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Summary of Blue Rockfish and Lingcod Life Histories; A Reef Ecology Study; And Giant Kelp, Macrocystis Pyrifera, Experiments In Monterey Bay, California

by
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ABSTRACT

This bulletin presents results of several studies related to marine sportfish in central and northern California. Since 1957, Dingell-Johnson funds have been used in central California to conduct life history studies of blue rockfish and lingcod, several sportfishing assessment studies, a reef ecology study, and a pilot kelp canopy harvesting study. Results of a blue rockfish study were published in 1967, however, important additional life history and catch data have been collected subsequently and a collation of all blue rockfish findings is presented.

Lingcod data have been collated with published lingcod life history data collected in British Columbia and Washington. Our studies emphasized maturity, age and growth, food analyses, and evidence of a vertical spawning migration.

In the reef ecology study, 727 underwater fish transect tallies were made over a 3 year period yielding seasonal variations, relative abundance between stations, and relative abundance between years from 1968 through 1970 of larger species in the kelp bed area.

Pilot kelp harvesting experiments included kelp frond growth and plant life expenctancy, effects of canopy harvesting on haptera growth, kelp standing crop estimates, and effects of canopy removal on kelp bed fish populations.

A thorough literature search of kelp-invertebrate-sea otter interactions was conducted and no valid documentation was found to substantiate reports that the apparent increase in Macrocystis canopy densities since 1958 in central California resulted from sea otter predation on sea urchins.

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1. INTRODUCTION

The inshore marine environment of central California includes many habitats: expansive mudflat areas within bays and estuaries; open sandy beaches; exposed rocky shoreline; rocky reefs in shallow waters in the euphotic zone on which lush growths of algae are found; deeper rocky reefs below the euphotic zone; muddy, silt, and gravelly bottoms from the surf zone to great depths; and the midwater or pelagic zone including, in the inshore area, the mesopelagic zone from 656 to 3281 ft. (200 to 1000 m) and the epipelagic zone from the surface to 656 ft. (200 m). There are several general publications describing many of the animals and their behavior living within these areas. The most informative of these are: McGinitie and McGinitie, 1949; Light, 1954; Smith, 1962; Hedgpeth, 1962; and Ricketts and Calvin, 1968.

There are publications specifically on fishes found in central California, the most informative of which are: Miller and Gotshall, 1965; Baxter, 1966; Fitch and Lavenberg, 1968, 1971; Fitch, 1969; Herald, 1972; Miller and Lea, 1972; and Hart, 1973.

Fairly complete life history studies of common marine fishes of central California have been published. These include studies on king salmon, silver salmon, striped bass, cabezon, starry flounder, barred surfperch, sablefish, Pacific sanddab, blue rockfish, and California halibut. Partial life histories have been published on lingcod, jacksmelt, several species of rockfishes, and petrale sole and several other flatfishes.

There have been few basic ecological shallow water studies depicting relationships between the more important organisms, including fishes present and their habitat requirements. In southern California studies along this line were conducted by Limbaugh (1955); Carlisle, Turner, and Ebert (1964); North and Hubbs (1968); and Turner, Ebert, and Given (1969); but no comparable studies have been conducted in central California.

Within recent years the need for basic ecological-environmental studies has become painfully evident. There is little knowledge of the far reaching ecological effects of overfishing, the many forms of pollution, heavy utilization of invertebrates by sea otters, kelp canopy harvesting, estuary and bay landfill, construction of breakwaters and harbors, siltation from runoff caused by man's land activities, oil spills, warming of ocean waters by power plant effluent, and academic and sport collecting in tidepools.

Over the years since 1957 the Central California Marine Sportfish Survey has evolved from a general sportfishing survey to include investigation of the effects of some of the human impact parameters outlined above on inshore fish populations. To determine the nature and extent of sport fisheries, an assessment survey (DJF12R) of all sportfishing methods from Pt. Arguello to Oregon was conducted from 1957–1961. Estimates of fishing days and catch by species in each fishery were made (Miller and Gotshall, 1965). This survey also disclosed the important bottomfish species. It was determined that blue rockfish and lingcod were the more important species in both numbers and weight, and that the stocks of blue rockfish at several ports were showing signs of overexploitation. Consequently the Blue Rockfish Management Study (DJF19R) was conducted from 1962 to 1964. The results of this survey were published as an MRO report (Miller, Odemar, and Gotshall, 1967). In 1966 a reassessment survey of all sportfishing methods was conducted from San Francisco to Yankee Pt., Monterey County. The results of this survey (Miller and Odemar, 1968) revealed continued decline of blue rockfish stocks at certain port areas, recorded a substantial increase in skiff fishing effort, and disclosed that lingcod appeared to be overutilized at several ports.

It became apparent during these surveys that shallow inshore habitats, especially the kelp bed environment, were vitally important as nursery grounds for young sport and commercial fish and contained a rich aggregate of fish and invertebrates. A survey of the life history studies of important fishes found in the inshore area reveals little understanding of the distribution and habitat requirements of younger stages. This especially applies to the young of rockfishes, lingcod, cabezon, and surfperches. The postlarvae of the rockfishes and lingcod are pelagic and little is known of their inshore distribution patterns nor of their recruitment into the harvestable stocks. Studies of adults of these species usually are not conducted in the same areas frequented by the postlarvae and juveniles. During the blue rockfish study the investigation of juvenile fish was conducted independently of the adult fish survey. The overall importance of the shallow water environment and kelp beds as nursery areas for many species became obvious during this investigation.

With the advent of rapidly increased alteration and use of the inshore environment by man, the Central California Marine Sportfish Survey (DJF25R) focused attention on the shallow water reef and kelp bed areas as well as investigating the lingcod. This study was concluded in 1972 and the results are presented here.

The scope of this publication is to describe the central California sportfishery, summarize the life histories and catch analysis of blue rockfish and lingcod, relate some of the behavioral and environmental relationships of fishes in an inshore kelp bed area, and describe the effects of canopy removal on resident fish populations and upon the growth of harvested kelp plants.

2. CENTRAL AND NORTHERN CALIFORNIA SPORT FISHERY

The inshore area from Pt. Arguello to Oregon is typified by distinct aggregations of sport species: large schools or aggregations of rockfishes; scattered aggregations and spawning schools of surfperches and silversides in kelp bed, pier, and harbor areas; schools of spawning osmerids or true smelts at certain sandy beaches north of Moss Landing; dense schools as well as wandering individuals of white croaker in shallow sandy areas; and aggregations of sanddabs and other flatfishes on certain sand and gravel areas. There are also many species that are solitary or nonschooling. These include: sculpins, family Cottidae; greenlings, family Hexagrammidae; many shallower water rockfishes, genus Sebastes, such as black-and-yellow rockfish, gopher rockfish, and grass rockfish; sharks and rays; and solitary inter- and subtidal forms such as the monkeyface-eel and rock prickleback.

In all, 130 species representing 41 families have been recorded in the central California sport fishery. Those taken almost entirely by trolling are king salmon, silver salmon, and albacore. Striped bass also are caught by trolling, but large numbers are taken by shore fishermen and drift skiff fisherman. Lingcod are taken by trolling from skiffs, but most of the catch is made by bottom fishermen. The bottomfish fishery consists of fish taken in middepth or near the surface as well as at the bottom. The criterion for "bottom" fishing is that the boat is not moving under its own power while fishing. Bottomfishing boats may be either anchored or at drift. All fish taken by skindivers, shore, and pier fishermen are considered bottomfish. The principal species groups in the inshore bottomfish fishery are rockfishes, surfperches, greenlings, sculpins, and flatfishes.

The 1957–61 assessment survey indicated the top ten hook-and-line species by numbers were blue rockfish, white croaker, barred surfperch, jacksmelt, shiner surfperch, redtail surfperch, walleye surfperch, yellowtail rockfish, silver surfperch, and striped bass. The top ten species by weight were lingcod, blue rockfish, striped bass, king salmon, redtail surfperch, barred surfperch, yellowtail rockfish, black rockfish, bocaccio, and white croaker.

of the total estimated 1,410,000 annual angler days for the 1957–61 period, the greatest number were expended by shore fishermen followed by pier fishermen, skiff fishermen, partyboat fishermen, and skindivers (Table 1). The inshore aggregate species frequenting rocky reefs and kelp beds are utilized by each of these fisheries. The partyboat catch is primarily taken on rocky reefs, and during the 1957–61 survey, 74.2% of all rockfish taken were by partyboat fishermen. Except for California halibut, all the skindiver's catch is from rocky and kelp bed areas. About 60% of the skiff catch is taken in the inshore rocky zone, with the remainder of the catch being salmon taken by trolling, or white croaker, flatfishes, and jacksmelt taken over a sandy bottom. Shore fishing effort from sandy beaches is about twice that from rocky shoreline, consequently the shore catch is dominated by surfperches which made up 59.2% of the shore catch in 1957–61. Rockfishes, greenlings, and cabezon were the principal species taken from rocky areas but they contributed only 13% of the total shoreline catch.

