.26	0.26	
4.6 (7)	1.8	1.1	0.31	0.40	0.68	0.25	0.26	
4.8 (8)	1.8	1.2	0.24	0.40	0.70	0.26	0.24	
4.9 (9)	1.9	1.2	0.30	0.48	0.82	0.27	0.34	
5.2 (13)	2.0	1.2	0.29	0.50	0.95	0.34	0.38	
5.6 (13)	2.1	1.2	0.30	0.47	1.0	0.37	0.34	
5.3 (19)	2.0	1.2	0.32	0.50	0.93	0.35	0.39	
5.7 (19)	2.2	1.4	0.44	0.57	1.1	0.48	0.50	
5.9 (19)	2.3	1.5	0.45	0.60	1.2	0.54	0.52	
6.1 (22)	2.6	1.6	0.45	0.66	1.3	0.59	0.52	
*7.6 (35)	3.3	2.2	0.58	0.81	1.7	0.93	0.82	0.05
*7.2 (46)	3.7	2.5	0.65	0.94	1.7	1.0	0.76	0.09

*Specimens undergoing notochord flexion

Table 5—Comparative morphometry (in mm) of preflexion larvae of nine *Sebastes* species ($\bar{x}$ ± SD/range).

Sebastes sp.	Snout to anus distance / Body length	Head length / Body length	Snout length / Head length	Eye diameter / Head length	Body depth / Body length	Pectoral fin length / Body length	Pectoral fin base depth / Body length
constellatus	37.8 ± 1.30	22.6 ± 0.89	28.0 ± 1.87	32.8 ± 2.49	15.8 ± 0.84	5.4 ± 0.55	6.8 ± 1.30
	36-39	22-24	26-30	29-35	15-17	5-6	5-8
dallii	42.4 ± 0.52	22.6 ± 1.06	25.6 ± 3.02	38.0 ± 1.85	17.6 ± 1.85	5.6 ± 0.52	5.9 ± 1.36
	42-43	21-24	19-29	35-41	15-20	5-6	3-7
jordani	36.5 ± 0.84	22.3 ± 1.51	26.8 ± 3.43	37.7 ± 0.82	17.0 ± 1.26	6.7 ± 0.52	6.5 ± 0.55
	36-38	21-25	23-31	36-38	16-19	6-7	6-7
levis	39.6 ± 2.30	24.7 ± 1.60	30.7 ± 2.63	33.1 ± 2.67	21.7 ± 1.11	17.4 ± 5.29	10.9 ± 1.57
	37-44	23-28	27-35	29-36	20-23	11-24	8-13
macdonaldi	42.4 ± 3.53	27.6 ± 2.25	30.6 ± 4.16	34.6 ± 2.34	23.1 ± 3.99	8.4 ± 1.21	9.8 ± 1.48
	36-47	24-31	25-36	31-37	13-27	6-10	8-12
ovalis	38.0 ± 3.00	23.7 ± 2.08	21.7 ± 2.08	38.0 ± 2.00	16.3 ± 1.53	6.0 ± 1.73	7.7 ± 1.15
	35-41	22-26	20-24	36-40	15-18	5-8	7-9
paucispinis	41.0 ± 2.74	26.8 ± 2.28	27.4 ± 3.21	32.8 ± 3.77	19.6 ± 1.67	16.4 ± 4.56	9.0 ± 0.71
	37-44	24-29	24-32	29-37	17-21	11-21	8-10
rufus	38.9 ± 1.44	23.9 ± 1.38	25.8 ± 3.19	38.6 ± 2.97	17.2 ± 2.18	6.7 ± 1.67	6.7 ± 1.67
	38-43	21-26	20-31	35-42	14-21	5-10	4-9
serranoides	36.5 ± 1.09	22.8 ± 1.40	28.3 ± 2.27	37.8 ± 1.90	15.9 ± 1.31	5.2 ± 0.62	6.2 ± 1.19
	35-38	20-26	25-32	35-41	14-18	4-6	5-8

pigmented by 5.6 mm and the pigment on the blade assumed a distinctive pattern (Fig. 2D, E). Late in the preflexion stage (ca. 6.0 mm), internal melanophores appeared above the dorsal surface of the notochord at the 17th-18th postanal myomeres and extended anteriorly to the 9th myomere in the 7.6-mm specimen (Fig. 2E). A few early larvae had a melanophore in the hypural region (Fig. 2B), but these melanophores did not persist.

Sebastes ovalis

Rearing—Larvae were 4.9-5.1 mm at extrusion and had the oil globule and a small amount of yolk invested in the liver tissue. The yolk persisted to day 5 and the oil globule to day 9. They did not feed on *Brachionus* and *Artemia* nauplii and experienced a massive die-off on day 11. The remaining few were fed wild plankton on day 13 and began to feed, with one specimen living to day 29.

Morphology—The larvae were similar to *S. rufus* (Fig. 3A-C; Tables 5, 6). In the 6.8 mm larva, the caudal rays were forming and the notochord was just beginning to flex. Head spines formed as in *S. rufus*, and the 6.8 mm larva had the following spines: pterotics, parietals, second and fourth anterior preoperculars, and the third posterior preopercular.

Pigmentation—Pigmentation was similar in pattern to that of *S. rufus* larvae but somewhat heavier. The youngest larvae sampled had a patch of 5-8 melanophores above the brain, several melanophores at the nape, a solid sheath above the gut, one or two spots on the medial surface of the pectoral fin base, scattered spots on the fin blade and dorsal and ventral postanal series. The ventral series extended from the fifth or sixth to the 18th or 19th postanal myomeres and contained 13-17 melanophores ($\bar{x}$ = 14.8±1.68 SD for all specimens). The dorsal series was composed of two irregular rows containing 11-12 melanophores in the smallest larvae,

Table 6—Measurements (mm) of larvae of *Sebastes ovalis*, *S. serranoides*, and *S. constellatus*.

Body length (age in days)	Snout-anus distance	Head length	Snout length	Eye diameter	Body depth	Pectoral fin Length	Pectoral fin Base depth	Pelvic fin length	Snout anal fin distance
Sebastes ovalis									
5.1 (5)	1.8	1.1	0.23	0.40	0.79	0.26	0.35		
4.8 (9)	1.8	1.1	0.22	0.44	0.75	0.25	0.34		
6.8 (29)	2.8	1.8	0.44	0.68	1.20	0.54	0.60		
Sebastes serranoides									
4.9 (2)	1.7	1.0	0.31	0.40	0.77	0.25	0.24		
5.0 (2)	1.8	1.1	0.32	0.40	0.74	0.24	0.24		
5.0 (3)	1.8	1.1	0.31	0.40	0.72	0.25	0.25		
5.3 (5)	1.9	1.2	0.33	0.46	0.87	0.27	0.32		
5.2 (7)	1.8	1.2	0.31	0.42	0.71	0.22	0.28		
5.7 (7)	2.1	1.3	0.32	0.47	0.91	0.30	0.36		
5.6 (9)	2.1	1.3	0.36	0.52	1.0	0.33	0.40		
5.8 (12)	2.1	1.3	0.36	0.53	1.0	0.32	0.39		
5.7 (13)	2.1	1.3	0.40	0.50	1.0	0.30	0.40		
5.8 (14)	2.2	1.4	0.45	0.54	0.95	0.32	0.44		
5.8 (16)	2.2	1.5	0.43	0.56	0.95	0.35	0.45		
Sebastes constellatus									
4.5 (4)	1.7	1.0	C.30	0.32	0.75	0.24	0.29		
4.6 (6)	1.8	1.1	C.30	0.32	0.71	0.25	0.30		
4.6 (8)	1.8	1.0	C.26	0.35	0.67	0.27	0.34		
4.4 (9)	1.6	1.0	0.27	0.33	0.72	0.26	0.35		
4.6 (11)	1.7	1.0	0.30	0.35	0.73	0.25	0.35		
*7.1 (38)	3.5	2.3	0.78	0.77	2.0	1.0	0.71	0.30	4.2

*Specimen undergoing notochord flexion

increasing to 19-21 melanophores in the largest larvae (Fig. 3). Pectoral fin pigmentation was similar to that in *S. rufus*. The tip of the lower jaw became pigmented at about day 9.

Sebastes serranoides

Rearing—Larvae from the two females caught on 18 Jan. 1979 were markedly different in stage of development. Larvae from female #1 were 4.2-4.3 mm long, with a yolk mass of 0.6 mm diameter, and were premature. Larvae from female #2 measured 4.8-5.4 mm, had no yolk and only a remnant of the oil globule in the liver tissue. These larvae began feeding immediately on wild plankton whereas the premature brood began feeding on day 5, when only a remnant of yolk was visible in the liver tissue. Both groups had massive die-offs due to improper water circulation and stratification on day 9; however, a few larvae from both broods survived to day 16.

Morphology—The larvae were similar to *S. rufus* (Fig. 3D-F; Tables 5, 6). Caudal fin rays were not forming in the largest specimens, nor were head spines.

Pigmentation—Pigmentation was similar to that of *S. rufus*. In a sample of 30 newborn larvae from female #1, 17% lacked pigment over the brain, 73% had 1 or 2 melanophoes, and 10% had 3-4 melanophores above the brain. Nape melanophores were lacking in 57% of the larvae, 33% had one nape spot, and 10% had 2-3 spots. By day 5, melanophores covered the brain and nape. Newborn larvae had a melanistic shield over the gut and a distinct series of melanophores along the ventral midline below the gut. All newborn larvae had a melanophore at the future hypural region. The postanal ventral midline series extended from the third or fourth postanal myomere to the 18th-20th and contained 14-20 melanophores ($\bar{x}$ = 16.0±1.60 SD for the entire growth series). Of 100 newborn larvae examined, 67 lacked dorsal midline melanophores, 28 had a single melanophore, and 5 specimens had 2 melanophores at the 17th-19th postanal myomeres. At the end of the first week, additional melanophores appeared in the dorsal midline series and 9 to 14 day larvae had 7-16 ($\bar{x}$ = 13.2±3.70 SD) melanophores in the series.

At day 5, the tip of the lower jaw and the pectoral fins were pigmented. The medial surface of the pectoral fin base had a large melanophore and the outer half of the fin blade had a covering of fine melanophores. By day 9 the medial surface of the fin blade was fully pigmented and the fin blade had a distinct pigment pattern (Fig. 3E). Also, at this stage melanophores appeared on the snout, opercular region, and lateral nape region. At day 14 the medial surface of the fin base was totally pigmented.

Sebastes constellatus

Rearing—Newborn larvae of *S. constellatus* were 4.0-5.0 mm at extrusion, had a small remnant of the oil globule, and began feeding immediately on wild plankton. There was a massive die-off at the end of the first week and the single larva remaining alive at the end of the second week lived to day 38.

Morphology—Early larvae of *S. constellatus* were morphologically indistinct (Fig. 4A-C; Tables 5, 6). The 38-day specimen (7.1 mm) was similar to larvae of other species of the subgenus *Sebastomus* (Moser et al. 1977; Richardson and Laroche 1979), in having a relatively large head with strong spination and the following head spines: second and third anterior preoperculars, second and fourth posterior preoperculars, pterotics, posttemporals, postoculars, and parietals. Each postocular spine was borne on a prominent supraocular shelf, and the heavily serrated parietals were elongated compared with those of *S. rufus*. Also, in this specimen the dorsal and anal fin bases and the pelvic fins were beginning to form.

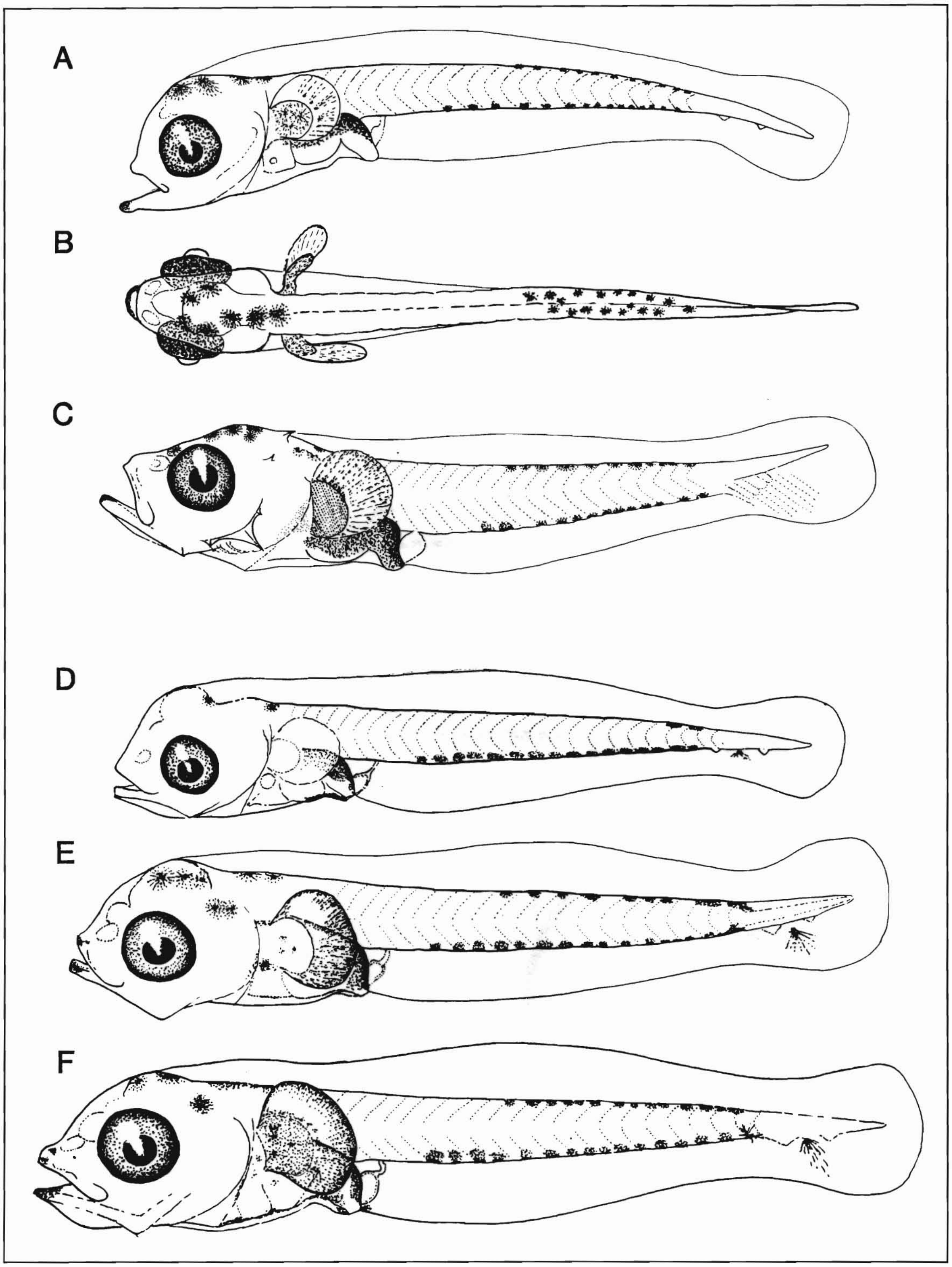

Figure 3—Larvae of *Sebastes ovalis* (A-C) and *S. serranoides* (D-F). A. 4.9 mm, day 9; B. 4.9 mm, day 9 (dorsal view); C. 6.8 mm, day 29; D. 5.0 mm, day 2; E. 5.6 mm, day 9; F. 5.8 mm, day 14.

