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Biological Aspects of Nearshore Rockfishes of the Genus Sebastes from Central California With Notes On Ecologically Related Sport Fishes

by

Robert N. Lea

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ABSTRACT

Rockfishes of the genus Sebastes comprise one of the most important and heavily utilized groups of commercial and recreational fishes occurring off California. In this study, carried out primarily in the 1980s, we examined various aspects of life history for the nearshore rockfishes and for cabezon, kelp greenling, and lingcod off central California. The following species of rockfishes were those primarily considered within this study: black, black-and-yellow, blue, canary, China, copper, gopher, grass, greenspotted, kelp, olive, rosy, starry, vermilion, yelloweye, and yellowtail.

During the study, 21 species of rockfish and 8 additional species of fish, including cabezon, kelp greenling, and lingcod, were tagged and released to study patterns of movement. of 7332 tagged fish, 197 (3%) representing 15 species, were recaptured. of these, only three species (canary and yellowtail rockfishes and lingcod) manifested substantial movement. Most nearshore rockfishes appear to be highly residential. Age and growth parameters were determined for 15 species of rockfish. Whole otoliths were the primary structure utilized for ageing. Most nearshore rockfishes examined appear to have life spans of moderate longevity, with maximum ages between 20 and 30 years. Weight-length relationships were calculated for 16 species of rockfish and for cabezon, kelp greenling, and lingcod. Reproductive patterns were determined for 18 species of rockfish and size at sexual maturation for 17 of these species. The majority of nearshore rockfishes appear to release larvae during the winter-spring period. However, timing of larval extrusion is species specific and must be examined on a case-by-case basis. General food habits were described for 11 species of rockfish. An Appendix, summarizing life-history characteristics for the 17 most commonly encountered species in this study, is included.

We conclude that the nearshore rockfishes are a valuable marine resource to the State of California and should be managed with the realization that, as with many of the world's fishery resources, they are vulnerable to human impacts and overexploitation.

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1. INTRODUCTION

Rockfishes of the genus Sebastes comprise one of the most important groups of commercial and recreational fishes occurring off the coast of central California. Fifty-nine species are known from Californian marine waters of which 52 (87%) are taken, at least to some degree, by the sport angler and diver (Table 1). Lingcod Ophiodon elongatus, cabezon Scorpaenichthys marmoratus, and kelp greenling Hexagrammos decagrammus are also important components of the sport catch and are included in our discussion of central California sport fishes.

Although these fishes are of great economic and ecological importance, information concerning their life histories is for the most part incomplete or lacking. Life-history information, of paramount importance in scientific fisheries management, ideally includes details on early life-stage parameters, ecological requirements, patterns of movement, age structure and composition, rates of growth, reproductive biology, and feeding habits. The primary purpose of this publication is to provide information on aspects of the life histories of the nearshore rockfishes, primarily those species taken inside the 40-fathom isobath, as well as other fishes which are a component of the sport fishery off central California. In addition, based on the included data, we consider implications regarding the present and future utilization, management, and conservation of these fishes.

Rockfishes belong to the highly speciose family Scorpaenidae, the scorpionfishes, which is perhaps best known for such tropical forms as the stonefishes and lionfishes. Four genera of scorpionfishes occur in Californian waters: Scorpaena (two species), Sebastolobus (two species), Scorpaenodes (one species), and Sebastes (60 species). Sebastes, the rockfishes, is the most diverse genus of fishes occurring within our state. This Sebastes complex is restricted for the most part to the temperate, boreal, and austral waters of the world oceans with the majority of the species found in the North Pacific Ocean; the eastern North Pacific contains a greater number of species than the western North Pacific. In the eastern North Pacific there are approximately 69 species occurring between the Gulf of California and the Bering Sea (Lea and Fitch 1979) with the greatest diversity off central and northern California. Ecologically, rockfishes are high-level predators at some stage in their life history and all form important links in the marine ecosystem. During the larval and juvenile stages, rockfishes form a part of the food chain for other marine organisms, both vertebrates and invertebrates, including members of their own genus.

As stated previously, most rockfishes are subject to both commercial and recreational fisheries (Table 1). Rockfishes are taken by most fishing methods. Set lines, gill and trammel nets, trawls, hook-and-line, and traps are commercial gears employed in their capture. Until recently, no size, catch, or seasonal limits were applied to most commercial rockfish fisheries in California. Sport fishermen,

TABLE 1. Rockfishes known to occur off California and their importance to commercial and recreational fisheries.[1]

Common name	Scientific name	Importance[2]		
Aurora rockfish	*Sebastes aurora*	C	S o	
Bank rockfish	*Sebastes rufus*	C	S o	
Black rockfish	*Sebastes melanops*	C	S	
Black-and-yellow rockfish	*Sebastes chrysomelas*	C	S	
Blackgill rockfish	*Sebastes melanostomus*	C	S o	
Blue rockfish	*Sebastes mystinus*	C	S	
Bocaccio	*Sebastes paucispinis*	C	S	
Bronzespotted rockfish	*Sebastes gilli*	C o	S o	U
Brown rockfish	*Sebastes auriculatus*	C	S	
Calico rockfish	*Sebastes dalli*	C o	S	
Canary rockfish	*Sebastes pinniger*	C	S	
Chameleon rockfish	*Sebastes phillipsi*	C o	S o	U
Chilipepper	*Sebastes goodei*	C	S	
China rockfish	*Sebastes nebulosus*	C	S	
Copper rockfish	*Sebastes caurinus*	C	S	
Cowcod	*Sebastes levis*	C	S	
Darkblotched rockfish	*Sebastes crameri*	C	S o	
Dwarf-red rockfish	*Sebastes rufinanus*	Rare		
Flag rockfish	*Sebastes rubrivinctus*	C	S	
Freckled rockfish	*Sebastes lentiginosus*	?	S o	U
Gopher rockfish	*Sebastes carnatus*	C	S	
Grass rockfish	*Sebastes rastrelliger*	C	S	
Greenblotched rockfish	*Sebastes rosenblatti*	C o	S o	U
Greenspotted rockfish	*Sebastes chlorostictus*	C	S	
Greenstriped rockfish	*Sebastes elongatus*	C o	S	
Halfbanded rockfish	*Sebastes semicinctus*		S	
Honeycomb rockfish	*Sebastes umbrosus*		S	
Kelp rockfish	*Sebastes atrovirens*	C	S	
Mexican rockfish	*Sebastes macdonaldi*	C o	S o	U
Olive rockfish	*Sebastes serranoides*	C	S	
Pacific ocean perch	*Sebastes alutus*	C o		U
Pink rockfish	*Sebastes eos*	C	S o	U

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TABLE 1. Rockfishes known to occur off California and their importance to commercial and recreational fisheries

including both anglers and divers, are currently restricted to 15 rockfish in any combination of species per day; there is no size or seasonal limitation.

Until Phillips' (1957) classic work, "A Review of the Rockfishes of California (Family Scorpaenidae)," the species comprising this taxon were for the most part treated collectively under the name rockfish or rockcod. The differentiation of species was confidently done by only a few ichthyologists and fishery biologists. A number of more recent studies have provided an understanding of rockfish biology and encompass (but certainly are not restricted to) the following publications: Phillips (1958, 1964); Moser (1967); MacGregor (1970); Chen (1971, 1975); Miller and Lea (1972, 1976); Miller and Geibel (1973); Westerheim (1973); Mearns et al. (1980), Parrish et al. (1981); Eschmeyer et al. (1983); Hartmann (1987), Wyllie Echeverria (1987), and Love et al. (1990).

During the last two decades, marine biologists and resource managers studying rockfishes in the eastern North Pacific have become concerned that certain local populations and species (e.g. Pacific ocean perch) were showing strong signs of overutilization. Indicators such as reduced catch-per-unit-of-effort, a reduction in size for certain species, catches consisting primarily of juvenile individuals, and changes in species composition have all been noted. Some species, especially the large "red" rockfishes (e.g. copper, yelloweye, and vermilion), are essentially disappearing from areas near coastal urbanized centers; these are the areas of heaviest utilization. Department biologists who have studied rockfishes prior to our investigations, such as Julius B. Phillips, John E. Fitch, Daniel J. Miller, and Daniel W. Gotshall, have all at times expressed concerns about the state of the rockfish resource off California. We strongly concur with their opinions. In the Conclusion of this bulletin we discuss one option we sanction as a conservation measure directed toward the future maintenance of the more vulnerable species of rockfish as well as other marine resources—the concept of marine resource refuges.

2. MATERIALS AND METHODS

Fishes reported on in this study were for the most part taken off central California (Figure 1 and Table 2) during the period July 1978 through December 1985. Ten research cruises were conducted between Monterey Bay and Morro Bay using the following research vessels: ALASKA, CHARGER (charter), KELP BASS, and PACIFIC CLIPPER (charter). Numerous day trips were made out of Monterey using the project vessel OPHIODON. Central California Council of Diving Clubs (Cen-Cal) spearfishing competitions were also a source of life-history specimens.

During the course of the study over 7300 fish were tagged and released, 784 of which were translocated to other reef systems to study homing behavior. Additionally, over 6000 specimens were analyzed for life-history characteristics. Rockfishes of the genus Sebastes were the species of primary concern although lingcod, cabezon, kelp greenling, rock sole Pleuronectes bilineatus, and several other species were also tagged and released or examined for life-history data.

Life-history specimens were primarily processed the day of capture either onboard ship, in the field, or at the Monterey laboratory of the Department of Fish and Game. Information recorded for each life-history specimen included: total length, board standard length (from the most anterior part of the head to the hypural plate—referred to throughout this text as standard length), body weight, gonad weight, stage of maturation or state of development of gonads, genital papilla size, and any condition that seemed noteworthy. It was not possible to record all parameters on all specimens.

2.1. Movement

Specimens were captured using traditional sport fishing techniques: hook-and-line with either artificial lures or dead bait (mainly squid). Fish that were to be tagged were first identified, measured, superficially examined to determine sex and reproductive condition, and noted for any special condition. The fish were then tagged and released at the site of capture (except for those that were translocated). Those fish which could not be tagged, which were hooked or handled in a damaging manner or displayed signs of gas expansion (everted stomach, inflated or crystallized eyes, etc.), were retained for life-history studies. Tagged fish were marked with serially numbered Floy anchor (spaghetti) tags which were yellow, 50 mm in length, and imprinted with the following information: "Reward CFG Monterey R 00321." The tags were inserted into the dorsal musculature using a Floy tagging gun. Posters describing the tagging program and instructions for returning tags, including the project's address, were posted at all sport landing locations between Santa Cruz and Morro Bay (Figure 2). Persons returning tags were given a reward of $5 for a tag or $10 if the fish was included (this provided us with additional life-history information). Also, a commendation card was sent to each person in recognition of his or her interest and effort in enhancing sport fish populations and research efforts.

2.2. Age and growth

2.2.1. Ageing structures and methods

Age determinations in our study were made from whole otoliths using transmitted light. Otoliths from 15 species of rockfish were represented in sufficient number to allow calculation of growth curves. Opercula were also collected from black-and-yellow, gopher, and vermilion rockfishes as an alternative ageing structure. The operculum was chosen as a secondary structure because it was easy to prepare, was relatively large, and had a wide edge area from which margin type could be determined. Otoliths and opercula were read submerged in water or 40% isopropyl alcohol in a black opaque dish using reflected light with a Wild M-5 dissecting microscope at magnifications of 6, 12, or 25x. While Six and

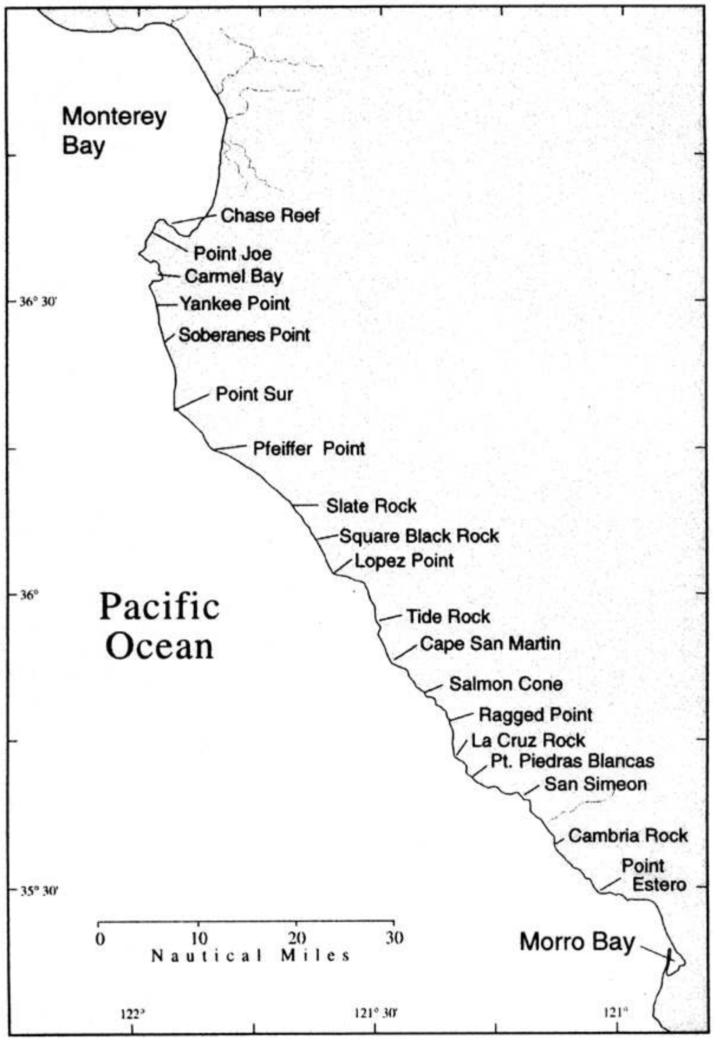


FIGURE 1. Map of study area showing major landmarks, fishing areas, and dive sites.

FIGURE 1. Map of study area showing major landmarks, fishing areas, and dive sites

TABLE 2. Locations of primary reef systems and fishing sites sampled during study.

Area[1]	Latitude[2]	Longitude	Depth (m)[3]
Tankers Reef	36° 37.0'	121° 52.0'	14–21
Monterey Breakwater	36° 36.5'	121° 53.0'	12–18
Cannery Row	36° 36.5'	121° 54.0'	12–21
Chase Reef	36° 38.0'	121° 55.0'	12–37
Point Joe	36° 36.5'	121° 57.5'	16–40
Cypress Point	36° 35.0'	121° 59.0'	18–55
Carmel Bay	36° 33.0'	121° 58.5'	18–73
Point Lobos	36° 31.5'	121° 57.5'	37–46
Yankee Point	36° 29.0'	121° 57.0'	16–64
Soberanes Point	36° 26.5'	121° 55.5'	18–37
Granite Canyon	36° 26.0'	121° 55.5'	18–37
Rocky Point	36° 15.0'	121° 52.5'	33–37
Point Sur	36° 16.5'	121° 53.0'	40–91
Big Sur River	36° 16.0'	121° 52.0'	18–30
Cooper Point (north of)	36° 15.0'	121° 52.5'	29–33
Pfeiffer Point (south of)	36° 13.5'	121° 47.0'	10–30
Partington Submarine Canyon	36° 11.5'	121° 43.5'	37–100
Slate Rock	36° 07.5'	121° 39.5'	13–37
Square Black Rock	36° 04.5'	121° 36.5'	17–45
Lopez Rock	36° 01.0'	121° 35.0'	20–46
Limekiln	35° 59.5'	121° 33.0'	64–69
Tide Rock	35° 56.5'	121° 29.5'	18–44
Plaskett Rock	35° 54.5'	121° 29.0'	14–27
Cape San Martin	35° 55.0'	121° 29.0'	18–46
Whaleboat Rock	35° 52.5'	121° 27.5'	18
White Rock No. 2	35° 49.5'	121° 23.5'	14–36
Salmon Head	35° 49.5'	121° 23.0'	22–31
Salmon Cone	35° 48.0'	121° 28.0'	25–31
Point Sierra Nevada	35° 42.0'	121° 19.5'	22–46
La Cruz Rock	35° 41.5'	121° 19.5'	13–31
Piedras Blancas	35° 40.0'	121° 20.5'	18–110
San Simeon (north of)	35° 37.5'	121° 14.0'	13–18
Cambria	35° 31.5'	121° 05.5'	18–27
Point Estero (north of)	35° 28.0'	121° 01.0'	16–37
Church Rock	35° 20.5'	120° 59.0'	59–82

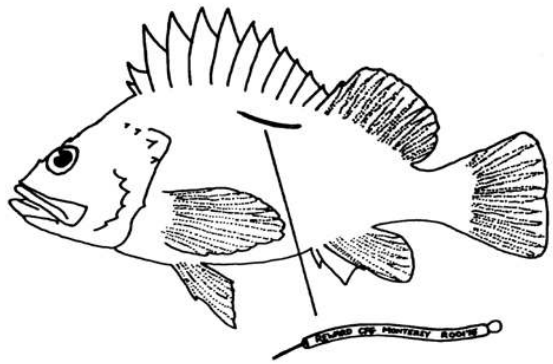
[1] *These sites represent general areas or localities and in some cases may be quite extensive (e.g. reef systems off Point Sur).*

[2] *Latitude and longitude are given to provide general locality information and are listed to the nearest 0.5 minute.*

[3] *Depth represents ranges of depth sampled; the limits of depth at the various sites may be greater than those listed.*

TABLE 2. Locations of primary reef systems and fishing sites sampled during study

TAGGED ROCKFISH



The California Department of Fish and Game is tagging rockfishes (and other sport species) off the central California coast in order to determine distribution, migratory patterns, and growth rates.

Tagged fish have a yellow plastic tag attached below the dorsal fin on the left side of the body.

You can help to maintain and improve the quality of marine sportfish angling. Send tag with date recovered, locality of capture (as exact as possible), name and address of person catching fish. If possible, include total length of fish.

A reward and information regarding tagging and recovery will be forwarded for each tag returned to:

CALIFORNIA DEPARTMENT OF FISH AND GAME
2201 GARDEN ROAD
MONTEREY, CALIF. 93940
PHONE: (408) 649-2870

FIGURE 2. Poster used to disseminate information of project tagging program. Note Floy tag, inscription on tag, and position of placement of tag on rockfish.

FIGURE 2. Poster used to disseminate information of project tagging program. Note Floy tag, inscription on tag, and position of placement of tag on rockfish

Horton (1977) read whole dry opercula with the naked eye, we found that observation under 6x magnification immediately after immersing the operculum in water or alcohol vastly improved ring resolution. Rings on immersed opercula become visible immediately, fading to obscurity when soaked for longer than 5 minutes; rings reappeared as the opercula dried. Determination of translucent or opaque margin type was much easier using opercula than otoliths as they were much larger and flatter. Because of this wider reading area, the winter translucent ring became distinguishable several months earlier on the operculum than on the otolith. In future studies opercula might be considered as the primary ageing structure; however, they are prone to vascular encroachment which render the earliest years indiscernible. Six and Horton (1977) considered opercula not a dependable ageing structure and found only three of 35 yellowtail rockfish opercula readable.

We considered an annual mark or annulus to be composed of the area from the inner opaque to the outer translucent ring and equated this to one year of growth. An arbitrary birthdate of 1 January was chosen for all fish. An opaque ring externally bounded by a translucent ring during the period 1 September to 31 December was not considered a complete annulus by this type of birthdate assignment. If a ring number or edge assignment was particularly difficult or could not be resolved by multiple readers, the otolith was not assigned an age nor included in this analysis.

2.2.2. Validation of otolith ageing

We attempted to validate ages by: i) analyzing otolith and operculum margin type, ii) comparing among- and within-reader ages, iii) comparing otolith and operculum age and margin type from each fish, and iv) fitting ages to a von Bertalanffy growth model.

First, we analyzed otolith margin characteristics over time. Margin type was assigned as either opaque, translucent, or unreadable. Percent of opaque margins by month were determined from otolith samples for the period 1978–84. Four species had sufficient readings by month to allow analysis: black-and-yellow, gopher, kelp, and olive rockfishes. This type of analysis confirms that one and only one annulus is formed per year.

Second, multiple readings by different readers (among) and by the same reader (within) were performed on aged structures. If readings did not agree, the otoliths were read an additional time. If readings could not be resolved, the ages were not included in this analysis. Averaging of age estimates was not done. This type of analysis is performed to estimate consistency of age assignments. Differences between readings were noted as no difference, plus or minus 1 year, or difference by 2 or more years.

Third, we compared age and margin characteristics of otoliths and opercula for black-and-yellow, gopher, and vermilion rockfishes. This analysis was done to confirm that readings from different structures of a given fish were consistent as well as to indicate whether or not there was bias in using any one structure for age assignments.

Fourth, we fitted individual length-at-age data to the von Bertalanffy growth model by the method of Tomlinson and Abramson (1961). The von Bertalanffy model is discussed by Ricker (1975) and Moreau (1987). The parameters *L* infinity ([L8]), *k*, and *t* were generated by microcomputer utilizing programs formulated by the Department's Technical Services Branch, Menlo Park. This model is reported solely for consistency and comparative purposes and is not suggested as the most appropriate model of choice for all species studied. An artificial data point (zero age, 0.1 mm TL) was inserted into each data set prior to calculation of these parameters. The inclusion of this point is conceptually sound and serves to improve estimation of *t* in those data sets lacking young-of-the-year specimens. For large data sets ($n > 150$) and those having many young-of-the-year fish, the inclusion of this point had little effect on any of the growth parameters. Model fitting is useful in order to provide parameters which can be compared between or within species.

2.3. Reproduction

Reproductive information was obtained from fish collected on nearshore reef systems ranging in depth from 2 to 100 m along the central California coast. The majority of specimens were collected within 20 km of Monterey. Many of the reef systems are the same areas utilized by local sport and commercial fishermen. Life-history specimens were collected primarily by hook-and-line and by spearfishing. Additional reproductive information was obtained from fish measured during tagging operations, an angler interview program at the Monterey public boat ramp, fish monitored at Cen-Cal spearfishing meets, and miscellaneous fish brought to the Monterey office by recreational and commercial fishermen.

Reproductive information on rockfishes was collected throughout the year by observation of developmental stages of testes and ovaries, monitoring gonadal weights, noting release of gonadal products (spermiation [Nagahama 1983] and parturition), and recording field observations on young-of-the-year fish. It was difficult or impossible to obtain reproductive information from field-measured fish unless they were in the process of releasing gonadal products, i.e. running-ripe. The criteria used to determine developmental stages of the gonadal tissues were derived from a modified version of reproductive stages by Kesteven (1960; Table 13, page 69). **Stage 1** gonads are not developed sufficiently to permit macroscopic determination of sex of the specimen. **Stage 2** gonads are from immature fish which have yet to undergo spawning; determination of sex may not be possible. **Stage 3** gonads are from sexually mature fish which are in a resting or quiescent period and not actively spawning. During **stage 4** gametogenesis has begun and gonads begin to increase in size and weight. Fertilization has not yet occurred in stage 4 females. During **stage 5**, fertilization of eggs has occurred. In **stage 6** the release of gonadal products, spermiation and parturition, occurs. **Stage 7** gonads are spent as the result of gonadal release. Reproductive data are discussed as stage 3 = resting; stages 4 and 5 = reproductively developing; stage 6 = spermiation for males and spawning for females; and stage 7 = spent. The reproductively active phase (4, 5, and 6) in the discussion of each species is termed "gonadal development" and represents spermatogenesis in males and vitellogenesis in females. The release of reproductive products is termed spermiation, spawning, or running-ripe, which is the period of insemination for males and parturition for females. This should not be confused with maturation of young into sexually "capable" reproductive individuals, which is herein referred to as achieving "sexual maturation."

To more accurately document gonadal development, the gonadal index (G.I.) was calculated using the formula: G.I. = $GWT/TL^3 \times 10^7$ where GWT = weight of gonads (in grams) TL = total length of fish (in millimeters) 10^7 = value to bring index to unity.

The gonadal index (G.I.) was chosen rather than gonosomatic index (G.S.I) for the following reasons: i) more data on total length of fish were collected than on weight; ii) length of the fish cubed can have a higher degree of correlation with ovarian weight as compared to body weight (deVlaming et al. 1982); and iii) sampling in Monterey Bay during the 1982–84 El Niño indicated that length is a more stable indicator than weight of overall age and maturity. During this El Niño period, blue rockfish experienced as much as a 20% reduction in weight. The mean monthly gonadal indices (MMGI) from all sampled years (1978–88) are presented in even-numbered Figures 36–48 (Pages 73–83).

In accordance with Gunderson et al. (1980), occurrence of running-ripe females was chosen to indicate peak spawning months. Running-ripe females were designated as stage 6 on the reproductive scale. Gunderson et al. (1980) caution that observations to determine length-maturity relationships should be obtained only when gonadal development of mature individuals is readily apparent. If this is not established, differentiation of sexually mature and immature individuals is imprecise and will lead to erroneous conclusions regarding the length-maturity relationship. Westrheim (1975) stated that error in estimating the true size (age) at maturity was minimized when samples were collected during the peak developmental stage (insemination season for males and parturition season for females).

Reproductive trends were evaluated using data from both laboratory- and field-measured fish.

2.4. Food habits

Specimens used for food habit studies were collected by Department biologists using hook-and-line or spear and by sport and commerical fishermen. The majority of specimens were collected from central California between 1978 and 1985. Additionally, 28 China rockfish collected at Point Arena in 1972 and 1973 were included. Only stomachs which contained identifiable food items were considered in our analysis; the percent of empty stomachs was not noted. In some cases anomalous plankton blooms or abundances of rare or uncommon prey items formed a high percentage of food items found in stomachs. For example, during the 1982–84 El Niño pelagic red crabs Pleuroncodes planipes, also known as tuna crabs, were carried in large numbers from their normal range off Baja California northward into Monterey Bay and as far north as Fort Bragg.

Identification of prey items was made to the lowest possible taxon. The percent frequency of occurrence of each major group of food items was determined by dividing the number of stomachs containing prey items by the total number of stomachs examined.

3. MOVEMENT

3.1. Introduction

During the course of this study, 7332 fish were tagged and released off the central coast of California (Table 3). of these, 6198 (85%) were rockfish which comprised 21 species. Eight rockfish species (black-and-yellow, blue, copper, gopher, kelp, olive, vermilion, and yellowtail) represented 96% of the rockfish tagged. Lingcod accounted for 1001 (14%) of the tagged fish.

The ability to successfully tag and release fish is often species-dependent (Table 4). Fishes such as lingcod and black-and-yellow, blue, copper, kelp, olive, and yellowtail rockfishes can be readily tagged and released and require little or no special handling. Canary, China, gopher, and vermilion rockfishes require a greater degree of care, and swim bladder deflation is often necessary prior to release. We were not able to tag and release rosy, starry, widow, yelloweye, or the majority of the deeper-dwelling rockfishes with any rate of success (Table 4). The stomachs in these species were often distended and at times the eyes were crystallized and filled with air (Gotshall 1964). Yellowtail rockfish, often caught as deep as 50 fathoms, presented essentially no difficulty in being released back into the marine environment. The ability of yellowtail rockfish to vertically migrate during feeding forays (Pereyra et al. 1969; Lorz et al. 1983) undoubtedly aids in facilitating the successful return of this species. Copper rockfish, a benthic species, are more successfully released than three closely related benthic forms: black-and-yellow, gopher, and China rockfishes. It may be that copper rockfish are more vertically mobile than other benthic congeners and may move up into the water column to feed at various times, although we have not noted this behavior.

TABLE 3. Summary of fish tagged.