At around 240 ft. (73 m) there is a change in rockfish species composition north of Pt. Arguello. Inside about 240 ft. (73 m) depth contour blue rockfish, olive rockfish, kelp rockfish, black rockfish, and brown rockfish are the principal rockfishes taken by hook-and-line and by spearfishermen. In depths greater than about 240 ft. (73 m) yellowtail rockfish, widow rockfish, bocaccio, chilipepper, greenspotted rockfish, rosy rockfish, and starry rockfish are the principal hook-and-line species.

Not many sport caught lingcod are taken in depths greater than 240 ft. (73 m), and most are taken in rocky areas. Demersal species such as sablefish, petrale sole, and English sole are usually taken deeper than 240 ft. (73 m), but nearly all sanddabs, starry flounder, sand sole, and rock sole are taken inside 240 ft. (73 m).

Most of the catch analysis presented in this bulletin pertains to the partyboat and skiff fisheries because of the importance of the inshore rocky and kelp bed areas to them.

TABLE 1

Average Annual Number and Percentages of Angler Days, Total Fish, Rockfish, Salmon, Lingcod, White Croaker, and Others in Five Sport Fisheries—Point Arguello to Oregon, 1957–61.

	Pier			*Skindiving*			*Shore*			*Partyboat*			*Skiff*			*Total*			
	Number	*Percent of pier*	*C/D of pier*	*Number*	*Percent of skindiving*	*C/D of skindiving*	*Number*	*Percent of shore*	*C/D of shore*	*Number*	*Percent of partyboat*	*C/D of partyboat*	*Number*	*Percent of skiff*	*C/D of skiff*	*Number*	*Percent of total*	*Pounds*	*Percent of total*
Angler days	530,702	—	—	39,700	—	—	603,097	—	—	115,701	—	—	121,038	—	—	1,410,238	—	—	—
Percent of total	37.6	—	—	2.8	—	—	42.8	—	—	8.2	—	—	8.6	—	—	100.0	—	—	—
Total fish	1,034,063	100.0	2.0	21,615	100.0	0.5	1,024,916	100.0	1.7	800,381	100.0	6.9	337,171	100.0	2.8	3,218,146	100.0	4,369,934	100.0
Percent of total	32.1			0.7			31.8			24.9			10.5			100.0			
Rockfishes	11,899	1.2	trace	9,790	45.3	0.2	35,317	3.4	0.1	682,484	85.3	5.9	179,779	53.3	1.5	919,269	28.6	1,685,680	38.6
Percent of total	1.3			1.1			3.8			74.2			19.6			100.0			
Surfperches	497,584	48.1	0.9	4,923	22.8	0.1	742,668	72.5	1.2	25	trace	trace	8,553	2.5	0.1	1,253,753	39.0	924,406	21.2
Percent of total	39.7			0.4			59.2			trace			0.7			100.0			
Salmon	64	trace	trace	0	0.0	0.0	190	trace	trace	37,935	4.7	0.3	15,565	4.6	0.1	53,754	1.6	420,860	9.6
Percent of total	0.1			0.0			0.3			70.6			29.0			100.0			
Lingcod	1,312	0.1	trace	2,923	13.5	0.1	3,045	0.3	trace	25,595	3.2	0.2	18,378	5.5	0.2	51,253	1.6	410,030	9.4
Percent of total	2.6			5.7			5.9			49.9			35.9			100.0			
White croaker	218,206	21.1	0.4	0	0.0	0.0	14,899	1.5	trace	1,024	0.1	trace	54,681	16.2	0.4	288,810	9.0	147,290	3.4
Percent of total	75.6			0.0			5.2			0.3			18.9			100.0			
All others	304,998	29.5	0.6	3,979	18.4	0.1	228,797	22.3	0.4	53,318	6.7	0.5	60,215	17.9	0.5	651,307	20.2	781,668	17.8
Percent of total	46.8			0.6			35.1			8.2			9.2			100.0			

*TABLE **1***

Average Annual Number and Percentages of Angler Days, Total Fish, Rockfish, Salmon, Lingcod, White Croaker, and Others in Five Sport Fisheries—Point Arguello to Oregon, 1957–61.

2.1. CATCH ANALYSIS

The rocky reef aggregate catch is complex and variable by nature. There are no applicable multispecies population dynamics models to evaluate the status of stocks supporting this catch nor to determine mortality rates and optimum levels of harvesting. For instance, blue rockfish is but one species in an aggregate catch in which only occasionally is there a choice in capturing a single species from among the 30 or so commonly caught fish. Mid-depth schooling species may be taken at the bottom at times, and variations in feeding habits and vertical distribution occur daily as well as seasonally. Seldom is there a "pure" catch of one rocky reef species. Over sandy bottom, however, it is not uncommon to land large numbers of one species such as Pacific sanddab or white croaker. When trolling, the fish sought such as salmon or California halibut is quite often the only species landed.

For inshore aggregate stocks in central and northern California, tagging and size composition data reveal that adult stocks within the range of boats at each port area do not intermingle with stocks farther apart than about 10 miles. Comparisons of fish caught on different reef areas near each port further reveal that there are more or less discrete fishable stocks on each reef.

Present evaluation of aggregate stocks near each port area is based on comparing catch parameters of species composition, size composition, catch-per-unit-of-effort of total fish, and catch-per-hour of the particular species in question. These parameters do not supply yield curves but do give indices of trends of availability of certain species in relation to other species, and in relation to the degree of fishing effort expended.

Species composition is expressed in percent of total fish and is related mathematically to catch-per-hour in that the catch-per-hour values of each species is computed by multiplying the percent composition of each species by the catch-per-hour of total fish. Thus in the following port area evaluation, only catch-per-hour of blue rockfish, catch-per-hour of total fish, mean length of fish, and length frequency polygons are presented to depict trends. Percentage composition values are given to express the relative "importance" of fish to sport fishermen in terms of frequency of capture and numbers caught.

The above parameters are required for each port area and each sport fishery in each port area since partyboat, skiff fishermen, and skindivers utilize essentially different fishing grounds. Gillnet and long-line commercial fisheries also should be surveyed when they are conducted within the range of the sport fishery. Total catch and effort is available for the partyboat fishery via the mandatory log system; nevertheless intensive sampling must be conducted to estimate these two parameters by port for the skiff and skindiving fisheries. Since 1966 we have determined the catch parameters outlined above on a catch index statum of Saturday-Sunday-Holiday (SSH) sampling during the June through November period. About # of the annual partyboat effort is expended during this 6 month interval, and in the skiff bottom fishery from 60 to 70% of the total catch and effort has been recorded during this period. Catch data from 1959 through 1966 were analyzed to test the assumption that the June–November period was representative of the total annual catch in determining trends