Pigmentation—Pigmentation in early larvae of *S. constellatus* was similar to that known for other species of *Sebastomus*. The pigment pattern consisted of a spot at the tip of the lower jaw, a shield over the gut, a ventral midline series below the gut, and a postanal ventral series extending from the third to the 15th postanal myomere and containing 12-16 melanophores (Fig. 4). During the first week, the pectoral fin blade became covered with small melanophores that were denser at the distal margin. The 7.1-mm larva had snout pigment, a covering of melanophores above the brain, nape spots, a solidly pigmented pectoral fin-base, pelvic fin pigment, and a hypural spot (Fig. 4C). Dorsal midline pigment was not present.

Sebastes rubrivinctus

Rearing—The brood of larvae collected on 15 Sept. 1976 was held at two temperature ranges, 8.8-9.3°C and 14.4-15.0°C, to provide specimens for sinking rate experiments, and were not fed subsequently. After two weeks, the least advanced individuals were about 4.8 mm long, had a yolk sac measuring about 0.6 × 0.7 mm, and an oil globule about 0.23 mm in diameter; the most advanced specimens lacked yolk and had an oil globule 0.10-0.20 mm in diameter. Sinking rates ranged from 0.6 cm/s for the least advanced to 0.09 cm/s for the most advanced (Table 7, Fig. 5).

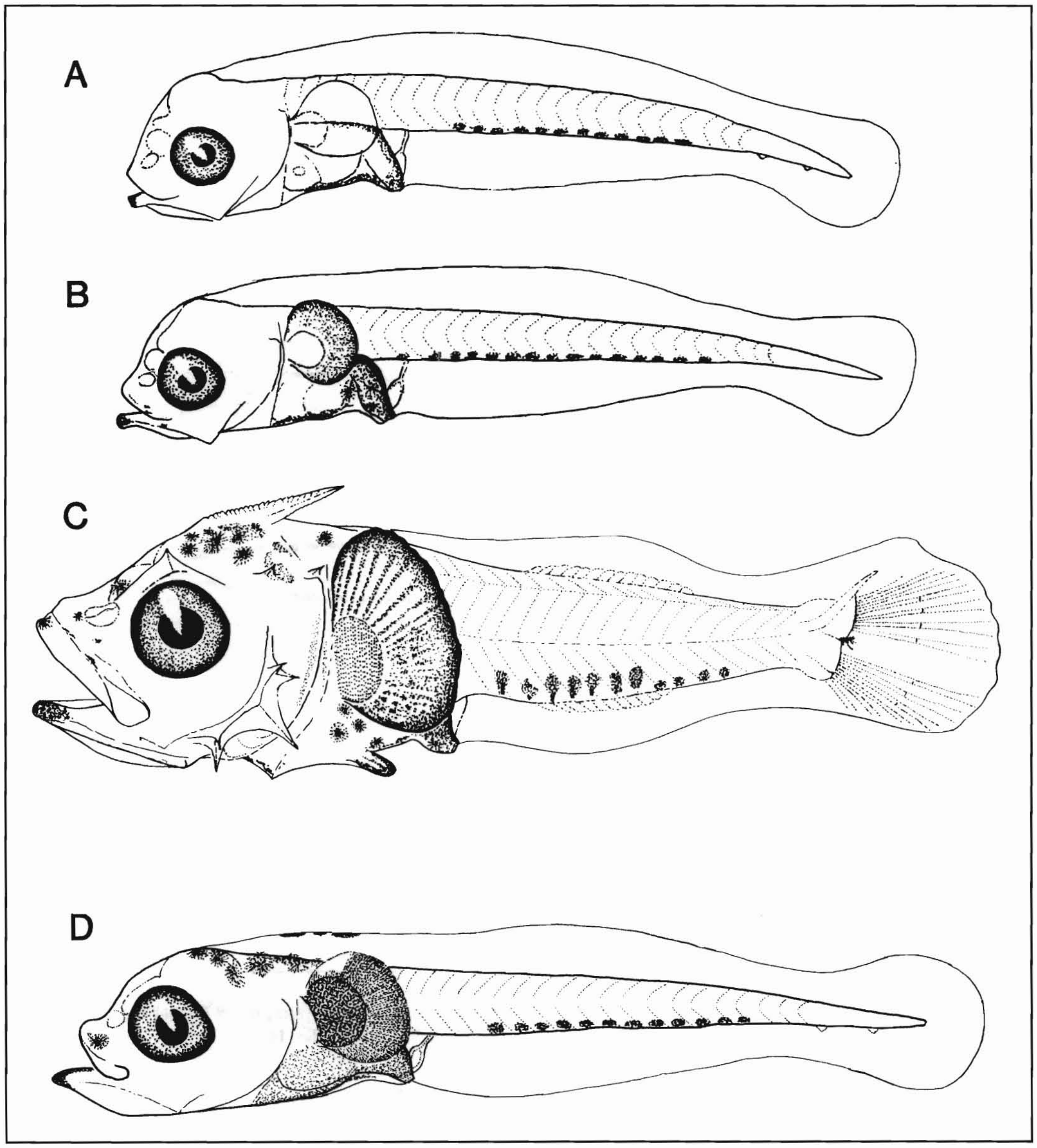

Figure 4—Reared larvae of *Sebastes constellatus* (A-C) and *S. rubrivinctus* (D). A. 4.5 mm, day 4; B. 4.6 mm, day 11; C. 7.1 mm, day 38; D. 5.1 mm, day 14.

Table 7—Sinking rates for anesthetized larvae of *Sebastes rubrivinctus* at different stages of yolk and oil globule utilization.

Specimen length (mm)	Yolk length (mm)	Yolk width (mm)	Yolk volume (mm^3)	Oil globule diameter (mm)	Sinking time (min:s)	Beaker height (cm)	Sinking rate (cm/s)
4.8	0.70	0.60	0.154	0.23	0:59.8	36.5	0.61
4.9	0.74	0.58	0.166	0.22	1:44.8	36.5	0.35
4.8	0.64	0.54	0.116	—	1:54.2	36.5	0.32
5.0	0.68	0.50	0.121	0.24	2:26.6	36.5	0.25
5.1	0.46	0.30	0.033	0.18	3:06.8	36.5	0.20
5.0	0.38	0.30	0.023	0.20	3:11.2	36.5	0.19
5.2	0.56	0.36	0.059	0.20	3:20.4	36.5	0.18
5.2	0.38	0.32	0.024	—	3:24.0	36.5	0.18
5.0	0.38	0.26	0.020	0.24	3:32.4	36.5	0.17
4.8	0	0	0	0.10	4:26.6	36.5	0.14
5.1	0	0	0	0.12	6:45.0	36.5	0.09
4.8	0.08	0.08	<0.001	0.20	7:05.8	36.5	0.09

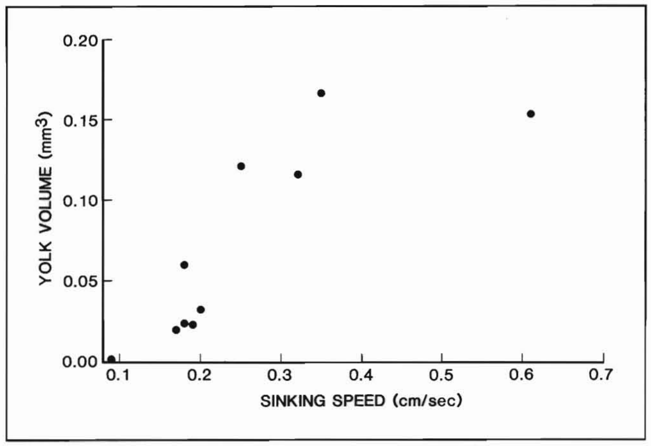

Figure 5—Sinking speed of larvae of *Sebastes rubrivinctus* at various stages of yolk utilization.

Pigmentation—In yolk-exhausted larvae, the head was heavily pigmented with melanophores covering the brain, nape, lower jaw, and with one or more melanophores in the snout (Fig. 4D). One to several melanophores were present at the margin of the dorsal finfold above the nape. Finfold pigmentation has not been reported in larvae of other species of *Sebastes*. The median surface of the pectoral fin base was covered solidly with melanophores as was the blade, except for a small dorsally located clear zone. The gut was pigmented solidly on all surfaces. Postanal pigmentation consisted of a ventral midline series of 13-23 melanophores ($\bar{x}$ = 16.4$\pm$1.82 SD for 50 specimens) extending from the third or fourth postanal myomere to the 15th-16th.

DISCUSSION

Our ability to identify the early-stage larvae of rockfishes has progressed so that, for some species, standard plankton surveys may be used to determine the temporal and areal extent of spawning and relative larval abundance (Moser et al. 1977). These surveys also provide the possibility for estimation of spawning biomass when critical information on fecundity, larval mortality, and duration of the early pelagic phase becomes available. The species with identifiable larvae are only a fraction of the rockfish species which are currently or potentially important to fisheries. Larval series which have been described have distinctive morphological features, pigmentation, temporal and spatial distributions, or a combination of these characters, and are readily identifiable compared with the unidentified species which have more subtle larval characters. Rearing of larval series provides the means for increasing the number of identifiable species; however, rockfish are difficult to rear. We have not been able to duplicate the Japanese success with *Artemia* as a food (Table 1) largely because eastern Pacific species are smaller and comparatively less developed at birth (Table 1) and we have had to rely on freshly collected wild plankton. Indeed, in our rearing attempts, high concentrations of *Brachionus* have not elicited feeding behavior. The recent successful rearing of copper and brown rockfish (*S. caurinus* and *S. auriculatus*) larvae to the stage of caudal fin formation on a diet of *Brachionus* and *Artemia* (Stahl-Johnson 1985) suggests a diversity in larval food requirements among eastern Pacific species.

The number and arrangement of postanal midline pigment series have been emphasized as key characters in identifying rockfish larvae (DeLacy et al. 1964; Moser 1967; Westrheim 1975; Moser et al 1977). Previously, early-stage rockfish larvae have been divided into two groups: those with both dorsal and ventral midline series and those with only ventral series. Larvae of *S. rufus* and *S. serranoides*, described herein, represent a third type which has only a ventral midline series at birth (most specimens) but soon develops a substantial dorsal midline series to which melanophores are added gradually. This must also happen in *S. entomelas* and *S. flavidus*, since newborn larvae lack dorsal midline series (Westrheim 1975) but early postflexion larvae (Laroche and Richardson 1980, 1981) have well developed dorsal midline series. The usefulness of the postanal pigment series as a larval character will depend on knowing the composition and arrangement of these series at precise developmental stages, knowledge which can be obtained only by rearing each species.

The distribution of dorsal and ventral midline pigment may provide characters for systematic analysis. Barsukov (1981) has hypothesized that the widow rockfish (*S. entomelas*) is most closely related to the blue rockfish (*S. mystinus*) and that these two are part of a group that includes *S. flavidus*, *S. melanops*, and *S. serranoides*. Also, Barsukov proposed that the sister group to the *S. entomelas* group includes *S. rufus*, *S. ovalis*, and *S. hopkinsi*. Characters of first-feeding larvae are now known for all of the above species. In the former group and *S. rufus*, first-feeding larvae have only a ventral row of postanal midline pigment but develop a dorsal row during the preflexion larval stage (not known for *S. mystinus*). First-feeding larvae of *S. ovalis* and *S. hopkinsi* have both dorsal and ventral postanal midline pigment. More precise knowledge of the number and arrangement of postanal midline pigment is needed to test the utility of this character in species identification and systematic analysis.

The larvae of the starry rockfish, *S. constellatus*, show the suite of pigment and morphological characters described for other members of the subgenus *Sebastomus* (Moser et al. 1977; Richardson and Laroche 1979). Preflexion and postflexion larvae of this group have a postanal ventral midline series only and pigment on the dorsal head region, on the lower jaw, and on the pectoral fins (heaviest on the distal margin). Late in the postflexion stage, *Sebastomus* larvae develop a blotch on the caudal peduncle and a saddle beneath the spinous dorsal fin. It is likely that early larval stages of this group will not be identifiable to species. In groups such as these, the late larval and pelagic juvenile stages could be used to estimate recruitment, depending on our ability to sample these stages adequately. Mid- and late-stage larvae are undersampled by plankton nets (Fig. 1) and juvenile habitats are diverse for the large array of *Sebastes* species. Those with distinct pelagic juvenile stages could be sampled with midwater trawls, surface nets, or small-mesh purse seines depending on their location in the water column (Moser and Ahlstrom 1978; Laroche and Richardson 1981). Those species which transform and quickly settle to soft-bottom habitats can be sampled by small-mesh bottom trawls; however, those which settle quickly to rocky habitats may be vulnerable only to traps.