Species	Number tagged	Percent of total	Size range (mmTL)	Mean size (mmTL)	Tags returned
Olive rockfish	2258	31	177–539	338.1	39
Blue rockfish	1536	21	195–462	326.7	18
Lingcod	1001	14	300–1041	595.6	41
Gopher rockfish	699	10	190–393	292.0	18
Copper rockfish	483	7	214–535	403.7	32
Kelp rockfish	315	4	220–391	324.9	11
Yellowtail rockfish	304	4	187–535	349.4	9
Vermilion rockfish	156	2	271–611	486.2	4
Black-and-yellow rockfish	127	2	187–340	273.6	10
Black rockfish	89	1	181–376	322.2	4
Cabezon	80	1	306–655	432.4	3
Bocaccio	56	1	247–725	532.1	3
Rosy rockfish	51	1	185–300	246.1	0
Canary rockfish	50	1	255–510	357.4	3
China rockfish	32	<1	241–386	317.2	1
Kelp greenling	31	<1	320–640	383.7	0
Starry rockfish	19	<1	252–420	341.2	0
Spiny dogfish	13	<1	675–1012	856.8	0
Yelloweye rockfish	9	<1	398–655	481.2	0
Brown rockfish	5	<1	293–394	353.2	0
Rock sole	5	<1	319–460	378.0	0
Widow rockfish	3	<1	355–425	389.0	0
Kelp bass	3	<1	420–456	433.0	0
Greenspotted rockfish	2	<1	354–358	356.0	0
Quillback rockfish	1	<1	345	-	0
Speckled rockfish	1	<1	373	-	0
Squarespot rockfish	1	<1	242	-	0
Unidentified rockfish	1	<1	311	-	0
California scorpionfish	1	<1	190	-	0
Ocean whitefish	1	<1	580	-	0
Totals	7332				197

TABLE 3. Summary of fish tagged

TABLE 4. Rate of success for fishes tagged and released during study.

	Rate of success[1]		
Species	High	Moderate	Low
Black rockfish	X		
Black-and-yellow rockfish	X		
Blue rockfish	X		
Bocaccio		X	
Brown rockfish	?		
Canary rockfish		X	
China rockfish		X	
Copper rockfish	X		
Flag rockfish		?	
Gopher rockfish		X	
Greenspotted rockfish			X
Kelp rockfish	X		
Olive rockfish	X		
Quillback rockfish		?	
Rosy rockfish			X
Speckled rockfish		?	
Starry rockfish			X
Vermilion rockfish		X	
Widow rockfish			X
Yelloweye rockfish			X
Yellowtail rockfish	X		
Cabezon	X		
Kelp greenling	X		
Lingcod	X		

[1]***Rate of success*** *is a subjective evaluation as to how frequently the listed species appeared to survive upon being released back into the marine environment.* ***High*** *success indicates > 85% survival;* ***moderate*** *indicates survival of 40–60%; and* ***low*** *signifies < 10% survival. Intermediate levels of survival (e.g. 25% or 75%) were not encountered. For those species listed with a question mark (?), the number of fish tagged and released was small and the level of success is based on our general impression.*

TABLE 4. Rate of success for fishes tagged and released during study

of the 29 species of fish tagged, 15 species (13 of which were rockfishes) were recaptured (Table 5). By number, 197 fish were recaptured and returned to this study. Recovery rate (for those species that were recaptured) varied from 1 to 20%, with an overall rate of return of 3%.

Most species of rockfish on which tagging studies have been conducted exhibited little or no movement (Miller and Geibel 1973; Larson 1980a, 1980b; Mathews and Barker 1983; Hallacher 1984; Hartmann 1987). Love (1981) and Hartmann (1987) presented evidence that deepwater rockfishes, primarily bocaccio, chili-pepper, and widow rockfish, were capable of moderate movement over short periods. Considerable movement has been speculated for yellowtail rockfish (Carlson and Haight 1972; Mathews and Barker 1983). Analysis of recaptured fish from this study suggests that eight of the 13 species of rockfish tagged and recaptured exhibited essentially no movement (Table 5 and 6). Five species of rockfish manifested movement, three species (copper, gopher, and olive rockfishes) moved up to 1.5 nautical miles, and two species (canary and yellowtail rockfishes) exhibited major movement covering distances up to 380 nautical miles.

TABLE 5. Summary of recaptured fish.

Species	Number tagged	Number returned	Percent returned	Days at liberty	Distance moved (nautical miles)
Black rockfish	89	4	4	18–552	0
Black-and-yellow rockfish	127	10	8	4–1263	0
Blue rockfish	1536	18	1	11–502	0
Bocaccio	56	3	5	161–545	0
Brown rockfish	5	1	20	149	0
Canary rockfish	50	3	6	1114–1439	3.5–380
China rockfish	32	1	3	217	0
Copper rockfish	483	32	7	2–1017	0–1.5
Gopher rockfish	699	18	3	22–3944	0–1.1
Kelp rockfish	315	11	3	18–552	0
Olive rockfish	2258	39	2	9–1413	0–1.0
Vermilion rockfish	156	4	3	225–1104	0
Yellowtail rockfish	304	9	3	66–1786	0–98
Cabezon	80	3	4	18–54	0
Lingcod	1001	41	4	3–950	0–67
Totals	7191	197	3		

TABLE 5. Summary of recaptured fish

TABLE 6. Movement and nonmovement patterns for nearshore fishes based on tag returns.[1]

No movement	To 1.5 nautical miles	More than 1.5 nautical miles
Black rockfish	Copper rockfish	Canary rockfish
Black-and-yellow rockfish	Gopher rockfish	Yellowtail rockfish
Blue rockfish	Olive rockfish	Lingcod
Bocaccio	Lingcod	
Brown rockfish		
China rockfish		
Copper rockfish		
Gopher rockfish		
Kelp rockfish		
Olive rockfish		
Vermilion rockfish		
Yellowtail rockfish		
Cabezon		
Lingcod		

[1]*Movement of translocated fish not included in this table.*

TABLE 6. Movement and nonmovement patterns for nearshore fishes based on tag returns

3.2. Nonmoving species

of the returned rockfishes, black, black-and-yellow, blue, bocaccio, brown, China, kelp, and vermilion were species which were taken at the same general locality at which they were released, hence demonstrating strong site fidelity. Copper, gopher, olive, and yellowtail rockfishes were recaptured primarily at their locality of release. However, individuals of these four species also demonstrated minor movement (to 1.5 nautical miles) and in the case of yellowtail rockfish movement of up to 98 nautical miles. Lingcod were mainly caught at their locality of release but some individuals displayed movement of up to 67 nautical miles. Thirty-one of 41 returned lingcod were recaptured at their original site of capture. Cabezon showed no movement. In several of the above cases, tag returns were so low that it would be premature to make statements regarding the capability of movement of those species. For example, bocaccio in this study showed no movement, but our evidence is based on only three tag returns. Love (1981) and Hartmann (1987) have shown that this species is capable of considerable movement. Based on morphology and ecology, one would anticipate bocaccio to be a relatively mobile species.

3.3. Species showing minor movement

Copper, gopher, and olive rockfishes exhibited patterns of minor movement (up to 1.5 nautical miles); however, all were recaptured over the reef system on which they were tagged. Matthews (1986) reported on movement of up to 1.2 km for black-and-yellow and gopher rockfishes which had traveled from low-relief natural reefs to high-relief artifical reefs. Although not mentioned by Matthews, differences in substrate type may have been a factor. The primary substrate at her study site was low-profile siltstone surrounded by sand flats; the artifical reef was constructed from concrete pipe and was of higher relief. Our observations of these two species, and the work of other investigators (Larson 1980a, 1980b; Hallacher 1984), suggest that they prefer, and occur primarily on, rocky substrate with caves and crevices. Brown and copper rockfishes are species which appear to be better adapted to low-profile siltstone and mudstone and are more frequently encountered on these types of substrate. As an example, in hundreds of diving hours in the kelp forests on the southern edge of Monterey Bay (off Pacific Grove), a high-profile rocky environment, we have observed only one brown rockfish. Black-and-yellow and gopher rockfishes are common elements in this habitat type. On the siltstone reefs off Del Monte Beach, between Monterey and Seaside, brown rockfish are frequently observed.

Love (1980) noted restricted movement for olive rockfish over shallow reef systems off Santa Barbara. of the olive rockfish that moved in our study, all remained on the reef system from which they were tagged. Olive rockfish are fast swimming, predatory fish which live up in the water column as an integral part of the kelp forest community. Morphologically, olive rockfish appear to be the rockfish analogue of kelp bass Paralabrax clathratus, a common southern Californian kelp forest species. This correlation is implied in the scientific name of the olive rockfish, serranoides, which translates to serranid-like in reference to the family of sea basses (Serranidae) of which Paralabrax is a member. It may be that olive rockfish reside on a particular reef system, move off during feeding forays, and then return to their "home" reef site. On several occasions we caught and released olive and blue rockfishes over open-water areas some distance from discrete reef systems. Our findings suggest that olive rockfish show strong fidelity to a particular reef or kelp forest system. Copper rockfish, as with most nearshore benthic rockfishes, appear to manifest little movement. We consider this species as epibenthic, living in close association with the bottom, but not to the degree observed in black-and-yellow, gopher, and China rockfishes. Copper rockfish are often observed positioned slightly off the bottom and when approached swim into caves and crevices for protection.

3.4. Species showing major movement

Canary rockfish, yellowtail rockfish, and lingcod demonstrated the capacity for moving great distances. of three canary rockfish returns, all showed movement.

of greatest interest was a canary rockfish tagged off Point Sur and recovered off southern Oregon, a distance of 380 nautical miles; the fish was at liberty 1439 days. The majority of the recaptured yellowtail rockfish also manifested movement. Linear distances of 4, 14, 40, 46, and 98 nautical miles were covered by individual yellowtail rockfish. As would be expected for movement of these distances, changes in depth were also noted. Lingcod also showed the capability of major movement with one fish covering 67 nautical miles. Eight of the 41 lingcod (those fish with recovery data) displayed movement (1.3, 2.3, 3.0, 5, 12.5, 14.3, 15, and 67 nautical miles). of these, five were males, two were females, and one was not sexed. In all eight cases, bathymetric change of up to 70 fathoms was noted.

3.5. Ontogenetic movement

In the case of many of the nearshore rockfishes, it appears that once settlement from the pelagic juvenile stage occurs, they become strongly residential to that reef system on which they settle. Species of the gopher-copper complex (subgenus Pteropodus) , which includes black-and-yellow, brown, China, grass, and quillback rockfishes, appear to be extremely residential (Table 5 and 6). Other rockfishes also appear to show a high degree of site fidelity (black, blue, olive, and vermilion). Cabezon (and most likely many of the smaller sculpins, Cottidae) fall into this category. There are a number of species, however, which appear to utilize the nearshore environment (kelp forests, rocky reef systems, and sand-reef interface) as young-of-the-year and 1-year olds (year-class 1), that apparently move into deeper water with ontogeny. Juvenile yellowtail rockfish often occur mixed with juvenile olive rockfish, primarily as young-of-the-year fish, in the kelp forest community but are seldom encountered beyond this stage in the nearshore environment. The main distribution for yellowtail rockfish upon entering the sport fishery is in open water at depths usually exceeding 40 fathoms.

Young-of-the-year and 1-year-old canary rockfish are commonly observed in small aggregations over sand pockets at depths of 50 to 70 feet. This species unquestionably migrates bathymetrically with age. of the three canary rockfish returned, all had moved considerable distances (3.5, 6, and 380 nautical miles) and all were recaptured at greater depth than when released. Young-of-the-year vermilion rockfish are frequently encountered over sand pockets in and just outside the kelp forest. Older juvenile and adult vermilion rockfish are more often associated with deeper reef systems (> 20 m). Large, individual vermillion rockfish are occasionally encountered at the outer edges of kelp forests, but in most cases their numbers are low.

Widow and halfbanded rockfishes recruit to the nearshore environment as young-of-the-year but are seldom if ever encountered there as subadult or adult fish. Young-of-the-year widow rockfish are occasionally found in association with blue and olive-yellowtail rockfishes of the same age which school in the kelp forest. Young-of-the-year halfbanded rockfish appear on the bottom on deeper reef systems (> 20 m) but are not observed in large quantities and are not seen at these depths beyond this life stage. Young-of-the-year bocaccio can at times be encountered in large numbers in the kelp forest community and also around structures such as wharfs, piers, and jettys. The occurrence of these bocaccio in the nearshore environment is sporadic and undoubtedly related to successful recruitment of a strong year-class or cohort. In years when young-of-the-year bocaccio are common, their numbers can be enormous. During these periods they appear to feed heavily on other species of young-of-the-year rockfish inhabiting the kelp forest, primarily blue and kelp rockfishes. Also, in those years when large numbers of these bocaccio recruit to the nearshore environment, large quantities are caught by anglers fishing from wharfs and piers. Individual catches can at times account for hundreds of fish (in violation of California sportfishing regulations—the current allowable limit for rockfish is "fifteen in any combination of species"). These young-of-the-year bocaccio are often referred to erroneously as "tom cod" by pier anglers. The success of recruitment of young-of-the-year rockfishes and the relationship of recruitment events to physical ocean- ographic parameters are just beginning to be adequately understood (Parrish et al. 1981; Norton 1987).

3.6. Modes of recapture

Modes of recapture of tagged fish encompassed sport (including project recapture) and commercial methods, each of which was further subdivided into additional categories (Table 7). These modes are considered as an indication of how this resource is utilized and the potential impact upon it in the future. The sport mode was subdivided into two categories: hook-and-line and spear fishing (diving). The commercial mode was subdivided into recapture by hook-and-line (including set line), trawl, and set gill net. A miscellaneous category treated fish for which little or no recapture information was available. However, we were able to determine whether these fish were taken by sport or commercial mode. By percent of recapture the two major modes were: sport 66% (of which 6% was project) and commercial 34%. Hook-and-line gear (for both modes) accounted for the greatest return, 76%. of the 15 species recaptured, all but one species (canary rockfish) were taken by hook-and-line gear. Sport diving accounted for 9% of the recaptured fish (12% when the project mode is included) and encompassed seven species. Gillnetting accounted for 6% of the recaptured fish and comprised six species. Only eight fish were returned from the commercial trawl catch, seven lingcod and one canary rockfish. We would anticipate this catch to be low as the substrate on which trawlers operate is quite different than the substrate on which we originally tagged and released most of the fish for this study. The majority of species of rockfish studied showed a high degree of site fidelity. Lingcod, conversely, are capable of a high degree of mobility and the inclusion of

TABLE 7. Summary of returned tagged fish by method of capture (by percent).

Species	Number returned	Project H & L	Project Spear	Sport H & L	Sport Spear	Commercial H & L	Commercial Trawl	Commercial Gill net	Misc.[1]
Black rockfish	4			25%	50%	25%			
Black-and-yellow rockfish	10			10%	30%	50%			10%
Blue rockfish	18			72%	6%	17%			6%
Bocaccio	3			33%		33%		33%	
Brown rockfish	1			100%					
Canary rockfish	3						33%	67%	
China rockfish	1					100%			
Copper rockfish	32	13%		41%	3%	41%		3%	
Gopher rockfish	18		11%	61%	6%	22%			
Kelp rockfish	11		36%	18%	27%	18%			
Olive rockfish	39	3%		69%		18%		3%	8%
Vermilion rockfish	4	25%		25%		50%			
Yellowtail rockfish	9			33%		11%		56%	
Cabezon	3			33%		67%			
Lingcod	41			54%	15%	7%	17%	2%	5%
Totals	197	3%	3%	50%	9%	23%	4%	6%	3%

[1] *Miscellaneous category: 1% sport unknown method; 2% commercial unknown method.*

TABLE 7. Summary of returned tagged fish by method of capture (by percent)

a relatively high number of tagged lingcod by commercial trawlers (17%) is not surprising.

3.7. Translocation of fish

During three cruises (81-KB-17, 82-KB-10, and 82-KB-19) fish were captured at one location and translocated to other discrete reef systems (Table 8), ranging from 3.5 to 34.5 nautical miles from site of original capture. Our primary objective in this study was to determine if certain rockfishes would take up residence on new reef systems to which they were introduced. Carlson and Haight (1972) noted that yellowtail rockfish off southeastern Alaska showed evidence of homing with individuals returning to a home site after being moved distances of 22.5 km. Hallacher (1984) noted a high percentage of return to site for black-and-yellow rockfish which were moved short distances (25, 40, and 50 m). Black-and-yellow rockfish moved 1.5 km from their territory did not return.

TABLE 8. Summary of translocated fish and indication of movement.

Species	Number translocated	Number recaptured	Movement			
			None	Toward site of capture	From site of capture	No information
Black-and-yellow rockfish	3	1	-	-	-	1
Blue rockfish	629	7	5	2*	-	-
Bocaccio	1	0	-	-	-	-
Canary rockfish	2	0	-	-	-	-
China rockfish	6	0	-	-	-	-
Copper rockfish	19	2	1	1	-	-
Gopher rockfish	34	1	-	1*	-	-
Kelp rockfish	1	0	-	-	-	-
Olive rockfish	75	2	-	1	1	-
Rosy rockfish	1	0	-	-	-	-
Starry rockfish	1	0	-	-	-	-
Vermilion rockfish	5	1	-	1	-	-
Cabezon	1	1	-	1	-	-
Lingcod	3	0	-	-	-	-
Rock sole	3	0	-	-	-	-
Totals	784	15	6	7	1	1

**These fish moved beyond original site of capture.*

TABLE 8. Summary of translocated fish and indication of movement

Seven hundred eighty-four fish, representing 15 species, were translocated (Table 8). of the total translocated fish, 629 (80%) were blue rockfish, 75 (10%) were olive rockfish, 34 (4%) were gopher rockfish, and 19 (2%) were copper rockfish. The other 27 fish represented 11 other species which included lingcod, cabezon, and rock sole. Only 15 (1.9%) of the translocated fish, encompassing seven of the 15 species, were recaptured. of the 15 fish which were recaptured, five blue rockfish and one copper rockfish were retaken at the site to which they were translocated, manifesting no movement after release. Seven fish, representing six species (including blue and copper rockfishes), exhibited what we interpret as an indication of site fidelity. Two blue rockfish, one copper rockfish, one gopher rockfish, one olive rockfish, one vermilion rockfish, and one cabezon were all recaptured outside the reef system on which they were translocated but in a direction toward or beyond their original site of capture. Only one individual, an olive rockfish, was recaptured in a direction opposite from the original site of capture. However, for the five species of rockfish (blue, copper, gopher, olive, and vermilion) and cabezon which moved, there is the implication of homing ability. Also, we suggest that the degree to which rockfish home is species specific. Hallacher (1984) demonstrated that black-and-yellow rockfish were capable of short-range homing. of the species which were translocated, we surmise that those strongly benthic species (China, gopher, grass, etc.) would prove to be highly residential, similar to black-and-yellow rockfish. Species which we consider as epibenthic (copper and vermilion rockfishes) would be predicted to have somewhat greater homing ability. We also predict the open-water and aggregating species (bocaccio and blue, olive, widow, and yellowtail rockfishes) to have the greatest capability for homing. However, our number of recaptures (15) is too low to conclusively demonstrate home-site fidelity.

If rockfish were to be translocated to reef systems which received heavy fishing pressure and on which fish densities were low or reduced, the tendency of the newly introduced fish to move off these areas might be reduced. However, translocation as a means of enhancing rockfish populations on heavily fished reef systems is unlikely to provide any long-lasting effect. Cold-temperate reef systems are primarily dependent upon the import and settlement of juvenile fish (especially in the case of rockfish) from strong year-classes or cohorts which may have originated (been released) at relatively great distances from their site of settlement.

4. AGE AND GROWTH

4.1. Ageing validation

Results of each of the four validation methods employed in this study and our general conclusions are considered below.

4.1.1. Otolith margin analysis

Changes in a fish's growth rate are observable on the otolith. A relatively wide opaque growth ring (indicative of summer growth) signifies a period of rapid growth which is followed by a translucent ring (winter growth) indicating a decrease in growth rate. Growth in all species examined typically began in spring (about April), peaked in August, and decreased into winter. Species examined demonstrated 0 to 3% opaque margins during the winter period (December to March). This pattern was extensively analyzed for gopher and kelp rockfishes (Figure 3) and was considered generally the same for all rockfishes examined. The transition from opaque to translucent margin between October and December was more easily detected in younger fish (under 5 years of age). These changes were more apparent at an earlier date in young fish because of greater width of the rings or annuli. Assignment of "translucent" or "opaque" to the narrow margins of thick otoliths from older fish was much more difficult due to crowding of rings near the edge.

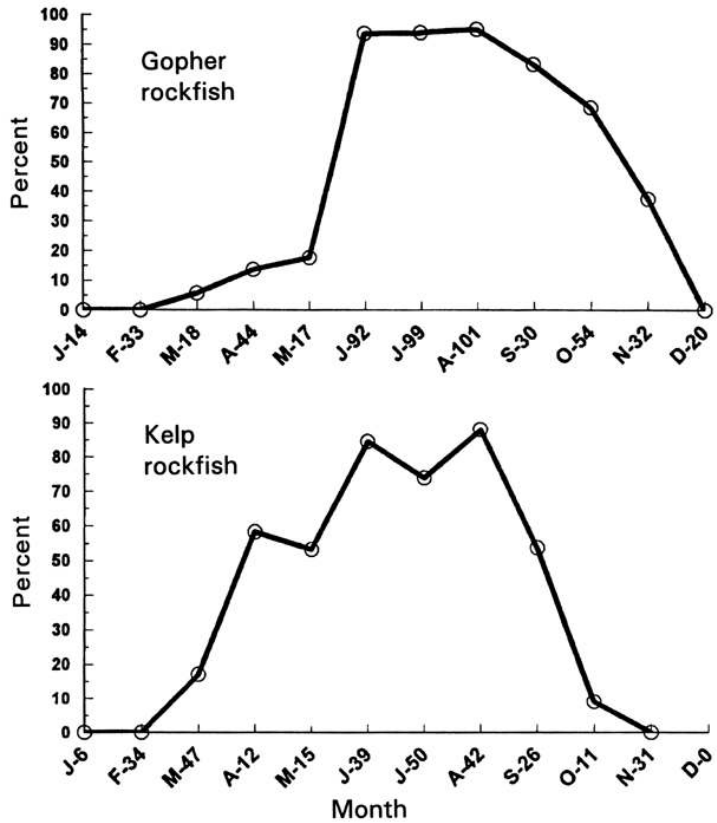


FIGURE 3. Percent of opaque otolith margins by month for gopher rockfish (n = 554) and kelp rockfish (n = 313). Number of readings by month is after the dash.

FIGURE 3. Percent of opaque otolith margins by month for gopher rockfish (n = 554) and kelp rockfish (n = 313). Number of readings by month is after the dash

Our analyses indicate one growth ring, composed of an opaque and a translucent band, is produced per year in all species examined.

4.1.2. Comparison of between- and within-reader ageing

Otolith age agreement between readers was considered very good. Only 4% of within-reader and 6% of between-reader ages disagreed by more than 2 years. Within- and between-reader age agreement was analyzed for black-and-yellow, gopher (between-only; Figure 4), kelp, and rosy rockfishes; only difficult otoliths were read an additional time. Within- and between-reader comparisons totaled 249 and 1526, respectively. Within-reader exact agreement was highest for gopher rockfish (51%) and lowest for rosy rockfish (29%). Exact agreement and plus or minus 1-year agreement for the three species combined averaged 47% and 89%, respectively (*n* = 249). Between-reader exact agreement was highest for kelp rockfish (63%) and lowest for rosy rockfish (36%). Exact agreement and plus or minus 1-year agreement for the four species combined averaged 50% and 84%, respectively (*n* = 1282). The lower rate of exact agreement for rosy rockfish reflects the increased difficulty all readers experienced when ageing this species. Chen (1971) also noted difficulty in ageing rosy rockfish.

Kelly and Wolf (1959) noted that disagreement of between-reader ages increased with an increase in the age of the redfish Sebastes marinus from the Gulf of Maine. We also found this to be true for gopher rockfish. Exact agreement for gopher rockfish between-reader comparisons ranged from 100% for ages 1 and

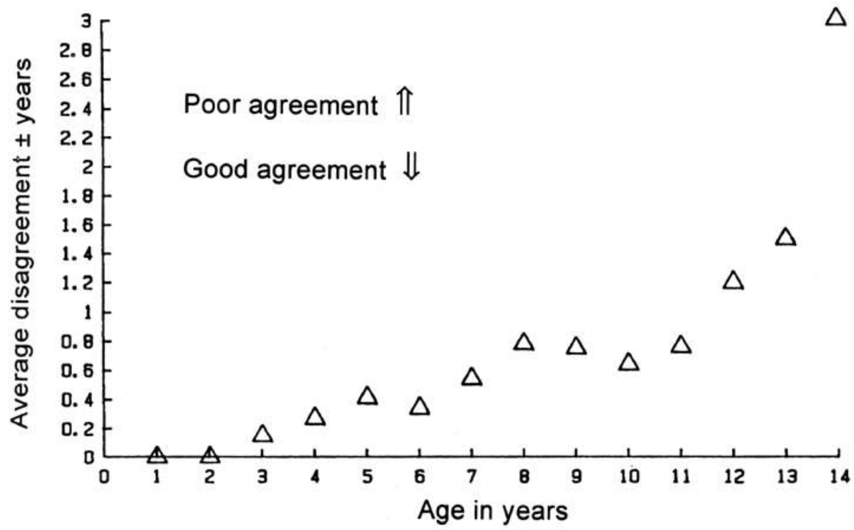


FIGURE 4. Average disagreements in whole otolith ages between readers for gopher rockfish (*n* = 273).

FIGURE 4. Average disagreements in whole otolith ages between readers for gopher rockfish (n = 273)

2 to no agreement for age-14 fish (Figure 4). Average between-reader disagreement for gopher rockfish increased with the age of the fish, becoming pronounced by age 12, the age at which gopher rockfish otoliths thicken and become more difficult to interpret.

With the exception of old fish, reader comparisons indicate the surface otolith ageing method is a relatively precise and repeatable method of ageing rockfish.

4.1.3. Comparison of different ageing structures from the same fish

Comparing ages assigned to two or more structures from the same fish is a primary method of age validation. To validate ages of gopher rockfish, otoliths and opercula were compared. Ages determined from operculum and otolith pairs were compared using the statistics program BMDP1R with the group option. This program (BMDP1R) calculates three regressions, one for each group (structure) and one on all data combined. An *F*-test is then performed comparing regression lines between groups. Regressions were run using natural logs of age as the independent variable and length as the dependent variable. Length-at-age determined from otoliths was not significantly different from that determined by opercula for gopher rockfish ($n = 282$, $P > 0.813$).

Analysis of covariance to test equality of gopher rockfish log of ages between the two ageing structures among three sex categories (male, female, and combined) with length as covariate was also investigated. No significant difference between ages derived from opercula or otoliths was found ($P > 0.936$). A subjective comparison (not statistically tested) between ages from these two structures for black-and-yellow and vermilion rockfishes also revealed very little disagreement. It should be noted that several opercula could not be used for ageing due to heavy calcification of the first two to three rings in older fishes. However, disregarding these few unusable structures, age assignment for these three species, and most likely for other rockfishes, can be accomplished using either otoliths or opercula.

4.1.4. Growth analysis using the von Bertalanffy model

Fitting of ages to the von Bertalanffy growth model was also used as a validation technique. The growth parameters [L8] (asymptotic length), *k* (metabolic rate constant), and t_0 (fitted age at zero length) were calculated for each species and are summarized in Table 9. Calculated [L8] for combined sexes ranged from 325 mm TL for rosy rockfish to 715 mm TL for canary rockfish. Assigned ages ranged from 0 year-class or young-of-the-year for many species to 29 years of age for vermilion and copper rockfishes. Age-length relationships and calculated and measured length-at-age are given for 15 species of rockfishes (Figures 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19).

Sizes of fish aged ranged from 44 mm TL for grass rockfish to 652 mm TL for yelloweye rockfish. Comparison of calculated and measured mean length-at-age for combined sexes of 15 species of rockfish are given in the Appendix. Calculated lengths are presented to the greatest age seen in the data set or to age 20,

TABLE 9. Von Bertalanffy growth parameters for 15 rockfish species.