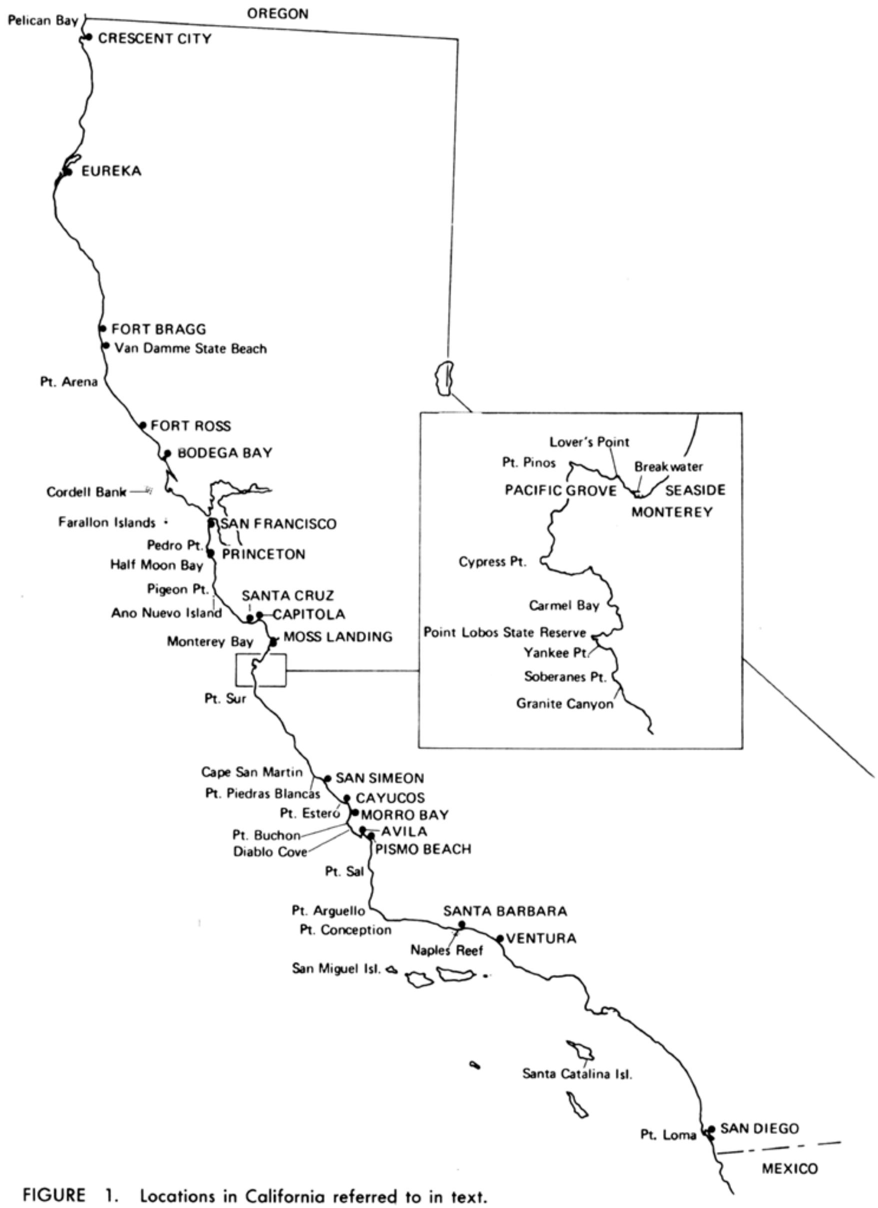

FIGURE 1. Locations in California referred to in text.

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of catch and effort. For blue rockfish, catch-per-hour values for the SSH June–November stratum were compared to catch-per-hour values of the total year for both partyboat and skiff catches for which we had total annual estimates (Figure 2). The slope line was fitted by the least squares method and the scatter of points shows a close fit. of interest is that the relationship of lower catch-per-hour values of the annual estimates (an average of around 86% of the SSH June–November stratum) is about the same at low population densities as it is at the highest levels. This relationship does not vary significantly between ports or between shallow and deeper water catches as represented by the partyboat and skiff catches. As will be described later, there is a seasonal behavioral pattern of blue rockfish wherein this species is relatively unavailable during February through April and throughout its range becomes more available in June or July.

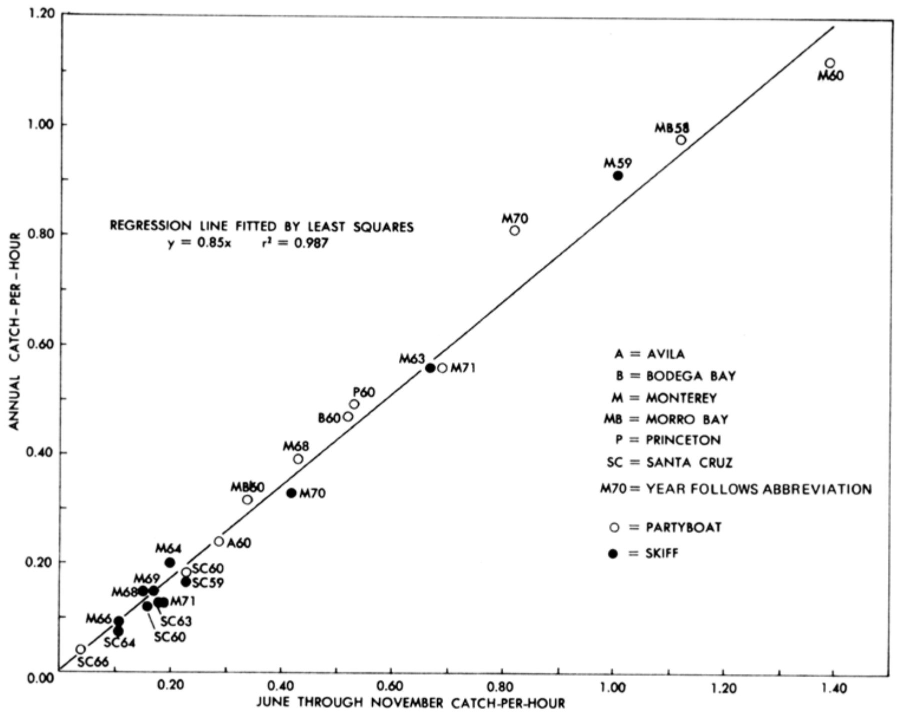

FIGURE 2. Relation of annual catch-per-hour to June through November SSH catch-per-hour for blue rockfish in partyboat and skiff catches from Avila to Bodega Bay, 1958–1971.

FIGURE 2. Relation of annual catch-per-hour to June through November SSH catch-per-hour for blue rockfish in partyboat and skiff catches from Avila to Bodega Bay, 1958–1971.

Even though catch-per-hour values are interdependent between all species in the catch, when blue rockfish is the only dominant species the relative changes in availability of any of the other species does not affect use of blue rockfish catch-per-hour value comparisons between years. However, if there is another dominant species in the aggregate catch, such as Pacific sanddab in the Monterey skiff catch, then changes in availability of that species will alter blue rockfish catch-per-hour values even though there may not have been an actual change in blue rockfish availability. Nevertheless, catch-per-hour values do indicate changes between seasons and years, and when correlated with size composition and total catch are valuable parameters in determining relative abundance.

2.2. THE PARTYBOAT FISHERY

This fishery consists of three distinct operations in central California: trolling for salmon, striped bass, and albacore; fishing for bottomfish while drifting or at anchor; and charter excursions by skindivers. Over the past ten years about 25% of the statewide partyboat effort has been expended from Avila to Crescent City; however, the numbers of partyboats operating south of Pt. Arguello is only slightly higher than to the north. Partyboats in southern California are, on the average, much larger than to the north, and there are more operations of half-day boats in southern California.

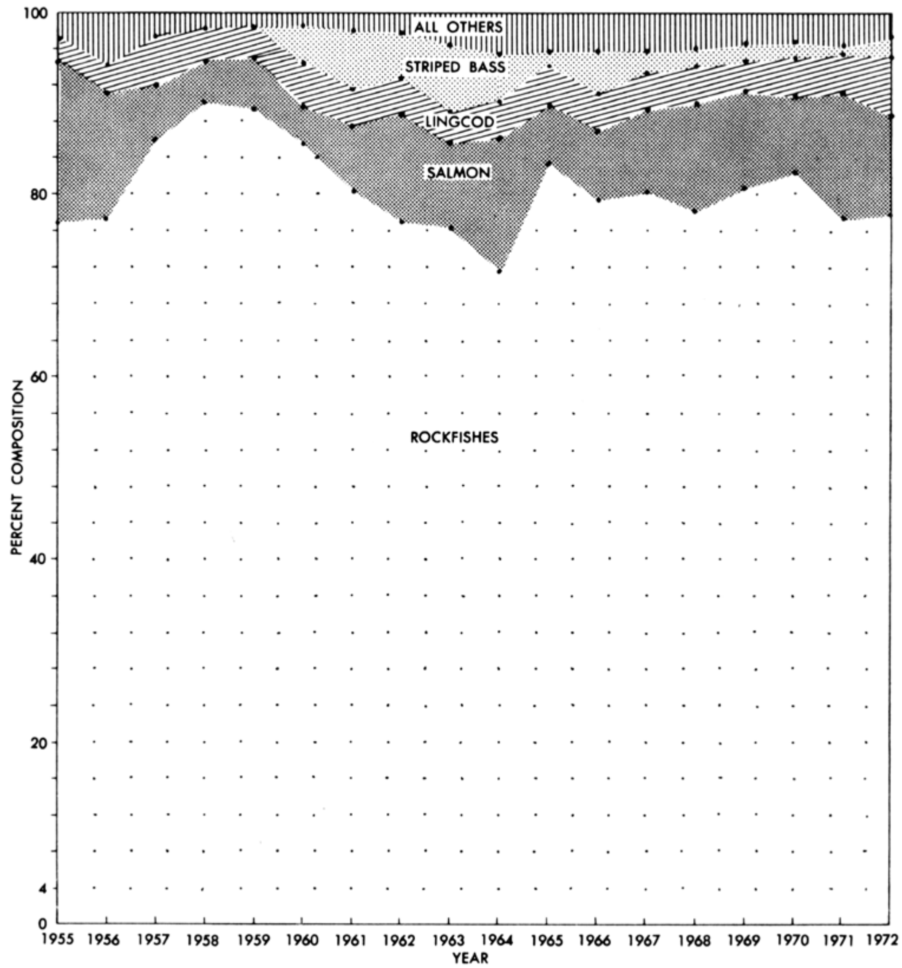

FIGURE 3. Annual percent composition by numbers of the Pt. Arguello to Oregon partyboat catch, 1955–1972. (Striped bass records were not separated prior to 1960.)