An important aspect of the life history of rockfish was addressed by the sinking rate experiment on *S. rubrivinctus* larvae reported in this paper. The sinking rate in rockfish embryos and yolked larvae decreases with decreasing yolk volume (Fig. 5), whereas in species with pelagic eggs such as the plaice (Blaxter and Ehrlich 1974) and the northern anchovy (Hunter and Sanchez 1976) sinking rate increases with decreasing yolk volume. Whereas the new-hatched larvae of fish species with pelagic eggs find themselves positioned or maintained in the upper water column by virtue of their buoyant eggs, all evidence indicates that rockfish larvae are extruded at the depth range of the adults and rise to the upper water column. Since prematurely born yolk-sac larvae would sink rapidly to the bottom and die, birth must be coordinated precisely with the time of yolk and oil globule exhaustion. Perhaps birth is initiated by behavioral or biochemical cues from the full-term larvae. If birth was initiated by the female, she would gain some latitude in the critical timing of extrusion, particularly if she were able to provide nutrition to the developing brood after yolk exhaustion. Indeed, maternal nutriton is suggested by the markedly greater rearing success of broods spawned spontaneously by captive females compared with broods taken from field-caught females. Recently, Boehlert and Yoklavich (1984) have demonstrated maternal nutrition in *Sebastes*.

Early mortality in *Sebastes* follows a vastly different path than in other fishes with a prolific larval stage. Rockfish have avoided the high mortality of the egg stage (e.g., 30-40%/day for northern anchovy reported by Stauffer and Picquelle 1980) since there is insignificant intraovarian mortality, even in species with brood sizes exceeding 2 million embryos (Moser 1967). The great reproductive potential inherent in being able to produce large numbers of fully-formed larvae that are ready to feed on zooplankters is balanced by the mortality encountered in the journey of these first-feeding larvae from their place of birth to the upper water column. This mortality is controlled to some degree by events during late intraovarian life since survival of newborn young depends on their state of organ development, energy reserves, and bouyancy. Studies on intraovarian physiology of *Sebastes* (Boehlert and Yoklavich 1984) and attention to brood condition in field-caught females will provide valuable insight into rockfish production.

ACKNOWLEDGMENTS

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Ageing and Growth of Widow Rockfish

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ABSTRACT

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

INTRODUCTION

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

MATERIALS AND METHODS

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

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

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

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

The von Bertalanffy growth curve was used to describe growth:

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

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

The computer program BGC3 (Abramson 1971) was used to estimate the parameters of the model. Most couplets of age and size used to estimate the parameters were averages of size at age by trimester and sampling area. If sample size from a given area and trimester was less than 10, data from more than one area were combined. Averages for entire years were used for fish older than 13 years because growth is relatively slow at this age and sample sizes were small. If sample size was smaller than 10 for fish older than 15 years, data from adjacent years were combined.

RESULTS

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

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

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

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

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

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

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

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

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

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

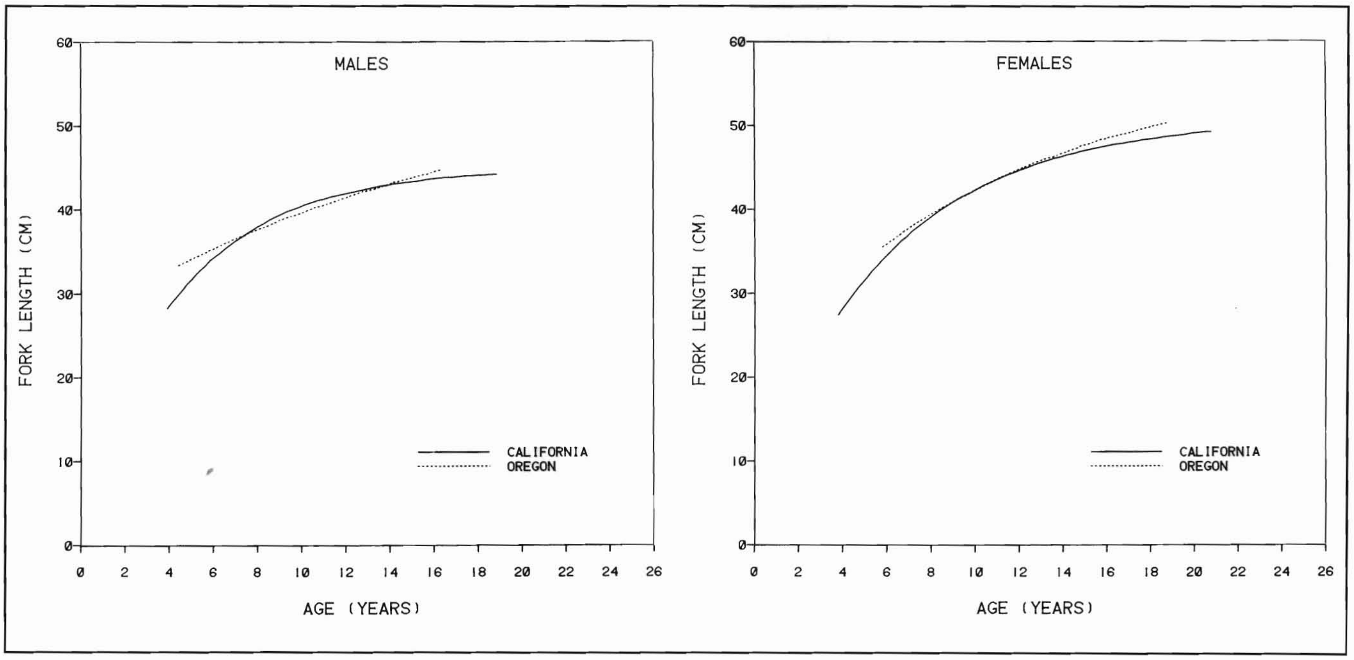

Figure 1—Estimated von Bertalanffy growth curves for male and female widow rockfish caught off Oregon and California.

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

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

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

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

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

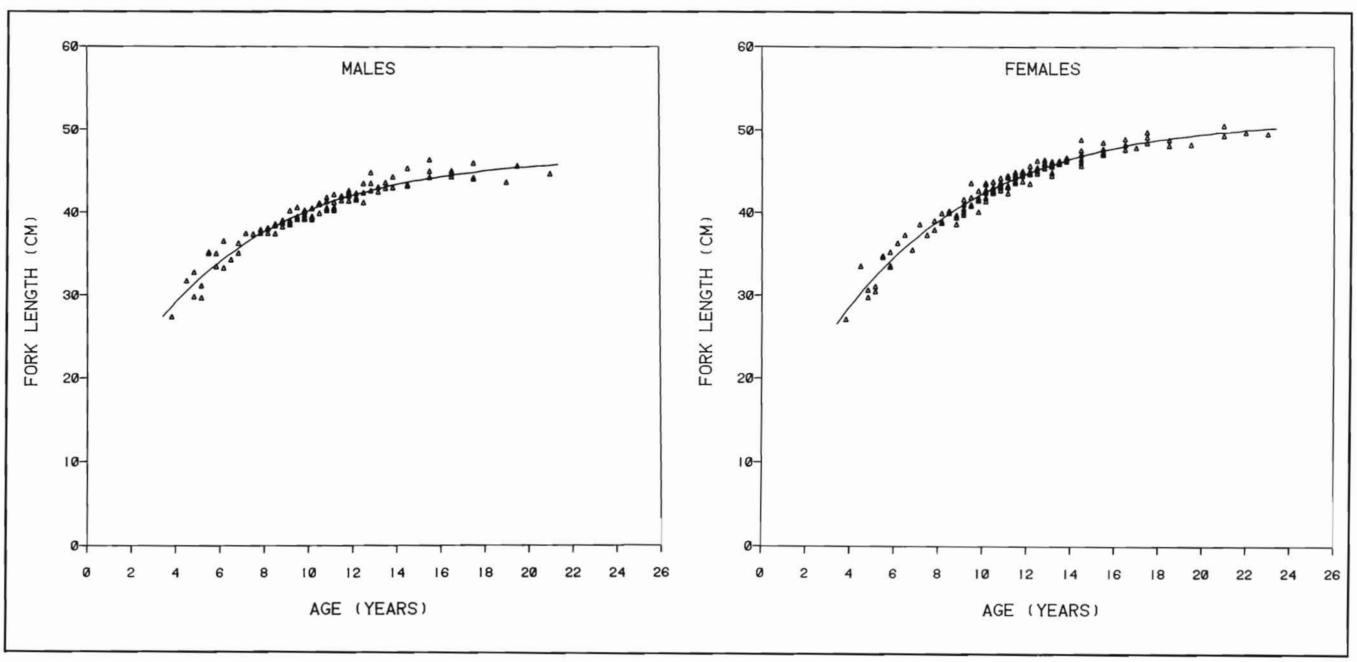

Figure 2—Estimated von Bertalanffy growth curves for male and female widow rockfish caught off California and Oregon, and observations of average size at age.

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

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

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

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

DISCUSSION

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

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

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

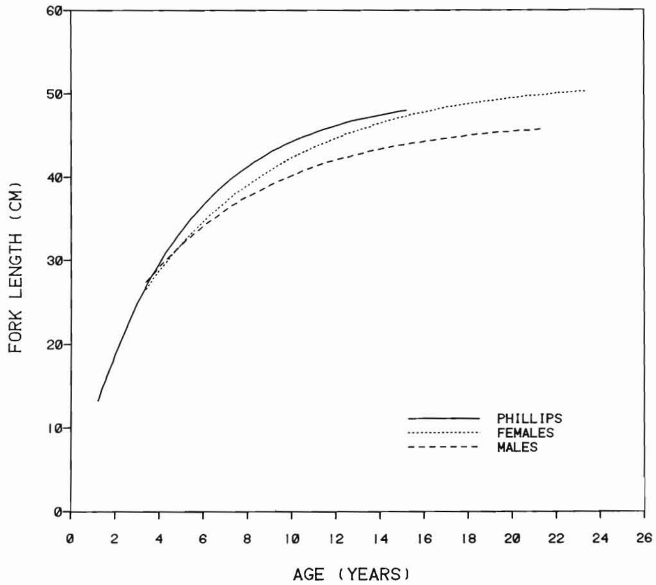

Figure 3—Comparison of growth curves estimated for widow rockfish by Phillips (1964) and this study. Phillips' data were converted from total length to fork length.

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The Diet of Widow Rockfish *Sebastes entomelas* in Northern California

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ABSTRACT

The diet of widow rockfish (*Sebastes entomelas*) taken in the commercial and partyboat fisheries from Northern California was examined. The only sampling category that had sufficient numbers to be reliable was the commercial catch from the Eureka area. The diet of these fish is dominated by four prey categories: salps; fish, primarily myctophids; caridean shrimp, almost exclusively *Sergestes similis*; and euphausiids. There is a seasonal trend in the composition of these four prey categories which corresponds with their life history. There are also size related trends in diet composition. These four major prey groups comprise the deep sounding layer. At night when the widow rockfish are caught at depths of around 140 m, the deep sounding layer is near the surface. This suggests that the widow rockfish is feeding during the day when the deep sounding layer is in deeper waters (400 m). The strong similarity between widow rockfish and blue rockfish (*Sebastes mystinus*) is pointed out, which suggests strong parallel forces are important in the evolution of both of these species.

INTRODUCTION

With the exception of nearshore species, very little work has been done on the feeding of rockfishes (Genus *Sebastes*). The only information available on commercially important rockfishes in California are comments by Phillips (1964) in his report on age and growth. In that paper he states, "The widow rockfish is mainly a macroplankton feeder, with hyperiid amphipods dominating their diet, but small fish are also eaten at times." From this he concludes that "Since amphipods are seldom found in the diet of other macroplankton-feeding rockfish, the widow rockfish might occupy a somewhat different habitat." In these comments and those on the relatively pure nature of widow rockfish commercial catches, Phillips makes the suggestion that the feeding behavior of the widow rockfish is radically different from other commercially important species of rockfish. This possibility warrants more detailed examination in light of the recent dramatic increase in the importance of the widow rockfish in the commercial fishing industry from San Francisco northward (Demory 1987; Quirollo 1987; Tagart 1987).

METHODS

The stomachs of widow rockfish were sampled from both commercial and partyboat catches at ports between Eureka and Monterey. From each catch a maximum of 20 fish was sampled. The sampling began March 1980 and continued until February 1981. All fish lengths used in this paper are total lengths. The digestive tract of each fish specimen was removed and preserved in 4% formaldehyde solution. For analysis, the contents were examined under a binocular dissecting microscope and, when necessary, a binocular compound microscope. A list was then compiled of the items in the gut, with species identified whenever feasible. The following data were then noted for the items in each listed category: 1) the number present; 2) prey size range; and 3) an estimate of its representation in the gut as a percent by volume of the contents. Empty stomach samples were excluded from the data.

RESULTS

Most of the stomach samples (74% or 283/381) of widow rockfish came from commercial catch sampling in the Eureka-Fields Landing area. This is the only sampling category that had sufficient numbers to be reliable. These samples came predominantly (over 75%) from the same California Department of Fish and Game statistical block just south of Cape Mendocino. The diet item with the largest mean percent volume (the average for any one prey category of its percent volume from all non-empty fish) was thaliacean urochordates or salps (Table 1). Salps are gelatinous herbivorous holoplankton which have the capacity for rapid population increase due to high growth rates and short generation time (Blackburn 1979). Because of this, they are considered opportunistic species, able to quickly produce large formations when high concentrations of food become available. Almost equally important in the diet are fish, which when identifiable are usually myctophids or Pacific hake. Myctophids are small fish with photophores which give off bioluminescence. They are probably the most common fish in midwater (Paxton 1967). Pacific hake (*Merluccius productus*) is a semipelagic fish extremely abundant off the coasts of California, Oregon, and Washington. The hake found in widow rockfish stomachs are all in the size range of age-1 fish or younger (Dark

Table 1—Diet of widow rockfish from catch samples landed in the Eureka-Fields Landing area. (Average TL = 467 mm, *n* = 283, min. size = 370 mm, max. size = 795 mm).