Species	Sex[1]	n	L_∞	k	t_0
Black-and-yellow rockfish	male	138	326	0.2409	-0.3
	female	150	339	0.2125	-0.6
	combined	310	336	0.2165	-0.5
Black rockfish	male	76	559	0.1373	-1.4
	female	81	669	0.1119	-1.1
	combined	186	705	0.0953	-1.5
Canary rockfish	male	24	465	0.2614	-0.3
	female	25	539	0.2297	0.0
	combined	112	715	0.1123	-0.6
China rockfish	male	40	375	0.1940	-0.2
	female	39	373	0.1924	0.2
	combined	114	382	0.1806	0.1
Copper rockfish	male	86	517	0.2235	0.1
	female	108	572	0.1269	-1.3
	combined	227	565	0.1354	-1.0
Gopher rockfish	male	255	329	0.2753	0.1
	female	241	341	0.2531	0.1
	combined	557	341	0.2256	-0.5
Grass rockfish	male	47	494	0.1701	-0.3
	female	78	535	0.1377	-0.6
	combined	131	525	0.1374	-1.0
Greenspotted rockfish	male	16	440	0.1359	0.0
	female	21	442	0.1311	0.0
	combined	39	444	0.1282	-0.2

TABLE 9. Von Bertalanffy growth parameters for 15 rockfish species

whichever is greater. Calculated and measured mean size-at-age agreed well for all species examined. Sizes of fish aged, range of age assignments, heaviest male and female fish, greatest total length observed during this project as well as greatest known total length and calculated [L8] for males, females, and combined sexes are given in the Appendix.

[L8] differed from observed maximum values in many cases. [L8] for combined sexes of black and starry rockfishes were greater than maximum reported sizes. The asymtotic length for starry rockfish of 467 mm TL was 10 mm greater than the maximum length reported for this species, while this theoretical maximum

TABLE 9. (continued).

Species	Sex[1]	n	L_∞	k	t_0
Kelp rockfish	male	168	377	0.2522	-0.3
	female	141	369	0.2552	-0.4
	combined	378	378	0.2307	-0.7
Olive rockfish	male	149	440	0.2610	-1.3
	female	129	539	0.1667	-1.5
	combined	336	524	0.1879	-1.0
Rosy rockfish	male	66	302	0.1557	-0.1
	female	84	329	0.1241	-0.7
	combined	159	325	0.1235	-0.8
Starry rockfish	male	42	460	0.1208	-0.1
	female	43	450	0.1241	0.0
	combined	89	467	0.1148	-0.1
Vermilion rockfish	male	79	575	0.2044	-0.2
	female	72	624	0.1396	-1.2
	combined	194	598	0.1595	-0.9
Yelloweye rockfish	male	18	756	0.0890	0.0
	female	21	646	0.1153	-0.2
	combined	39	666	0.1117	0.0
Yellowtail rockfish	male	16	451	0.2474	0.0
	female	19	561	0.1565	0.0
	combined	68	527	0.1513	-0.8

[1]*Combined sex category includes individuals for which sex could not be determined and juveniles (stages 1 and 2).*

TABLE 9. Von Bertalanffy growth parameters for 15 rockfish species

length for black rockfish was 691 mm TL, 88 mm greater than reported for this species. Asymptoptic lengths for combined sexes of greenspotted (444 mm TL), yelloweye (666 mm TL), and yellowtail (528 mm TL) rockfishes were over 100 mm less than maximum reported sizes. [L8] differing markedly from expected maximum length is most likely due to underrepresentation of the youngest or oldest specimens in our data sets. With the exception of canary and black rockfishes, [L8] appears reasonable when compared to sizes of fish collected within our sample area.

In summary, the four validation methods we used to confirm ages were: i) performing otolith margin analysis, ii) analyzing between- and within-reader comparison agreement, iii) comparing otolith and opercular ages, and iv) fitting age and total lengths to the von Bertalanffy growth equation. All four methods employed suggest surface otolith reading as a valid ageing technique for the fishes examined in this study.

4.1.5. *Comparison of growth between sexes*

Growth difference between sexes was analyzed by testing differences in linear regression of log of length on age. The resulting probability value (*P*) of each test was computed and is summarized in Table 10. The probability of error of rejecting the hypothesis of equal growth rate was selected as 0.05. Therefore, a *P* value less than 0.05 rejects this hypothesis and signifies a significant difference in

TABLE 10. Linear regression analysis for growth differences between sexes for 15 species of rockfish[1].

Species	Male *n*	Female *n*	*P* value[2]
Black rockfish	75	81	0.5086
Black-and-yellow rockfish	138	150	0.0001
Canary rockfish	24	25	0.0033
China rockfish	40	39	0.4541
Copper rockfish	86	108	0.3683
Gopher rockfish	255	241	0.0099
Grass rockfish	47	78	0.9510
Greenspotted rockfish	16	21	0.8946
Kelp rockfish	168	141	0.0453
Olive rockfish	149	129	0.0001
Rosy rockfish	66	84	0.0151
Starry rockfish	42	43	0.9556
Vermilion rockfish	79	72	0.1763
Yelloweye rockfish	18	21	0.3545
Yellowtail rockfish	16	19	0.3805

[1]*Dependent variable is log of length, independent variable is age, and grouping is sex.*

[2]*Probability of error of rejecting hypothesis of equal growth rate.*

TABLE 10. Linear regression analysis for growth differences between sexes for 15 species of rockfish

growth rate between the sexes. Significant differences in growth between the sexes at $P < 0.05$ were noted for black-and-yellow, canary, gopher, kelp, olive, and rosy rockfishes. However, due to sample-size differences, interpretation of statistical results should be viewed with caution. Some tests may not be significant due to sample-size limitation. Conversely, the highly significant P value for growth differences between male and female black-and-yellow and gopher rockfishes had an [L8] for each sex which differed by only 13 mm and 14 mm, respectively.

4.2. Ageing difficulty

Readability of otoliths differed markedly among species. Black-and-yellow and starry rockfishes were considered easy to age while China and rosy rockfishes were more difficult. Generally, reading of the otolith became more difficult at the point where the otolith began to thicken rather than grow in length and width. We observed the age where this occurred for the following species of rockfish: black-and-yellow, 16; gopher, 12; grass, 12; kelp, 10; rosy, 7; vermilion, 14; and yelloweye, 15.

Operculum reading difficulty also differed among the three species examined. Vermilion rockfish opercula readability was lower than either gopher or black-and-yellow rockfishes. Operculum ageing difficulty was generally due to additional calcification near the operculum base. This made determination of the first few years impossible.

4.3. Ageing results

Ageing results and comparisons are presented for the following species of rockfishes:

Black rockfish. Based on the von Bertalanffy growth equation, [L8] for female black rockfish (670 mm TL) was considerably greater than for males (559 mm TL). A linear regression test for differences in growth between the sexes was not significant ($n = 156$, $P > 0.50$). However, Six and Horton (1977) found significant growth differences for black rockfish off Oregon; our [L8] values exceeded their calculations by 28 mm for males and 71 mm for females. Sizes reported by Six and Horton (1977) were fork length. We used the calculations given by Echeverria and Lenarz (1984) to convert from fork length and standard length to total length in this and other cases where the measurement used in other studies was different than total length. The oldest black rockfish observed in our study were 11 years for males and 13 years for females. Our calculated length-at-age suggested females overtake males by age 5 and average 60 mm longer than males by age 15. Although calculations suggested an [L8] of 691 mm TL for combined sexes (Figure 5), the largest black rockfish reported by Miller and Lea (1972) was 603 mm TL. Barker (1979) and Gowan (1983) reported [L8] of 610 and 680 respectively for combined sexes of black rockfish from Puget Sound, Washington. Because our data set did not include specimens over age 13, [L8] may be overestimated.

Black-and-yellow rockfish. The von Bertalanffy length-at-age agreed well with observed length-at-age for this species. Maximum age observed was 21 years. However, confidence concerning ages beyond 16 was relatively low due to increased thickness of the otolith. [L8] for females was 339 mm and for males 327 mm TL. The linear regression test suggested a highly significant difference in growth between sexes ($n = 288$, $P < 0.01$). However, little difference was observed in calculated length-at-age between sexes; length of females exceeded males by only 8 mm TL by age 15.

Canary rockfish. Calculated values based on the von Bertalanffy equation suggested females surpassed the size of males by age 5. By age 15, females averaged 546 mm TL, 109 mm greater than males at this age. Six and Horton (1977) and Boehlert (1980b) also observed that females grew to a larger size than males for this species. The linear regression test indicated there is a significant difference in growth rate between sexes ($n = 49$, $P < 0.01$). Specimens collected for our study were much smaller than those examined by Boehlert (1980b) in the Oregon-Washington area. Our oldest specimens were 8, 10, and 13 years of age with only two specimens larger than 500 mm TL. Calculated [L8] for females (539 mm TL) and combined sexes (715 mm TL) exceeded that of Westrheim and Harling (1975) and Six and Horton (1977). Our male [L8] (465 mm TL) was considerably less than either of their values. Small sample size for both males (24) and females (25) and sensitivity of calculated values to changes in the data set decreased our confidence in these parameters. This sensitivity was demonstrated when [L8] for combined sexes decreased from over 800 to 718 mm TL when one fish aged at 13 years was added to the data set.

China rockfish. Variance for China rockfish length-at-age was greater than the other species we investigated. Greater variance could have been due to inclusion of specimens from separated geographic areas (northern and central California) and from different periods. Samples were combined from northern California (primarily the Point Arena area) for the years 1972–83 with those from central California. Age-curve calculation was further complicated by a paucity of young specimens, especially males. Few China rockfish were aged at less than 6 years. [L8] for males was 376 mm TL and for females 375 mm TL. Linear regression results suggested no difference in growth between sexes ($n = 79$, $P > 0.45$). Ageing of China rockfish was difficult; definition of the otolith focus was a particular problem. The focus in this species was the smallest of the 15 species of rockfish aged. Because some otoliths did not have an easily discernable focus, age may have been underestimated by one or more years for some specimens.

Copper rockfish. Von Bertalanffy growth curves suggested females grew faster than males for the first year. However, from ages 2 to 11 male size-at-age was greater than that of females. The linear regression test indicated no difference in growth between sexes ($n = 194$, $P > 0.36$). Largest reported length for copper rockfish is 582 mm TL (Reilly et al. 1993). Calculated [L8] was 501 mm TL for males and 521 mm TL for females, which was less than our maximum observed size. Calculated length-at-age compared well with observed means. Our [L8] values were less for males and more for females than those of Gowan (1983) for copper rockfish from Puget Sound. Barker (1979) calculated [L8] values of 700 mm (male) and 780 mm (female) for copper rockfish from Puget Sound, which were considerably larger than ours and those of Gowan (1983). Barker (1979) also obtained ages up to 34 years for females. A comparison of our calculated size-at-age with Patten (1973) and Gowan (1983) demonstrated good agreement below age 7. Sizes reported by Patten (1973) were fork length. Our calculated length-at-age for both sexes were nearly identical, differing by only 7 mm at age 15. Both Pattern (1973) and Gowan (1983) found males to grow larger than females while we found the converse to be true. Whether copper rockfish in our area grow faster after reaching maturity (ca. age 7) than those in Puget Sound remains to be shown.

Otoliths were relatively easy to age, posessing large well-defined annular rings. Even otoliths from larger specimens (over 400 mm TL) were easily readable and had readily definable opaque and translucent edges. We have high confidence in assigned ages for this species.

Gopher rockfish. Asymptotic length was calculated as 341 mm TL for females and 329 mm TL for males. The linear regression test suggested there is a highly significant difference in growth rate between sexes ($n = 496$, $P < 0.01$); however, calculated length-at-age by sex suggested this difference is very small.

The maximum age assigned this species was 14 years with one exception: one specimen had an unusually clear otolith aged at 24 years. The 24-year-old fish had been tagged at 316 mm TL and manifested only 4 mm of growth in nearly 11 years at liberty. Calculated age for this fish would have been 13 to 14 years at time of tagging and 24 to 25 years at time of recapture. Another gopher rockfish, tagged at 272 mm TL, exhibited only 10 mm growth in 6.7 years at liberty. Age for this fish was 15 years at time of recapture. Spacing of otolith annular rings for this specimen indicated average growth until approximately the time of tagging when growth declined sharply. This return was the only indication that tagging may affect natural growth since this fish grew much less than would have been expected. These tag returns supported our assumption that small rings near the otolith margin in this species are real annuli. Otolith readers could have confused these small rings near the otolith edge in other gopher rockfish as a single annulus; however, readability of gopher rockfish otoliths was good below age 13 and confidence in calculated growth parameters was high.

This species is closely allied with the black-and-yellow rockfish. Calculated [L8] was very similar for these species as is average length-at-age. Average size of gopher rockfish landed from ramp surveys (280 mm TL, $n = 1081$) was almost exactly the same as that of black-and-yellow rockfish (279 mm TL, $n = 653$). Except for color, these two species are very difficult or impossible to differentiate.

Grass rockfish. Males and females appeared to grow at nearly the same rate and had almost the same maximum length. [L8] for males was 494 mm TL and for females 535 mm TL. Calculated values of [L8] were close to maximum observed length but were less than reported by Miller and Lea (1972; 559 mm TL). No difference in growth between sexes was detected by the linear regression test ($n = 125$, $P > 0.95$).

The smallest grass rockfish collected was 44 mm TL and was aged as age-0 or young-of-the-year. Both this fish and three others which measured 49, 101, and 144 mm TL had otoliths which appeared to be one year older than expected. The operculum was aged as one year less than the otolith for these four fish. We therefore assumed these otoliths had a very clear core and primordium zone which we had not seen on other rockfishes. Other investigators are cautioned that this central area could be confused as a complete ring and the otolith inaccurately designated as one year older. Ageing confidence was high for fish under 12 years. However, age assignments beyond this age were difficult due to rapid otolith thickening.

Greenspotted rockfish. Chen (1971) obtained a maximum age of 13 years for this species while our study obtained ages up to 21 and observed a maximum length of 460 mm TL (not aged). Chen calculated length at age 21 as 338 mm TL while we obtained 414 mm TL. Chen reported standard length which we multiplied by 1.2 to obtain total length. We obtained larger specimens than Chen; however, our data set did not have sexed individuals below 9 years of age. No significant difference in growth rate between sexes was found by the linear regression test ($n = 37$, $P > 0.89$). [L8] for males was 440 mm TL and for females 442 mm TL.

We, as Chen (1971), did not find greenspotted rockfish easy to age. Many of our otoliths had indefinite or cloudy rings making them impossible to age by the surface technique.

Kelp rockfish. Little difference was noted in [L8] between males and females (377 mm and 369 mm TL, respectively); however, the linear regression test noted a significant difference in growth between the sexes ($n = 309$, $P < 0.05$). Specimens up to 388 mm TL were aged. The largest kelp rockfish we observed, 425 mm TL, was equal to the largest reported by Miller and Lea (1972). Otoliths from kelp rockfish beyond age 10, or about 325 mm TL, became increasingly difficult to age due to their thickness. However, most specimens collected were below this length and did not present ageing difficulty. Measured average size-at-age corresponded well with calculated values, and the von Bertalanffy model appeared to fit the growth pattern of this species well.

Olive rockfish. Calculated length-at-age of females surpassed that of males around age 5. Length differences between males and females beyond age 5 continued to increase until at age 10 calculated female length was 461 mm TL compared to 416 mm TL for males. Linear regression analysis noted a highly significant difference in growth between the sexes ($n = 278$, $P < 0.01$). Calculated [L8] for females, 539 mm TL, was also much greater than that of males, 440 mm TL. Our length-at-age and weight-at-length calculations agreed closely with Love and Westphal (1981). However, they encountered ages up to 25 years while we saw none beyond age 14.

Rosy rockfish. The [L8] reported by Chen (1971) of 202 mm SL was converted by us to 242 mm TL, which was considerably less than our [L8] for combined sexes of 325 mm TL (Figure 15). There was a difference in growth between sexes found by the linear regression test ($n = 150$, $P < 0.02$). Our collections included specimens up to 304 mm TL. Chen used back-calculated lengths and noted much difficulty in ring interpretation. We also encountered indefinite ring circuli, many incomplete rings, and a nondistinct pattern of translucent-opaque ring deposition. By age 7 rosy rockfish otoliths already had indistinct rings and were difficult to age. For this reason the surface technique of otolith reading was not entirely satisfactory for this species.

Starry rockfish. [L8] for males was 460 mm TL and for females 450 mm TL. Very small differences were found for calculated lengths-at-age between males and females, and no difference was noted in growth between the sexes by the linear regression test ($n = 85$, $P > 0.95$). Calculated [L8] for combined sexes (467 mm TL) exceeded the greatest length observed during our study (442 mm TL). [L8] may have been slightly high due to lack of fish below age 5 (206 mm TL).

Mean length-at-age compared very well with calculated length-at-age. Starry rockfish otoliths were comparably easy to age. They had definite ring patterns and no reading difficulty was noted due to otolith thickening even in the two individuals aged at 17 and 19 years.

Vermilion rockfish. Our oldest sample was 29 years old and measured 597 mm TL (Figure 17). Phillips (1964), using scales, obtained a maximum age of 19 years at 607 mm TL. Our calculated sizes were larger than Phillips' at all ages. However, our [L8] of 598 mm TL was considerably less than Phillips' maximum of 688 mm TL. [L8] for females and males was 624 and 575 mm TL, respectively. The linear regression test indicates no difference in growth between the sexes ($n = 151$, $P > 0.17$).

The largest vermilion rockfish we observed was 622 mm TL compared to the record of 660 mm TL (Miller and Lea 1972).

We, as Phillips (1964), aged very few fish beyond 14 years of age. This was in part due to our sparse collection of larger specimens, but also due to our inability to differentiate outer rings in thickened otoliths using the surface-reading technique. The otoliths of this species became particularly thick beyond 14 years of age, and in many cases opaque or translucent margin types could not be distinguished, making an accurate age assignment impossible. In several cases, the first ring in otoliths of specimens beyond 14 years of age would also become obscured, as verified by the measurement of the first ring on otoliths of younger specimens. The first and second annular rings were also obscured in many opercula from specimens over 14 years of age.

Yelloweye rockfish. Confidence was low for our calculated [L8] of males (756 mm TL) and females (646 mm TL), due to the limited data set of 39 specimens, which included males between 9 and 17 years of age only (Figure 18). The linear regression test detected no significant difference in growth between the sexes ($n = 39$, $P > 0.35$). The largest reported yelloweye rockfish is 914 mm TL (Miller and Lea 1972), while the largest fish observed during this study was only 655 mm TL. Yelloweye rockfish are not a common species off central California and obtain greater sizes off British Columbia and Alaska. The largest male and female aged were 604 mm TL and 611 mm TL, respectively. This species approaches [L8] at about 15 years of age.

Otoliths were generally very readable up to age 12 to 14. At age 15 and beyond thickness and curvature of the otolith allowed ageing of only exceptionally good specimens. One exceptionally clear otolith aged at 23 years was from a fish measuring 567 mm TL. This suggests that individuals in excess of 550 mm TL may have been underaged by the surface ageing technique.

Yellowtail rockfish. Calculated length-at-age suggested male yellowtail rockfish grew faster than females until age 7. Beyond age 7 male yellowtail rockfish growth rate slowed more rapidly than females, resulting in an [L8] of 451 mm TL for males compared to 561 mm TL for females. Six and Horton (1977) noted sexual growth differences in this species; however, we found no growth difference between the sexes using the linear regression test ($n = 35$, $P > 0.38$). While this inability to find sexual growth differences may have been due to small sample size, the difference in our [L8] values for males and females suggested a growth difference may exist.

Calculated length-at-age agreed well with measured means. [L8] and calculated size-at-age compare well with Phillips (1964), although our maximum size for male yellowtail rockfish (451 mm TL) is slightly lower than either Fraidenberg (1980) or Westrheim and Harling (1975). Sizes reported by Westrheim and Harling are fork length. We converted their values to total length using conversions of Echeverria and Lenarz (1984). Our [L8] values agreed well with Six and Horton (1977) even though they obtained a poor fit of their data using the von Bertalanffy growth model. Our calculated size-at-age for both males and females also agreed well with Clark et al. (1986) and were about 30 and 50 mm larger than male and female values of Barker (1979). Small male sample size (16) and one male aged at 20 with a length of only 416 mm TL (considerably under the expected length for this age) were reasons our [L8] may have been smaller than that of other investigators.

FIGURE 5. Age-length relationship for black rockfish.

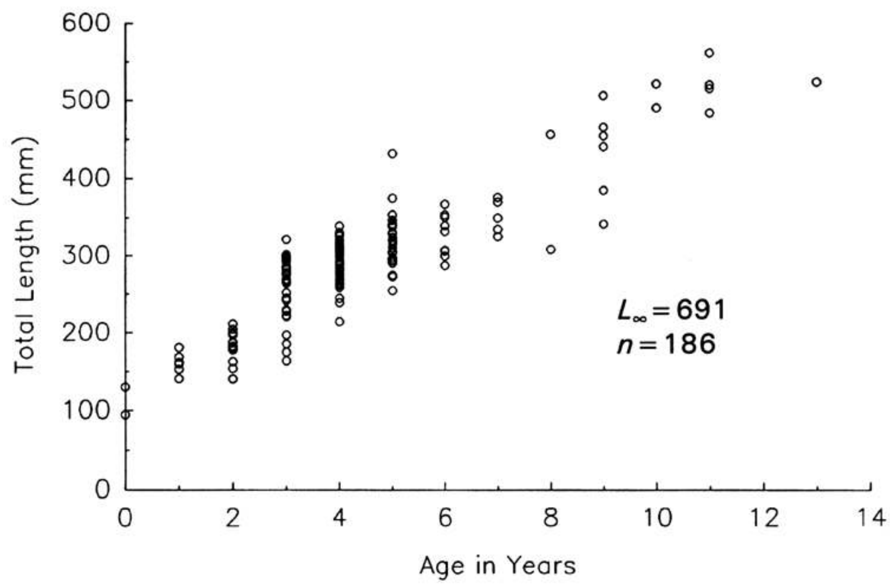


FIGURE 5. Age-length relationship for black rockfish

Calculated and measured lengths at age for black rockfish.

Age	*n*	Calculated mean mmTL	Measured mean mmTL	Range mmTL	Standard error[1]
0	1	-	95	-	-
1	6	148	157	140–181	15.4
2	16	200	178	130–205	21.5
3	36	246	259	163–321	38.7
4	63	289	296	212–338	25.8
5	34	327	319	252–385	27.3
6	9	361	325	288–354	25.9
7	5	392	349	325–375	21.6
8	2	421	382	308–455	-
9	6	447	423	340–491	55.3
10	3	470	523	485–563	-
11	4	491	504	466–525	-
12	-	510	-	-	-
13	1	527	522	-	-
14	-	542	-	-	-
15	-	557	-	-	-
16	-	569	-	-	-
17	-	581	-	-	-
18	-	591	-	-	-
19	-	601	-	-	-
20	-	609	-	-	-

[1]*Standard error of measured mean where $N \geq 5$*

FIGURE 6. Age-length relationship for black-and-yellow rockfish.

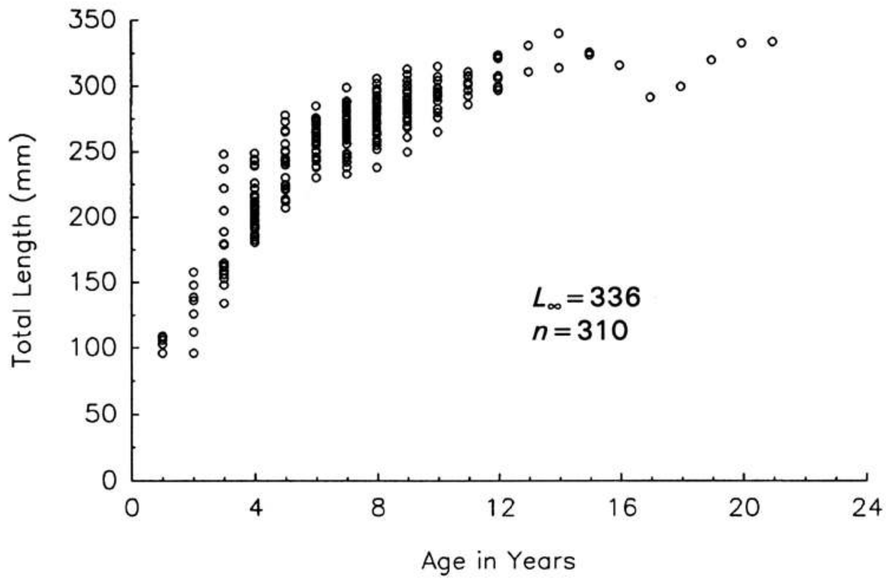


*FIGURE **6.** Age-length relationship for black-and-yellow rockfish*

Calculated and measured lengths at age for black-and-yellow rockfish.

Age	*n*	Calculated mean mmTL	Measured mean mmTL	Range mmTL	Standard error[1]
0	-	-	-	-	-
1	6	95	105	96–109	4.9
2	10	142	130	96–158	17.6
3	15	179	180	134–248	33.9
4	35	210	210	181–249	18.1
5	26	234	240	207–278	19.6
6	32	254	260	230–285	13.3
7	49	270	268	233–299	14.0
8	54	283	278	238–306	12.9
9	36	293	287	250–313	13.7
10	17	301	293	265–315	12.2
11	9	308	301	286–311	7.9
12	9	313	308	297–324	11.2
13	2	318	321	311–331	-
14	2	321	327	314–340	-
15	2	324	325	324–326	-
16	1	326	316	-	-
17	1	328	292	-	-
18	1	329	300	-	-
19	1	331	320	-	-
20	1	332	333	-	-
21	1	332	334	-	-

[1]*Standard error of measured mean where N ≥ 5*

FIGURE 7. Age-length relationship for canary rockfish.

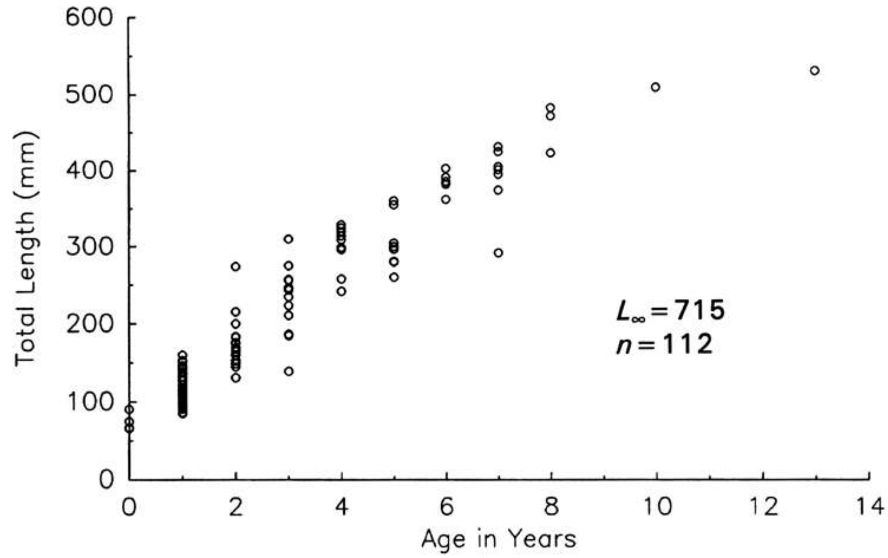


FIGURE 7. Age-length relationship for canary rockfish

Calculated and measured lengths at age for canary rockfish.