FIGURE 3. Annual percent composition by numbers of the Pt. Arguello to Oregon partyboat catch, 1955–1972. (Striped bass records were not separated prior to 1960.)

North of Pt. Arguello rockfishes contributed from 71.7% to 90.0% of the total partyboat catch by numbers from 1955 through 1971 (Figure 3), with salmon, lingcod, and striped bass the only other species consistently contributing materially to the catch. Rockfishes also dominated the catch by weight contributing 62.6% of the catch in 1960, followed by salmon, lingcod, and striped bass. of the top 20 species by weight in the 1960 central and northern California partyboat catch, 14 were rockfishes, while by number in the same area, 15 of the top 20 species were rockfishes.

Twenty-nine species of rockfish have been recorded in the central California partyboat catch. of these, blue rockfish and yellowtail rockfish contributed to 26.9% and 18.2% respectively to the total catch of all species and 31.4% and 21.2% respectively of the rockfish catch. By weight yellowtail rockfish was first with 13.7% of the total catch followed by blue rockfish with 11.9% of the total catch.

2.3. THE SKIFF FISHERY

The central California skiff fishery varies considerably by port. In 1959 rockfishes dominated the catch at Santa Cruz, Monterey, Cayucos, Morro Bay, and Avila, although by individual species white croaker was more important at many of these ports. White croaker and Pacific sanddabs were more numerous at Pedro Pt., Princeton, Capitola, and Moss Landing. of the rockfishes, blue rockfish was the most numerous species in the late 1950's; however, in 1966 brown rockfish outnumbered blue rockfish in the skiff catch from Pedro Pt. to Monterey. During several years since 1959, Pacific sanddabs were more numerous in the catch at Monterey, where blue rockfish had been previously most important (Table 2).

One of the more interesting relationships in the skiff aggregate catch is the change in the relative numbers of blue rockfish and Pacific sanddabs in the Monterey bottomfish catch (Figure 4). Pacific sanddabs contributed about 12% of total skiff catch in 1959, but by 1969 had increased to over 65%. Fishermen interviews disclosed that blue rockfish was the more preferred of the two species until about 1966; however, since then Pacific sanddab has become a favored food fish and catches increased irrespective of the blue rockfish availability.

Skiff fishing effort has been expanding in central California. Construction of new harbors and launching ramps has been underway since the late 1950's and new boating and fishing equipment has enticed more anglers to use the ocean for recreation and fishing. In the area from San Francisco to Monterey fishing effort increased by 59% from 1959 to 1966.

2.4. SKINDIVING

All the skindiver's catch is made inside 100 ft. (32.8 m) depth contour with rockfishes contributing over 45% of 1960 catch by numbers, followed by lingcod. By weight, lingcod was by far the most important species. Compared to the hook-and-line sport fisheries, skindiving effort is of small magnitude, contributing to but 2.8% of the total sportfishing effort from Pt.

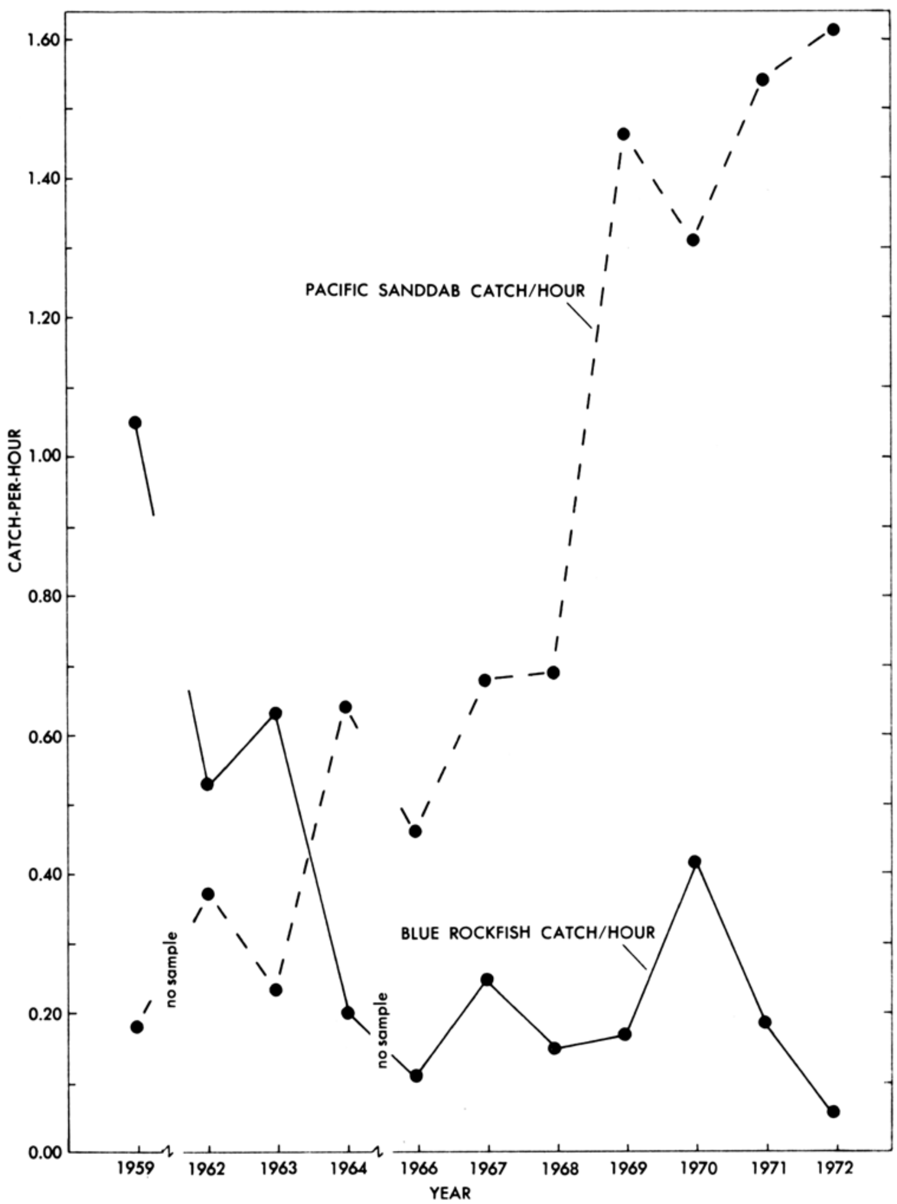

FIGURE 4. Catch-per-hour of blue rockfish and Pacific sanddab in the Monterey skiff catch, 1959–1972.

FIGURE 4. Catch-per-hour of blue rockfish and Pacific sanddab in the Monterey skiff catch, 1959–1972.

Arguello to Oregon (Table 1). of concern to inshore management, however, is the effects of concentrated spearfishing activity at certain accessible beaches where resident stocks of kelp bed fishes have been materially reduced by skindivers.