	Mean number	Mean % volume	Mean prey size (mm)	Freq. of occurrence
Hydromedusae				
Unid. sp.	0.01	0.017	—	0.004
Physonectid siphonophore	0.22	1.359	11.00	0.028
Ctenophora				
Pleurobrachia bachei	0.13	0.836	20.63	0.018
Oligochaeta				
Unid. sp.	—	0.042	90.00	0.004
Polychaeta				
Alciopidae	0.01	0.408	—	0.007
Heteronereis sp.	0.09	0.428	26.00	0.004
Gastropoda				
Unid. sp.	0.07	0.491	1.50	0.018
Turridae	0.07	0.038	—	0.004
Vermiculuridae	0.07	0.428	—	0.004
Cephalopoda				
Unid. sp.	0.15	0.352	181.00	0.028
Loligo opalescens	0.02	0.338	46.25	0.007
Octopus sp.	0.01	0.193	33.50	0.007
Mysidacea				
Unid. sp.	0.01	0.022	10.00	0.004
Isopoda				
Jaeropsis sp.	0.01	0.428	12.50	0.004
Gammaridea				
Unid. sp.	0.06	0.587	2.80	0.028
Hyperiidae				
Unid. sp.	0.57	1.281	70.38	0.109
Phronimidae	0.02	0.095	26.25	0.007
Vibilliadae	0.73	0.639	36.00	0.085
Caprellidea				
Unid. sp.	—	0.008	35.00	0.004
Euphausiacea				
Unid. sp.	27.36	17.759	49.86	0.325
Unid. larvae	3.53	0.428	—	0.004
Euphausia pacifica	0.02	0.428	24.50	0.004
Thysanoessa spinifera	—	0.013	—	0.004
Natantian Decapoda				
Unid. sp.	5.14	9.513	30.94	0.102
Unid. megalopa	0.01	0.150	10.00	0.007
Caridea	—	0.428	—	0.004
Pandalus jordani	0.01	0.107	—	0.004
Sergestes similis	8.44	11.600	27.75	0.166
Thaliacea				
Unid. sp.	14.87	25.332	131.07	0.329
Larvacea				
Unid. sp.	0.14	0.008	4.50	0.004
Chaetognatha				
Unid. sp.	—	0.428	35.00	0.007
Sagitta sp.	—	0.408	—	0.004
Fish				
Unid. sp.	0.05	10.045	124.84	0.113
Mustelus henlei	0.05	0.034	22.50	0.004
Engraulis mordax	0.02	1.029	60.00	0.004
Myctophidae	6.01	5.513	37.46	0.152
Lampanyctus ritteri	—	0.215	60.00	0.004
Tarletonbeania crenularis	0.02	1.221	63.25	0.014
Merluccius productus	0.14	6.812	114.07	0.060
Aulorhynchus flavidus	—	0.086	56.00	0.004
Anoplopoma fimbria	—	0.428	—	0.004
Mycteroperca jordani	0.03	0.019	27.50	0.004

1974). Data on age-1 fish suggest that they are almost completely segregated, even from age-2 fish (J. Taynor, Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, unpubl. data). Hake spawn from February to April, peaking in March (Ahlstrom and Counts 1955). In the January-March quarter, hake appear in the diet of widow rockfish both as young-of-the-year fish and 1-yr fish. Hake then virtually disappear from the diet until the October-December quarter when they are the major item. Caridean shrimp, almost all those identifiable being *Sergestes similis*, account for another 22% of the diet. The final major prey category of the widow rockfish is euphausiid crustaceans which comprise about 19% of the diet.

These prey types represent about 91% of the diet of widow rockfish, again in terms of volume. The stomach contents of an individual averaged 1.8 different types of prey per stomach. There are virtually no hyperiid amphipods (1.25%) in the widow rockfish's diet, and most of those which are identified (Vibilliadae 0.95%) are from a genus that has been reported as living in association with salps (Madin and Harbison 1977). In fact, these data are pretty much in direct contradiction with Phillips' description of the widow rockfish's diet of "primarily hyperiid amphipods, occasionally salps, pyrosomes, small squid and anchovies." This contradiction may be due to difference in location of fish capture and to differences in sample sizes.

Seasonality in the diet of widow rockfish was examined through quarterly diets (Jan.-Mar., Table 2; Apr.-June, Table 3; July-Sept., Table 4; Oct.-Dec., Table 5). Average size of fish was similar for all quarters (range 449 to 487 mm), but samples were small for some quarters. The four major groups mentioned above account for between 73 and 97% of the quarterly diet volumes (versus 91% for the annual diet), but the distribution of diet volume during the quarters is different among these groups. In the winter quarter, shrimp, primarily sergestids, are an important part of the diet. This was true both in 1980 and 1981. The seasonal occurrence of these prey may be due to an onshore migration during this period (Pearcy and Forss 1966a). The spring quarter (April through June) is the only time that salps are a major part of the diet. This is also the period of high absolute volume of prey per millimeter of fish size and highest number of prey species per fish, but neither is statistically significant. The diet information from the summer quarter is limited by sample size, but during this period euphausiids dominate the diet. During the fall, fish is the principal prey item, particularly juvenile hake.

To investigate possible changes in feeding with size, the widow rockfish from Fields Landing are broken down into three size classes: <450 mm, 450-500 mm, and >500 mm. The two major trends in diet with increasing fish size are the decreasing importance of euphausiids and a corresponding increase of fish in the diet (Table 6). The increase of fish is greater than the decrease in euphausiids, but there is also a slightly increasing trend in salps with larger fish size. Prey size generally increases as the fish size-class increases, with the exception of shrimp. The larger fish come from several collections spread over different months, so it is not likely that these changes are simply a sampling artifact.

There are numbers of fish collected from May and June at each of the three southern areas: Fort Bragg, San Francisco, and Monterey. Average sizes of fish from these three areas are within 100 mm of those from Eureka. In the Fort Bragg samples (Table 7), which are commercially caught, the diet is predominantly salps. In San Francisco Bay (Table 8), where the samples are sport-caught, the diet is predominantly euphausiids. In Monterey, where the samples are a mixture of commercial and sport-caught fish, the diet is a mixture of salps and euphausiids (Table 9). Fish and shrimp are virtually absent from these samples.

Table 2—Diet of widow rockfish from Eureka, January-March 1981. (Average TL = 487 mm, n = 32, min. size = 419 mm, max. size = 795 mm).

	Mean number	Mean % volume	Mean prey size (mm)	Freq. of occurrence
Hyperiidea				
Paraphronima sp.	5.63	3.215	32.50	0.063
Euphausiacea				
Unid. sp.	0.44	3.723	13.75	0.094
Natantian Decapoda				
Unid. sp.	19.13	27.074	31.43	0.250
Sergestes similis	23.88	35.159	30.91	0.375
Thaliacea				
Unid. sp.	0.19	3.723	20.00	0.063
Fish				
Unid. sp.	0.03	2.031	25.00	0.094
Merluccius productus	1.13	1.558	36.25	0.156
Myctophidae	0.22	23.518	118.00	0.219

Table 3—Diet of widow rockfish from Eureka, April-June 1980. (Average TL = 467 mm, n = 176, min. size = 390 mm, max. size = 528 mm).

	Mean number	Mean % volume	Mean prey size (mm)	Freq. of occurrence
Ctenophora				
Pleurobrachia bachei	0.22	1.342	20.63	0.028
Oligochaeta				
Unid. sp.	0.01	0.069	9.00	0.006
Gastropoda				
Unid. sp.	0.03	0.079	1.50	0.017
Turridae	0.11	0.062	—	0.006
Vermiculuridae	0.11	0.688	—	0.034
Cephalopoda				
Unid. sp.	0.23	0.544	65.00	0.034
Loligo opalescens	0.02	0.516	52.50	0.006
Octopus sp.	0.01	0.275	55.00	0.006
Isopoda				
Jaeropsis sp.	0.01	0.688	12.50	0.006
Gammaridea				
Unid. sp.	0.10	0.254	2.80	0.045
Hyperiidae				
Unid. sp.	0.48	0.164	15.81	0.091
Phronimidae	0.03	0.151	26.25	0.011
Vibilliadae	1.15	0.971	15.43	0.114
Caprellidea				
Unid. sp.	0.01	0.013	35.00	0.006
Euphausiacea				
Unid. sp.	42.11	22.101	15.50	0.415
Unid. larvae	5.68	0.688	—	0.006
Natantian Decapoda				
Unid. sp.	4.78	9.763	30.76	0.119
Unid. megalopa	0.01	0.172	10.00	0.006
Caridea	—	0.688	—	0.006
Sergestes similis	9.19	10.642	26.11	0.188
Thaliacea				
Unid. sp.	23.20	37.019	158.21	0.472
Fish				
Unid. sp.	0.35	4.527	26.67	0.142
Mustelus henlei	0.08	0.054	22.50	0.006
Myctophidae	9.46	8.530	37.62	0.216

Table 4—Diet of widow rockfish from Eureka, July-September 1980. (Average TL = 449 mm, n = 27, min. size = 374 mm, max. size = 506 mm).

	Mean number	Mean % volume	Mean prey size (mm)	Freq. of occurrence
Hydromedusae				
Unid. sp.	0.07	0.257	—	0.037
Physonectid siphonophore	0.11	1.285	—	0.037
Gastropoda				
Heteropod	0.56	6.423	—	0.037
Cephalopoda				
Loligo opalescens	0.11	0.257	40.00	0.037
Mysidacea				
Unid. sp.	0.11	0.321	10.00	0.037
Hyperiidae				
Unid. sp.	2.59	18.175	9.50	0.360
Vibilliadae	0.11	0.513	7.50	0.111
Euphausiacea				
Unid. sp.	3.93	46.564	20.00	0.444
Euphausia pacifia	0.22	6.423	24.50	0.037
Natantian Decapoda				
Pandalus jordani	0.11	1.606	—	0.037
Thaliacea				
Unid. sp.	0.44	1.477	—	0.740
Fish				
Unid. sp.	0.08	3.853	—	0.037
Anoplopoma fimbria	0.04	6.423	—	0.037
Merluccius productus	0.04	6.423	—	0.037

Table 5—Diet of widow rockfish from Eureka, October-December 1980. (Average TL = 465 mm, n = 48, min. size = 370 mm, max. size = 531 mm).

	Mean number	Mean % volume	Mean prey size (mm)	Freq. of occurrence
Hydromedusae				
Physonectid siphonophore	1.21	7.296	11.00	0.146
Polychaeta				
Alciopidae	0.04	2.333	—	0.042
Gastropoda				
Unid. sp.	0.02	0.074	—	0.021
Cephalopoda				
Unid. sp.	0.04	0.074	13.00	0.042
Octopus sp.	0.02	0.123	12.00	0.021
Hyperiidae				
Unid. sp.	0.14	0.467	4.33	0.104
Vibilliadae	0.02	—	5.00	0.021
Euphausiacea				
Unid. sp.	4.42	2.333	12.50	6.083
Thysanoessa spinifera	0.02	0.074	—	0.021
Natantian Decapoda				
Sergestes similis	0.13	2.948	32.50	0.042
Thaliacea				
Unid. sp.	2.21	9.702	18.42	0.125
Larvacea				
Unid. sp.	0.83	0.050	4.50	0.021
Chaetognatha				
Unid. sp.	—	2.456	—	0.021
Fish				
Unid. sp.	1.14	38.442	35.00	0.542
Engraulis mordax	0.10	5.895	60.00	0.063
Lampanyctus ritteri	0.02	1.228	60.00	0.021
Tarletonbeania crenularis	0.13	7.001	63.25	0.083
Merluccius productus	0.69	19.503	104.25	0.188

Table 6—Diet of widow rockfish broken down into size classes from Eureka-Fields Landing area using only major prey categories.

	Mean number	Mean % volume	Mean prey size (mm)	Freq. of occurrence
Widow rockfish <450 mm (Avg. TL = 435 mm, *n* = 89)				
Fish	1.98	18.272	51.60	0.161
Euphausiids	67.10	21.554	17.50	0.301
Shrimp	10.56	13.288	41.22	0.277
Salps	6.90	19.560	27.50	0.313
Widow rockfish 450-500 mm (Avg. TL = 473 mm, *n* = 186)				
Fish	7.95	22.322	46.55	0.304
Euphausiids	17.98	14.785	63.63	0.352
Shrimp	16.00	22.414	37.67	0.296
Salps	18.29	22.987	41.00	0.333
Widow rockfish >500 mm (Avg. TL = 512, *n* = 29)				
Fish	1.05	32.264	76.66	0.385
Euphausiids	2.93	6.857	50.00	0.069
Shrimp	12.96	19.668	45.84	0.241
Salps	22.76	29.159	45.00	0.379

Table 7—Diet of widow rockfish from the Fort Bragg area. (Average TL = 457 mm, *n* = 28, min. size = 380 mm, max. size = 524 mm).

	Mean number	Mean % volume	Mean prey size (mm)	Freq. of occurrence
Hydromedusae				
Calycophoran siphonophore	0.04	0.781	30.00	0.036
Gammaridea				
Unid. sp.	0.04	0.039	—	0.036
Hyperiidae				
Vibilliadae	2.04	4.609	4.00	0.250
Euphausiacea				
Unid. sp.	15.29	5.469	7.50	0.179
Thysanoessa spinifera	0.11	0.196	2.50	0.036
Ascidiacea				
Dolioid	0.21	3.125	17.50	0.036
Thaliacea				
Unid. sp.	26.64	82.070	74.00	0.607
Fish				
Sebastes saxicola	0.04	0.781	30.00	0.036

Table 8—Diet of widow rockfish from the San Francisco Bay area. (Average TL = 382 mm, *n* = 20, min. size = 305 mm, max. size = 461 mm).

	Mean number	Mean % volume	Mean prey size (mm)	Freq. of occurrence
Hyperiidae				
Unid. sp.	0.20	1.113	13.50	0.150
Vibilliadae	0.45	4.016	8.50	0.200
Euphausiacea				
Unid. sp.	6.90	70.481	26.57	0.500
Natantian Decapoda				
Sergestid larvae	0.50	5.750	3.50	0.050
Thaliacea				
Unid. sp.	0.50	9.274	15.00	0.050
Gelatinous material, undet.	—	9.274	3.00	0.050
Fish				
Unid. sp.	0.05	0.093	6.00	0.050

Table 9—Diet of widow rockfish from the Monterey area. (Average TL = 436 mm, *n* = 50, min. size = 266 mm, max. size = 557 mm).