Age	*n*	Calculated mean mmTL	Measured mean mmTL	Range mmTL	Standard error[1]
0	4	52	75	66–91	-
1	43	120	118	85–170	21.8
2	16	181	178	131–274	34.9
3	13	236	232	139–310	43.9
4	11	285	303	242–329	28.3
5	8	329	305	260–360	35.5
6	6	369	385	362–403	13.4
7	7	405	389	292–431	46.8
8	3	437	459	423–483	-
9	-	466	-	-	-
10	1	491	510	-	-
11	-	514	-	-	-
12	-	535	-	-	-
13	1	554	531	-	-
14	-	571	-	-	-
15	-	586	-	-	-
16	-	599	-	-	-
17	-	611	-	-	-
18	-	622	-	-	-
19	-	632	-	-	-
20	-	641	-	-	-

[1]*Standard error of measured mean where N ≥ 5*

FIGURE 8. Age-length relationship for China rockfish.

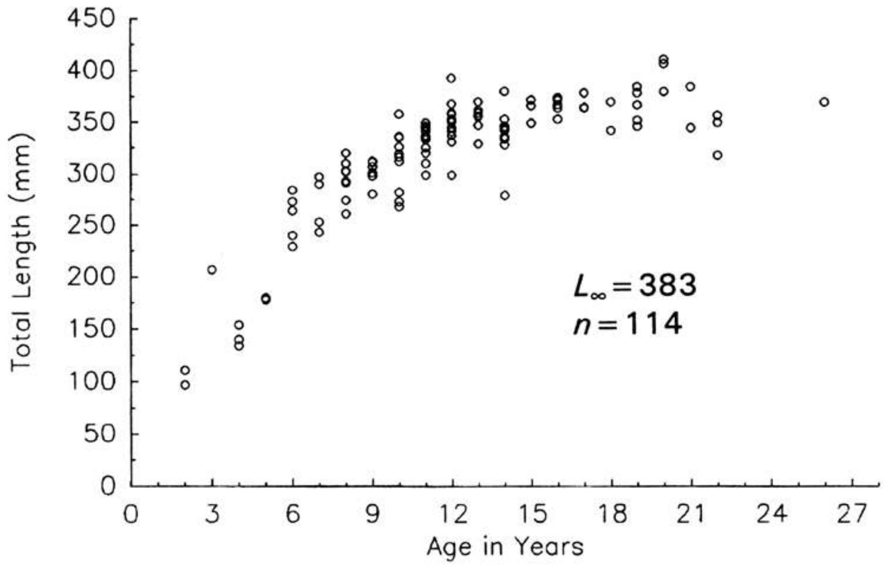


FIGURE 8. Age-length relationship for China rockfish

Calculated and measured lengths at age for China rockfish.

Age	*n*	Calculated mean mmTL	Measured mean mmTL	Range mmTL	Standard error[1]
0	-	-	-	-	-
1	-	48	-	-	-
2	3	103	106	97–111	-
3	1	149	207	-	-
4	3	188	143	134–154	-
5	2	220	179	178–180	-
6	5	247	258	229–284	22.9
7	4	270	271	243–297	-
8	9	289	296	261–320	18.7
9	6	304	301	280–312	11.9
10	11	317	310	268–358	29.5
11	14	328	333	299–349	14.5
12	12	337	348	299–393	22.5
13	7	345	354	329–370	13.1
14	9	351	338	279–380	26.7
15	3	356	362	349–372	-
16	6	361	364	353–374	9.1
17	3	364	369	364–379	-
18	2	367	356	342–370	-
19	5	370	366	346–385	16.8
20	3	372	399	380–411	-
21	2	374	365	345–385	-
22	3	375	342	318–357	-
23	-	377	-	-	-
24	-	378	-	-	-
25	-	379	-	-	-
26	1	379	370	-	-

[1]*Standard error of measured mean where $N \geq 5$*

FIGURE 9. Age-length relationship for copper rockfish.

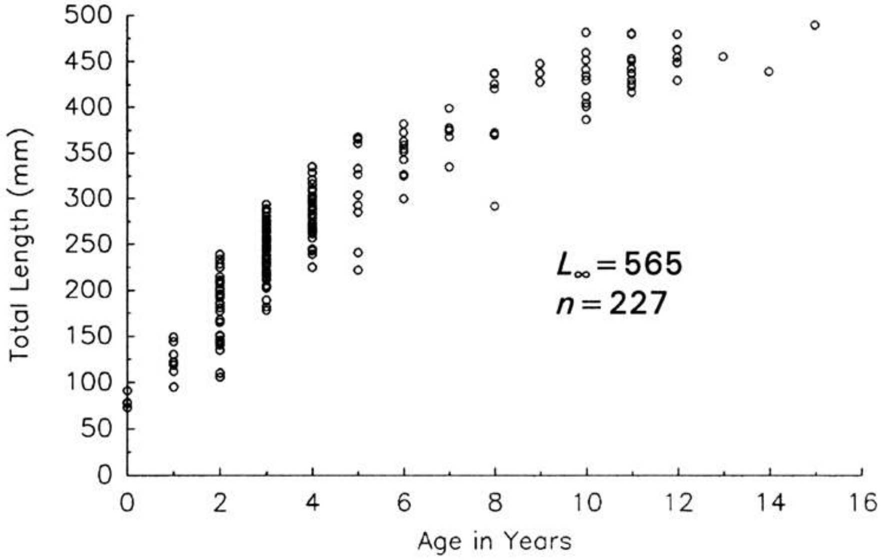


FIGURE 9. Age-length relationship for copper rockfish

Calculated and measured lengths at age for copper rockfish.

Age	*n*	Calculated mean mmTL	Measured mean mmTL	Range mmTL	Standard error[1]
0	5	-	82	73–91	8.4
1	8	129	123	95–149	17.8
2	36	189	181	106–239	32.9
3	66	240	245	178–294	29.2
4	37	282	285	225–335	25.8
5	11	319	315	222–368	51.2
6	10	350	348	300–382	24.7
7	7	376	351	226–399	58.3
8	8	399	391	292–438	49.8
9	3	418	438	428–448	-
10	10	434	431	387–482	29.6
11	13	447	444	417–481	19.7
12	8	459	466	430–538	32.4
13	1	469	456	-	-
14	1	477	440	-	-
15	1	484	490	-	-
16	-	490	-	-	-
17	-	495	-	-	-
18	-	500	-	-	-
19	-	503	-	-	-
20	-	507	-	-	-
21	1	509	492	-	-
22	-	511	-	-	-
23	-	513	-	-	-
24	-	515	-	-	-
25	-	516	-	-	-
26	-	518	-	-	-
27	-	519	-	-	-
28	1	519	562	-	-

[1]*Standard error of measured mean where $N \geq 5$*

FIGURE 10. Age-length relationship for gopher rockfish.

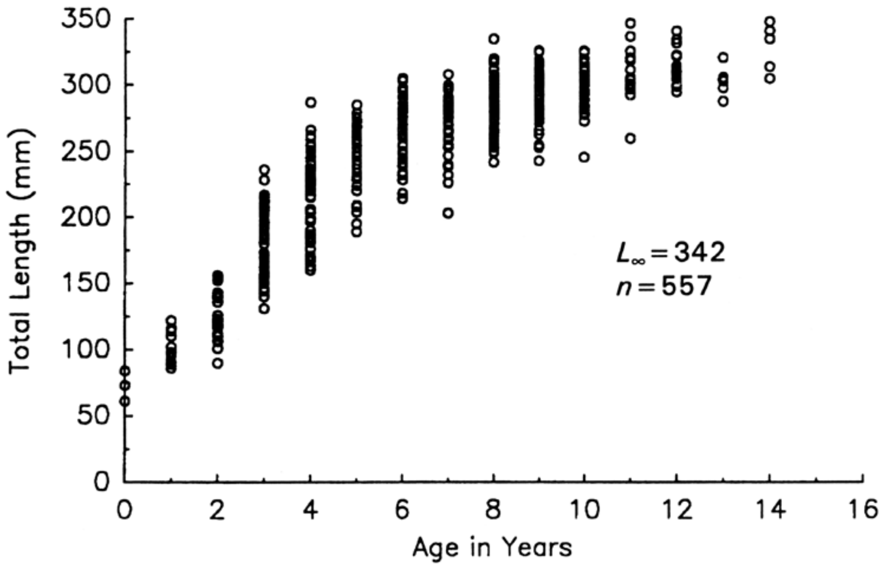


*FIGURE **10.** Age-length relationship for gopher rockfish*

Calculated and measured lengths at age for gopher rockfish.

Age	*n*	Calculated mean mmTL	Measured mean mmTL	Range mmTL	Standard error[1]
0	3	-	73	61–84	-
1	11	99	102	86–122	12.1
2	27	147	124	90–156	17.5
3	49	186	183	131–236	25.4
4	52	217	216	160–287	30.4
5	44	242	246	189–285	23.1
6	54	262	267	214–305	20.8
7	56	278	274	203–308	21.1
8	87	291	285	242–335	19.0
9	85	301	294	243–326	16.8
10	38	309	299	246–326	16.5
11	17	315	311	260–347	19.6
12	22	321	312	295–341	12.1
13	6	325	303	288–321	10.8
14	5	328	329	305–348	18.3
15	-	331	-	-	-
16	-	333	-	-	-
17	-	335	-	-	-
18	-	336	-	-	-
19	-	337	-	-	-
22	-	338	-	-	-
21	-	339	-	-	-
22	-	339	-	-	-
23	-	340	-	-	-
24	1	340	320	-	-

[1]*Standard error of measured mean where $N \geq 5$*

FIGURE 11. Age-length relationship for grass rockfish.

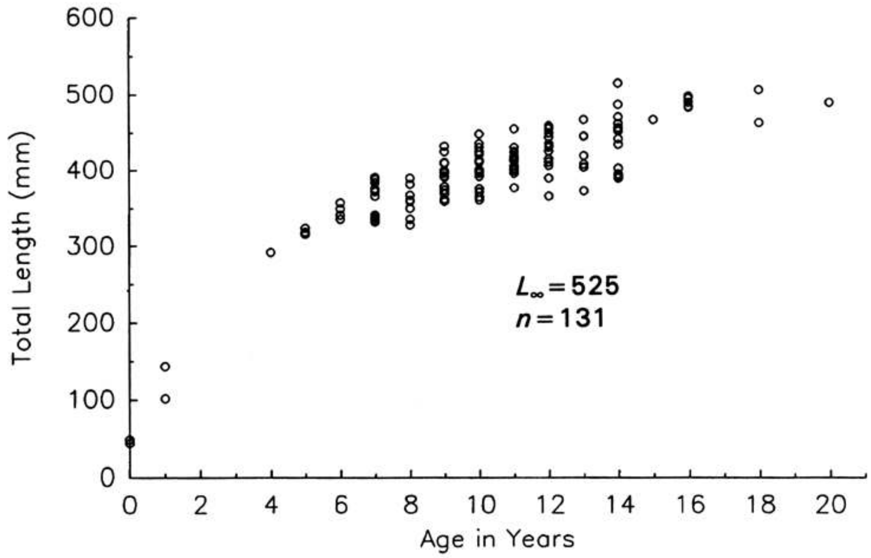


FIGURE 11. Age-length relationship for grass rockfish

Calculated and measured lengths at age for grass rockfish.

Age	*n*	Calculated mean mmTL	Measured mean mmTL	Range mmTL	Standard error[1]
0	2	-	47	44–49	-
1	2	116	123	101–144	-
2	-	170	-	-	-
3	-	216	-	-	-
4	1	260	292	-	-
5	3	292	320	316–324	-
6	4	323	346	336–357	-
7	13	349	365	332–391	21.0
8	9	372	360	328–390	20.0
9	18	392	393	359–432	20.9
10	20	409	402	361–448	25.8
11	13	424	414	377–455	18.8
12	17	437	430	366–459	25.8
13	8	448	429	373–467	33.2
14	14	458	443	390–515	37.3
15	1	467	467	-	-
16	7	474	489	483–498	5.9
17	-	481	-	-	-
18	2	486	485	463–506	-
19	-	491	-	-	-
20	1	495	490	-	-

[1]*Standard error of measured mean where $N \geq 5$*

FIGURE 12. Age-length relationship for greenspotted rockfish.

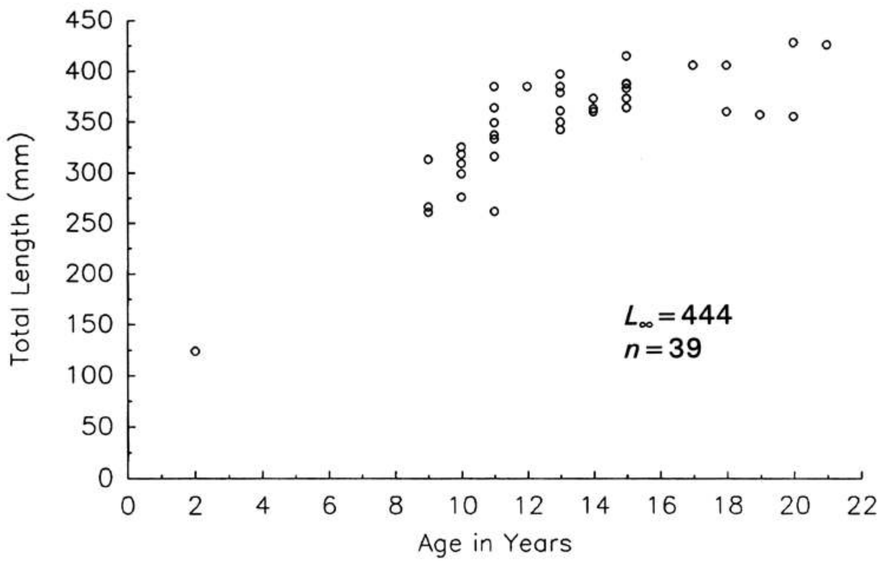


FIGURE 12. Age-length relationship for greenspotted rockfish

Calculated and measured lengths at age for greenspotted rockfish.

Age	*n*	Calculated mean mmTL	Measured mean mmTL	Range mmTL	Standard error[1]
0	-	-	-	-	-
1	-	62	-	-	-
2	1	108	124	-	-
3	-	148	-	-	-
4	-	184	-	-	-
5	-	215	-	-	-
6	-	243	-	-	-
7	-	267	-	-	-
8	-	288	-	-	-
9	3	307	280	261–313	-
10	5	323	305	276–325	19.1
11	7	338	335	262–385	39.2
12	1	351	385	-	-
13	6	362	369	342–397	21.4
14	3	372	365	360–373	-
15	6	380	385	364–415	17.3
16	-	388	-	-	-
17	1	395	406	-	-
18	2	401	383	360–406	-
19	1	406	357	-	-
20	2	410	392	355–428	-
21	1	414	426	-	-

[1]*Standard error of measured mean where $N \geq 5$*

FIGURE 13. Age-length relationship for kelp rockfish.

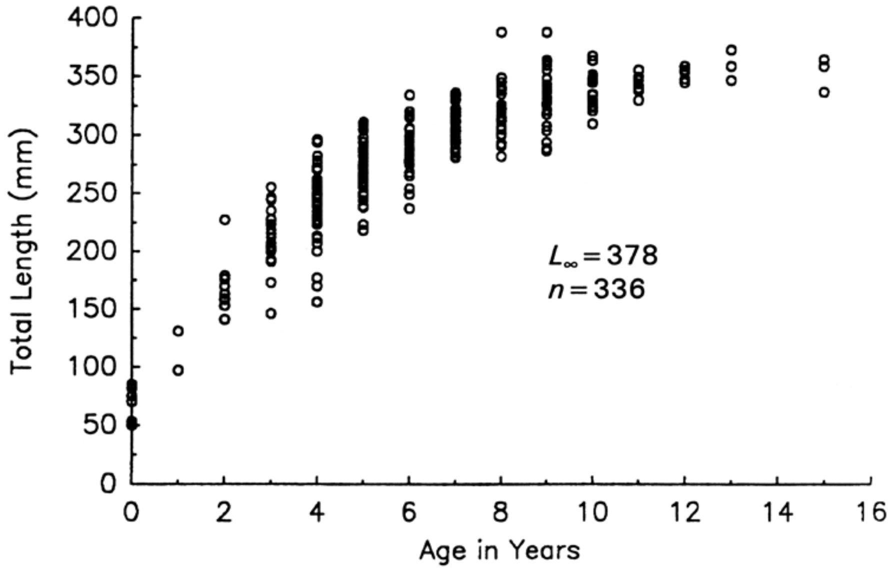


FIGURE 13. Age-length relationship for kelp rockfish

Calculated and measured lengths at age for kelp rockfish.

Age	*n*	Calculated mean mmTL	Measured mean mmTL	Range mmTL	Standard error[1]
0	6	56	69	50–85	14.7
1	2	122	114	97–131	-
2	9	173	170	141–227	24.5
3	20	215	208	146–255	28.1
4	52	248	242	156–296	28.9
5	50	274	273	218–311	21.5
6	44	295	288	237–334	18.0
7	43	312	309	281–336	15.9
8	36	325	319	215–388	26.7
9	33	336	333	287–388	21.4
10	20	344	339	310–368	15.4
11	9	351	343	330–356	9.0
12	6	356	353	345–359	5.3
13	3	361	360	347–373	-
14	-	364	-	-	-
15	3	367	354	337–365	-
16	-	369	-	-	-
17	-	371	-	-	-
18	-	372	-	-	-
19	-	373	-	-	-
20	-	374	-	-	-

[1]*Standard error of measured mean where $N \geq 5$*

FIGURE 14. Age-length relationship for olive rockfish.

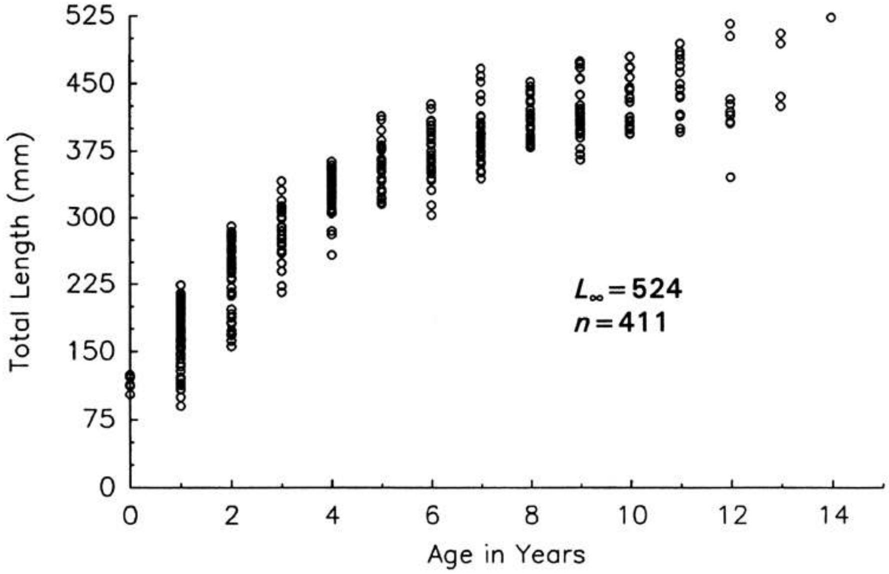


FIGURE 14. Age-length relationship for olive rockfish

Calculated and measured lengths at age for olive rockfish.

Age	*n*	Calculated mean mmTL	Measured mean mmTL	Range mmTL	Standard error[1]
0	6	-	115	103–125	7.9
1	86	163	178	90–230	28.9
2	40	225	228	113–290	45.8
3	28	276	278	100–341	46.5
4	39	318	328	258–363	22.7
5	28	353	361	315–414	26.7
6	36	383	373	303–427	28.5
7	38	407	390	344–467	29.6
8	28	427	411	379–452	20.6
9	31	443	416	365–475	27.9
10	20	457	429	394–480	27.7
11	16	469	450	396–526	37.4
12	10	478	428	346–517	49.3
13	4	486	466	425–506	-
14	1	492	524	-	-
15	-	498		-	-
16	-	502		-	-
17	-	506		-	-
18	-	509		-	-
19	-	511		-	-
20	-	514		-	-

[1]*Standard error of measured mean where $N \geq 5$*

FIGURE 15. Age-length relationship for rosy rockfish.

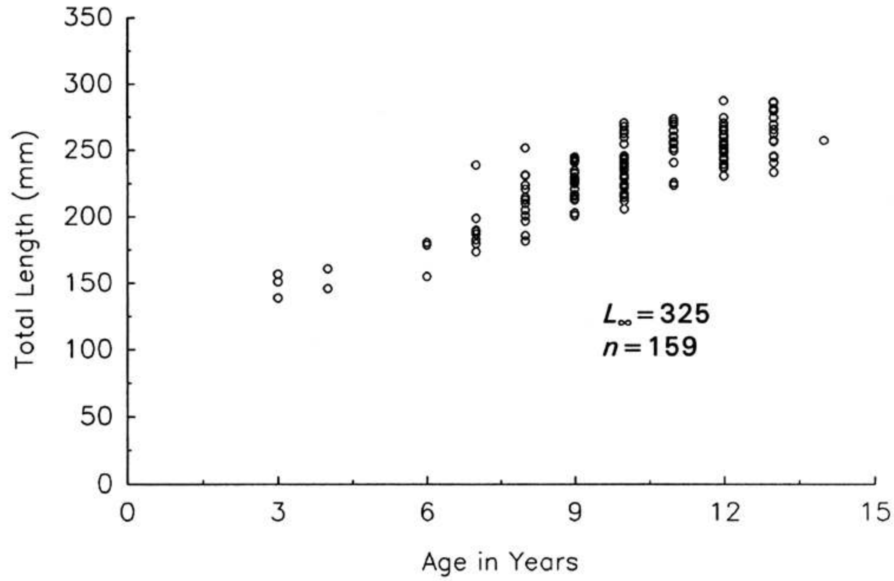


FIGURE 15. Age-length relationship for rosy rockfish

Calculated and measured lengths at age for rosy rockfish.

Age	*n*	Calculated mean mmTL	Measured mean mmTL	Range mmTL	Standard error[1]
0	-	-	-	-	-
1	-	65	-	-	-
2	-	95	-	-	-
3	3	122	149	139–157	-
4	2	146	154	146–161	-
5	-	166	-	-	-
6	3	185	172	155–181	-
7	8	201	193	174–239	20.2
8	14	216	212	182–252	18.9
9	28	228	227	201–245	12.8
10	38	240	238	206–271	15.4
11	20	250	256	224–274	13.0
12	27	258	254	231–288	13.6
13	15	266	265	234–287	17.8
14	1	273	258	-	-
15	-	279	-	-	-
16	-	284	-	-	-
17	-	289	-	-	-
18	-	293	-	-	-
19	-	297	-	-	-
20	-	300	-	-	-

[1]*Standard error of measured mean where $N \geq 5$*

FIGURE 16. Age-length relationship for starry rockfish.

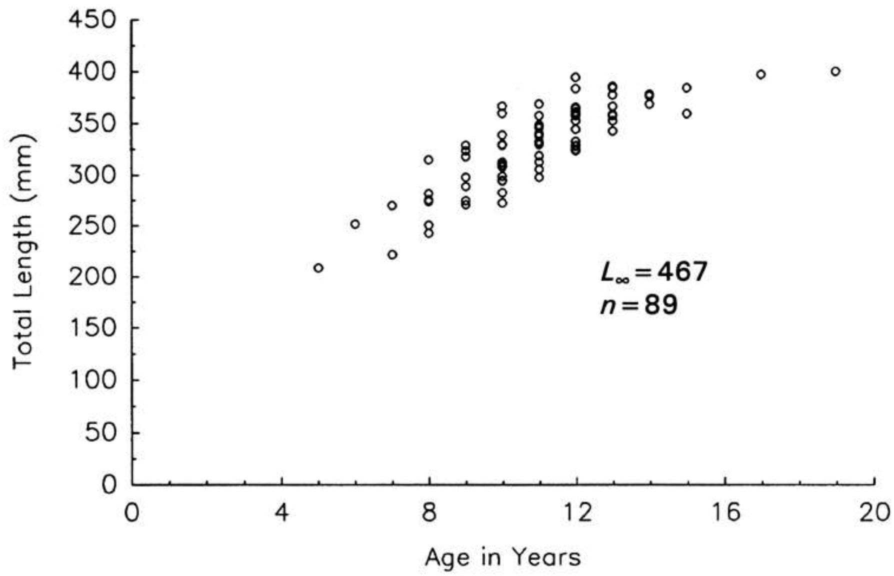


FIGURE 16. Age-length relationship for starry rockfish

Calculated and measured lengths at age for starry rockfish.

Age	*n*	Calculated mean mmTL	Measured mean mmTL	Range mmTL	Standard error[1]
0	-	-	-	-	-
1	-	54	-	-	-
2	-	99	-	-	-
3	-	139	-	-	-
4	-	174	-	-	-
5	1	206	209	-	-
6	1	234	252	-	-
7	2	260	246	222–270	-
8	6	282	273	243–315	25.5
9	7	302	301	271–329	23.6
10	17	320	313	273–367	25.2
11	20	336	336	298–369	17.1
12	19	350	353	324–395	19.4
13	9	363	368	343–386	16.1
14	3	374	375	369–379	-
15	2	384	372	360–385	-
16	-	393	-	-	-
17	1	401	398	-	-
18	-	409	-	-	-
19	1	415	401	-	-
20	-	421	-	-	-

[1]*Standard error of measured mean where N ≥ 5*

FIGURE 17. Age-length relationship for vermilion rockfish.

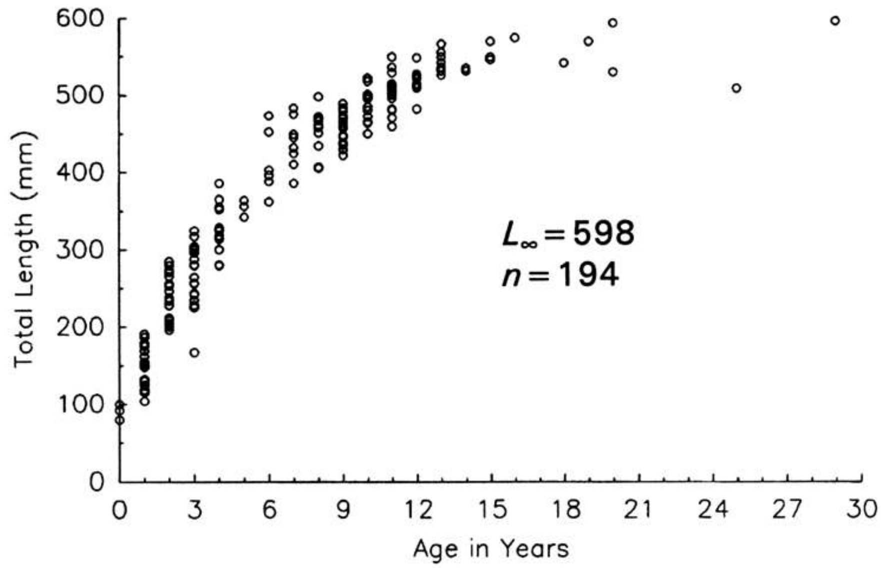


FIGURE 17. Age-length relationship for vermilion rockfish

Calculated and measured lengths at age for vermilion rockfish.

Age	*n*	Calculated mean mmTL	Measured mean mmTL	Range mmTL	Standard error[1]
0	2	-	96	92–100	-
1	21	155	143	80–191	28.7
2	21	220	238	196–285	27.5
3	19	276	267	167–325	38.7
4	16	323	324	280–386	28.8
5	3	364	354	342–364	-
6	6	398	412	362–473	41.8
7	8	428	438	386–483	32.3
8	11	453	454	405–498	28.3
9	18	474	457	422–489	19.8
10	13	493	488	450–522	21.4
11	21	508	505	459–549	20.5
12	14	521	518	482–548	14.2
13	9	533	542	526–567	13.1
14	2	542	533	531–535	-
15	2	551	548	546–549	-
16	2	558	573	570–575	-
17	-	563	-	-	-
18	1	569	542	-	-
19	1	573	570	-	-
20	2	577	562	530–594	-
21	-	280	-	-	-
22	-	582	-	-	-
23	-	585	-	-	-
24	-	587	-	-	-
25	1	588	509	-	-
26	-	590	-	-	-
27	-	591	-	-	-
28	-	592	-	-	-
29	1	593	597	-	-

[1]*Standard error of measured mean where N ≥ 5*

FIGURE 18. Age-length relationship for yelloweye rockfish.