TABLE 2

Three Most Numerous Species in the Skiff Bottomfish Catch, 1959 Through 1971 at Five Port Areas

	First		Second		Third	
	Species	*Percent of Total*	*Species*	*Percent of Total*	*Species*	*Percent of Total*
Pedro Pt.						
1959	White Croaker	44.0	Black Rockfish	27.6	Blue Rockfish	19.3
1966	Brown Rockfish	40.1	Black Rockfish	28.2	White Croaker	13.1
Princeton						
1959	White Croaker	45.8	Blue Rockfish	10.9	Canary Rockfish	10.5
1961	White Croaker	64.4	Brown Rockfish	15.9	Lingcod	15.2
1962	White Croaker	27.1	Blue Rockfish	15.7	Canary Rockfish	13.8
1963	White Croaker	60.1	Brown Rockfish	5.4	Black Rockfish	4.8
1966	White Croaker	32.7	Brown Rockfish	13.2	Black Rockfish	12.4
Santa Cruz						
1959	White Croaker	30.5	Blue Rockfish	22.7	Black Rockfish	5.9
1961	White Croaker	26.9	Blue Rockfish	15.3	Pacific Sanddab	10.5
1962	Blue Rockfish	23.2	White Croaker	16.2	Gopher Rockfish	8.3
1963	Blue Rockfish	16.2	White Croaker	13.0	Gopher Rockfish	11.9
1964	White Croaker	30.8	Blue Rockfish	10.0	Black Rockfish	8.2
1966	White Croaker	26.7	Blue Rockfish	9.8	Brown Rockfish	9.8
1967	White Croaker	30.0	Blue Rockfish	19.3	Pacific Sanddab	11.3
1968	White Croaker	38.2	Blue Rockfish	23.8	Brown Rockfish	4.8
1969	White Croaker	52.6	Blue Rockfish	15.0	Brown Rockfish	11.0
1970	Blue Rockfish	26.4	White Croaker	25.0	Brown Rockfish	9.4
Capitola						
1959	White Croaker	70.0	Jacksmelt	4.9	Grass Rockfish	3.4
1961	White Croaker	41.8	Jacksmelt	9.6	Grass Rockfish	6.5
1962	White Croaker	50.6	Jacksmelt	7.0	Blue Rockfish	5.4
1963	White Croaker	37.6	Pacific Sanddab	11.0	Grass Rockfish	9.1
1964	White Croaker	54.7	Jacksmelt	8.7	Brown Rockfish	7.2
1966	White Croaker	65.7	Jacksmelt	8.2	Brown Rockfish	8.0
Monterey						
1959	Blue Rockfish	57.9	Pacific Sanddab	12.1	Pacific Mackerel	5.0
1961	Pacific Sanddab	29.8	Blue Rockfish	25.2	Rosy Rockfish	10.7
1962	Blue Rockfish	30.4	Pacific Sanddab	28.3	Rosy Rockfish	5.1
1963	Blue Rockfish	39.1	Pacific Sanddab	13.1	Olive Rockfish	6.4
1964	Pacific Sanddab	39.4	Blue Rockfish	13.7	Sablefish	10.0
1966	Pacific Sanddab	41.9	Blue Rockfish	10.5	Copper Rockfish	6.8
1967	Pacific Sanddab	42.3	Blue Rockfish	15.5	Copper Rockfish	8.4
1968	Pacific Sanddab	45.6	Rosy Rockfish	8.1	Blue Rockfish	7.6
1969	Pacific Sanddab	65.7	Blue Rockfish	6.8	Copper Rockfish	5.0
1970	Pacific Sanddab	53.0	Blue Rockfish	16.8	Copper Rockfish	6.0
1971	Pacific Sanddab	63.6	Blue Rockfish	7.6	Copper Rockfish	4.8

*TABLE **2***

Three Most Numerous Species in the Skiff Bottomfish Catch, 1959 Through 1971 at Five Port Areas

2.5. PIER AND SHORE FISHERIES

These two sport fisheries contribute over 80% of the total hook-and-line effort from Pt. Arguello to Oregon; however, few species taken in these fisheries appeared in the partyboat, skiff, and skindiving catches. of the rockfishes taken by pier and shore fishermen (5.1% of rockfishes taken in all sport fisheries), blue rockfish was most common.

3. BLUE ROCKFISH CATCH ANALYSIS AND LIFE HISTORY

A partial life history study was published by Wales (1952) and Miller, Odemar, and Gotshall (1967) published a life history and catch analysis of the blue rockfish of central California. Inasmuch as the latter publication received limited distribution, additional catch data has been collected, and further tagging and behavioral studies have been conducted since 1965, the following summary incorporates the principal findings of Miller, Odemar, and Gotshall (1967) with more recent evidence.

3.1. CATCH ANALYSIS OF PORT AREA

There are port areas where blue rockfish may be abundant but are of lesser importance in the catch due to ready availability of more preferred large bottomfish such as copper rockfish, olive rockfish, vermilion rockfish, yellowtail rockfish, yelloweye rockfish, and lingcod. In these "virgin" fisheries a few large blue rockfish may be taken along with the above species, and until the stocks of larger fish become heavily utilized blue rockfish will remain relatively unimportant. The fisheries at Pt. Sur and San Simeon are of this nature at present. Blue rockfish stocks in some areas are naturally of low abundance compared to other species and do not contribute steadily to the bottomfish catch. These conditions exist in the Bodega Bay partyboat and skiff fisheries; in the Farallon Isl. partyboat fishery; and in the Pedro Pt., Capitola, and Moss Landing skiff fisheries. At the remaining bottomfishing areas blue rockfish have historically been the major rocky reef species; however, in later years catches of this species have declined considerably at several port areas. These areas are at Princeton, Ano Nuevo Island, Santa Cruz, Monterey, Pacific Grove, Morro Bay, and Avila.

3.1.1. Bodega Bay

Blue rockfish do not appear to be abundant near this port because when catches of larger rockfish and lingcod decline there is not the consequent increase in blue rockfish catches as occurs at ports south of San Francisco. Blue rockfish entering the skiff and partyboat fisheries are large fish, and there is no apparent correlation between catch-per-hour values and mean lengths to indicate overutilization.

3.1.2. Farallon Islands

The principal species sought are yellowtail rockfish and lingcod. Blue rockfish contributed 3 to 25% of the annual catch in this area from 1961 through 1966. There was a sharp drop in partyboat catch-per-hour values of total fish and blue rockfish from 1962 to 1964 indicating a decrease in availability or abundance of all fish (Figure 5). From 1964 to 1966 there was an increase of total fish caught but not of blue rockfish. The mean size of blue rockfish has remained the largest recorded for all fishing areas and has not changed significantly despite changes in fish abundance. There are apparently no large stocks of blue rockfish in this area. Results of a tagging program conducted by the California Department of Fish and Game in 1962 indicated few blue rockfish present in this area, especially of younger age groups.

3.1.3. Princeton

This is the northernmost port area where blue rockfish are of major importance in the partyboat catch. In the early 1960's this species contributed around 40% of the total catch by numbers, but by 1970 made up about 11% of the catch. The total take of fish from 1960 to 1963 fluctuated in direct relationship to the number of blue rockfish landed, but since 1963 blue rockfish catches have been below a level capable of effecting a major change in total fish catch-per-hour values. The mean size of blue rockfish also has declined, indicating that fishing mortality may have been a major factor in this decline (Figure 6).

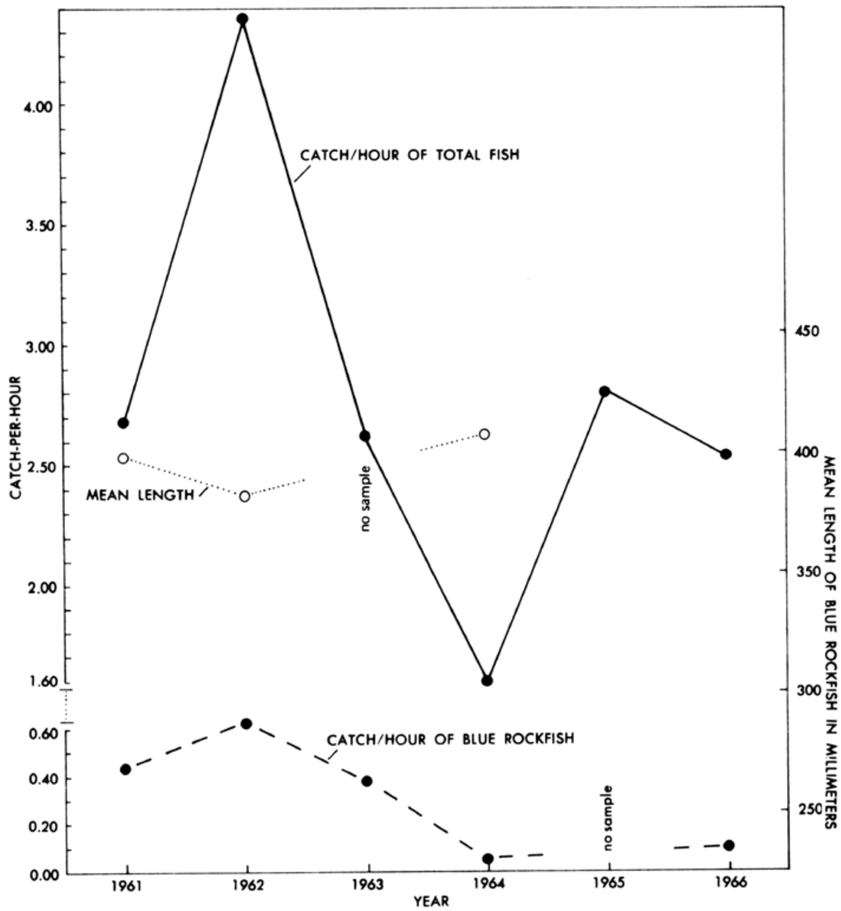

FIGURE 5. Partyboat catch-per-hour of total fish and blue rockfish, and mean length of blue rockfish caught near the Farallon Islands, 1961–1966.