	Mean number	Mean % volume	Mean prey size (mm)	Freq. of occurrence
Hydromedusae				
Calycophoran siphonophore	0.02	0.061	4.00	0.020
Physonectid siphonophore	1.56	1.768	21.67	0.100
Gastropoda				
Carinaria japonica	0.04	2.439	70.00	0.040
Isopoda				
Unid. sp.	—	0.030	2.00	0.020
Gammaridea				
Unid. sp.	0.14	0.152	—	0.060
Caprellidea				
Unid. sp.	—	0.061	—	0.020
Hyperiidae				
Unid. sp.	0.10	0.640	6.25	0.080
Vibilliadae	1.56	1.280	4.00	0.100
Euphausiacea				
Unid. sp.	11.72	39.268	10.00	0.380
Decapoda				
Glaucothoe larvae	0.16	3.049	9.00	0.020
Thaliacea				
Unid. sp.	8.60	46.341	57.50	0.420
Fish				
Unid. sp.	0.40	4.695	80.00	0.060
Unid. larvae	0.06	0.152	25.00	0.020
Agonidae	0.02	0.061	19.00	0.020

DISCUSSION

The four major groups—salps, euphausiids, sergestid shrimp, and myctophids—include mostly species reported to be strong vertical migrators (salps - Harbison and Campenot 1979, Wiebe et al. 1979; euphausiids - Brinton 1967; *Sergestes similis* - Pearcy and Forss 1966b; myctophids - Pearcy 1964, Pearcy and Laurs 1966, Paxton 1967). These species comprise the major components of what has been labeled the deep sounding layer. So the principal prey species of the widow rockfish are those that migrate up toward the surface (upper 100 m) during the night and back down into deeper water (400 m) during the day. This means that the widow rockfish is feeding in the upper levels of the water column at night or in deeper water during the day. The commercial fishery operates predominantly at night and makes large, relatively pure catches of widow rockfish exclusively at depths greater than 100 m (Demory 1987; Quirollo 1987; Tagart 1987). There is also evidence that widow rockfish disperse around sunrise and reform during nighttime (Gunderson et al. 1981). These catches from large, tight nocturnal aggregations rule out feeding in the upper levels during the day and indicate that these fishes are feeding either at deeper depths predominantly during the day or crepuscularly on the deep sounding layer during its ascent or descent. The bulk of the stomach samples come from the spring quarter, and this interpretation may be somewhat limited by seasonal feeding patterns. Gunderson et al. (1980) examined a limited number of stomach samples of widow rockfish from nighttime tows when the fish are in schools. They concluded that their data indicated little night feeding by widow rockfish was occurring and that most prey were captured during diurnal periods.

There are major differences in the seasonal diets of widow rockfish, while there is little seasonal variation in abundance of the prey species in plankton collections (Pearcy et al. 1977). Most prey items are at their greatest abundance during the April-June quarter, which is the most intense feeding period. This period directly follows the release of the young larval fish by the adult widow rockfish, at which time fat reserves are traditionally low. Over the range of fish sizes available here, there are some significant changes in diet. Euphausiids are gradually replaced by fish in the diet. This, plus a general increase in size in all diet categories, results in an increase in average prey size with increasing fish size. The results from the geographical data are confounded with the effects of commercial and sport-caught fish. The results are intriguing, but sampling sizes are too small to be reliable.

Most species of rockfish have apparent defense structures, such as strong head spines and large dorsal fins, and live on and/or near-bottom (Phillips 1957). However, the widow rockfish is a member of a group of rockfish species, including most commercially and sport-caught species, which have evolved a streamlined body shape with reduced head spines and a smaller dorsal fin for living high in the water column. This smoother, more fusiform shape plus a smaller head (32.8% of standard length), smaller mouth (13.6%), and a smaller orbit diameter (7.9%), characterize the widow rockfish's unique morphology (Phillips 1957). The other rockfish species which is the most similar (streamlined body, small mouth, eyes and head) is the blue rockfish, *Sebastes mystinus*. This species is traditionally the most important component of the partyboat and skin-diving fishery in central California. The blue rockfish is a near-shore species which is active during the daytime and hides among rocks and algae at night (Ebeling and Bray 1976). The diet of the blue rockfish is also similar to that of the widow rockfish. The principal components are gelatinous plankton (tunicates and scyphozoids), crustaceans (amphipods), and fish (Gotshall et al. 1965). The similarities in morphology and diet of these two species suggests strong parallel forces are important in their evolution.

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Results of an Investigation of Widow Rockfish *Sebastes entomelas* Behavior

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ABSTRACT

The behavior of widow rockfish (*Sebastes entomelas*) relative to its environment and fishing gear was investigated in order to provide researchers better information on how to best approach the task of assessing the size of the resource. The rapid development of the fishery and lack of information on the species' biology concerned the resource managers responsible for assuring continued production from the resource. Highly vulnerable schools of widow rockfish form at night, making large catches possible with minimal effort. When the dense schools disperse at dawn, the fish are undetectable and fishing usually ceases. Traditional survey methods were inadequate to assess population size due to the species' contagious, midwater distribution at night. From a statistical viewpoint, the best time to sample is when the species is dispersed. In order to establish whether widow rockfish are susceptible to sampling when the schools are dispersed, a grid of bottom trawl stations surrounding a seamount known to attract widow rockfish aggregations was sampled in August 1980 during both daylight and darkness. Sampling was repeated during April 1981. Widow rockfish catches were extremely small during both daylight and darkness, and there was some indication that the fish stayed closer to the seamount during the night than during the day. Hydroacoustic measurement of detectable schools seemed to be the appropriate survey method. Widow rockfish aggregations were found to be distinguishable from concentrations of other fish species using hydroacoustic observations of fish aggregations during the survey and aboard commercial trawlers, substantiated by trawl sampling of the aggregations. It was possible to generalize a typical pattern of school formation and dispersal which indicated that the best time to detect and measure the population was at night. Since widow rockfish seem to inhabit only a few small, well-defined areas along the coast, concentrated hydroacoustic sampling with midwater trawling is more feasible for assessing this resource than for most other groundfish species. A survey design should incorporate replicate sampling because of the variability seen in the location and abundance of widow rockfish aggregations between consecutive nights.

INTRODUCTION

The widow rockfish (*Sebastes entomelas*) fishery along the Washington, Oregon, and California coast began in 1978 and its rapid growth over the following years caused serious concern to resource managers. Little was known about the habits and biology of the species (Hitz 1962; Phillips 1964) and even less was known about the size and distribution of the resource. This paper will describe a study undertaken by the Resource Assessment and Conservation Engineering (RACE) Division of the Northwest and Alaska Fisheries Center (NWAFC) which was designed to gather information on the behavior and schooling characteristics of widow rockfish.

The nature of the fishery as it developed made it apparent that the behavior of widow rockfish differed substantially from that of other commercially important species of the genus *Sebastes*. Extremely large catches of this species were taken by midwater trawlers operating almost exclusively during hours of darkness and fishing on very dense midwater schools, or groups of schools, which appeared in only a few small areas along the coast. The tools available to biologists for assessing stock size were judged inadequate given the tight, contagious, midwater distribution of the resource. A new method to survey the resource was needed.

The first phase of the project was a study of the behavior and habits of widow rockfish using demersal and midwater trawling and hydroacoustic observations to determine the distribution patterns of the species. This included determining where the fish go when the dense, nighttime midwater schools disperse; whether there are components of the stock other than the typical midwater aggregations; and at what period in their daily cycle their availability is most stable. Other objectives were to study the possible causes of their diel aggregation habits and to develop an ability to distinguish widow rockfish schools from those of other species on the basis of echosign characteristics and test fishing. Echosign can be defined as the echo return output (paper echograms, video ''chromoscope'' displays, etc.) of an echosounder aimed at targets in the water column.

METHODS

To observe widow rockfish schooling behavior and to collect information on biological characteristics which might influence the growth and dispersal of schools (e.g., food habits and reproductive cycles), a brief survey was performed 11-13 August 1980 by the chartered trawlers *Pat San Marie* and *Mary Lou*. In addition, the NOAA ship *Miller Freeman* concurrently transected the study area with a conventional echo integration survey and made four midwater tows to identify the species composition of the schools sighted. The survey was repeated during 10-26 April 1981 by the NOAA ship *Chapman* and included 7 days of hydroacoustic/sonar observations (Thomas et al. 1981). A description of the vessels and trawls employed appears in Table 1.

Demersal trawl stations were located in the vicinity of a seabed rise known as Nelson Island, off Newport, Oregon, to determine if significant quantities of widow rockfish occurred on or near the bottom in an area where they were known to form dense midwater aggregations. A 4×4 station grid with interstation distances of 2.5 nmi (4.6 km) (Fig. 1) was established between the depths of 110 m and 360 m with the rise at the center. Two trawl hauls were attempted at each station: One during daylight and one during darkness. When significant midwater fish schools were observed, they were sampled with midwater trawl gear for species composition.

Table 1—Vessels and fishing gear used during studies of widow rockfish behavior by the Northwest and Alaska Fisheries Center.

Vessel	Survey type	Dates	Length (m)	Main engine horsepower	Trawl type	Approximate fishing dimensions
Pat San Marie	Behavior	11-13 Aug 1980	31	765	Nor'eastern[1] (bottom)	9.1 m vertical 13.4 m horizontal
Mary Lou	Behavior	11-13 Aug 1980	26	700	Nor'eastern[1]	
Miller Freeman	Behavior and hydroacoustic	11-13 Aug 1980	66	2,200	Norsenet (midwater)	9.1 m vertical 13.4 m horizontal
Chapman	Behavior and sonar/ hydroacoustic	7-26 Apr 1981	39	1,165	Nor'eastern[2]	6.1 m vertical 16.7 m horizontal
					Alaska Diamond (midwater)	12.8 m vertical 15.2 m horizontal

[1]fished with 1.5 × 2.1 m steel V-doors
[2]fished with 1.8 × 2.7 m steel V-doors

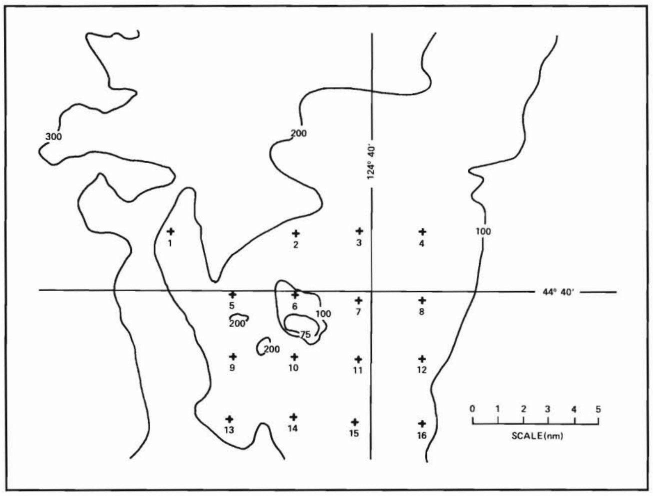

Figure 1—Demersal trawl station grid occupied during 1980 and 1981 widow rockfish behavior studies on the Nelson Island ground off Newport, Oregon.

The contents of each trawl haul were sorted by species, weighed, counted, and recorded. Otoliths were removed from samples selected for age determination, and stage of maturity was recorded for some individuals. Stomach sample collections, stratified by fish length, were also taken and preserved for food habit analyses (Adams 1987). Since few specimens were caught in these demersal hauls, biological data were too sparse to provide a meaningful description of age and length compositions.

Additional information about widow rockfish behavior and distribution was gained through observations of school activity on and around widow rockfish fishing grounds. Consultation with commercial fishermen, observation trips aboard commercial trawlers, study of echograms and corresponding catch records, and observations during research operations provided information about school characteristics and diel behavior patterns of widow rockfish and other species on the fishing grounds.

RESULTS

Twenty-seven demersal tows were completed during the August 1980 widow rockfish behavior study, including 12 at night and 15 during the day. The trawl was damaged during two night hauls. The widow rockfish catch was small, with 1 or 2 specimens in six hauls and 20 specimens in one night haul during which the trawl was damaged (Fig. 2A). The small number of widow rockfish captured during the 1980 study make any conclusions about diel movement patterns highly conjectural.

The *Miller Freeman* transected the Nelson Island area during the same study period and found one school of widow rockfish which was sampled with midwater trawl gear (Fig. 3). It was not possible to stay in contact with the school long enough to observe diel changes in behavior.

When the study was repeated in April 1981, only 4 of 20 demersal tows contained widow rockfish. Two of these tows contained only a single specimen each, while the others contained 20 and 28 specimens. Results again indicated that widow rockfish are relatively unavailable to demersal trawl gear and that their distribution was somewhat more closely associated with Nelson Island during the night than during the day (Fig. 2B).

To draw conclusions about their behavior, distribution, and abundance, it is important to be able to distinguish widow rockfish from other species on the basis of echosign. Commercial fishermen targeting on this species have shown that this can be done. We have begun to characterize the echosign produced by widow rockfish, and other species occurring on widow rockfish grounds, using echograms obtained aboard research and commercial vessels, and through discussions with commercial fishermen on echograms and corresponding catches. Widow rockfish schools most frequently appeared on echograms as tall, slender columns suspended over an irregular bottom (Fig. 4). These are often accompanied by less dense layers composed of salps and other zooplankton. Sometimes in evening and morning hours, somewhat smaller schools were observed relatively high in the water column (Fig. 5). Species which have similar echosign characteristics and are most likely to be confused with widow rockfish off the Oregon coast are shortbelly rockfish (*Sebastes jordani*) and redstripe rockfish (*S. proriger*) (Figs. 6, 7). Other detectable midwater targets in the area were identified as layered schools of Pacific whiting (*Merluccius productus*) (Fig. 7) or less dense layers of zooplankton.