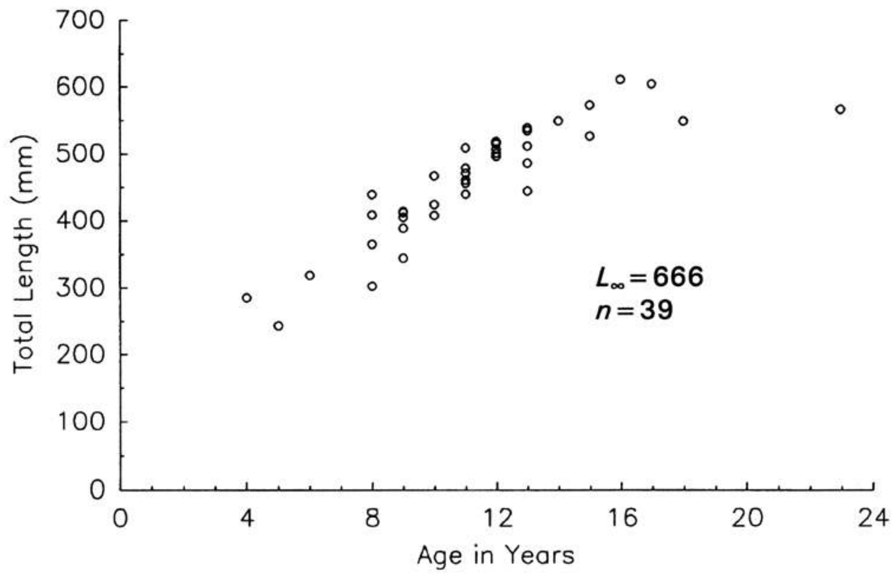


FIGURE 18. Age-length relationship for yelloweye rockfish

Calculated and measured lengths at age for yelloweye rockfish.

Age	*n*	Calculated mean mmTL	Measured mean mmTL	Range mmTL	Standard error[1]
0	-	-	-	-	-
1	-	73	-	-	-
2	-	135	-	-	-
3	-	191	-	-	-
4	1	241	285	-	-
5	1	286	243	-	-
6	1	326	319	-	-
7	-	362	-	-	-
8	4	394	379	303–439	-
9	6	423	397	345–414	27.0
10	3	448	433	408–467	-
11	6	471	469	440–509	23.6
12	5	492	508	496–519	9.5
13	5	510	503	445–539	38.9
14	1	527	549	-	-
15	2	541	550	527–573	-
16	1	554	611	-	-
17	1	566	604	-	-
18	1	577	549	-	-
19	-	586	-	-	-
20	-	594	-	-	-
21	-	602	-	-	-
22	-	609	-	-	-
23	1	615	567	-	-

[1]*Standard error of measured mean where $N \geq 5$*

FIGURE 19. Age-length relationship for yellowtail rockfish.

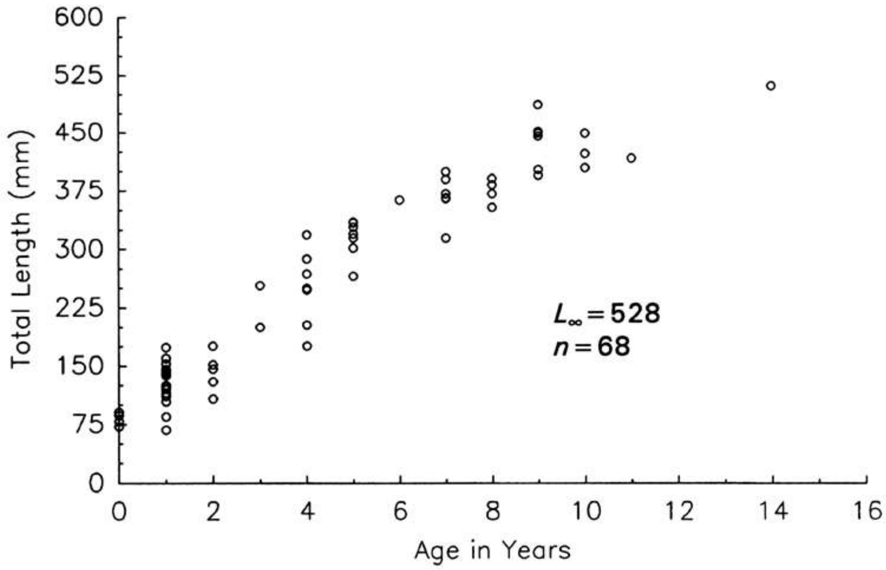


FIGURE 19. Age-length relationship for yellowtail rockfish

Calculated and measured lengths at age for yellowtail rockfish.

Age	*n*	Calculated mean mmTL	Measured mean mmTL	Range mmTL	Standard error[1]
0	4	-	82	72–91	-
1	20	124	130	68–174	26.2
2	5	181	142	108–176	25.3
3	2	229	227	200–254	-
4	7	271	250	176–319	48.7
5	7	307	314	266–335	24.3
6	1	338	363	-	-
7	6	365	368	315–400	29.5
8	4	388	375	354–391	-
9	6	407	439	395–487	34.3
10	3	424	426	405–450	-
11	1	439	417	-	-
12	-	451	-	-	-
13	-	462	-	-	-
14	1	471	512	-	-
15	-	479	-	-	-
16	-	486	-	-	-
17	-	492	-	-	-
18	-	497	-	-	-
19	-	501	-	-	-
20	1	505	416	-	-

[1]*Standard error of measured mean where N ≥ 5*

5. HISTORICAL PERSPECTIVE

In our markets we find fishes constantly offered for sale, in great numbers, under the name of Rock Fish *and* Rock Cod. *They bear always a high price, and constitute one important item in the sum total of our fisheries, and of course in the resources of the State. They are taken in rocky localities along the coast and in the Bay, and the title Rock Fish applies to them very well. One more inappropriate, on the contrary, than that of Rock Cod, could scarcely have been selected—inasmuch as they are widely removed from the family in which the Codfishes are classed. Five distinct species of them we have already detected here, all belonging to the* Sebastes, *and four of them believed to be new....*

—

William O. Ayres

, from a communication presented by Ayres (first president of the Academy) to the California Academy of Natural Sciences, September 11, 1854.

6. LENGTH AND WEIGHT-LENGTH RELATIONSHIPS

6.1. Standard length-total length relationships

Standard length/total length and total length/standard length ratios (including sample size and range in length) for 17 species of rockfish are summarized in Table 11. Range for the SL/TL ratio of the rockfishes considered was 0.811 to 0.841 and for TL/SL the range was 1.189 to 1.233.

6.2. Weight-length relationships

Weight varies throughout a fish's life as some power of length, represented by the formula $w = al^b$. Value constants for the formula for 16 rockfishes, cabezon, kelp greenling, and lingcod are listed in Table 12. Average *b* for male, female, and combined sexes for the rockfishes considered in this study was 2.97, 3.06, and 3.12, respectively. Additionally, length-weight relationship graphs for 15 species of rockfish are represented in Figures 20–34. Largest weight and length for each species of rockfish, by sex, examined by us, is given in the Appendix.

TABLE 11. Standard length-total length relationship for 17 species of rockfish.

Species	*n*	Range of lengths (TL)	SL/TL	TL/SL
Black rockfish	254	54–597	0.823	1.215
Black-and-yellow rockfish	340	80–340	0.825	1.212
Blue rockfish	1666	51–421	0.817	1.225
Brown rockfish	22	127–373	0.825	1.213
Canary rockfish	147	47–568	0.813	1.231
China rockfish	143	97–477	0.828	1.208
Copper rockfish	307	53–562	0.827	1.210
Gopher rockfish	773	61–348	0.825	1.212
Grass rockfish	193	44–538	0.822	1.219
Greenspotted rockfish	81	124–441	0.828	1.208
Kelp rockfish	575	42–388	0.811	1.233
Olive rockfish	631	64–548	0.831	1.204
Rosy rockfish	291	109–304	0.830	1.206
Starry rockfish	164	127–401	0.841	1.189
Vermilion rockfish	250	58–597	0.817	1.225
Yelloweye rockfish	55	177–652	0.837	1.195
Yellowtail rockfish	87	50–512	0.834	1.201

TABLE 11. Standard length-total length relationship for 17 species of rockfish

TABLE 12. Weight-length relationship, $w = a\,l^b$, for 16 species of rockfish and cabezon, kelp greenling, and lingcod (weight in grams and length in millimeters.)

Species	Sex[1]	*n*	*a*	*b*	*r*
Black rockfish	male	93	5.254E−05	2.806	0.964
	female	100	7.156E−06	3.150	0.985
	combined	228	5.810E−06	3.187	0.990
Black-and-yellow rockfish	male	142	1.420E−05	3.070	0.971
	female	162	1.024E−05	3.130	0.980
	combined	330	1.117E−05	3.114	0.991
Blue rockfish	male	177	2.934E−05	2.889	0.962
	female	512	3.408E−05	2.874	0.956
	combined	757	9.774E−06	3.090	0.989
Canary rockfish	male	12	1.873E−05	2.951	0.995
	female	18	2.182E−05	2.940	0.995
	combined	101	6.883E−06	3.147	0.996
China rockfish	male	41	8.793E−06	3.153	0.970
	female	46	6.644E−06	3.206	0.988
	combined	108	7.789E−06	3.177	0.991
Copper rockfish	male	91	2.106E−05	2.981	0.982
	female	118	1.088E−05	3.100	0.995
	combined	255	8.976E−06	3.132	0.966
Gopher rockfish	male	233	1.691E−05	3.027	0.974
	female	237	1.921E−05	3.010	0.980
	combined	537	1.299E−05	3.077	0.993
Grass rockfish	male	50	1.595E−04	2.661	0.928
	female	79	4.092E−05	2.894	0.966
	combined	140	7.310E−06	3.178	0.997
Greenspotted rockfish	male	16	2.827E−06	3.291	0.994
	female	17	4.773E−06	3.210	0.990
	combined	34	1.558E−05	3.001	0.990
Kelp rockfish	male	232	1.327E−05	3.038	0.963
	female	191	9.984E−06	3.094	0.982
	combined	479	6.291E−06	3.172	0.995

TABLE 12. Weight-length relationship, $w = al^b$, for 16 species of rockfish and cabezon, kelp greenling, and lingcod (weight in grams and length in millimeters.)

TABLE 12. (continued).

Species	Sex[1]	*n*	*a*	*b*	*r*
Olive rockfish	male	149	1.675E-05	2.966	0.982
	female	123	3.015E-05	2.874	0.970
	combined	432	6.310E-06	3.136	0.995
Rosy rockfish	male	31	1.198E-05	3.048	0.972
	female	39	9.049E-06	3.108	0.977
	combined	74	9.890E-06	3.088	0.982
Starry rockfish	male	14	1.594E-06	3.371	0.907
	female	8	1.486E-05	3.009	0.980
	combined	23	8.537E-06	3.112	0.986
Vermilion rockfish	male	33	1.971E-05	2.985	0.997
	female	44	1.967E-05	2.992	0.996
	combined	124	1.458E-05	3.041	0.998
Yelloweye rockfish	male	9	5.893E-04	2.424	0.989
	female	12	3.780E-06	3.252	0.992
	combined	22	4.313E-06	3.228	0.992
Yellowtail rockfish	male	4	4.942E-05	2.796	0.997
	female	6	6.947E-06	3.137	0.998
	combined	49	6.690E-06	3.144	0.998
Cabezon	male	17	2.546E-06	3.307	0.935
	female	19	8.780E-06	3.113	0.991
	combined	37	5.498E-06	3.185	0.986
Kelp greenling	male	25	3.586E-06	3.225	0.991
	female	7	9.213E-05	2.675	0.971
	combined	34	4.180E-06	3.198	0.996
Lingcod	male	98	1.211E-06	3.323	0.979
	female	22	2.573E-06	3.194	0.994
	combined	124	7.125E-07	3.405	0.995

[1]*Combined sex category includes individuals for which sex could not be determined and juveniles (stages 1 and 2).*

TABLE 12. Weight-length relationship, $w = al^b$, for 16 species of rockfish and cabezon, kelp greenling, and lingcod (weight in grams and length in millimeters.)

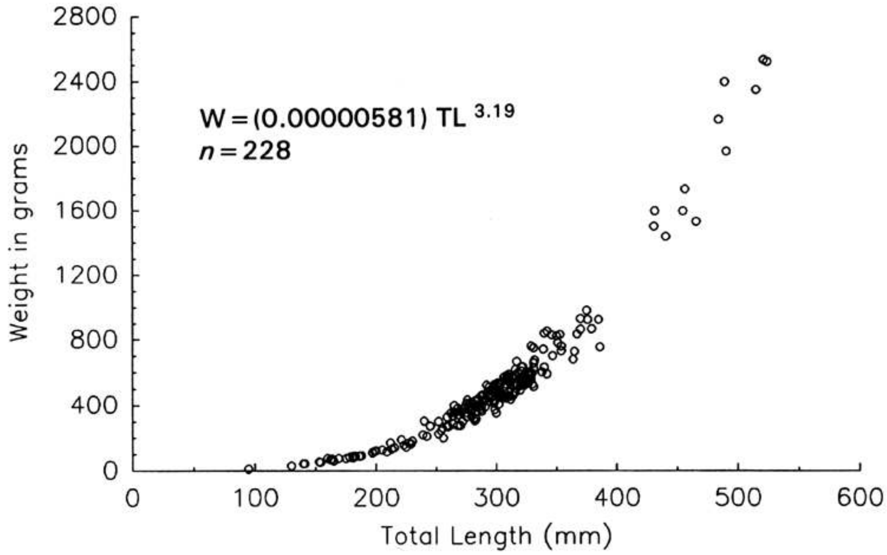


FIGURE 20. Length-weight relationship for black rockfish.

FIGURE 20. Length-weight relationship for black rockfish

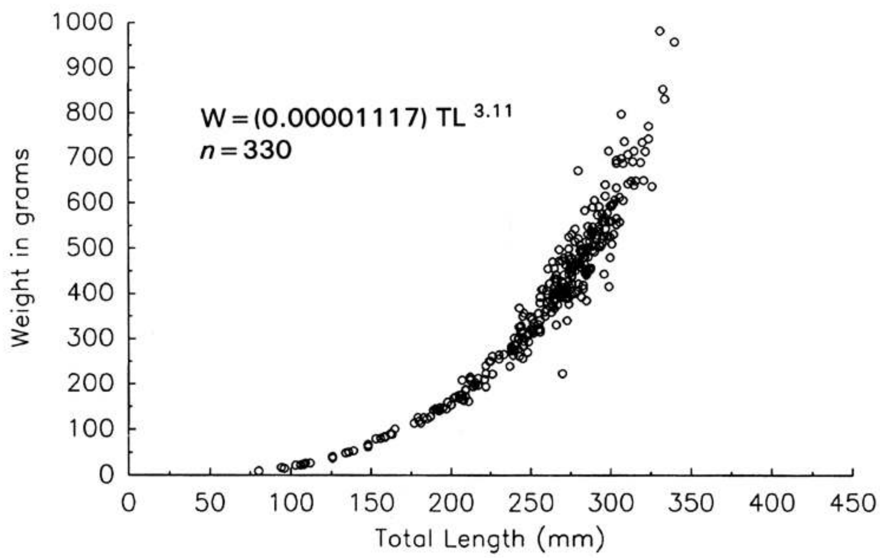


FIGURE 21. Length-weight relationship for black-and-yellow rockfish.

FIGURE 21. Length-weight relationship for black-and-yellow rockfish

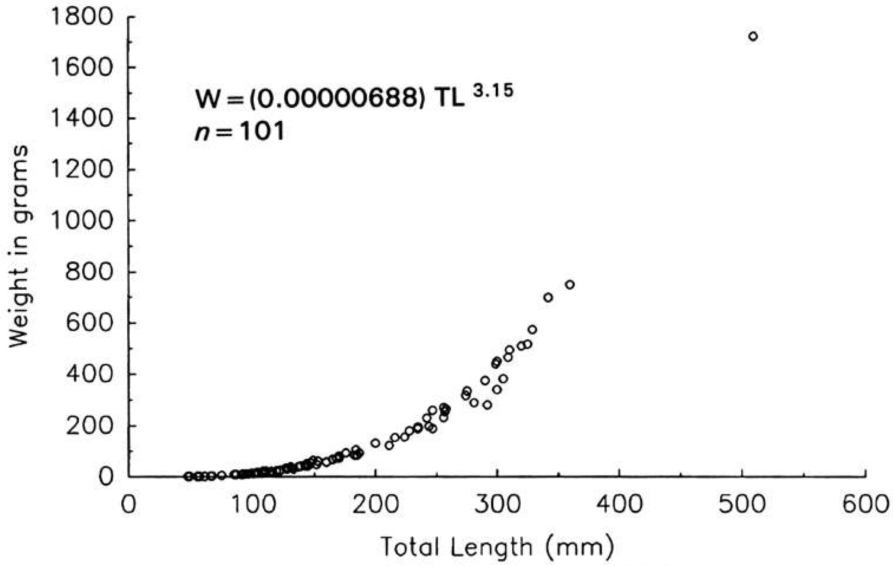


FIGURE 22. Length-weight relationship for canary rockfish.

FIGURE 22. Length-weight relationship for canary rockfish

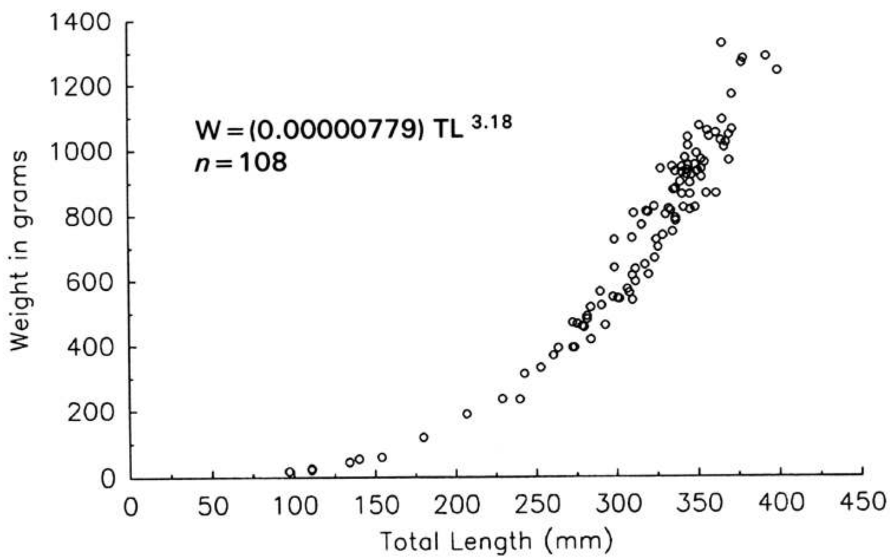


FIGURE 23. Length-weight relationship for China rockfish.

FIGURE 23. Length-weight relationship for China rockfish

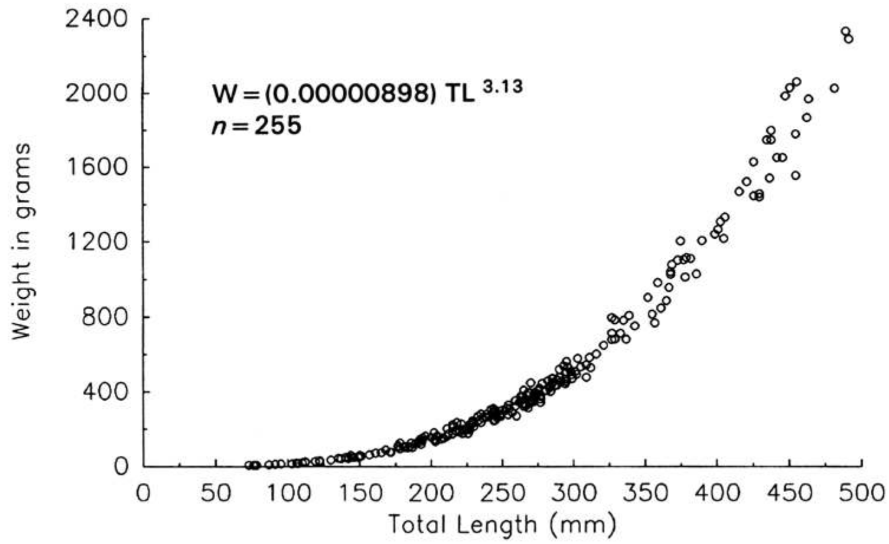


FIGURE 24. Length-weight relationship for copper rockfish.

FIGURE 24. Length-weight relationship for copper rockfish

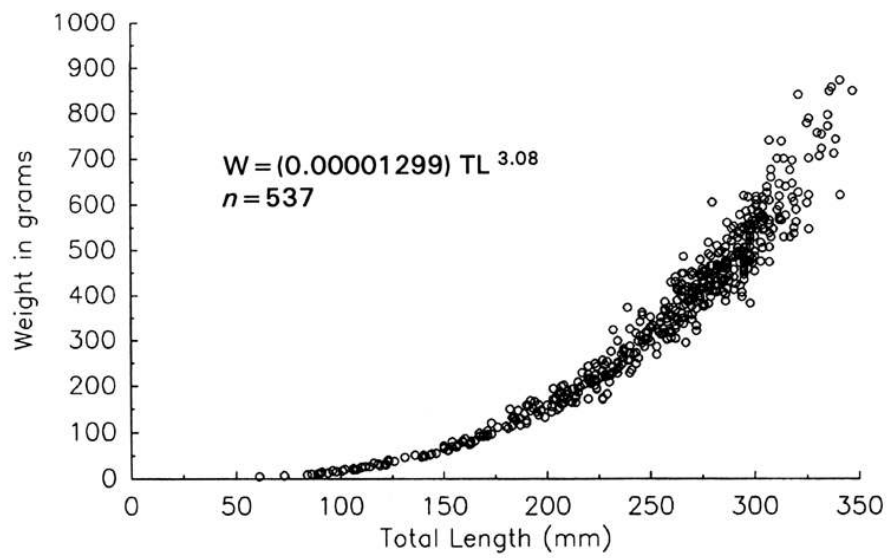


FIGURE 25. Length-weight relationship for gopher rockfish.

FIGURE 25. Length-weight relationship for gopher rockfish

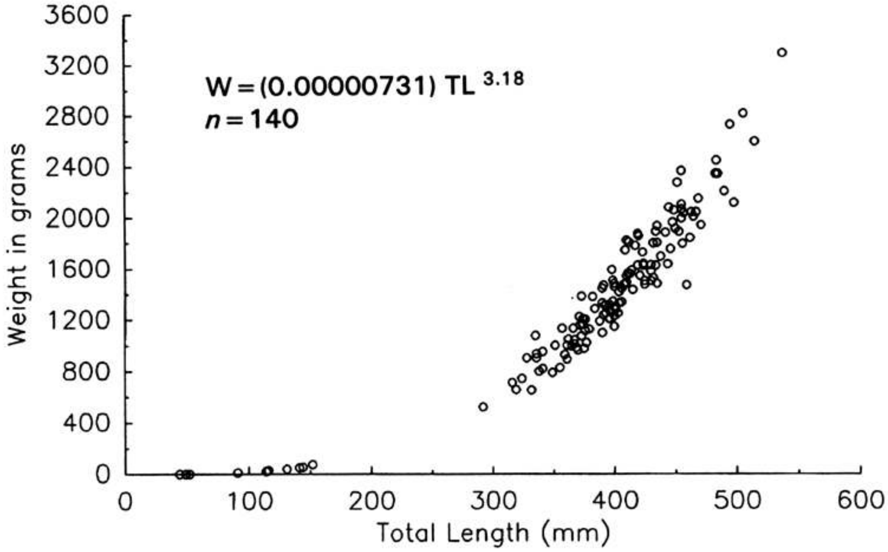


FIGURE 26. Length-weight relationship for grass rockfish.

FIGURE 26. Length-weight relationship for grass rockfish

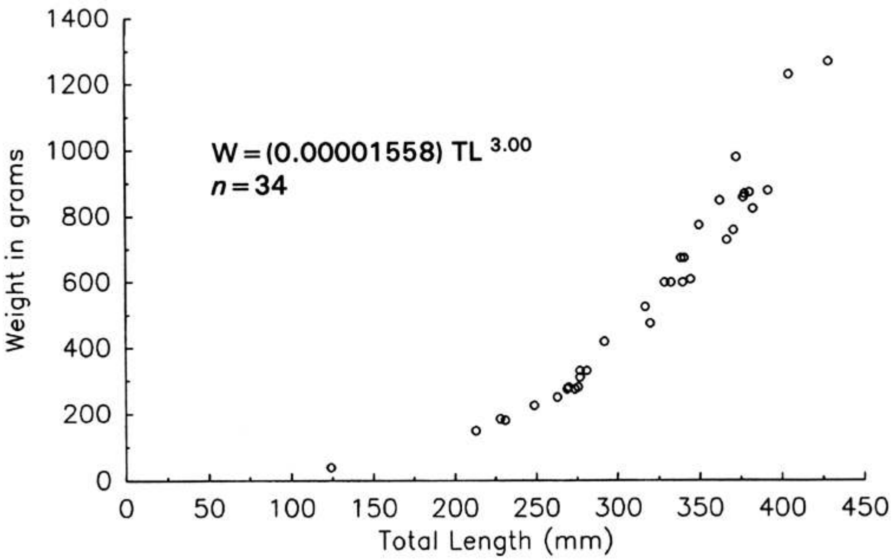


FIGURE 27. Length-weight relationship for greenspotted rockfish.

FIGURE 27. Length-weight relationship for greenspotted rockfish

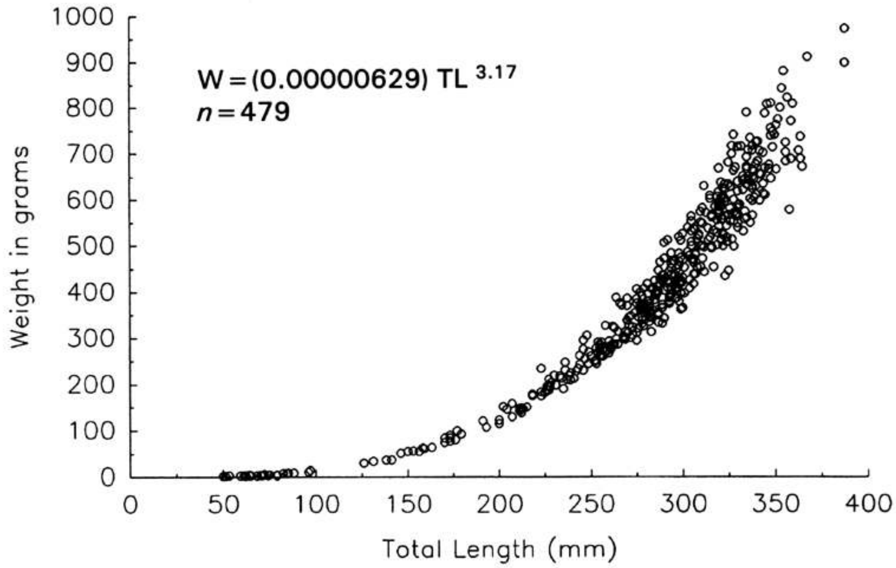


FIGURE 28. Length-weight relationship for kelp rockfish.