FIGURE 5. Partyboat catch-per-hour of total fish and blue rockfish, and mean length of blue rockfish caught near the Farallon Islands, 1961–1966.

The skiff catch of blue rockfish shows a comparable pattern of decline; however, since skiff fishermen do not travel as far as partyboat fishermen, they must utilize nearby reefs which are not extensive in this area. The highest percent composition of blue rockfish in the skiff catch was 16% which occurred in 1962. Skiff caught blue rockfish were taken primarily in kelp beds and averaged smaller throughout the sampling period than those taken in the partyboat fishery. Partyboats range from off Pedro Pt. south to Pigeon Pt. and offshore about 12 miles (19.3 km).

3.1.4. Ano Nuevo Island Area

The partyboat fishery is primarily for lingcod and is conducted over a relatively small area comprised of four isolated reefs. Only partyboats operated out of Santa Cruz fish in this area. Blue rockfish are abundant on these reefs and are the major fish by numbers contributing 25 to 60% of the total catch annually from 1960 through 1971. Total fish catch-per-hour values reflect blue rockfish abundance and have shown a marked decline from 1960 to 1968 and an increase in 1969 and 1970 (Figure 7).

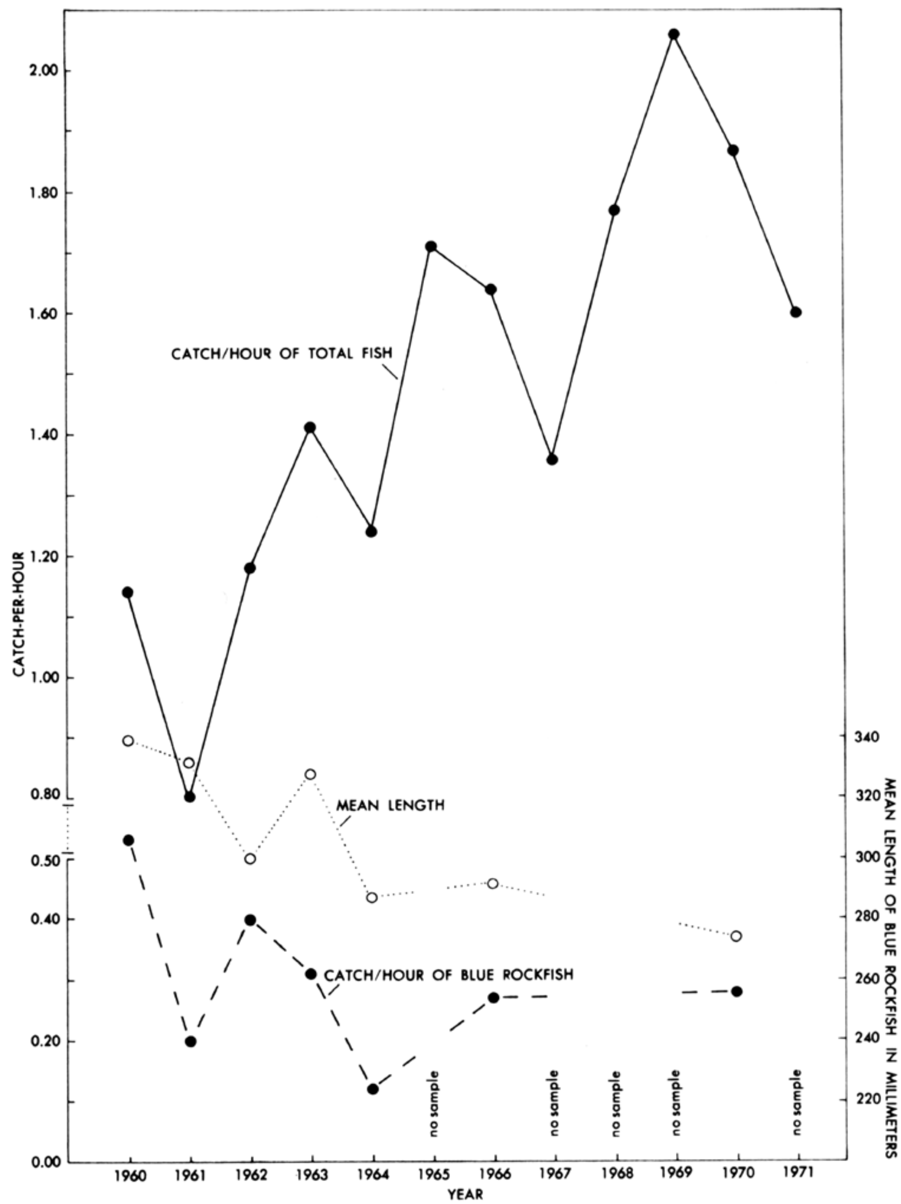

FIGURE 6. Partyboat catch-per-hour of total fish and blue rockfish, and mean length of blue rockfish landed at Princeton, excluding fish caught near Farallon Isls., 1960–1970.

FIGURE 6. Partyboat catch-per-hour of total fish and blue rockfish, and mean length of blue rockfish landed at Princeton, excluding fish caught near Farallon Isls., 1960–1970.

Several dominant modes of young fish peaking around 240 to 250 mm TL have appeared in length frequency polygons (Figure 8) in 1962, 1968, and 1970; however, since 1967 there has not been a secondary mode of fish over 300 mm TL as was present in 1960 and 1961. The recruitment appearing in 1962 persisted, but in diminishing abundance, for 4 years with the mean size reaching 300 mm TL in 1966.

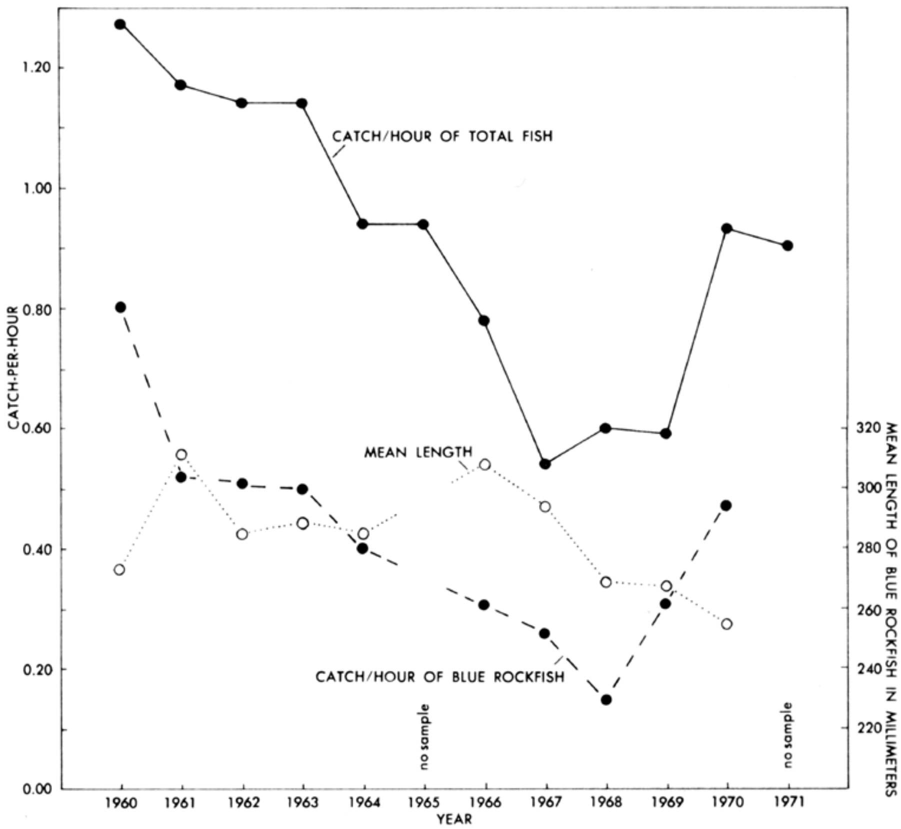

FIGURE 7. Partyboat catch-per-hour of total fish and blue rockfish, and mean lengths of blue rockfish caught near Ano Nuevo Island, 1960–1971.