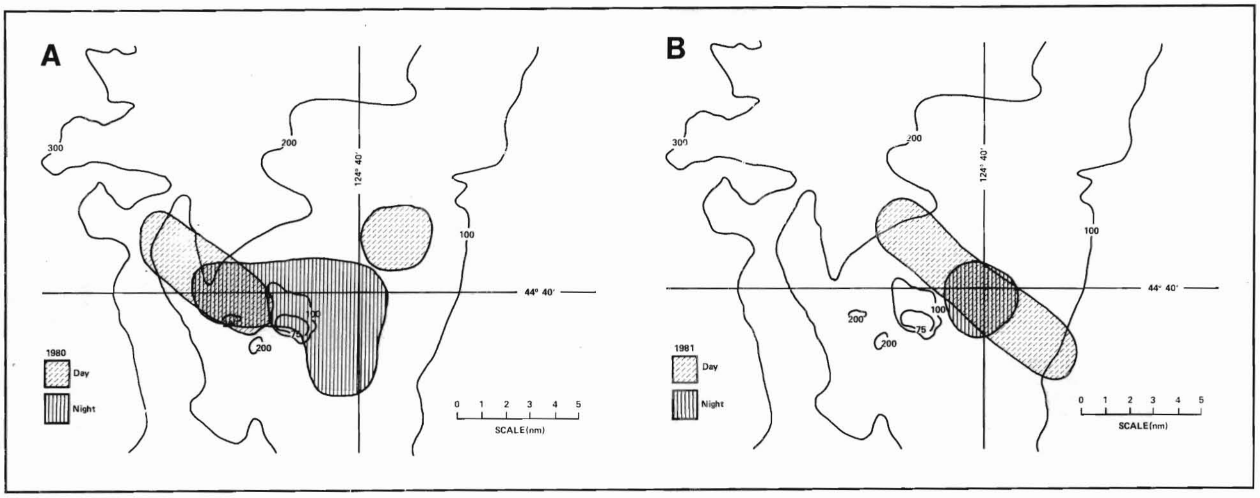

Figure 2—Distribution of demersal tows which contained widow rockfish during day (light shading) and night (dark shading) sampling of the 1980 (A) and 1981 (B) behavior studies.

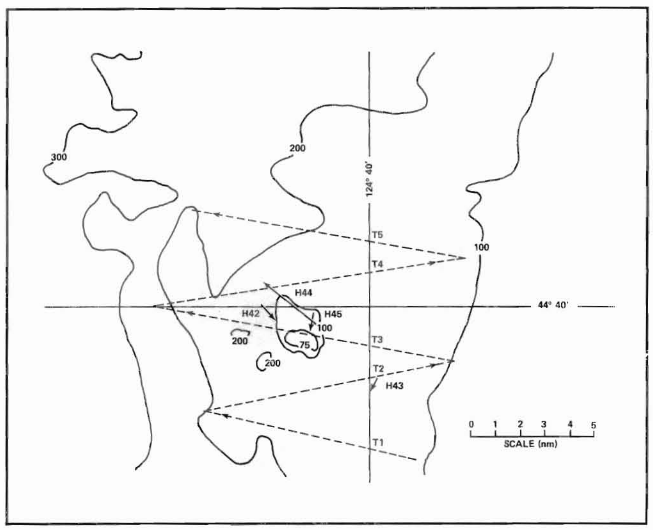

Figure 3—Hydroacoustic transects (dashed lines) and midwater trawl hauls (solid arrows) conducted by the NOAA ship *Miller Freeman* during the 1980 behavior study.

The formation and dispersal of widow rockfish aggregations were observed during the research cruises. During a typical night, small schools would usually appear in late evening (2000-2400) either near bottom or relatively high in the water column. As the night progressed, these schools tended to grow and those high in the water would often settle toward the bottom. Peak school size and density occurred usually between 0200 and dawn. Shortly after daybreak most schools would separate into smaller schools and rise off the bottom. In some instances the schools would move over deeper water while maintaining their nighttime configuration.

Departures from the typical behavior patterns have been reported. While observing widow rockfish schools over the continental shelf (not aggregating around a seamount) Gunderson et al. (1981) noted a progressive offshore shift in the location of the schools over the course of one night. By sunrise most of the schools were located near the edge of the shelf. Most of these schools dispersed after dawn but some remained on the bottom in the area (in one case as late as 1037 hours when observations were terminated). This apparent shift may have been depth-related behavior modified by bottom depth which gave the appearance of offshore movement (Pereyra et al. 1969).

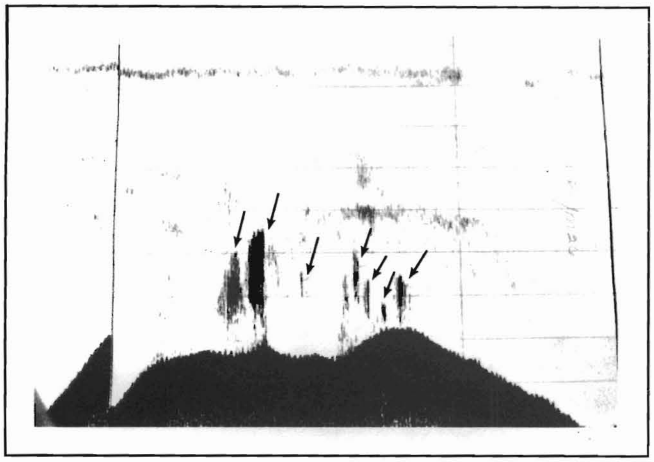

Figure 4—Echogram showing the typical columnar configuration of widow rockfish schools (arrows).

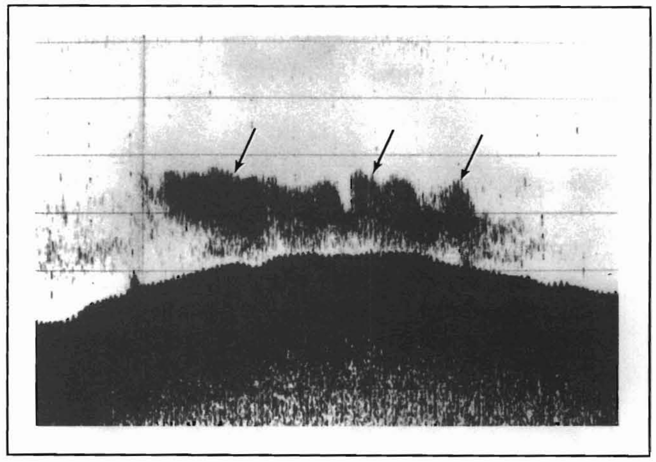

Figure 6—Echogram showing the typical configuration of shortbelly rockfish schools appearing as a thick blanket near the bottom.

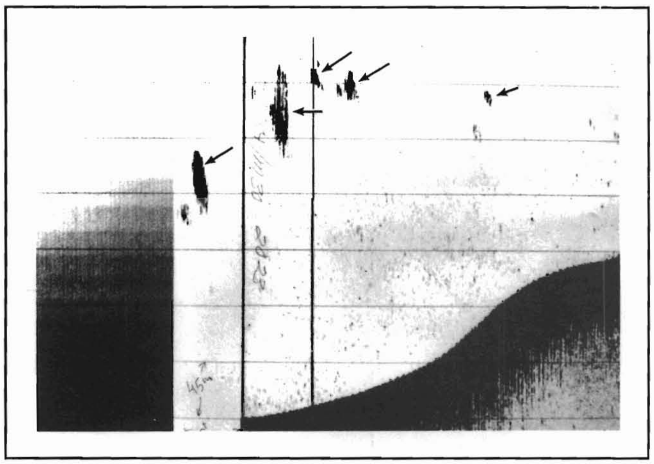

Figure 5—Echogram showing the configuration of "evening/morning" widow rockfish schools which occur high in the water column (arrows).

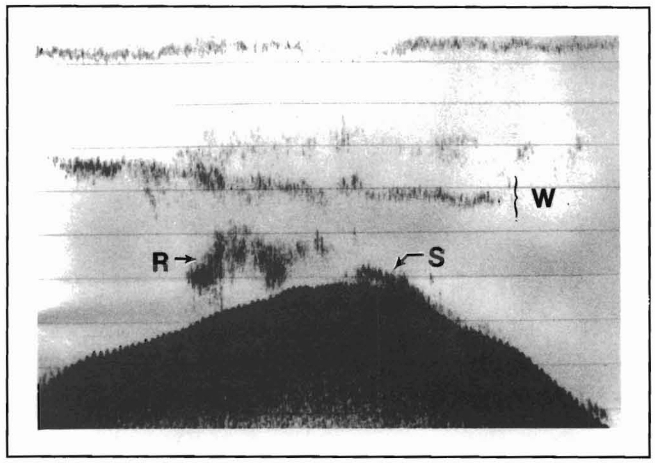

Figure 7—Echogram showing the typical layered configuration of Pacific whiting schools (W), redstripe rockfish appearing slightly above bottom (R), and shortbelly rockfish as a thick blanket near the bottom (S).

DISCUSSION

The objective of this project was to study the habits and schooling characteristics of widow rockfish well enough to provide a base to design effective surveys. Bottom trawl catches during the 1980 and 1981 surveys indicate that this species is relatively unavailable to bottom trawls in an area where widow rockfish are known to aggregate at night.[1] Consequently, when midwater schools disappear during the day, it is unlikely that they disperse along the bottom. In recent years, skippers of midwater trawlers have commented that widow rockfish have become more evasive and dive below their nets to avoid capture. Some skippers have taken advantage of this behavior by purposely driving the schools toward the bottom where they can be captured with bottom trawls equipped with roller gear. Although these are classified as bottom trawl landings, the fishermen are, in a sense, actually capturing midwater schools. Some fishermen have reported encountering daytime aggregations of this species over the continental slope in waters deeper than they are usually found at night (>500 m).

Another consideration in the design of any survey of widow rockfish concerns the proportion of the stock which is detectable in schools at any given time. Even when schools are most abundant, an unknown proportion of the stock may be undetectable because of the dynamic and transitory nature of school behavior. Clark and Mangel (1979) proposed a study of rates of school formation and dispersal to evaluate a similar relationship between overall stock size and the proportion of the stock occurring as schools in the yellowfin tuna seine fishery. Such a technique should receive further consideration, but present low school abundance (schools/km^2) and lack of definite patterns of school formation and dispersal would probably make its application in widow rockfish assessment very difficult.

[1]Observations of midwater echosign and landing information from commercial vessels fishing in the area confirmed that the usual dense nighttime midwater widow rockfish aggregations were present in the area during the 1981 bottom trawl survey.

Through these surveys and consultations with commercial fishermen, our ability to correctly identify widow rockfish echosign has been improved. The ability to identify the species composition of a school on the basis of echosign remains an art and depends heavily on field experience. The accuracy of species identifications varies depending on the nature of the species complex in the survey area. Where shortbelly and redstripe rockfish are present, the potential for misidentification increases. Technological improvements in sonar equipment may help to reduce this problem. The density of a school is an important criterion for distinguishing widow rockfish from other species. Newer sonar equipment includes density-graded color video displays similar to an echosounder "chromoscope" rather than the "radar" type CRT screeen employed by the system we used. Other techniques, such as underwater photography or remote video camera vehicles, might also prove to be valuable tools for species identification. Even with the best of technologies, however, I believe that test fishing will always be a necessary component of remote detection resource assessment surveys.

The general diel behavior of this species (schooling at night and dispersing or moving during the early morning hours) indicates that the most effective sampling period is at night. Observations during these surveys showed that the location, number, size, and formation of widow rockfish schools are constantly and unpredictably changing during the night. Observations from hydroacoustic transects, which were replicated on several nights, show that longer-term variability in abundance (e.g., night-to-night or week-to-week) is even more marked than over a shorter time (Thomas et al. 1981). These results are substantiated by other surveys (Gunderson et al. 1980, 1981) and illustrate that the magnitude of the distributional variability inherent in widow rockfish populations contributes to the difficulty of estimating their abundance.

The fishery has expanded over a broad area from central California to northern Washington as catches declined in originally exploited areas. Consequently most areas containing fishable concentrations of the species have probably been identified. There are a limited number of these grounds (probably 12-20); nearly all of them are characterized by ridges or rises on the outer continental shelf or upper slope and are relatively small in area. Concentrated sampling of widow rockfish, therefore, is more feasible than for most other groundfish species inhabiting less well-defined and expansive areas. The dynamic behavior of widow rockfish schools suggests that the survey method should cover large areas in a relatively short time in order to survey a given fishing ground at least once during a night. Because of day-to-day variability, any survey should include sampling each area during several nights over a 1- or 2-week period.

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Commercial Passenger Fishing Vessel Landings of Widow Rockfish *Sebastes entomelas* in Central California

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ABSTRACT

Commercial fishing for widow rockfish (*Sebastes entomelas*) has increased significantly in northern and central California since the summer of 1981. In central California, widow rockfish are also found in commercial passenger fishing vessel landings. For this reason, the importance of widow rockfish to the central California recreational partyboat fishery was investigated during a three-year study period from 1977 to 1979. Landings of widow rockfish by the recreational partyboat fishery were minor. Only 3.7% of the catch per unit of angling effort were widow rockfish. The catch of widow rockfish was greatest in northern ports and on trips taken during winter months. This rockfish may have been the target species of some winter recreational partyboat trips at San Francisco and Bodega Bay.

INTRODUCTION

Rockfish fishing by commercial passenger fishing vessels (CPFV) and commercial trawl vessels is highly developed in some areas of northern and central California. Landings of rockfish by the commercial trawl fishery have been increasing since 1977, and projections indicate that they will continue to do so (Pac. Fish. Manage. Council 1981). Increased markets as well as the ability of commercial fishermen to target on one species, widow rockfish (*Sebastes entomelas*), have contributed significantly to these landings. Concurrently, the increasing proportion of rockfish (genus *Sebastes*) in the CPFV catch is projected to be a trend in the recreational partyboat landings of central California for the next ten years (Gruen and Gruen 1979). Potential exists, therefore, for competition between the recreational partyboat and commercial trawl fisheries for the available resource. This paper presents analyses of the CPFV rockfish fishery, the relative importance of widow rockfish to this fishery, and the estimated effect upon the recreational partyboat catch in the event of a significantly reduced widow rockfish stock.

Very few data are available from the complex recreational and commercial fisheries for rockfish of central California. These fisheries are complex due to their multispecies nature, the fact that landing and catch-per-unit-effort statistics do not specify species, and sampled landings traditionally have not included age and sex composition. Because of this lack of necessary data, the Tiburon Laboratory of the National Marine Fisheries Service and the California Department of Fish and Game have been cooperating since 1977 in a program to routinely sample both recreational and commercial landings for species, sex, length, and age composition. Presented here is an analysis of the central California CPFV fishery sample data obtained during a three-year study period from 1977 to 1979. Also presented, for comparison, are expanded sample data from the central and northern California commercial trawl fishery for the same period. Because a change in the widow rockfish fishery occurred during 1981, preliminary data for that year are also reviewed.