FIGURE 28. Length-weight relationship for kelp rockfish

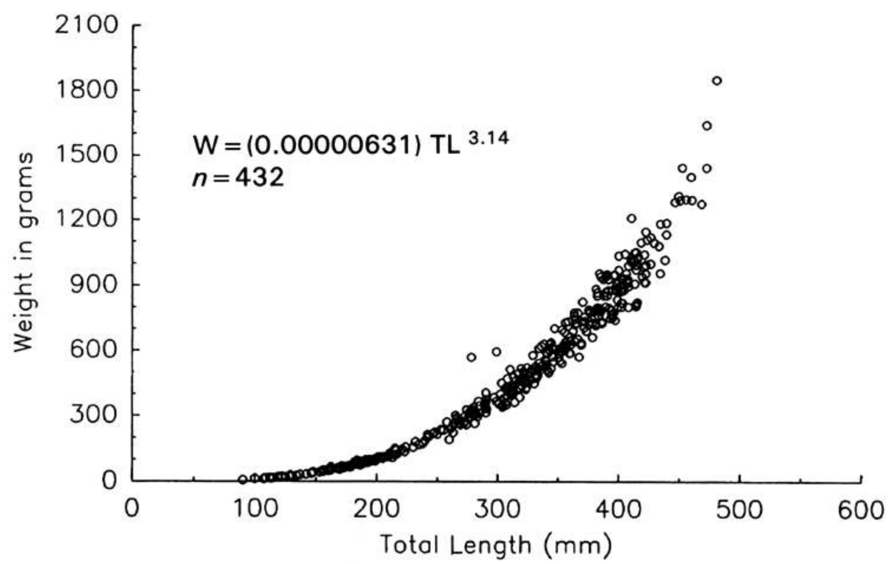


FIGURE 29. Length-weight relationship for olive rockfish.

FIGURE 29. Length-weight relationship for olive rockfish

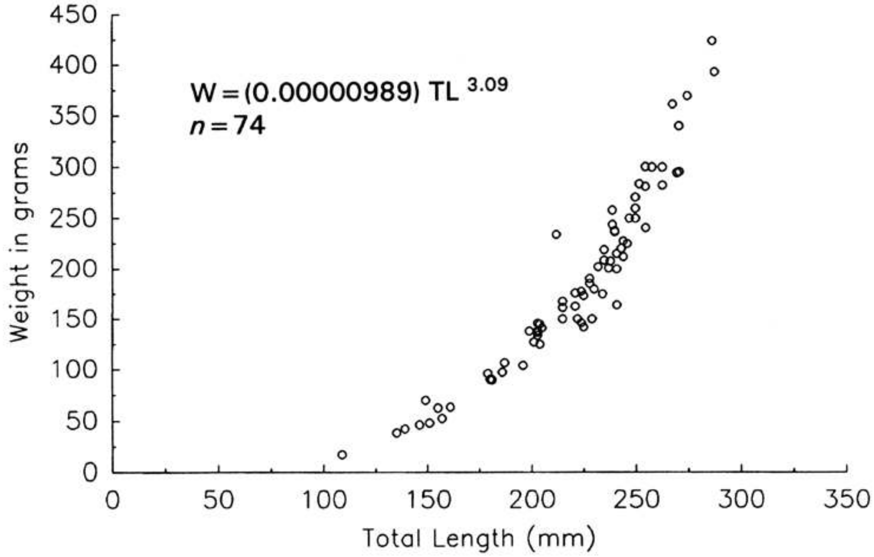


FIGURE 30. Length-weight relationship for rosy rockfish.

FIGURE 30. Length-weight relationship for rosy rockfish

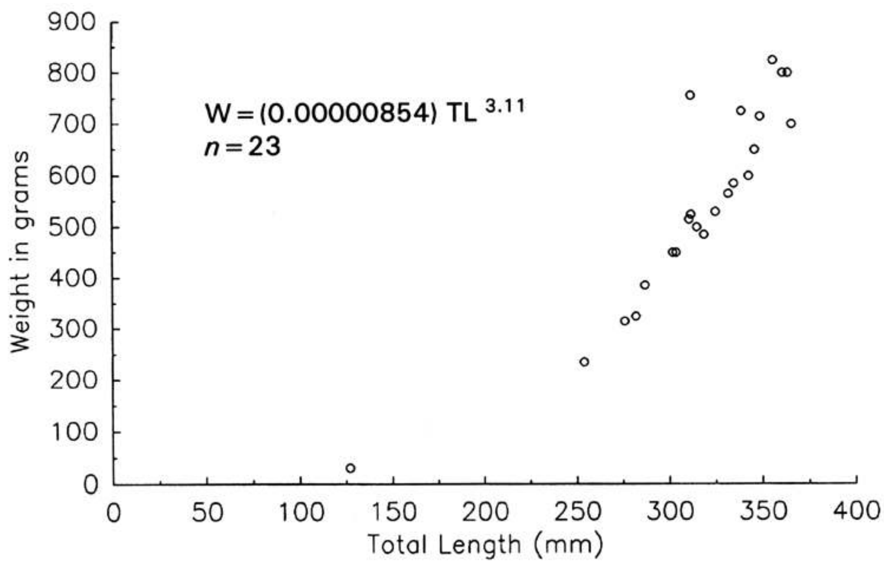


FIGURE 31. Length-weight relationship for starry rockfish.

FIGURE 31. Length-weight relationship for starry rockfish

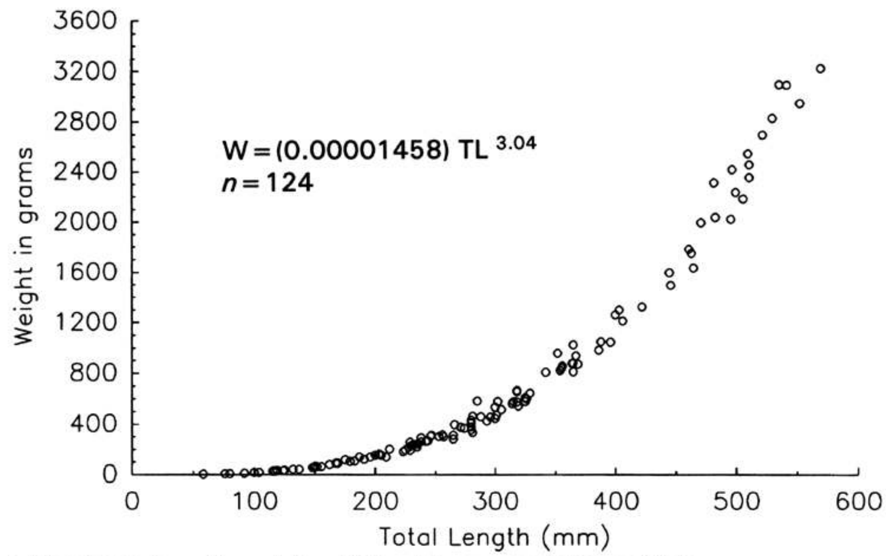


FIGURE 32. Length-weight relationship for vermilion rockfish.

FIGURE 32. Length-weight relationship for vermilion rockfish

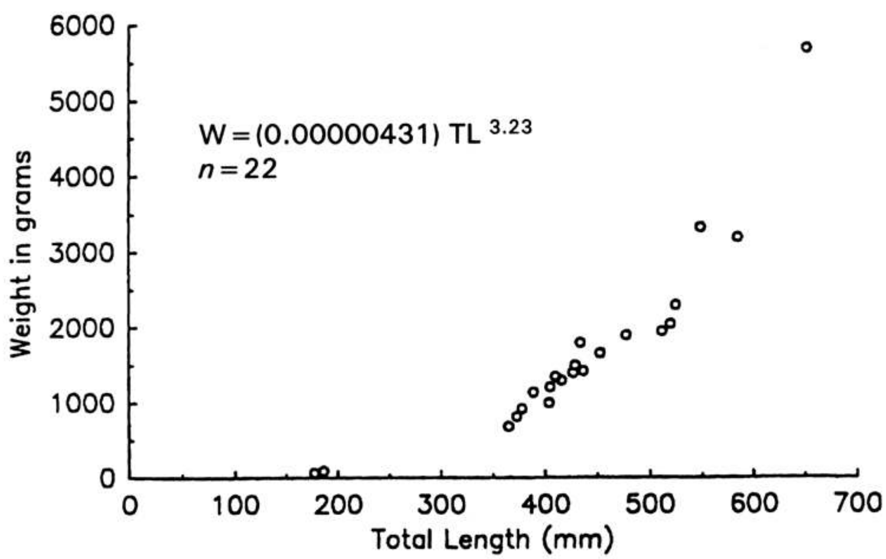


FIGURE 33. Length-weight relationship for yelloweye rockfish.

FIGURE 33. Length-weight relationship for yelloweye rockfish

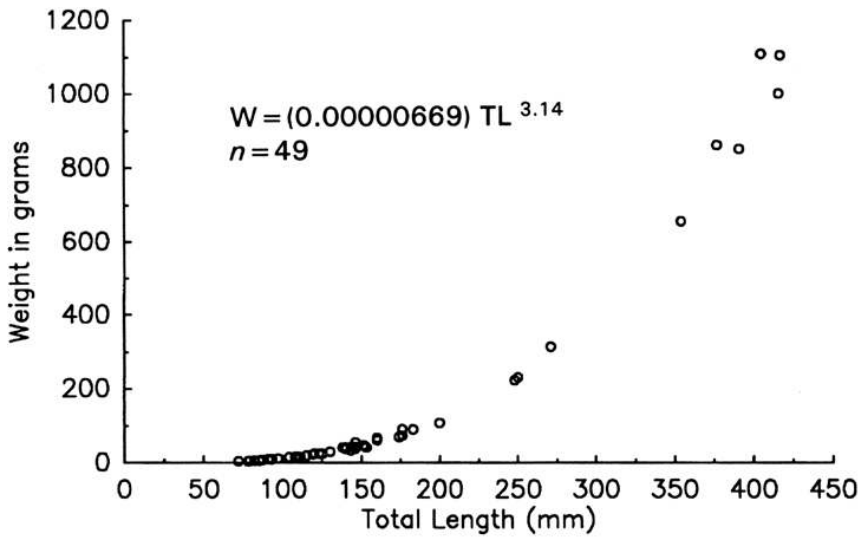


FIGURE 34. Length-weight relationship for yellowtail rockfish.

FIGURE 34. Length-weight relationship for yellowtail rockfish

7. REPRODUCTION

7.1. Introduction

Reproductive processes, similar to other life-history characteristics, are dictated by evolutionary responses to the environment. Viviparous teleost fishes have evolved a reproductive strategy which protects their young during vulnerable early life-history stages. Viviparity in rockfishes is a significant adaptation to environmental conditions. A major oceanographic process of the eastern North Pacific, the geographic range of the majority of rockfishes, is upwelling. This phenomenon makes this region one of the most biologically active marine environments in the world oceans (Chelton et al. 1982; McLain and Thomas 1983). The viviparous rockfishes of the eastern North Pacific, along with the surfperches of the family Embiotocidae, contribute to a marine ichthyofauna that probably contains a higher proportion of species of live-bearing fish than any other region in the world (MacGregor 1970; Boehlert and Yoklavich 1984). Cushing (1975) views reproductive strategies of fishes as an evolutionary adaptation to the food webs of their environment, matching larval production to that of their food supply. Our data indicate a relationship between upwelling and the timing of larval release for most nearshore rockfishes of the central California coast.

Numerous investigators have documented the reproductive cycles of selected species of rockfish. Although courtship behavior has been observed in blue rockfish (Helvey 1982), the timing of copulation has not been well documented for other members of the genus. Moser (1967) found that for many Californian rockfishes male spermatogenesis occurs several months before female gestation. It has been hypothesized that copulation occurs before ovulation and that sperm is stored until fertilization (DeLacy et al. 1964; Miller et al. 1967). Sorokin (1961) found evidence that females of some rockfishes store sperm for up to 6 months. Boehlert and Yoklavich (1984) observed, in laboratory experiments, that despite recent separation from males, females ovulated, ova were fertilized, and embryonic development followed. The gestation period for most rockfishes has been established at 1 to 2 months (Eigenmann 1892; Moser 1967; Boehlert and Yoklavich 1984; Boehlert et al. 1986; Dygert 1986).

The majority of central California rockfishes release their larvae during the winter–spring period; however, some are spring–summer spawners (Wales 1952; Phillips 1964; Moser 1967; Burge and Schultz 1973; Miller and Geibel 1973; Larson 1980b; Wyllie Echeverria 1987). MacGregor (1970) analyzed the larval rockfish catch from plankton net tows made during 1950–57 from Oregon to the tip of Baja California and found that the first 4 months of the year accounted for 68% of all Sebastes larvae taken. For most species of Sebastes parturition occurs but once a year; however, Moser (1967), MacGregor (1970), and Wyllie Echeverria (1987) have observed multiple spawns within a year for bocaccio, and brown, speckled, and starry rockfishes.

Studies dealing with effects of overexploitation of fish stocks and subsequent reductions of population densities have shown changes in species reproductive patterns. These changes include: i) a reduction in age at maturity, ii) a decrease in fecundity, and iii) a change in gonadal index (Adams 1980; Gunderson et al. 1980). These changes are complicated by the problem of annual recruitment. The success or failure of recruitment is not a random event but follows trends that appear to be linked with oceanographic variations (Cushing 1975; Parrish et al. 1981; Norton 1987).

During this study we analyzed the reproductive patterns of nine species of central California nearshore rockfish and provided limited information on an additional nine species. The majority of males exhibited active reproductive development during the fall and winter; females during the winter to spring. For each species the timing of larval release (parturition) often varied among years. Most rockfishes have a protracted juvenile life-history stage and do not achieve sexual maturation until 5 to 8 years of age.

A summary of the reproductive patterns for each of the species studied follows. All specimens were collected from central California. Data from angler surveys and spearfish meets may be biased because fishers tend to select for larger fish. Additionally, heavy fishing pressure in Monterey Bay may bias toward

TABLE 13. Guide to gonadal maturation in rockfish.

Stage	Morphology of male gonads	Morphology of female gonads
1. Immature	Testes are very small, thread-like, and lie very close under the vertebral column. Sex is unable to be determined grossly at this stage.	Ovaries are small, thread-like and lie very close under the vertebral column. Sex is unable to be determined grossly at this stage.
2. Juvenile	Testes are small, thin, thread-like, and of uniform thickness throughout the length. They are transparent pink and lie very close under the vertebral column.	Ovaries are small, short, and rounded, opaque light pink, and lie very close under vertebral column. Sex may be difficult to determine.
3. Mature resting	Testes are ribbon-like and not restricted to lying close under the vertebral column. Testes are red-brown, compressed in shape, and with an edge.	Ovaries occupy less than 1/2 of the upper section of the body cavity just under swim bladder. They are rounded, light pink to orangish-yellow, and contain remnants of eye lenses if fish has previously spawned.
4. Early developing	Testes are enlarged. Portion of testes appear pink, the other portion white. Testes are swollen, however still have an edge. If the edge is not discernible, testes are no longer stage 4.	Ovaries occupy at least 2/3 of upper section of body cavity. Ovaries are enlarged and oblong, bright yellow in color. Individual eggs, although discernible, are not easily separated.
5. Late developing	Testes are enlarged, white, with the only pink being the blood supplying them. Edge is not discernible.	Ovaries seem to fill the ventral cavity and are translucent. Eyed larvae may be present. Individual eggs are easily separated.
6. Spawning	Testes are enlarged, fill the upper section of body cavity just below swim bladder, and are completely white. Milt appears at the vent with slight pressure on the abdomen.	Ovaries seem to fill the upper section of body cavity. Eyed larvae appear at the vent with slight pressure on the abdomen.
7. Spent	Testes are thin and ribbon-like, dark brown or black, and flacid.	Ovaries are flaccid, maroon, with some eyed larvae normally present.

This guide to the stages of maturity for rockfish is a modification of a generalized listing of stages by Kesteven (1960). It was initially developed for rockfish by Glen F. Black, California Department of Fish and Game, and is further modified here.

TABLE 13. Guide to gonadal maturation in rockfish

smaller fish when compared to the entire population along the central California coast. Detailed reproductive patterns are presented only for species for which statistically significant data are available. Data for all species considered are summarized in Tables 14 and 15. The size and age of the smallest sexually mature and the largest sexually immature individuals observed are presented in Table 16 and a summary of general life-history characteristics is presented in the Appendix.

7.2. Results

Black-and-yellow rockfish. Gonadal development in mature male black-and-yellow rockfish was greatest from October through December (Table 14). The mean monthly gonadal index (MMGI) was highest in November and 100% of males were reproductively active (Figures 35 and 36). Running-ripe males were observed in only December (Table 15). In January no reproductively active males were noted, the gondal index dropped significantly, and spent males were first

TABLE 14. Months of reproductive development (stages 4, 5, and 6) for 18 species of rockfish. Reproductive development of gonads derived from Table 13.

Species	Sex	*n*	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Black rockfish	M	2		X			X							
	F	5		O		O	O							
Black-and-yellow rockfish	M	7				X	X	X						
	F	45				O	O	O	O	O	O		O	
Blue rockfish	M	69	X	X	X	X	X	X						X
	F	174		O	O	O	O	O	O	O				
Brown rockfish	M	4				X	X		X			X		
	F	4								O	O	O		
Canary rockfish	M	5			X				X			X		
	F	6			O	O		O						
China rockfish	M	1										X		
	F	8										O	O	
Copper rockfish	M	19		X	X	X	X							
	F	26		O	O	O	O			O	O	O		
Gopher rockfish	M	30				X	X	X	X	X	X			
	F	74	O			O	O	O	O	O	O	O	O	O
Grass rockfish	M	8		X			X							
	F	15		O			O		O					

TABLE 14. Months of reproductive development (stages 4, 5, and 6) for 18 species of rockfish. Reproductive development of gonads derived from Table 13

observed. Spent males were frequently observed for the next 2 months (February and March). From February through September (8 months) less than 1% exhibited spermatogenesis and the MMGI was low.

The majority of female reproductive development was observed from November through March (Table 14 and Figure 35). Mean monthly gonadal index steadily increased from October to a peak in February and high percentages of females were developing from December into March (Figures 35 and 36). Gravid females were observed from January to May (Table 15). No reproductively active females were noted during April and 50% were spent. For 7 months (April through October) MMGI was low and ovarian development minimal.

Gonadal indices and developmental data indicate that black-and-yellow rockfish release larvae only once annually. The reproductive period lasts 6 months. Males begin to exhibit spermatogenesis in October and reach a peak in November and December. Insemination appears to occur during these months and possibly into January. Females show signs of vitellogenesis in November which increase

TABLE 14. (continued)

Species	Sex	*n*	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Greenspotted	M	2			X								X	
rockfish	F	21					O				O	O	O	O
Greenstriped	M	0												
rockfish	F	2									O			O
Kelp	M	62					X	X	X	X	X	X		
rockfish	F	107						O	O	O	O	O	O	
Olive	M	38	X	X	X	X	X	X	X					
rockfish	F	77			O	O	O	O	O	O	O		O	
Rosy	M	20			X	X	X						X	
rockfish	F	46	O	O	O	O	O	O		O	O	O	O	O
Starry	M	7			X				X			X		
rockfish	F	29			O				O	O	O	O	O	O
Vermilion	M	12			X							X	X	
rockfish	F	45	O	O	O			O	O			O	O	O
Yelloweye	M	2			X								X	
rockfish	F	7			O				O			O		
Yellowtail	M	1			X									
rockfish	F	6			O				O					

[1]*Number of sexually mature fish observed.*

TABLE 14. Months of reproductive development (stages 4, 5, and 6) for 18 species of rockfish. Reproductive development of gonads derived from Table 13

TABLE 15. Months of male spermatozoa release and female parturition (stage 6) for 15 species of rockfish.

Species	Sex	*n*	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Black-and-yellow rockfish	M	2						X						
	F	18							O	O	O		O	
Blue rockfish	M	2					X	X						
	F	18				O		O	O	O				
Brown rockfish	M	1							X					
	F	2								O	O			
China rockfish	M	0												
	F	7										O	O	
Copper rockfish	M	0												
	F	2								O	O			
Gopher rockfish	M	2								X	X			
	F	32	O						O	O	O	O	O	
Grass rockfish	M	0												
	F	4							O					
Greenspotted rockfish	M	0												
	F	10										O	O	O
Greenstriped rockfish	M	0												
	F	1												O
Kelp rockfish	M	4								X	X	X		
	F	51								O	O	O	O	
Olive rockfish	M	1							X					
	F	7							O	O	O			
Rosy rockfish	M	0												
	F	21	O	O	O			O		O	O	O	O	O
Starry rockfish	M	0												
	F	19							O		O	O	O	O
Vermilion rockfish	M	0												
	F	15			O			O				O	O	O
Yelloweye rockfish	M	1											X	
	F	2										O		

TABLE 15. Months of male spermatozoa release and female parturition (stage 6) for 15 species of rockfish

to a peak in December through March when most parturition occurs. Young-of-the-year are observed in the kelp beds in July and August at a size of ca. 20–30 mm TL.

Blue rockfish. From June through December mature male blue rockfish were observed exhibiting gonadal development (Table 14). In June, spermatogenesis began and MMGI rose significantly [L8] and 38). Reproductive activity was highest during July and August; however, males releasing sperm were not observed until November and December (Table 15). In November, the percentage

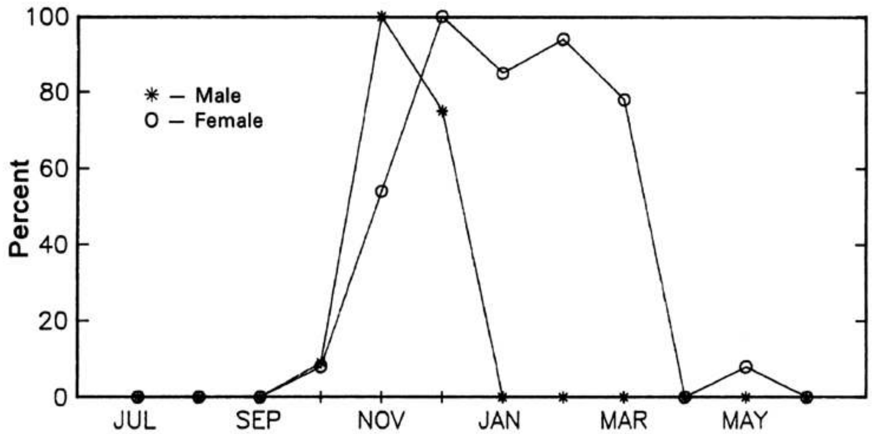


FIGURE 35. Percent gonadal development for black-and-yellow rockfish (stages 4, 5, and 6) based on reproductive developmental information.

FIGURE 35. Percent gonadal development for black-and-yellow rockfish (stages 4, 5, and 6) based on reproductive developmental information

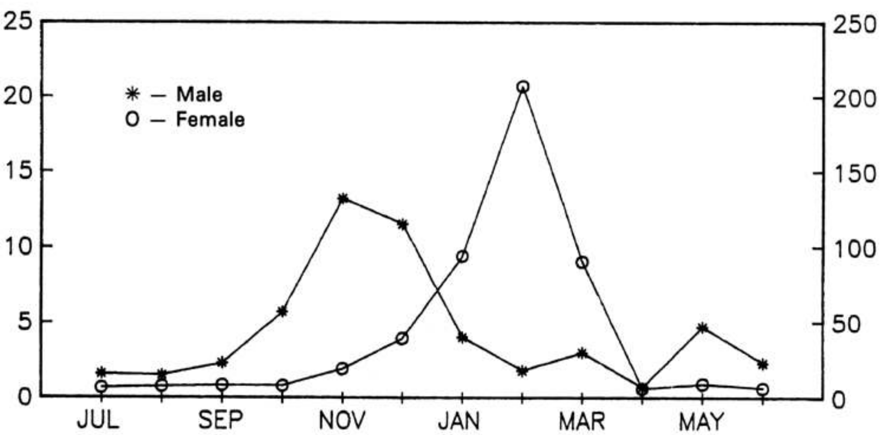


FIGURE 36. Gonadal indices for black-and-yellow rockfish based on mean gonadal index (male: left axis, female: right axis).

FIGURE 36. Gonadal indices for black-and-yellow rockfish based on mean gonadal index (male: left axis, female: right axis)

TABLE 16. Length of smallest sexually mature and largest sexually immature fish observed for 17 rockfish species.

Species	Sex	n^1	Smallest sexually mature observed: Total length (mm)	Smallest sexually mature observed: Age[2]	Largest sexually immature observed: Total length (mm)	Largest sexually immature observed: Age[2]
Black	M	95	370	-	441	9
rockfish	F	107	422	-	385	7
Black-and-yellow	M	145	239	4	301	9
rockfish	F	184	243	6	270	7
Blue	M	253	219	-	332	-
rockfish	F	956	196	-	293	-
Brown	M	14	316	-	335	-
rockfish	F	15	293	-	287	-
Canary	M	31	187	3	431	7
rockfish	F	42	296	-	423	8
China	M	27	342	-	353	14
rockfish	F	28	262	-	320	8
Copper	M	116	370	8	327	5
rockfish	F	161	295	-	325	6
Gopher	M	330	237	10	237	10
rockfish	F	342	207	-	306	9
Grass	M	53	359	8	432	12
rockfish	F	88	324	5	292	4

TABLE 16. Length of smallest sexually mature and largest sexually immature fish observed for 17 rockfish species

of spent males rose to 53% and to 100% in February. From January through May gonadal development ceased and males were in a resting stage.

Female gonadal development was highest for the year from September through February (Table 14 and Figure 37). Vitellogenesis and MMGI began increasing in September, peaked in December, and sharply declined in January (Figures 37 and 38). Reproductive activity declined during the next 2 months. Although the first gravid female was observed in October, the majority of parturition occurred in December and January (Table 15). Spent females were observed during every

TABLE 16. (continued)

Species	Sex	n^1	Smallest sexually mature observed: Total length (mm)	Age[2]	Largest sexually immature observed: Total length (mm)	Age[2]
Greenspotted	M	41	333	11	373	14
rockfish	F	50	299	10	262	11
Kelp	M	251	246	4	338	-
rockfish	F	244	218	5	320	7
Olive	M	231	269	3	409	6
rockfish	F	223	285	3	354	7
Rosy	M	138	218	-	255	11
rockfish	F	145	245	-	246	10
Starry	M	80	265	-	358	-
rockfish	F	100	270	7	262	-
Vermilion	M	103	365	-	452	6
rockfish	F	110	365	-	318	3
Yelloweye	M	24	471	11	467	10
rockfish	F	26	408	10	414	9
Yellowtail	M	21	284	-	372	5
rockfish	F	20	315	-	321	-

[1]*Total number of each sex observed.*

[2]*Ages listed only for those specimens from which otoliths were read.*

TABLE 16. Length of smallest sexually mature and largest sexually immature fish observed for 17 rockfish species

month of the year; however, the highest percentages were noted from January through May. For 5 months, March through July, females were in a resting stage.

Gonadal indices and condition data indicate that individual females release larvae once a year. The reproductive period for blue rockfish lasts 9 months. Males begin to develop in June and reach their peak in August. Peak insemination probably occurs from September through November. Females show first signs of gonadal activity in September and continue development through February. The majority of parturition occurs in December and January. Young-of-the-year

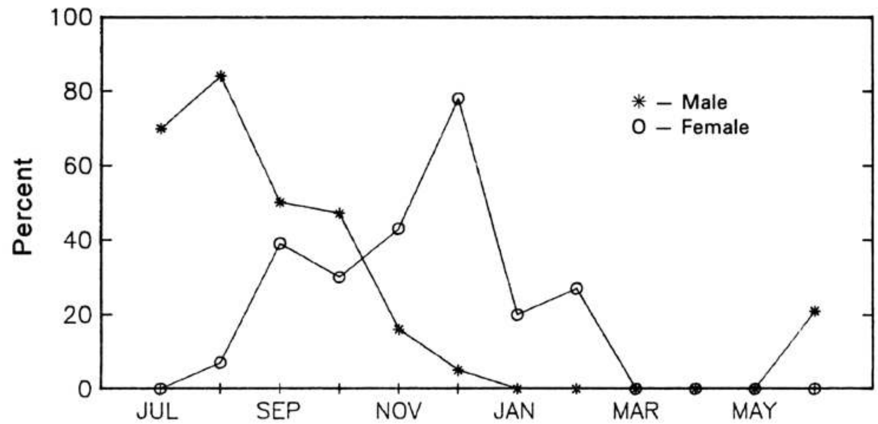


FIGURE 37. Percent gonadal development for blue rockfish (stages 4, 5, and 6) based on reproductive developmental information.