FIGURE 7. Partyboat catch-per-hour of total fish and blue rockfish, and mean, lengths of blue rockfish caught near Ano Nuevo Island, 1960–1971.

3.1.5. Santa Cruz

Since 1960 partyboat and skiff catches of blue rockfish have been taken from essentially different fishing grounds. Routine monthly sampling was initiated at this port in 1960; however, in 1958 and 1959 trips were taken by project personnel on partyboats to determine sampling procedures for 1960. Notes were taken in 1958 and 1959 on the nature of the fishery, including the areas fished and species composition of the catch, and interviews were made of partyboat operators concerning the fishery for several years previously. From 1956 through 1959 possibly 70 to 80% of the total catch was blue rockfish, and nearly all this catch was made on local reefs within 6 miles (9.7 km) of port. This heavy blue rockfish take continued until 1960 when the percent composition of blue rockfish declined to 18% of the total catch. In 1970, as at other central California ports, there was an increase of blue rockfish catch-per-hour; however, the catch-per-hour of total fish landed did not increase (Figure 9). Total fish catch-per-hour values have declined since 1964 with less than half the fish taken per hour in 1971 as in 1965. A shift of this fishery to deeper water occurred in 1960 in quest of yellowtail rockfish, chilipepper, bocaccio, and sablefish. Since 1960 most of the local Santa Cruz partyboat catch has been made at the deeper reefs with occasional trips made to the inshore reefs near Davenport where blue rockfish are taken.

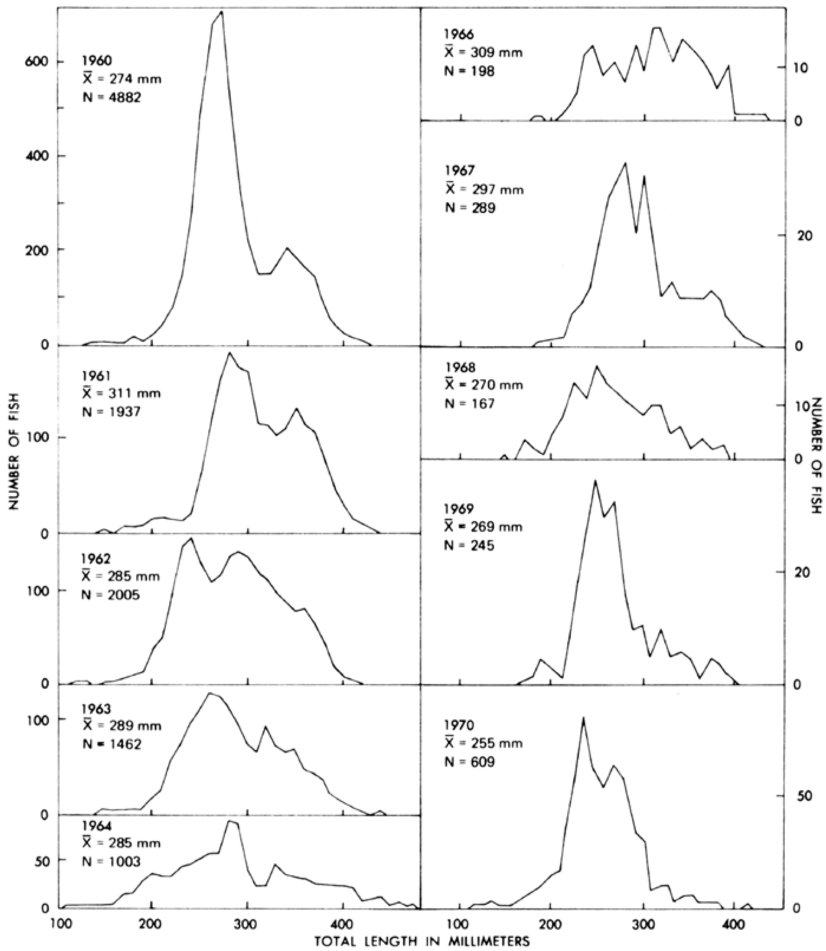

FIGURE 8. Length frequency polygons, mean annual size, and number of blue rockfish, sampled in the Ano Nuevo partyboat catch, 1960–1970.

FIGURE 8. Length frequency polygons, mean annual size, and number of blue rockfish, sampled in the Ano Nuevo partyboat catch, 1960–1970.

The skiff fishery exhibits a more fluctuating pattern of catch-per-hour values, with blue rockfish contributing a smaller portion of the total catch than in the local partyboat fishery. Skiff fishery catch-per-hour values are more affected by changes in catches of white croaker and Pacific sanddab than by blue rockfish fluctuations; nevertheless in 1968 and 1970 the influx of blue rockfish contributed to higher total catch-per-hour values (Figure 10). The mean size of blue rockfish has declined slightly since 1959.

3.1.6. Capitola

Blue rockfish are of minor importance here due to turbid water conditions on nearby reefs. Water conditions within 2 miles (3.2 km) of the Capitola pier are more turbid and warmer during the summer months than off Santa Cruz or Monterey. Blue rockfish are more commonly found in clear cool moving waters over rocky pinnacles and near the outer edges of kelp beds.

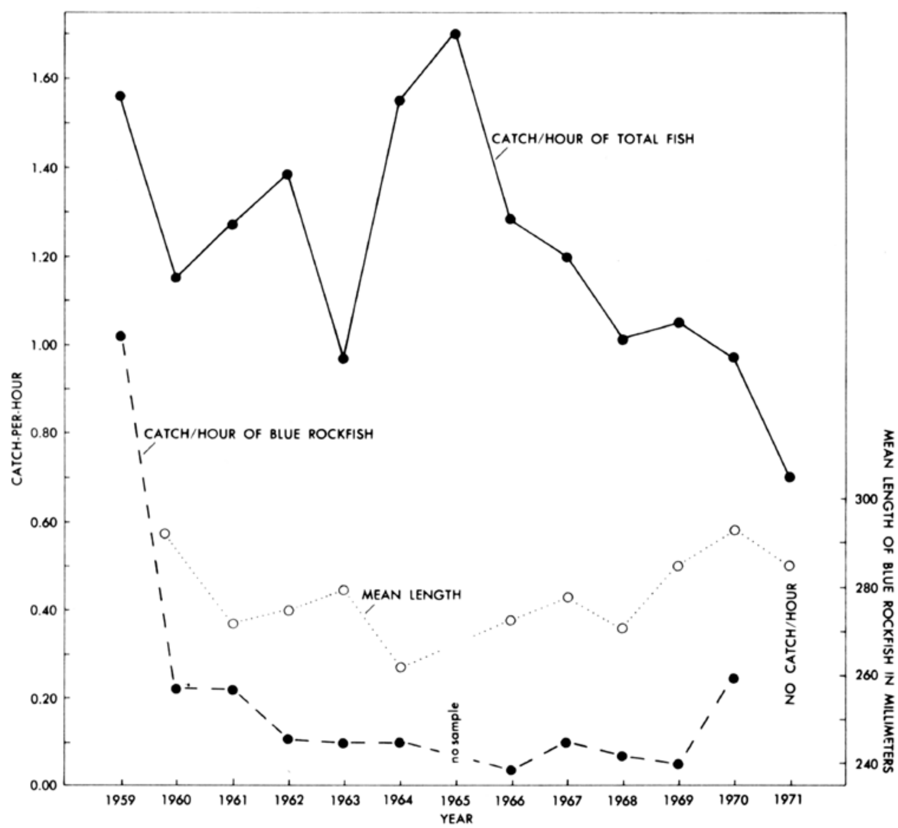

FIGURE 9. Partyboat catch-per-hour for total fish and blue rockfish, and mean lengths of blue rockfish landed at Santa Cruz (Ano Nuevo catch excluded), 1959–1970.

FIGURE 9. Partyboat catch-per-hour for total fish and blue rockfish, and mean lengths of blue rockfish landed at Santa Cruz (Ano Nuevo catch excluded), 1959–1970.

3.1.7. Monterey and Pacific Grove

The Monterey area partyboat and skiff fisheries utilize essentially different stocks of blue rockfish, although in more recent years private skiffs are traveling greater distances south of Carmel Bay. Skiffs operated out of Monterey harbor rarely venture south of Carmel Bay, whereas partyboats are operating in an area bordered by a deep reef about 11 miles (17.7 km) northwest of Monterey and Pt. Sur, approximately 20 miles (32.2 km) south of Monterey.