METHODS

Sampling was concentrated on rockfishing trips around the major ports of Monterey, Half Moon Bay, San Francisco, Bodega Bay, Fort Bragg, and Eureka. There were, however, virtually no CPFV landings of rockfish north of Bodega Bay. Sampling effort averaged 290 samples per year; each sample consisted of from one to four clusters. Fish traditionally were landed whole and placed in burlap bags. The fish in a bag often were the combined catches of several anglers and there was little possibility of telling which fish were caught by a particular angler. Tomlinson's (1977) recommended sampling frame used, therefore, not the more traditional angler but the burlap bag as the sampling unit.

Catch data were obtained from interviews of a random sample of anglers for each sampled trip. A principal assumption during the interview was that the content of each bag was the catch of one angler. However, since more than one angler may contribute to one bag, estimates of catch per angler may be positively biased. Biological data, including species, sex, length, and otoliths, were collected in the field. Age determinations were made later at the Tiburon Laboratory.

Expansion of sample data to the total catch, as depicted in each table, was completed at the Tiburon Laboratory, using the Lawrence Berkeley Laboratory CDC 7600, by the method indicated below:

$$\widehat{YR} = \hat{A}\ \widehat{YR}$$

where $\widehat{YR}$ = estimated total number of fish captured (species-sex-length-age) derived from total trips and mean number of anglers per trip.

$$\hat{A} = N\bar{a}$$

where $\hat{A}$ = estimated total rockfish anglers,
N = total number of rockfish trips,
$\bar{a}$ = mean number of anglers per sampled trip,

$$\widehat{YR} = \sum_{i=1}^{n} (y_i/l_i)L_i / \sum_{i=1}^{n} A_i$$

where $\widehat{YR}$ = mean number of fish (species-sex-length-age) captured per angler,
n = sampled trips,
A_i = anglers per trip i,
y_i = fish (species-sex-length-age) sampled per trip i,
l_i = total fish sampled per trip i,

$$L_i = (\sum_{j=1}^{m_i} l_{i,j})A_i/m_i$$

where L_i = total fish captured per trip i,
$l_{i,j}$ = catch for jth bag ith trip,
m_i = number bags examined during interview (assumed equal to number of anglers interviewed) per trip i.

All variables were derived from sampled data with the exception of N which is summary information provided by California Department of Fish and Game CPFV logs. Mean catch per sample unit $\left[(\sum_{j=1}^{m_i} l_{i,j})/m_i\right]$ data were insufficient to conduct within-trip expansion of the 1977 sample data. Estimates of average $l_{i,j}$ from 1978 and 1979 were substituted, therefore, to provide total fish number expansion values presented in Tables 1 and 2.

RESULTS AND DISCUSSION

Species composition

The estimated number of rockfish landed by the CPFV and commercial trawl fisheries during 1977-79 in northern and central California ports totaled 13,310,187. Rockfish landings from CPFV accounted for 30.5% of this total (Table 1). An estimated 244,511 widow rockfish also were landed by both gear types, of which the CPFV fishery contributed 50.7%. There was no evidence, at the time of this study, of a clear gear-type dominance in the number of widow rockfish landed. Subsequent to this study, a large expansion of the northern and central California commercial trawl fishery occurred. During 1981, the first year of the expanded fishery, the annual number of widow rockfish landed by the commercial trawl fishery increased by a factor of 35. Preliminary data do not indicate that there was a comparable expansion of the CPFV fishery. Thus the relative importance of the partyboat fishery in landings of all rockfish and widow rockfish probably has declined since 1979.

The CPFV fishery landed more rockfish in the second and third quarters than during the other quarters (Table 2). Both the number of trips and anglers were also higher during the two middle quarters (Table 3). However, when compared to the two middle quarters, fishing success was considerably higher for widow rockfish and all rockfish combined during the first and fourth quarter (Table 3). Thus the relatively high landing of fish during the middle quarters was due to high fishing effort, not high fishing success.

While the largest percentage of rockfish partyboat trips, rockfish anglers (Table 5), and all rockfish landed by the CPFV fishery (Table 4) occurred in the port of Monterey, the largest contribution by widow rockfish to the catch-per-unit of sampling effort was made in the northern ports of San Francisco and Bodega Bay (Table 5). Widow rockfish contributed 4 percent to this annual catch and 7 percent during the first and fourth quarter in the northern ports. When widow rockfish did appear in the catch of trips taken from the northern ports, they appeared in relatively large concentrations. The mean percent of widows in the catch-per-bag, for those trips with any widows in the catch, was 19% for the first and fourth quarter. Furthermore, when all trips are considered, widow rockfish were important to the success of certain trips taken during the first and fourth quarter and from the northern ports of San Francisco and Bodega Bay. During the last quarter of the year, the catch for over 12% of the trips was more than 25% widow rockfish, and in 5 percent of the trips widow rockfish comprised at least 45% of the total catch.

Age composition

A comparison of data between sample years 1978 and 1979 indicates a noticeable increase in landings of younger widow rockfish (Fig. 1). An estimated 26% of the widow rockfish landed during 1978 were less than 9 years old, and 7 percent were 4 years and younger. In 1979, landings of widow rockfish less than 9 years old increased to 53%, and those less than 4 years increased to 22%. Widow rockfish first became vulnerable to the CPFV fishery at the age of 4 and 2 years during 1978 and 1979, respectively.

Full recruitment is traditionally defined as that point in the catch curve closest to the modal age (Ricker 1975). The first ages at which recruitment could be considered complete for widow rockfish captured by the CPFV fishery were 10 years-old in 1978 and 4 or 5 years-old in 1979. By comparison, the northern and central California commercial fishery during the same sampling period typically had modal ages for widow rockfish of 9 and 10 (W. H. Lenarz, Tiburon Lab., Natl. Mar. Fish. Serv., NOAA, Tiburon, CA, pers. commun.). Therefore, it appears widow rockfish may be fully recruited to the recreational partyboat fishery 5 years earlier than to the commercial fishery during periods of influx by a strong year-class. Other than during such times, the data indicate that both fisheries tend to rely upon the same year-classes.

Table 1—Comparison of the estimated number of all rockfish and widow rockfish, *Sebastes entomelas*, landed by the commercial passenger fishing vessel (CPFV) and commercial trawler rockfish fisheries at Monterey, Half Moon Bay, San Francisco, and Bodega Bay, CA.

	CPFV		Commercial trawler	
Year	All rockfish	Widow rockfish	All rockfish	Widow rockfish
1977	1,488,939	67,796	2,574,463	9,817
1978	1,269,921	20,506	2,519,546	39,673
1979	1,298,904	35,764	4,158,414	70,955
1981[1]			5,487,582	1,403,020

[1]First year of widow rockfish fishery expansion into study area.

Table 2—Quarterly landings at Monterey, Half Moon Bay, San Francisco, and Bodega Bay, CA, of widow rockfish, *Sebastes entomelas*, and all rockfish, by the commercial passenger fishing vessel (CPFV) and commercial trawler rockfish fisheries, 1977-79 and 1981.

	CPFV 1977-79	
Quarter	All rockfish	Widow rockfish
1	177,280	6,228
2	340,547	5,820
3	517,936	9,262
4	248,651	6,826

	Commercial trawler			
	1977-79		1981	
Quarter	All rockfish	Widow rockfish	All rockfish	Widow rockfish
1	655,738	35,086	834,094	98,604
2	946,250	1,356	866,825	8,572
3	752,484	18,366	1,426,128	122,832
4	984,510	507	2,360,535	1,173,012

Table 3—Estimates derived from expanded sample data of fishing effort by quarter for commercial passenger fishing vessels (CPFV) at Monterey, Half Moon Bay, San Francisco, and Bodega Bay, CA, 1977-79.

	Percent		Catch per bag	
Quarter	Boat trips	Angler days	All rockfish	Widow rockfish
1	14.9	14.7	15.0	0.52
2	27.0	26.1	11.5	0.23
3	35.7	39.7	12.2	0.30
4	22.5	19.6	13.7	0.89

Table 4—Estimates derived from expanded sample data of percentage of all rockfish and widow rockfish landed in N. Calif. by area, commercial passenger fishing vessel (CPFV), and commercial trawler rockfish fisheries.

	CPFV 1977-79	
Port	All rockfish	Widow rockfish
Monterey	43.3	20.9
Half Moon Bay	23.7	14.5
San Francisco and Bodega Bay	32.7	64.6

	Commercial trawler			
	1977-79		1981	
Port	All rockfish	Widow rockfish	All rockfish	Widow rockfish
Monterey	55.3	45.8	31.4	9.9
Half Moon Bay	2.5	2.2	0.2	0.1
San Francisco and Bodega Bay	42.2	52.0	68.4	90.0

Table 5—Estimates derived from expanded sample data of fishing effort by area for commercial passenger fishing vessel rockfish fishery during 1978 and 1979.

	Percent		Catch per bag	
Area	Boat trips	Angler days	All rockfish	Widow rockfish
Monterey	44.0	48.6	13.9	0.1
Half Moon Bay	30.6	24.4	11.2	0.4
San Francisco and Bodega Bay	25.4	27.0	14.4	0.7

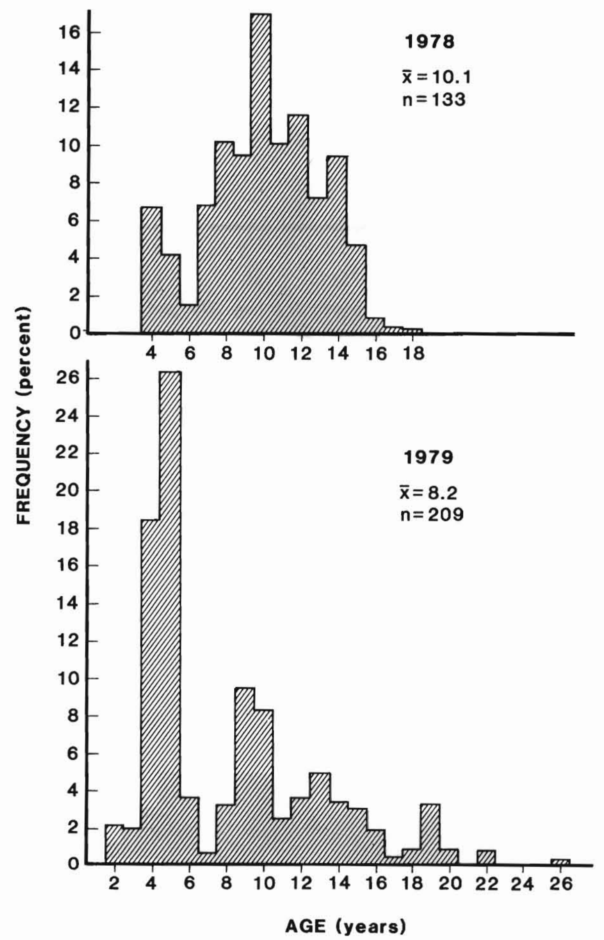

Figure 1—Age composition of widow rockfish, *Sebastes entomelas*, from 1978 and 1979 commercial passenger fishing vessel samples expanded to total landings for Monterey, Half Moon Bay, San Francisco, and Bodega Bay. Mean age ($\bar{x}$) and number of specimens sampled (n) indicated.

CONCLUSION

Widow rockfish is not an important species in the total landings of the CPFV rockfish fishery in central California. A depletion of widow rockfish stocks would decrease the annual catch of a CPFV angler by less than one-half a fish. Widow rockfish stock depletion would, however, noticeably reduce the CPFV catch in the northern ports, especially during the fourth quarter. The high percentage of widow rockfish landed on some trips taken out of Bodega Bay and San Francisco during the last quarter suggests fishermen were targeting on widow rockfish. A reduction in widow rockfish availability may then necessitate a change in CPFV fishing tactics in northern ports during portions of a year.

The results of this study suggest that monitoring the CPFV fishery age-catch data would be useful in indicating the presence of a strong year-class of widow rockfish 4-5 years prior to its full recruitment by the commercial trawl fishery. They would provide evidence for projections of widow stock strength or weakness.

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Widow Rockfish Fishery

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ABSTRACT

Widow rockfish (*Sebastes entomelas*) was the most important West Coast groundfish species in 1980. Prior to 1978, fishermen sold only limited amounts never exceeding 1,000 MT. This paper predicts that sold landings of widow rockfish will expand to 25,000 MT and account for one-fourth of domestic landings by 1983. The possible reason why widow rockfish were not widely sold prior to 1979, why this fishery has developed and what may occur after 1983 are also discussed.

INTRODUCTION

In 1980 widow rockfish (*Sebastes entomelas*) accounted for 20,000 mt or 45 percent of the estimated 44,000 mt of rockfish landed on the West Coast. Widow rockfish in 1980 was the most important commercial groundfish species, with catches amounting to 22 percent of the 90,000 mt total landings. The current importance of the widow rockfish fishery is surprising since landings had never exceeded 1,000 mt prior to 1978. This paper discusses possible reasons for the lack of earlier development, the current rapid development, and the future of widow rockfish.

ROCKFISH FISHERY

Rockfish, *Sebastolobus* sp. and *Sebastes* sp., have been part of the domestic groundfish fishery off California, Oregon, and Washington since 1876 (Scofield 1948). Domestic and foreign retained catches of rockfish are given in Table 1. Domestic landings from 1962 to 1975 were fairly constant, averaging 9,800 mt, but the fishery started to expand rapidly in 1976 and landings increased to 44,000 mt in 1980. Estimated foreign catches of rockfish were 44,000 mt in 1967. Following this and other large removals in the late 1960's, an agreement was reached between the United States and the Soviet Union, Japan, and Poland. These international agreements prohibited directed foreign fishing for rockfish, and since the enactment of the Fishery Conservation and Management Act of 1976, both regulation and reduction in foreign fishing have resulted in foreign landings below 1,000 mt.