FIGURE 37. Percent gonadal development for blue rockfish (stages 4, 5, and 6) based on reproductive develop-mental information

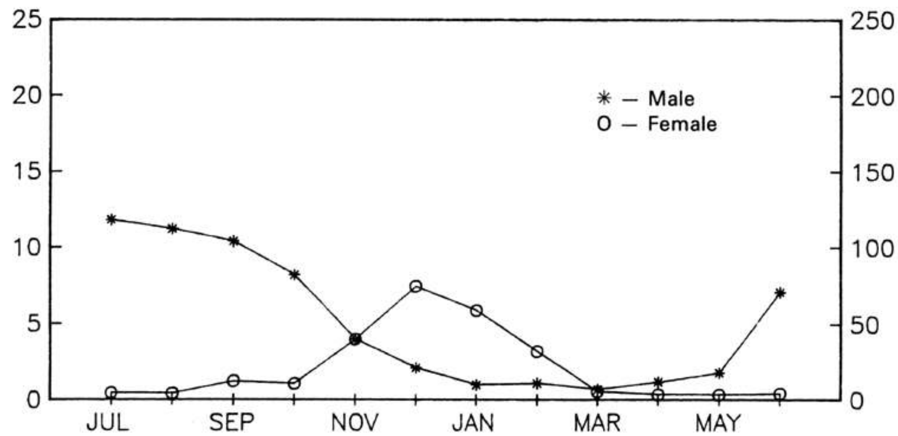


FIGURE 38. Gonadal indices for blue rockfish based on mean gonadal index (male: left axis, female: right axis).

FIGURE 38. Gonadal indices for blue rockfish based on mean gonadal index (male: left axis, female: right axis)

were first observed in nearshore kelp beds in May and June at a size of 40 to 60 mm TL. This species often recruits in large numbers, as a schooling fish, and is an important forage item in the nearshore environment during its first year.

Copper rockfish. Mature male copper rockfish were observed reproductively active from August through November (Table 14). From September through November gonadal development and MMGI were high (Figures 39 and 40). No running-ripe or recently spent males were observed during our study.

From August through November and February through April females showed signs of vitellogenesis (Table 14). Two peaks of gonadal development were observed, one in October-November and the other in March (Figure 39). Mean monthly gonadal index was highest for the year in November (Figure 40). Gravid females were observed in February and March (Table 15) and spent females were noted throughout the year.

Males were reproductively active from August through November. Reproductive information for females indicates either two peaks of gonadal development

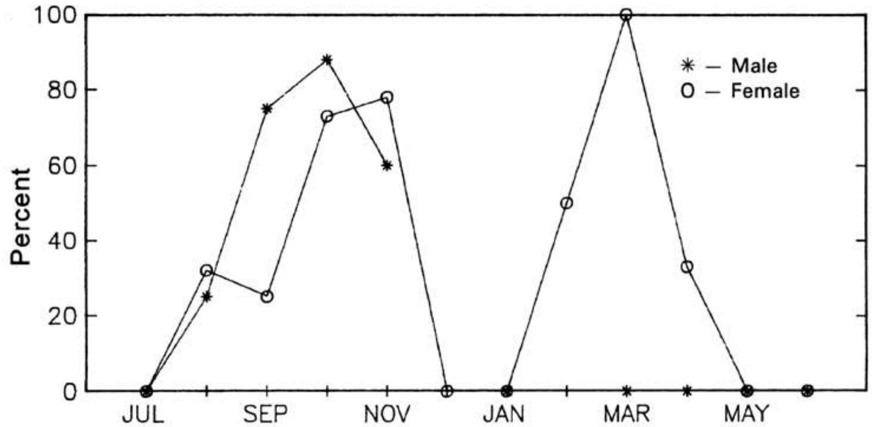


FIGURE 39. Percent gonadal development for copper rockfish (stages 4, 5, and 6) based on reproductive developmental information.

FIGURE 39. Percent gonadal development for copper rockfish (stages 4, 5, and 6) based on reproductive developmental information

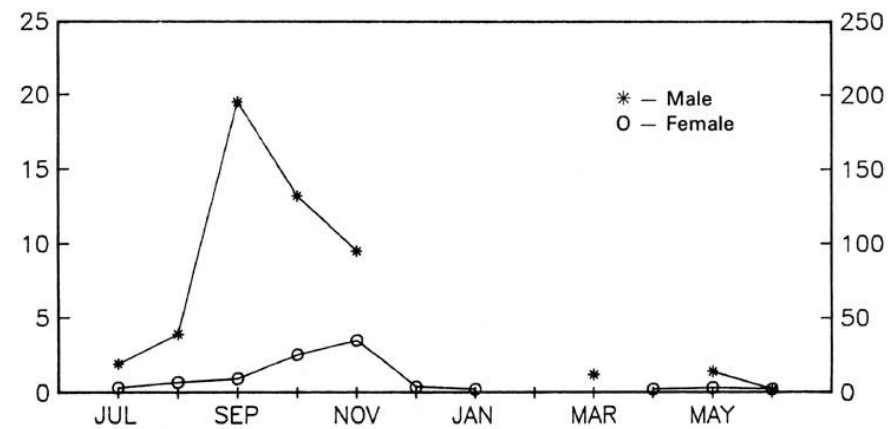


FIGURE 40. Gonadal indices for copper rockfish based on mean gonadal index (male: left axis, female: right axis).

FIGURE 40. Gonadal indices for copper rockfish based on mean gonadal index (male: left axis, female: right axis)

in October-November and in March or a single prolonged period from October through March.

Gopher rockfish. From October through March mature male gopher rockfish were observed to be most reproductively developed (Table 14 and Figure 41). Although MMGI was highest for the year from October to December, no stage 4 males were noted until February and March (Table 15). Spent males were observed from January through August but most frequently in May. Beginning in April and continuing through September (6 months), gonadal development was minimal and MMGI was low.

Female gonadal development was greatest from December through April (Table 14 and Figure 41). In December, 50% of mature females showed signs of vitellogenesis and MMGI rose slightly (Figures 41 and 42). During the following 3 months (January through March) more than 94% of females were reproductively developing and MMGI increased to a annual peak. Running-ripe females were observed from January through July (Table 15); however, the greatest percentages were noted in February and March (53% and 59%, respectively). Spent females were observed most frequently during May. For 7 months, from May through November, gonadal development was minimal.

The reproductive period for gopher rockfish lasts 10 months. Males begin development in October and reach a peak in November and December, when insemination occurs. Females exhibit vitellogenesis in October and development continues through July. Young-of-the-year were first observed associated with nearshore reefs in July and August at a size of 20 to 40 mm TL.

Grass rockfish. Spermatogenesis was noted in grass rockfish from August through November (Table 14) and individuals in spent condition were observed most frequently from May through July. These data indicate that insemination occurs during the fall and winter.

Female gonadal development was noted to occur in August, November, and January, when 100% of the adult fish sampled were gravid (Tables 14 and 15). Individual females in spent condition were observed from May through August.

The majority of grass rockfish were collected from May through August at Central California Council of Diving Clubs freediving competitions.

Kelp rockfish. Gonads of mature male kelp rockfish were observed to be most developed from November through March (Table 14 and Figure 43). Spermatogenesis was first noted in November and peaked from December to February (Figure 43). Mean monthly gonadal indices were highest during December and January (Figure 44); however, running-ripe males were not noted until February (Table 15). Spent males first appeared in March, increased in April, and peaked in May. Males were in a resting stage from May to October.

From December through May female gonadal development was at a peak (Table 14 and Figure 43). During December and January 50% and 54%, respectively, of adult females showed signs of vitellogenesis. However, the MMGI rose

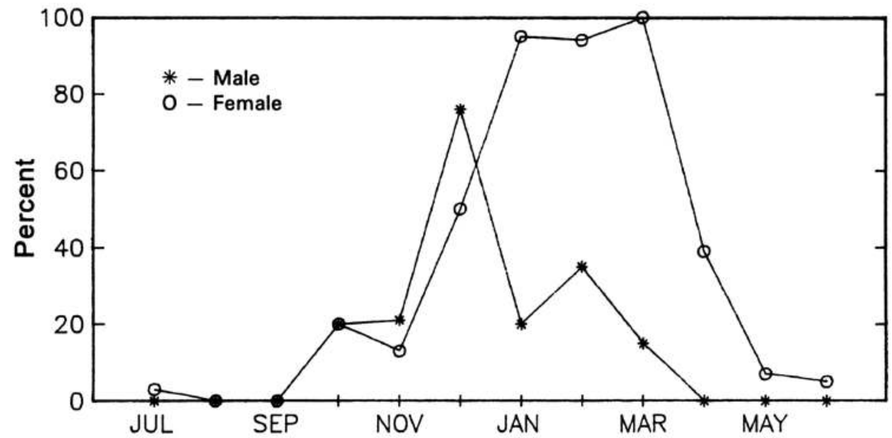


FIGURE 41. Percent gonadal development for gopher rockfish (stages 4, 5, and 6) based on reproductive developmental information.

FIGURE 41. Percent gonadal development for gopher rockfish (stages 4, 5, and 6) based on reproductive developmental information

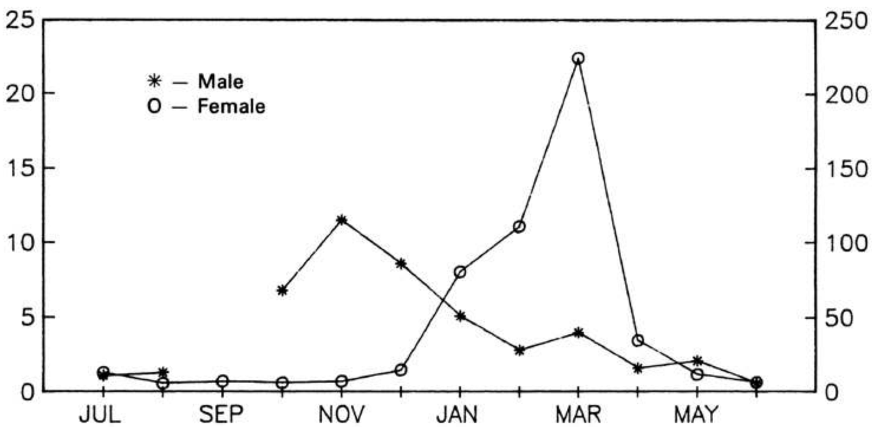


FIGURE 42. Gonadal indices for gopher rockfish based on mean gonadal index (male: left axis, female: right axis).

FIGURE 42. Gonadal indices for gopher rockfish based on mean gonadal index (male: left axis, female: right axis)

only slightly (Figure 44). In the following 4 months (February-May) development peaked and MMGI increased to an annual high. In April and May the greatest percentage of running-ripe females was noted (Table 15). A significant increase in the percent of spent females was observed in June and continued until October. For the following 6 months (June-November) MMGI was low and females were observed to be in a resting stage.

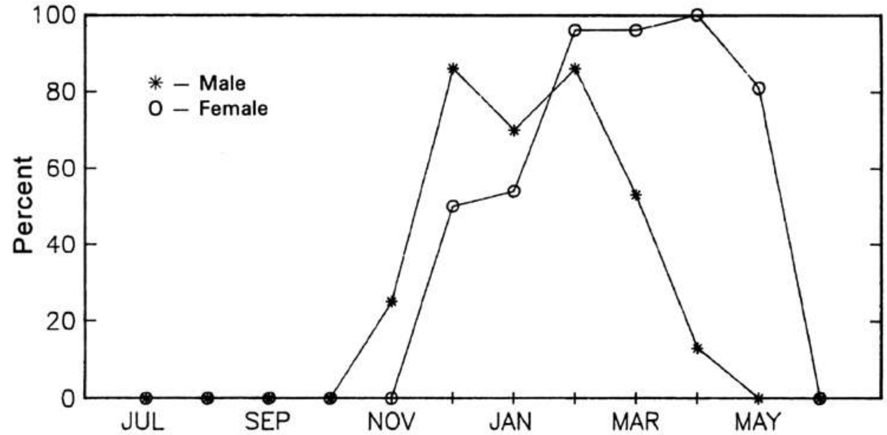


FIGURE 43. Percent gonadal development for kelp rockfish (stages 4, 5, and 6) based on reproductive developmental information.

FIGURE 43. Percent gonadal development for kelp rockfish (stages 4, 5, and 6) based on reproductive developmental information

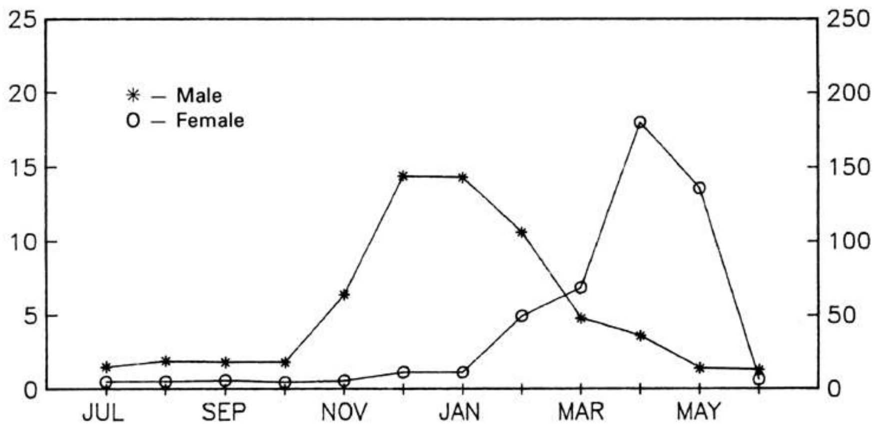


FIGURE 44. Gonadal indices for kelp rockfish based on mean gonadal index (male: left axis, female: right axis).

FIGURE 44. Gonadal indices for kelp rockfish based on mean gonadal index (male: left axis, female: right axis)

The reproductive period for kelp rockfish lasts 7 months; males begin to develop in November and peak in December to February when insemination of females occurs. Females show first signs of gonadal development in December and continue into April-May when the majority of parturition was noted. Young-of-the-year kelp rockfish were first observed under the canopy of nearshore kelp beds in July and August, then as schooling fish in the water column from August through October. Size during this time frame was 20 to 40 mm TL.

Olive rockfish. From August through December, gonadal activity in mature male olive rockfish was elevated (Table 14 and Figure 45). Development began in August and continued through December (Figure 45 and 46). Although spermatogenesis and MMGI were highest during September, no running-ripe males were observed until January. Insemination probably occurs from September through January (Table 15). Spent males were observed from December through July. From February through June (5 months) males were reproductively inactive.

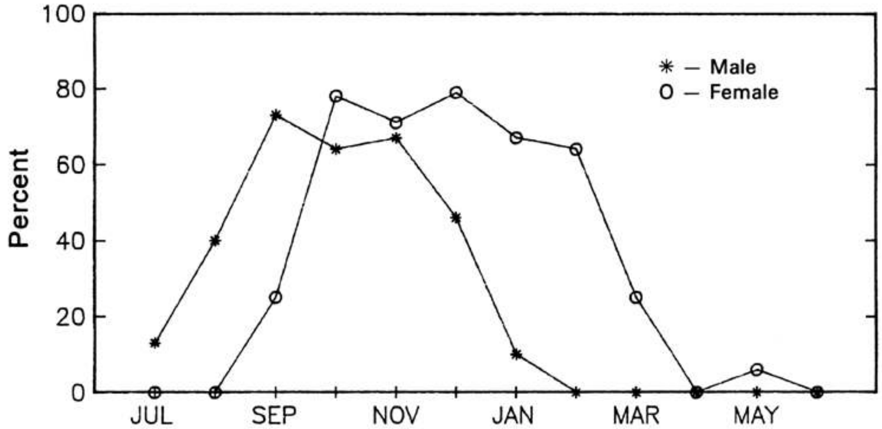


FIGURE 45. Percent gonadal development for olive rockfish (stages 4, 5, and 6) based on reproductive developmental information.

FIGURE 45. Percent gonadal development for olive rockfish (stages 4, 5, and 6) based on reproductive developmental information

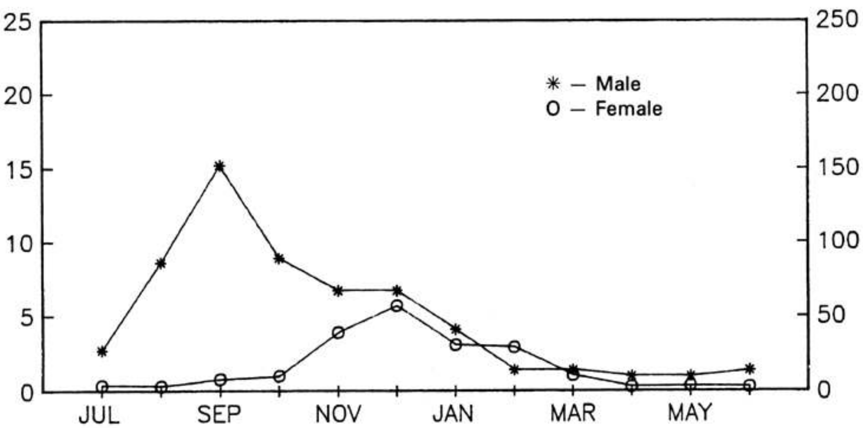


FIGURE 46. Gonadal indices for olive rockfish based on mean gonadal index (male: left axis, female: right axis).

FIGURE 46. Gonadal indices for olive rockfish based on mean gonadal index (male: left axis, female: right axis)

Females were most developed from October through February (Table 14 and Figure 45). In September a small percentage exhibited vitellogenesis and MMGI increased slightly (Figures 45 and 46). Although a high percent of females were reproductively active in October, MMGI remained low until November. Parturition was observed from January through March (Table 15) with the greatest percentage of larval release in February. Spent females were observed throughout the year but were most abundant from March through May.

Olive rockfish release larvae once a year during the period January through March (3 months). Males become reproductively active in August and continue into December with most insemination occurring in August and September. Females exhibit gonadal development from October through February when the majority of parturition occurs. Young-of-the-year were observed in the kelp forest commencing in May at a size of 40 to 60 mm TL.

Rosy rockfish. The greatest percentage of male rosy rockfish exhibiting gonadal development was observed from September through November (Table 14). No running-ripe males were noted during this study; however, in June 34% of males were spent.

Developing females were observed throughout the year (Table 14) and gravid females during 9 months. The majority of gonadal development and parturition occurred from February through December (Tables 14 and 15). No females in a spent condition were noted during this study.

Male rosy rockfish exhibit gonadal development from September through November. Females are reproductively active throughout the year. Our data indicate that females may release larvae more than once a year or perhaps throughout the year.

Vermilion rockfish. In April, May, and September gonads of mature male vermilion rockfish were observed to be actively developing (Table 14 and Figure 47). June was the month of highest MMGI (Figure 48). No running-ripe males were noted during our study; however, spent individuals were most frequently observed from June through November. October through March appears to be a quiescent period for males.

Females appear to be reproductively active throughout the year (Table 14 and Figures 47 and 48). Gravid females were most abundant in September and spent individuals were observed in the highest percentage during October and November.

Spermatogenesis was observed in April–May and insemination probably occurs in June through October. The parturition period is lengthy and gravid females were observed sporadically for 5 months of the year, with September being the month of highest release (Table 15).

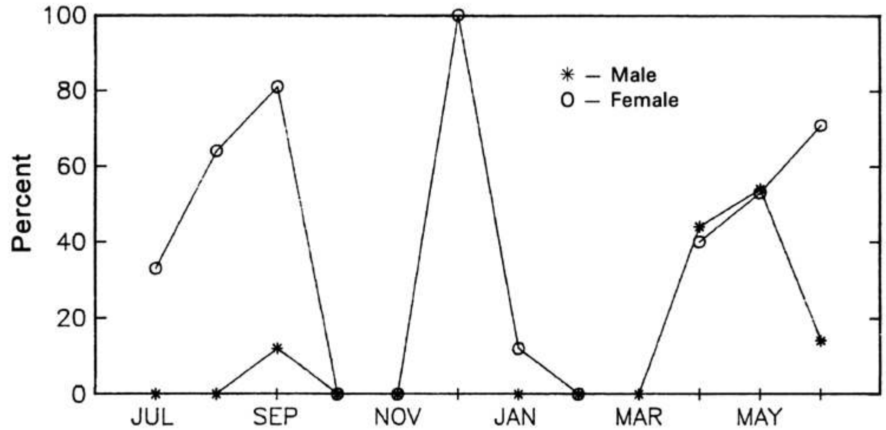


FIGURE 47. Percent gonadal development for vermilion rockfish (stages 4, 5, and 6) based on reproductive developmental information.

FIGURE 47. Percent gonadal development for vermilion rockfish (stages 4, 5, and 6) based on reproductive developmental information

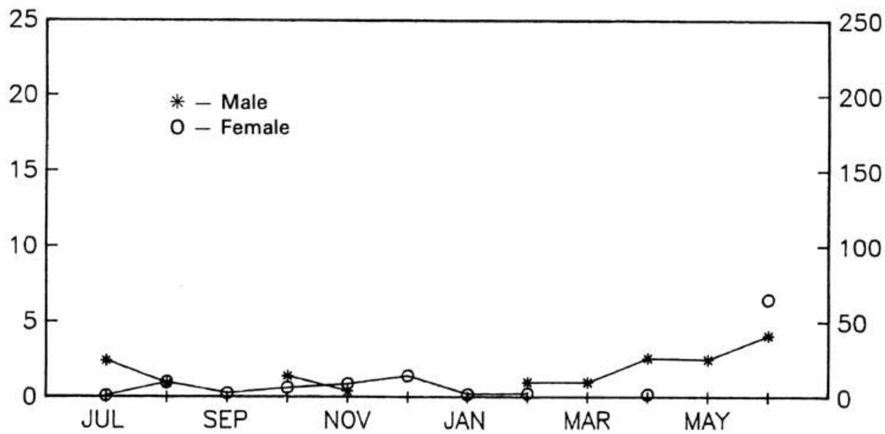


FIGURE 48. Gonadal indices for vermilion rockfish based on mean gonadal index (male: left axis, female: right axis).

FIGURE 48. Gonadal indices for vermilion rockfish based on mean gonadal index (male: left axis, female: right axis)

7.3. Miscellaneous observations

Black rockfish. The majority of black rockfish examined in this study were immature. Mature males were observed to be reproductively active in August and November; mature females in August, October, and November (Table 14).

Brown rockfish. One male brown rockfish was observed to be releasing sperm in January. Two females were noted releasing larvae during February and March (Table 15).

Canary rockfish. Male canary rockfish were observed reproductively active during January, April, and September. Vitellogenesis was noted in September through December. Young-of-the-year canary rockfish show a strong habitat preference for the sand-rock interface of nearshore reefs and sand pockets at depths of 50 to 60 ft. They appear on this habitat in August and September at a size of about 40 mm TL.

China rockfish. Female China rockfish were noted releasing larvae during April and May (Tables 14 and 15). Spent females were noted during April, June, and October.

Greenspotted rockfish. Spent male greenspotted rockfish were noted during June and September. Gravid females were observed from March through June and in November, with parturition noted in the April–June period (Tables 14 and 15). Spent females were observed in June and August suggesting this species spawns in spring-early summer.

Greenstriped rockfish. One mature female greenstriped rockfish was observed releasing larvae in June (Table 15).

Starry rockfish. Starry rockfish exhibiting spermatogenesis were observed during January, April, and September (Table 14). Males in spent condition were noted from March through June. Females were noted releasing larvae in January and March through June (Table 15). Spent females were found from March through June and also in September. Starry rockfish appear to be reproductively active during the winter and spring.

Yelloweye rockfish. One running-ripe male yelloweye rockfish was observed in May and two females releasing larvae were observed during April (Table 15). Female were noted in spent condition in June and September.

Yellowtail rockfish. One fish exhibiting spermatogenesis was observed in September (Table 14) and spent males were noted from January though March. Gonadal development was observed in females in January and September; during February and May spent individuals were observed.

Young-of-the-year yellowtail rockfish are observed schooling in association with the nearshore kelp forest from May through August at a size of 45 to 70 mm TL. In the field, and at this size, yellowtail rockfish are extremely similar to olive rockfish. These two species commonly school together during their first year of life. One-year-old yellowtail rockfish are seldom encountered in this same environment.

8. FOOD HABITS

8.1. Introduction

Various authors have described food preferences for selected species or certain life stages of rockfishes (Phillips 1964; Gotshall et al. 1965; Prince and Gotshall 1975; Lorz et al. 1983; Brodeur 1984; Singer 1985; Rosenthal et al. 1988; and others). However, food habit studies for the numerous species of rockfish are far from complete. Studies on food habits, in general, are valuable in documenting the complexities of resource partitioning, resource utilization, and community trophodynamics. Additionally, in a complex such as the rockfishes, elucidating the factors involved in the coexistence of morphologically similar species can also be considered.

Difficulties in describing completely the food habits for a taxon as large and diverse as the rockfishes are numerous. Many specimens must be collected over a considerable period of time to offset variables such as empty stomachs, rapid digestion, stomach eversion, food preferences by different life stages, changes in prey distribution due to spatiotemporal variation in abundance, and the sporadic occurrence of rare prey items. Our purpose in this section is to present a general qualitative description of food habits of the rockfishes encountered during our study. We feel that although these observations are limited, a general impression concerning the selectivity and specificity in food preference can be inferred.

8.2. Results

Stomachs from 392 rockfish, representing 11 different species, were analyzed. Only stomachs containing food items were considered. All principal marine animal phyla were represented as food items, at least to some degree.

Black rockfish. Nine of 18 black rockfish examined had consumed fish, primarily young-of-the-year rockfish (Table 17). One specimen contained a northern clingfish Gobiesox maeandricus, 62 mm TL. Isopods Idotea spp. occurred with a frequency of 17%. Other items encountered included pelagic red crabs, octopus, and polychaete worms.

Total length of black rockfish examined for food habits ranged from 178 to 563 mm; most were subadult specimens.

Black-and-yellow rockfish. Benthic organisms comprised the greatest portion of the diet of the 38 black-and-yellow rockfish examined (Table 18). Crustaceans occurred with the highest frequency (89%). Brachyurans (crabs), carideans (shrimp), isopods, and anomurans comprised 85, 11, 2, and 2%, respectively,

TABLE 17. Black rockfish food items.

Food item	Number of stomachs in which item occurred	Percent frequency of occurrence	Minimum number of taxa observed
Fishes	9	50	2
Crustacea	5	28	3
Octopus	1	6	1
Polychaeta	1	6	1
Number of stomachs examined = 18			

TABLE 17. Black rockfish food items

TABLE 18. Black-and-yellow rockfish food items.

Food item	Number of stomachs in which item occurred	Percent frequency of occurrence	Minimum number of taxa observed
Crustacea	34	89	16
Mollusca	7	18	5
Fishes	5	43	2
Ectoprocta	1	3	1
Hydrozoa	1	3	1
Number of stomachs examined = 38			

TABLE 18. Black-and-yellow rockfish food items

of the total crustaceans. The most commonly encountered brachyurans were members of the genus Cancer, encompassed by C. products, C. antennarius, and C. jordani. Other brachyurans observed were, Loxorhynchus crispatus, Mimulus foliatus, Paraxanthias taylori, Pugettia richii, and Scyra acutifrons. Anomurans were Hapalogaster cavicaudia and Petrolisthes spp. Identifiable carideans were Lebbeus lagunae and Alpheus spp.