Increases in domestic landings were caused by changes in the market for fresh rockfish, as well as changes in fishing technology. A major market change was the commencement of sales of rockfish fillets to areas other than the West Coast. Changes in fishing technology have been occurring for years and include high rise nets in 1943 (Scofield 1948), roller gear improvements in 1964 (J. Robinson, Ore. Dep. Fish. Wildl., Newport, OR, pers. commun. 1980) and 1970 (Fisher 1972), single-vessel midwater trawl in 1967

Table 1—U.S. and foreign retained catches of rockfish from California, Oregon, and Washington, 1962-80.

Year	Domestic (1000 mt)	Yearly changes (%)	Foreign (1000 mt)	Total (1000 mt)
1962	12.3	—	—	12.3
1963	12.2	+01	—	12.2
1964	11.2	−08	—	11.2
1965	13.4	+20	—	13.4
1966	10.0	−25	—	10.0
1967	7.0	−30	44.0	51.0
1968	7.5	+07	20.0	27.5
1969	8.2	+09	3.0	11.2
1970	7.5	−09	3.0	10.5
1971	7.5	±00	2.0	9.5
1972	9.2	+23	4.0	13.2
1973	10.5	+14	11.0	21.5
1974	9.5	−10	10.0	19.5
1975	11.3	+19	8.0	19.3
1976	15.6	+38	5.0	20.6
1977	18.2	+17	+	18.3
1978	25.5	+40	+	25.6
1979	27.4	+07	1.0	28.4
1980	44.0	+61	1.0	45.0

Source: Anonymous 1980.

(Pereyra and Richards 1970), and advances in electronics which have greatly enhanced detection of fish and precise determination of vessel position.

The expanding rockfish fillet market from 1976 through 1978 stimulated greater landings of traditional rockfish; however, these landings were not sufficient to supply both the old and new markets. This shortfall in supply was a factor in causing the real (deflated) ex-vessel price of rockfish to increase (Table 2). Between 1972 and 1979 the ex-vessel value of rockfish averaged about 32 percent of the total ex-vessel value of the groundfish fishery. The 1980 estimate of the ex-vessel rockfish value accounted for about half of the ex-vessel groundfish fishery value, even though other groundfish landings have also increased. This large increase in rockfish value was due to increases in both landings and ex-vessel prices. The real ex-vessel price had increased about 2 percent per year from $0.12/kg in 1962 to $0.21/kg in 1977. In 1978 the real ex-vessel price reached a maximum of $0.23/kg.

I believe a number of events contributed to the increase in rockfish landings from 1975 through 1978, including:

1. Increases in real ex-vessel rockfish prices from $0.16/kg in 1975 to $0.23/kg in 1978 (Fishermen's Marketing Assn., Eureka, CA 95501).
2. Enactment of the Fishery Conservation and Management Act, which many fishermen believed excluded foreign fishing.
3. Increased investments in midwater trawlers built for use in other fisheries but which entered the rockfish fishery.
4. Increased expenses of larger vessels which necessitated greater fishing effort.
5. Expanded markets for fresh rockfish fillets.

However, since 1978 prices have declined to $0.13/kg in 1980. This was a 43 percent decline in 2 years.

Table 2—Average real and nominal ex-vessel prices for rockfish, and percentage of total ex-vessel value of groundfish attributed to rockfish.

Year	Nominal (¢/kg)	Real (¢/kg)	CPI[1] 1967=100	Total ex-vessel value rockfish/groundfish Percent
1962	11.2	12.3	91.5	n.a.
1963	11.2	12.1	92.9	n.a.
1964	12.3	13.0	94.7	n.a.
1965	12.3	12.8	95.9	n.a.
1966	12.9	13.2	97.1	n.a.
1967	12.9	12.9	100.0	n.a.
1968	12.3	11.8	104.5	n.a.
1969	13.4	12.1	110.2	n.a.
1970	13.4	12.1	110.2	n.a.
1971	14.6	12.5	115.8	n.a.
1972	16.8	13.4	124.3	32
1973	19.0	14.6	131.5	31
1974	25.8	17.7	144.4	30
1975	25.8	16.1	159.1	29
1976	31.4	18.6	168.0	32
1977	38.7	21.3	180.0	37
1978	41.4	22.6	183.0	33
1979	44.8	22.2	210.7	32
1980	33.6	13.4	251.4	49

Source: Anonymous 1980.

[1]Consumer Price Index for San Francisco, Bureau of Labor Statistics, U.S. Dep. Labor.

WIDOW ROCKFISH

Yellowtail and canary rockfish (*Sebastes flavidus* and *S. pinniger*, respectively) accounted for most increases in rockfish landings in 1976 and 1977. By 1978, widow rockfish, also called brownies, brown bombers, and soft browns, began being landed in large amounts. Although canary and yellowtail rockfish increases were expansions of previously utilized species, widow rockfish had generally been underutilized.

Substantial domestic utilization of widow rockfish did not occur until 1978 because many processors believed that widow rockfish had several negative characteristics, including:

1. Short shelf life of both fresh and frozen products.
2. Excessive loss of fluid after packaging.
3. Loss of color or a gray color.
4. Unusual smell.
5. Softer flesh than other rockfish.
6. Poor quality of defrosted product.
7. Low fillet yield.

These presupposed characteristics generally kept domestic processors from buying widow rockfish, and prior to 1975 landings were under 1,000 mt. Occasionally during the 1960's, processors did purchase widow rockfish but only in late winter or early spring when inventories of other rockfish were low and demand for rockfish fillets high.

In 1978 a few West Coast fishermen and processors began to experiment with better fishing methods, at-sea preservation, and onshore rapid processing of Pacific whiting. At the same time, fishermen and processors began to use these newly developed techniques to catch, preserve, and process widow rockfish with the result that the widow rockfish did not have the negative characteristics many processors had attributed to this species. Once processors and wholesalers realized widow rockfish were marketable in the retail rockfish market, widow rockfish fillets began to be sold in volume with few complaints about quality.

The increased utilization of widow rockfish in 1978 was stimulated by the strong market for rockfish. A record amount of rockfish was sold, 25,000 mt, even though fishermen received a record real ex-vessel price, $0.23/kg. Processors also received record real wholesale prices (Table 3) and fillets accounted for 80 percent of the gross revenue from rockfish (Proctor 1980).

DECLINE IN THE ROCKFISH FISHERY

Landings of most rockfish continued to increase in 1979 and 1980, but prices paid to fishermen and processors declined. I believe the price declined because the supply of rockfish exceeded the demand at the 1978 prices, and lower prices were needed to stimulate the sales of rockfish fillets. Lower prices were first reported for frozen rockfish fillets from October 1978 to March 1979. Processors realized that ex-vessel prices would also have to be lowered to enable them to sell increased supplies. Midwater trawl fishermen believed they could make a profit at a lower ex-vessel price, because they would catch large volumes of widow rockfish and maintain their gross revenues without increasing their costs.

By the winter of 1979-80, the wholesale price for fresh fillets had fallen 50 percent from the summer of 1979, and processors imposed trip limits for rockfish, Dover sole, and other species (Anonymous 1980). By the summer of 1980, the real wholesale price in Los Angeles for rockfish fillets was $0.54/kg, compared

Table 3—Estimated sales of rockfish and Pacific ocean perch (POP)[1] by West Coast processors in 1978.

Product form	Category	Quantity (kg)	Price ($/kg)	Real price (1967) ($/kg)	Round weight (kg)	Conversion[2] factors (%)	Processors' 1978 gross revenue ($)
Fresh whole fish	Rockfish	1,849,633	0.74	0.37	1,849,633	0	1,368,728
	POP	139,835	1.01	0.50	139,835	0	141,233
Fresh fillets	Rockfish	4,835,973	2.62	1.31	17,271,332	28	12,670,249
	POP	1,631,446	2.82	1.41	6,525,784	25	4,600,678
Frozen fillets	Rockfish	224,469	2.82	1.41	801,675	28	502,810
	POP	129,213	2.71	1.36	516,852	25	350,167
Unspecified product	Rockfish	336,044	5.00[3]	2.50	1,680,220	20	1,680,220
	POP	31,768	2.60	1.30	127,072	25	82,596
Total		9,178,381			28,912,403		21,396,681
Actual Commercial Landing					27,557,500[4]		

Source: Proctor (1980). West Coast summaries of common product forms for Dungeness crab, pink shrimp and West Coast groundfish. Pacific Fishery Management Council. Portland, OR.
[1]POP is separated here because of price difference with other rockfish.
[2]Estimated by author after discussion with processors.
[3]Possibly individually-wrapped portions.
[4]Anonymous 1980.

with the 1978 high of $1.63/kg. In the fall of 1980 the wholesale price for rockfish fillets stabilized at about $0.77/kg. Processors, however, could not make a profit at this price while paying fishermen at the contracted ex-vessel price of $0.18/kg. The inability of processors to make a profit is because of the costs associated with factoring fillets. The fillet factoring costs are presented in Table 4 as a general guide to show how ex-vessel prices may affect the processors' selling price.

In 1980 the contracted real ex-vessel price for trawl-caught rockfish was $0.18/kg. Processors needed either to restrict supply and sell at higher wholesale prices, or lower the ex-vessel price. Although some processors restricted landings of rockfish, most lowered the ex-vessel price and by October 1980 the real ex-vessel price for widow rockfish ranged from $0.08 to $0.13/kg. Some Oregon buyers were reported to have paid $0.06/kg, and rumors were everywhere about still lower ex-vessel prices.

One factor contributing to the decline in ex-vessel price was that processors stopped freezing rockfish. Processors sold most rockfish fresh, because wholesale prices for frozen fillets were close to fresh fillet prices, and freezing and inventory costs added substantially to their total processing costs. Inventory costs were high because the prime interest rate was 20 percent.

Another factor thought to have contributed to the lower rockfish price is the higher risk associated with freezing and defrosting widow rockfish fillets. Whereas retailers can successfully freeze surpluses of other types of rockfish, widow rockfish fillets tend to lose quality when defrosted. Hence, retailers consider surpluses of fresh widow rockfish to be a total loss. The poor quality of defrosted widow rockfish fillets could be detrimental to the entire rockfish market if widow rockfish are not specifically labeled as such.

By December 1980, a market equilibrium appeared to exist for widow rockfish among fishermen, processors, wholesalers, and retailers at the real ex-vessel price of $0.13/kg. This ex-vessel price is only one factor in the market equilibrium for widow rockfish fillets. Another important factor is the widow rockfish fillet yield, which is reported to be greater than or equal to other rockfish fillet yields. This yield is between 26 and 34 percent. Therefore, the raw material cost of producing widow rockfish fillets is generally less than that for producing an equal weight of other rockfish fillets.

Table 4—Comparisons of the estimated costs of producing one kilogram of rockfish fillets at five ex-vessel prices, two product yields, and a fixed 15 percent cost for profit and overhead.

	Ex-vessel price (¢/kg) 6		10		12		15		20	
Product Yield (%)	26	34	26	34	26	34	26	34	26	34
a) Raw material cost (¢/kg)	23	18	38	29	46	35	58	44	77	59
b) Filleting costs (¢/kg)	13	13	13	13	13	13	13	13	13	13
c) Packing costs (¢/kg)	37	37	37	37	37	37	37	37	37	37
d) 15% of a,b,c, for overhead (¢/kg)	11	10	13	12	14	13	16	14	19	16
Total cost/fillet (¢/kg)	84	80	101	93	110	98	124	108	146	125
Profit margin of 15% (¢/kg)	13	12	15	14	17	15	19	16	22	19
Processor selling price (¢/kg)	97	92	116	107	127	113	143	124	168	144

FUTURE OF THE WIDOW ROCKFISH FISHERY

I have presented some data from 1962 to 1980; now I will make some estimates of the widow rockfish fishery in the future. I believe that widow rockfish landings of 25,000 mt are likely by 1983. This estimate is based on the continued growth of the fishery and market, and is contingent on the size of the widow rockfish stocks, fish age-class structure within the stocks, and stock availability which allows fishermen the opportunity to catch them. Also, in the future new freezing techniques may allow widow rockfish fillets to be IQF (individually quick frozen), shatterpacked, or made into blocks. If the ability to freeze large landings of widows can be coupled with machine filleting and packing, widow rockfish could become competitive with similar frozen products. Already, one processor in

California and one in Washington have been selling frozen widow rockfish fillets and report no complaints.

The increases in landings predicted above may not be reached unless industry guards against the marketing of even a limited amount of poor quality widow rockfish fillets. Small amounts of poor quality widow rockfish fillets could affect the entire rockfish market. If industry does not differentiate widow rockfish from other rockfish, jobbers, brokers, and retailers will have no way of knowing the shelf life of the rockfish product they buy, or if the product can be frozen. A retailer buying widow rockfish fillets under the label rockfish, rock cod, red snapper, Pacific red snapper, or Pacific snapper may freeze them unknowingly and end up with an inferior and possibly unsalable product when the fish is defrosted. Many industry persons also feel widow rockfish should be differentiated, and some do sell fillets at prices lower than other rockfish fillets. This price difference will reflect the lower ex-vessel price, higher yield of fillets, and the increased risk the retailer may be taking because of not being able to freeze surplus.

Other conditions which may retard the development of the widow rockfish fishery are:

1. Greater profitability in other fisheries.
2. Government restrictions.
3. Labor resistance to automation.
4. Social pressure within the fishing community which discourages widow rockfish fishing.

Even with all these possible negative factors, widow rockfish is sure to be the major species caught and processed by the West Coast groundfish industry in the near future, and widow rockfish products will be of good quality and relatively inexpensive to the consumer.

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POSTSCRIPT

Landings of widow rockfish have exceeded my prediction of 25,000 mt per year as early as 1981, when 28,000 mt were landed. In 1982, 26,000 mt is estimated to have been landed. These large catches of widow rockfish exceed the maximum sustainable yield of the widow rockfish stocks (Anonymous 1982). In 1983 a total allowable catch of 10,500 mt and a trip limit have been established. The real ex-vessel price of widow rockfish for 1983 is contracted at \$0.15/kg, which is roughly its mode price over the last 20 years. With these restrictions, many of the fishermen who relied on widow rockfish will have to fish for other groundfish off California, Oregon, Washington, and Alaska.

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