A wide variety of mollusks (including snails, bivalves, chitons, and octopi) occurred with a frequency of 18%. Juvenile rockfishes and sculpins (Cottidae) occurred in 13% of the stomachs examined. Hydrozoans, ectoprocts (bryozoans), and kelp fragments were encountered, but infrequently. A 3.0-g rock was found in one stomach.

Black-and-yellow rockfish examined ranged from 97 to 326 mm TL and exhibited the greatest diversity of prey items in their stomachs of the rockfishes we examined.

Blue rockfish. A detailed analysis of the food habits of blue rockfish was presented by Gotshall et al. (1965). Sixty-seven blue rockfish ranging from 236 to 381 mm TL were examined for food habits in our study. Food items were primarily midwater organisms (Table 19). Pelagic red crabs, the major food item, were abundant off central California during the later part of the 1982–84 El Niño event and occurred with a frequency of 57%. Under normal oceanographic conditions, pelagic red crabs do not occur north of Point Conception and are rare even in southern California. The sand crab Emerita analoga, another anomuran, was found in one stomach.

Squid Loligo opalescens, a seasonal prey item, was second in abundance with a frequency of 28%. The only other mollusk observed was a small unidentifiable gastropod.

TABLE 19. Blue rockfish food items.

Food item	Number of stomachs in which item occurred	Percent frequency of occurrence	Minimum number of taxa observed
Anomura	39	58	2
Mollusca	20	30	2
Fishes	9	13	2
Tunicata	3	5	1
Coelenterata	1	2	1
Number of stomachs examined = 67			

TABLE 19. Blue rockfish food items

Fish, mainly young-of-the-year shortbelly rockfish Sebastes jordani, occurred with a frequency of 13%. In addition, unidentified fishes and tissue from the ocean sunfish Mola mola were also noted.

Planktonic tunicates Doliolum spp. and the scyphozoan coelenterate Chrysaora melanaster were observed infrequently.

Canary rockfish. Canary rockfish, ranging from 114 to 459 mm TL, the majority of which were juveniles and subadults, showed a preference for crustaceans (Table 20). Crustacea occurred with a frequency of 82%. Planktonic euphausiids and mysids composed the majority (56%) of the crustaceans, while carideans and pelagic red crabs accounted for 33% and 11%, respectively.

Fish, which included one young-of-the-year rockfish, were observed in two of the stomachs.

China rockfish—central California. Crustaceans and ophiuroids (brittle stars) occurred with frequencies of 70% and 60%, respectively, in the 10 stomachs of China rockfish from central California that we examined (Table 21). Loxorhynchus crispatus, a masking crab, accounted for 80% of the crustaceans.

TABLE 20. Canary rockfish food items.

Food item	Number of stomachs in which item occurred	Percent frequency of occurrence	Minimum number of taxa observed
Crustacea	9	82	5
Fishes	2	18	1
Number of stomachs examined = 11			

TABLE 20. Canary rockfish food items

TABLE 21. China rockfish, central California, food items.

Food item	Number of stomachs in which item occurred	Percent frequency of occurrence	Minimum number of taxa observed
Crustacea	7	70	2
Ophiuroidea	6	60	1
Mollusca	3	30	3
Fishes	2	20	1
Number of stomachs examined = 10			

TABLE 21. China rockfish, central California, food items

Mollusks, comprised of nudibranchs, the snail Erato vitellia, and red abalone Haliotis rufescens occurred with a frequency of 30%. Fish were found at a lower frequency.

The size of China rockfish examined ranged from 104 to 353 mm TL.

China rockfish—northern California. Crustaceans (79%) and mollusks (64%) occurred with the greatest frequency in the 28 stomachs from northern California specimens (most specimens were collected from the area proximal to Point Arena, Mendocino County; Table 22). Ninety-three percent of the crustaceans were comprised of brachyuran crabs of which Loxorhynchus crispatus, Cancer spp., and Scyra actifrons were the most common.

Octopi, abalones, and chitons comprised 42, 29, and 25% respectively, of the total mollusks. Two species of abalone were noted—red abalone Haliotis rufescens and flat abalone H. walallensis. A top snail Calliostoma sp. was found in one stomach.

Fish, most of which were highly digested, were observed with a frequency of 25%. The northern clingfish Gobiesox maeandricus was one item which was identifiable. Ophiuroids occurred in 18% of the stomachs.

TABLE 22. China rockfish, northern California, food items.

Food item	Number of stomachs in which item occurred	Percent frequency of occurrence	Minimum number of taxa observed
Crustacea	22	79	11
Mollusca	18	64	10
Fishes	7	25	1
Ophiuroidea	5	18	1
Number of stomachs examined = 28			

TABLE 22. China rockfish, northern California, food items

The size of the China rockfish from northern California ranged from 299 to 477 mm TL.

As would be expected, China rockfish collected from two separate areas off California, but within the same zoogeographic province, manifested only minor differences in their selection of forage items.

Copper rockfish. The 56 copper rockfish examined exhibited a wide array of prey items (Table 23). Crustaceans represented the greatest portion of the diet, occurring with a frequency of 52%. Fifty-three percent of the crustacea were brachyurans, the majority of the genus Cancer (including C. jordani, C. productus, and C. antennarius) . Other crabs noted were Pugettia (P. producta, P. gracilis, and P. richii) and Loxorhynchus crispatus. Carideans followed brachyurans and occurred with a frequency of 24%. This category was composed of Crangon spp. and unidentified shrimp. Planktonic euphausiids and mysids occurred with a frequency of 5%.

Mollusks occurred with a frequency of 39%, 80% of which were of the genus Octopus. Squid Loligo opalescens, bivalves, and snails occurred at frequencies less than 10%.

Fish were observed at a frequency of 36%, the majority being young-of-the-year rockfishes. Other species which we were able to identify included spotted cusk-eel Chilara taylori, eelpouts (Zoarcidae), and sculpins (Cottidae).

The size of copper rockfish examined ranged from 135 to 490 mm TL.

Gopher rockfish. Thirty-seven gopher rockfish, ranging in size from 139 to 339 mm TL, were examined. The majority of the food items identified were benthic organisms (Table 24). Crustaceans were the most frequently occurring food item (70%), of which 76% were brachyurans. The most commonly encountered crabs were Cancer spp. and Loxorhynchus crispatus, all of which are found in association with rocky subtidal substrate. Caridean shrimps, including Alpheus spp., comprised 19% of the total crustaceans. Anomurans (pelagic red crabs and Petrolisthes spp.) comprised the remaining 5%.

TABLE 23. Copper rockfish food items.

Food item	Number of stomachs in which item occurred	Percent frequency of occurrence	Minimum number of taxa observed
Crustacea	29	52	11
Mollusca	22	39	5
Fishes	20	36	5
Number of stomachs examined = 56			

TABLE 23. Copper rockfish food items

TABLE 24. Gopher rockfish food items.

Food item	Number of stomachs in which item occurred	Percent frequency of occurrence	Minimum number of taxa observed
Crustacea	26	70	10
Fishes	10	27	1
Cephalopoda	4	11	4
Polychaeta	3	8	2
Echinodermata	3	8	1
Number of stomachs examined = 37			

TABLE 24. Gopher rockfish food items

Fish, of which 80% were young-of-the-year rockfish, had a frequency of occurrence of 27% and ranged in size from 35 to 50 mm TL. Fish eggs were found in one stomach.

Gopher rockfish also consumed food items from three additional major taxa: Cephalopoda (squids and octopi), Annelida (polychaetes), and Echinodermata (principally ophiuroids or brittle stars).

Examination of the stomachs of gopher rockfish (as well as black-and-yellow rockfish) often reveals only a thick mortar-like material. We surmise this to be the crushed calcareous exoskeletons of crustaceans and the discs and arms of brittle stars.

Grass rockfish. In the 57 grass rockfish stomachs examined, fishes were the most frequently occurring forage item (65%; Table 25). of the 37 stomachs which contained fish, 59% contained from one to three plainfin midshipman Porichthys notatus, which ranged in size from 160 to 305 mm TL. Other fishes noted were rubberlip surfperch Rhacochilus toxotes (89–93 mm TL), a white croaker Genyonemus lineatus, kelpfishes of the genus Gibbonsia; and an unidentified blennioid "eel."

TABLE 25. Grass rockfish food items.

Food item	Number of stomachs in which item occurred	Percent frequency of occurrence	Minimum number of taxa observed
Fishes	37	65	5
Brachyura	14	25	6
Isopoda	1	2	1
Cephalopoda	1	2	1
Number of stomachs examined = 57			

TABLE 25. Grass rockfish food items

Brachyurans had a frequency of occurrence of 25%. Fifty percent of these crabs were of the genus Pugettia (comprised of P. producta and P. richii) and 43% were of the genus Cancer, which included C. antennarius, C. gracilis, and C. jordani.

Other food items consisted of an octopus and an isopod, Cymadusa uncinata. Kelp fragments and rocks were occasionally found in stomachs. A rock weighing 22.6 g was found in the stomach of a grass rockfish which weighed 1.39 kg (rock constituted 1.6% of the fish's body weight).

Central California Council of Diving Clubs (Cen-Cal) spearfish competitions were the major source of our specimens. Grass rockfish are high-point competition fish, as they are often heavier than the other nearshore rockfishes, and are sought out by the more experienced competitive divers. Grass rockfish for this study ranged in size from 270 to 495 mm TL.

Kelp rockfish. Thirty-nine kelp rockfish, ranging in size from 173 to 357 mm TL, were examined. The major food items were crustaceans and fishes, which occurred with a frequency of 54% and 36%, respectively (Table 26). of the crustacea, brachyurans, isopods (Idotea spp.), pelagic red crabs, and planktonic forms (mysids, euphausiids, and copepods) comprised this category. The principal fishes noted were young-of-the-year rockfishes which ranged in size from 18 to 75 mm TL (blue rockfish were a part of this component). A kelpfish (Gibbonsia sp.), a prickleback (Stichaeidae), and a sculpin (Cottidae) were also identified.

Cephalopods and gastropods were observed in three stomachs (8%). A planktonic tunicate, Doliolum sp., was found in one stomach (3%).

Olive rockfish. Fifteen olive rockfish stomachs were examined of which nine (60%) contained crustaceans and five (33%) contained fishes (Table 27). Pelagic red crabs comprised 78% of the crustaceans. Under normal oceanographic conditions off central California this forage item would not be available. Planktonic brachyuran zoeal larvae and isopods of the genus Idotea were the other crustaceans eaten.

TABLE 26. Kelp rockfish food items.

Food item	Number of stomachs in which item occurred	Percent frequency of occurrence	Minimum number of taxa observed
Crustacea	21	54	6
Fishes	14	36	4
Mollusca	3	8	3
Doliolum sp.	1	3	1
Number of stomachs examined = 39			

TABLE 26. Kelp rockfish food items

TABLE 27. Olive rockfish food items.

Food item	Number of stomachs in which item occurred	Percent frequency of occurrence	Minimum number of taxa observed
Crustacea	9	60	3
Fishes	5	33	2
Mollusca	3	20	2
Number of stomachs examined = 15			

TABLE 27. Olive rockfish food items

Young-of-the-year rockfishes were found in 60% of the stomachs which contained fish. Additionally, a jack mackerel Trachurus symmetricus and an unidentified fish were also noted.

Molluscans, consisting of the squid Loligo opalescens and an octopus, occurred with a frequency of 20%.

Olive rockfish examined ranged from 122 to 444 mm TL and were mainly subadult specimens.

Vermilion rockfish. Sixteen stomachs from vermilion rockfish, which ranged in size from 92 to 536 mm TL, were examined. Crustaceans (63%) and fishes (38%) occurred with greatest frequency (Table 28). The majority of crustaceans (80%) were planktonic euphausiids, copepods, and mysids ranging in size from about 5 to 10 mm. Unidentified amphipods and caridean shrimp were also noted. Fishes encountered encompassed northern anchovy Engraulis mordax, plainfin midshipman, and several unidentified specimens too digested to determine. Molluscan food items were comprised of two squid (Loligo opalescens) and one octopus.

TABLE 28. Vermilion rockfish food items.

Food item	Number of stomachs in which item occurred	Percent frequency of occurrence	Minimum number of taxa observed
Crustacea	10	63	5
Fishes	6	38	2
Cephalopoda	3	19	2
Number of stomachs examined = 16			

TABLE 28. Vermilion rockfish food items

8.3. Discussion

The purpose of this study was only to provide a general overview of the types of forage items utilized by nearshore rockfishes off central California. The 11 species of rockfish analyzed in this study utilized a wide array of prey items. For each species considered, forage items encountered were an expression of microhabitat preference and morphological feeding adaptation.

Blue, olive, and black rockfishes are predominately active-swimming, midwater fishes. They have elongate, streamlined bodies which suit them for living in midwater and capturing swimming prey. Fishes and cephalopods were food items occurring with the highest frequency. Pelagic red crabs also occurred with a high frequency; their appearance off central California was related to a warmwater or El Niño phenomenon during part of our study.

Black-and-yellow, China, copper, gopher, grass, and vermilion rockfishes are heavier bodied, have relatively larger heads, and normally occur on or near the bottom. Food items most frequently encountered for these species were benthic invertebrates such as shrimps, crabs, brittle stars, and octopi. Kelp rockfish appears to be a species morphologically and ecologically intermediate between the free-swimming and benthic forms. Kelp rockfish are found most commonly in the water column in association with giant kelp Macrocystis, but at times are closely associated with the bottom. Both benthic and midwater-associated prey items were found in their stomachs.

As stated above, the analysis of food habits of the included rockfishes is far from comprehensive and was of secondary focus in this study. Nonetheless, the plethora of food items utilized by the various species of rockfish examined exemplifies the diverse nature of the feeding ecology manifested by this group of fishes.

9. CONCLUSION

The rockfishes of the genus Sebastes are a large group of ecologically diverse fishes and are represented in the marine waters of California by 60 species. Rockfishes are an important part of the sport fish catch, especially off the central and northern part of the state. Historically, salmon have been the primary sport fish off northern California and were of considerable importance off central California. However, in recent years the salmon resources of California have manifested alarming signs of decline (Lufkin 1991). Rockfishes and other sport fishes such as lingcod, cabezon, and certain species of sharks have become significant in filling their dwindling role as recreational fishes. We envision that as salmon populations in California (as well as other northwestern states) become even more distressed and diminished, the demand on rockfishes as recreational fishes will become even greater. Fisheries resources such as these obviously are renewable only up to some point. It is the point of overutilization that is of great concern to marine biologists and fishery managers of our Department as well as the marine conservationist who is concerned with the wise utilization of our marine resources. It is with this consideration in mind that we have compiled this Fish Bulletin. Rockfishes, in general, are long-lived species, many are primarily residential, and most take a number of years to become sexually reproductive. We feel that a basic understanding of the life histories of the various rockfishes, as well as other recreational species, is prerequisite to their proper management and the protection and conservation of populations for future generations. A summary of our findings follows:

i) The majority of the nearshore rockfishes are highly residential and once they have settled out of the plankton as juveniles, they remain on a given reef system for life. Some species do not adhere to this life-history pattern and may move over considerable distances. Those species which live in the water column have a much greater tendency for movement than benthic species.

ii) Most species of nearshore rockfish appear to be fairly long-lived. Whole otoliths were used as the primary ageing structure. Ages up to 29 years were assigned for some of the "premium" species, such as the "red rockfishes" (e.g. copper, vermilion, and yelloweye rockfishes).

iii) Most species of nearshore rockfish have rather prolonged juvenile life-history stages and do not become sexually mature until their fourth or fifth year of life. In considering size at which rockfishes enter the sport catch, juveniles often represent a large percentage of the sport take. Obviously, if the juvenile proportion of the catch is substantial, the effect upon the population structure of the species may have serious implications.

iv) Food habits were considered in a very general manner. As would be anticipated in such a diverse group of closely related species, a plethora of food items are utilized. A detailed study of feeding would most likely show a great degree of resource partitioning. Crustaceans, mollusks (mainly cephalopods and gastropods), and fishes (including young-of-the-year rockfishes) were the principal food items.

As the nearshore sport fish resource continues to become more heavily utilized, the effects on the population structures of the various species would seem predictable. Due to their life-history characteristics, some species of sport fish are more susceptible than others; rockfishes and lingcod fall into this category. Species such as blue and olive rockfishes are more resilient than copper and vermilion rockfishes. In heavily utilized areas few, if any, reproductive individuals of some rockfishes can be found. It is our considered opinion that unless protective measures (in addition to number limits) of some sort are instituted, especially for the more sensitive species, heavy utilization will have a detrimental effect on population structure. We feel that providing protection in the form of "marine reserves, refuges, refugia, area closure"—fundamentally a zone set aside which precludes utilization—is the most realistic management tool available which will assure the existence of sound and reliable populations of our sport fishes, and especially rockfishes of the genus Sebastes.

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APPENDIX
Summary of life-history characteristics for 17 species of rockfish from this study

Black rockfish Sebastes melanops
Age range observed: 0–13, n = 186; males 3–11, n = 76, females 3–13, n = 81
Length of fish aged: 95–563 mm; males 183–485 mm; females 169–563 mm
Heaviest fish observed: male 2165 g (485 mm); female 2536 g (522 mm)
Largest fish observed: 565 mm
Reported maximum length: 25.5 inches (648 mm; pers. files, RNL)
Calculated maximum length: combined sexes 691 mm; male 559 mm; female 670 mm
Largest immature juvenile: male 441 mm (age 9); female 385 mm (age 7)
Smallest size at sexual maturity: male 370 mm; female 442 mm

Black-and-yellow rockfish Sebastes chrysomelas
Age range observed: 1–21, n = 310; males 4–19, n = 138; females 3–21, n = 150
Length of fish aged: 96–340 mm; males 181–326 mm; females 134–340 mm
Heaviest fish observed: male 772 g (324 mm); female 985 g (331 mm)
Largest fish observed: 378 mm
Reported maximum length: 15.25 inches (387 mm; Miller and Lea 1972)
Calculated maximum length: combined sexes 336 mm; male 327 mm; female 339 mm
Largest immature juvenile: male 301 mm (age 9); female 270 mm (age 7)
Smallest size at sexual maturity: male 239 mm (age 4); female 243 mm (age 6)

Blue rockfish Sebastes mystinus
See Miller and Geibel (1973) for life history data on this species.
Heaviest fish observed: male 1016 g (376 mm); female 1161 g (408 mm)
Largest fish observed: 425 mm
Reported maximum length: 21 inches (533 mm; Miller and Lea 1972)
Largest immature juvenile: male 332 mm; female 293 mm
Smallest size at sexual maturity: male 219 mm; female 196 mm

Brown rockfish Sebastes auriculatus
Age range observed: 0–10, n = 17
Length of fish aged: 55–382 mm; males 208–382 mm; females 127–373 mm
Heaviest fish observed: male 830 g (335 mm); female 969 g (373 mm)
Largest fish observed: 382 mm
Reported maximum length: 21.5 inches (546 mm; Miller and Lea 1972)
Calculated maximum length: not calculated
Largest immature juvenile: male 335 mm; female 301 mm
Smallest size at sexual maturity: male 310 mm; female 292 mm

Canary rockfish Sebastes pinniger

Age range observed: 0–13, n = 112; males 1–7, n = 24; females 2–13, n = 25
Length of fish aged: 66–531 mm, males 92–431 mm; females 168–531 mm
Heaviest fish observed: male 450 g (300 mm); female 1727 g (510 mm)
Largest fish observed: 568 mm
Reported maximum length: 30 inches (762 mm; Miller and Lea 1972)
Calculated maximum length: combined sexes 718 mm; male 465 mm; female 632 mm
Largest immature juvenile: male 431 mm (age 7); female 423 mm (age 8)
Smallest size at sexual maturity: male 187 mm (age 3); female 296 mm

China rockfish Sebastes nebulosus

Age range observed: 2–26, n = 114; males 3–22, n = 40; females 4–26, n = 39
Length of fish aged: 97–411 mm; males 140–411 mm; females 134–385 mm
Heaviest fish observed: male 1331 g (366 mm); female 1283 g (379 mm)
Largest fish observed: 477 mm
Reported maximum length: 17 inches (432 mm; Miller and Lea 1972)
Calculated maximum length: combined sexes 383 mm; male 376 mm; female 375 mm
Largest immature juvenile: male 353 mm (age 14), female 320 mm (age 8)
Smallest size at sexual maturity: male 342 mm; female 262 mm

Copper rockfish Sebastes caurinus

Age range observed: 0–28, n = 227; males 2–21, n = 86; females 2–28, n = 108
Length of fish aged: 73–562 mm; males 168–538 mm; females 150–562 mm
Heaviest fish observed: male 2338 g (490 mm); female 3730 g (562 mm)
Largest fish observed: 578 mm
Reported maximum length: 22.9 inches (582 mm; Reilly et al. 1993)
Calculated maximum length: combined sexes 524 mm; male 501 mm; female 521 mm
Largest immature juvenile: male 327 mm (age 5); female 325 mm (age 6)
Smallest size at sexual maturity: male 370 mm (age 8); female 295 mm

Gopher rockfish Sebastes carnatus

Age range observed: 0–24, n = 557; males 3–14, n = 255; females 3–24, n = 241
Length of fish aged: 61–348 mm; males 171–348 mm; females 140–341 mm
Heaviest fish observed: male 853 g (336 mm); female 877 g (341 mm)
Largest fish observed: female 375 mm
Reported maximum length: 16.7 inches (425 mm; Reilly et al. 1993)
Calculated maximum length: combined sexes 342 mm; male 329 mm; female 341 mm
Largest immature juvenile: male 237 mm (age 10); female 306 mm (age 9)
Smallest size at sexual maturity: male 237 mm (age 10); female 207 mm

Grass rockfish Sebastes rastrelliger

Age range observed: 0–20, n = 131; males 5–20, n = 47; females 4–18, n = 78
Length of fish aged: 44–515 mm; males 319–490 mm; females 292–515 mm
Heaviest fish weighed: male 2214 g (490 mm); female 3300 g (538 mm)
Largest fish observed: female 538 mm
Reported maximum length: 22 inches (559 mm; Miller and Lea 1972)
Calculated maximum length: combined sexes 522 mm; male 494 mm; female 535 mm
Largest immature juvenile: male 432 mm (age 12); female 292 mm (age 4)
Smallest size at sexual maturity: male 359 mm (age 8); female 324 mm (age 5)

Greenspotted rockfish Sebastes chlorostictus

Age range observed: 2–21, n = 39; males 9–20, n = 16; females 10–21, n = 21
Length of fish aged: 124–428 mm; males 266–428 mm; females 262–426 mm
Heaviest fish weighed; male 1270 g (429 mm), female 1230 g (405 mm)
Largest fish observed: female 460 mm
Reported maximum length: 19.75 inches (502 mm; Miller and Lea 1972)
Calculated maximum length: combined sexes 444 mm; male 440 mm; female 442 mm
Largest immature juvenile: male 373 (age 14); female 262 mm (age 11)
Smallest size at sexual maturity: male 333 (age 11); female 299 mm (age 10)

Kelp rockfish Sebastes atrovirens

Age range observed: 0–15, n = 336; males 2–15, n = 168; females 2–13, n = 141
Length of fish aged: 50–388 mm; males 177–388 mm; females 146–388 mm
Heaviest fish weighed: male 976 g (388 mm); female 914 g (368 mm)
Largest fish observed: 425 mm
Reported maximum length: 16.75 inches (425 mm; Miller and Lea 1972)
Calculated maximum length: combined sexes 378 mm; male 377 mm; female 369 mm
Largest immature juvenile: male 338 mm; female 320 mm (age 7)
Smallest size at sexual maturity: male 246 (age 4); female 218 mm (age 5)

Olive rockfish Sebastes serranoides

Age range observed: 0–14, n = 411; males 1–13, n = 149; females 1–14, n = 129
Length of fish aged: 90–526 mm; males 192–475 mm; females 201–526 mm
Heaviest fish weighed: male 1023 g (438 mm)- female 2446 g (524 mm)
Largest fish observed: female 548 mm
Reported maximum length: 24 inches (610 mm; Miller and Lea 1972)
Calculated maximum length: combined sexes 524 mm; male 440 mm; female 539 mm
Largest immature juvenile: male 409 mm (age 6); female 354 mm (age 7)
Smallest size at sexual maturity: male 269 (age 3); female 285 mm (age 3)

Rosy rockfish Sebastes rosaceus

Age range observed: 3–14, n = 159; males 4–13, n = 66; females 3–14, n = 84
Length of fish aged: 139–288 mm; males 146–282 mm; females 151–288 mm
Heaviest fish weighed: male 300 g (263 mm); female 424 g (287 mm)
Largest fish observed: male 304 mm
Reported maximum length: 14.2 inches (361 mm; Miller and Lea 1976)
Calculated maximum length: combined sexes 325 mm; male 302 mm; female 329 mm
Largest immature juvenile: male 255 mm (age 11); no immature female rosy rockfish examined
Smallest size at sexual maturity: male 218 mm; female 245 mm

Starry rockfish Sebastes constellatus

Age range observed: 5–19, n = 89; males 6–17, n = 42; females 7–19, n = 43
Length of fish aged: 209–401 mm; males 252–398 mm; females 251–401 mm
Heaviest fish weighed: male 825 g (356 mm); female 715 g (349 mm)
Largest fish observed: 442 mm
Reported maximum length: 18.0 inches (457 mm; Miller and Lea 1976)
Calculated maximum length: combined sexes 467 mm; male 460 mm; female 450 mm
Largest immature juvenile: male 358 mm; female 262 mm
Smallest size at sexual maturity: male 265 mm; female 270 mm (age 7)

Vermilion rockfish Sebastes miniatus

Age range observed: 0–29, n = 194; males 1–20, n = 79; females 2–29, n = 72
Length of fish aged: 80–597 mm; males 162–575 mm; females 196–597 mm
Heaviest fish weighed: male 3101 g (536 mm); female 3230 g (570 mm)
Largest fish observed: 622 mm
Reported maximum length: 30 inches (762 mm; Miller and Lea 1972)
Calculated maximum length: combined sexes 598 mm; male 575 mm; female 605 mm
Largest immature juvenile: male 452 mm (age 6); female 318 mm (age 3)
Smallest size at sexual maturity: male 365 mm; female 365 mm

Yelloweye rockfish Sebastes ruberrimus

Age range observed: 4–23, n = 39; males 9–17, n = 18; females 4–23, n = 21
Length of fish aged: 243–611 mm; males 389–604 mm; females 285–611 mm
Heaviest fish weighed: male 1660 g (453 mm); female 3335 g (549 mm)
Largest fish observed: 655 mm
Reported maximum length: 36 inches (914 mm; Miller and Lea 1972)
Calculated maximum length: combined sexes 666 mm; male 756 mm; female 646 mm
Largest immature juvenile: male 467 mm (age 10); female 414 mm (age 9)
Smallest size at sexual maturity: male 471 mm (age 11); female 408 mm (age 10)

Yellowtail rockfish Sebastes flavidus

Age range observed: 0–20, n = 68; males 3–20, n = 16; females 4–14, n = 19
Length of fish aged: 68–512 mm; males 254–450 mm; females 203–512 mm
Heaviest fish weighed: male 1107 g (417 mm); female 1356 g (446 mm)
Largest fish observed: 535 mm
Reported maximum length: 26 inches (660 mm; Miller and Lea 1972)
Calculated maximum length: combined sexes 528 mm; male 451 mm; female 561 mm
Largest immature juvenile: male 372 mm (age 5); female 321 mm
Smallest size at sexual maturity: male 284 mm; female 315 mm

EPILOGUE

At length did cross an Albatross,
Through the fog it came;
As if it had been a Christian soul,
We hailed it in God's name.
...
The self-same moment I could pray;
And from my neck so free
The Albatross fell off, and sank
Like lead into the sea.

—Samuel Taylor Coleridge
The Rime of the Ancient Mariner