Unlike other central California ports, Monterey partyboat catches exhibit extreme fluctuations of catch parameters and do not show obvious declines in blue rockfish stocks. The irregular catch fluctuations are primarily due to the fact that when blue rockfish become scarce at certain reefs partyboat operators fish more productive areas until the catch declines, then move to other reefs. There are large areas of rocky reef available from Monterey to Pt. Sur and as yet fishing pressure has not adversely affected all the semi-isolated blue rockfish stocks in this area. While the mean sizes of blue rockfish have fluctuated, there is only a slight decline in average size (Figure 11). However, modal progressions show the fishery is becoming more dependent on incoming small fish rather than on older reservoir stocks of

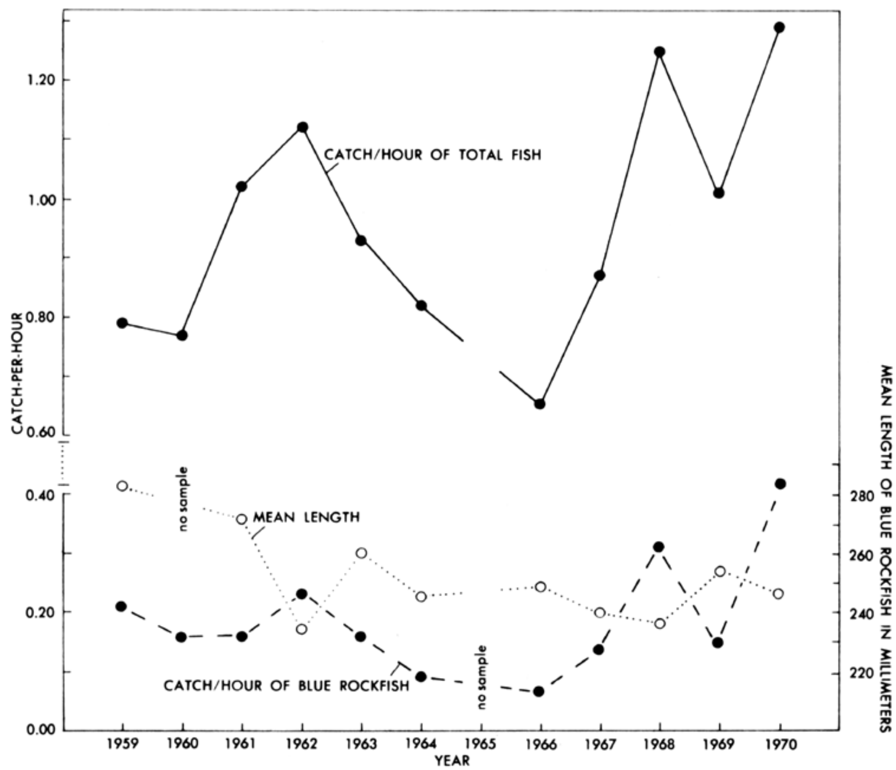

FIGURE 10. Skiff catch-per-hour of total fish and blue rockfish, and mean lengths of blue rockfish landed at Santa Cruz, 1959–1970.

FIGURE 10. Skiff catch-per-hour of total fish and blue rockfish, and mean lengths of blue rockfish landed at Santa Cruz, 1959–1970.

large fish (Figure 12). The influx of younger fish appeared in the partyboat catch in 1969, as at Ano Nuevo Island.

The skiff fishery was dominated by blue rockfish in 1960 when this species contributed to about 60% of the total annual catch by numbers. There has been a decline of catch-per-hour since 1960 (Figure 13); but in 1970 there was an increase in blue rockfish caught. This increase in abundance was short lived and the lowest blue rockfish catch-per-hour values since 1960 were recorded in 1972. Pacific sanddab is now the major bottomfish species in the Monterey skiff catch (Table 2). The skiff fishery at Pacific Grove is comparable to that at Monterey since boats from both launching sites fish in the same areas.

3.1.8. Pt. Sur

Species composition and size composition of blue rockfish have been recorded since 1966; however, we do not have catch-per-hour values for this area. The fishery is by partyboats only and is principally for yellowtail rockfish, olive rockfish, and lingcod. Blue rockfish is a minor species in the catch although results of a 1962 tagging cruise demonstrate large stocks of blue rockfish are present in the area. The fishery is comparable to those at the Farallon Islands and San Simeon where new bottomfish fisheries concentrate on the largest fish available.

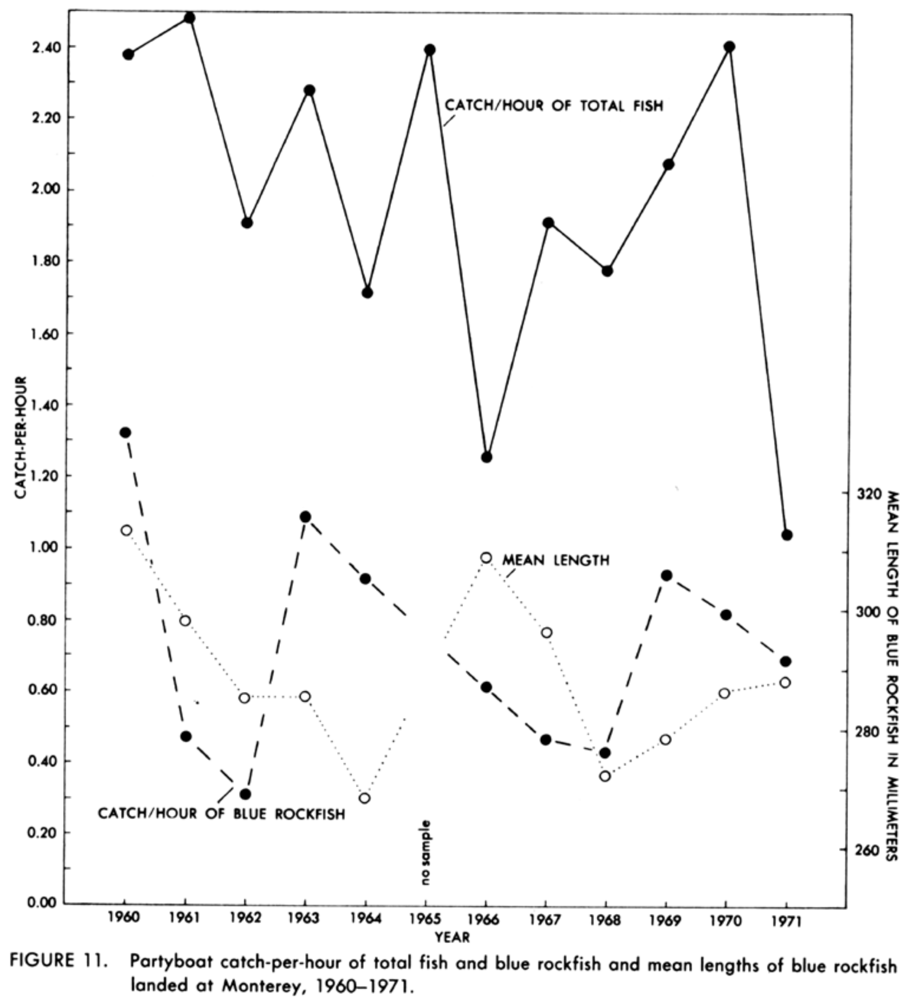

FIGURE 11. Partyboat catch-per-hour of total fish and blue rockfish and mean lengths of blue rockfish landed at Monterey, 1960–1971.

3.1.9. San Simeon

Blue rockfish contributed about 20% of the total catch by numbers in 1960 and from 1967 through 1969, but in 1970 an increase in abundance brought their contribution up to about 50%. Catch-per-hour values of total catch decreased from 1960 to 1970, indicating the heavy use initiated in 1969 may have reduced the stocks of larger rockfishes. The mean size of blue rockfish is remaining high, indicating these stocks are still not overutilized.

3.1.10. Morro Bay

The catch pattern in the partyboat fishery is similar to that at Santa Cruz and Avila where exceptionally large blue rockfish catches were made in the late 1950's, diminished in the 1960's, showed a slight recovery in 1970, and again declined in 1971. Blue rockfish mean sizes have exhibited a general decline since 1960; however, the average size fish is larger than at most other ports. Partyboats operate over many reef areas from Pt. Buchon north to near San Simeon, and are utilizing several isolated or semi-isolated blue

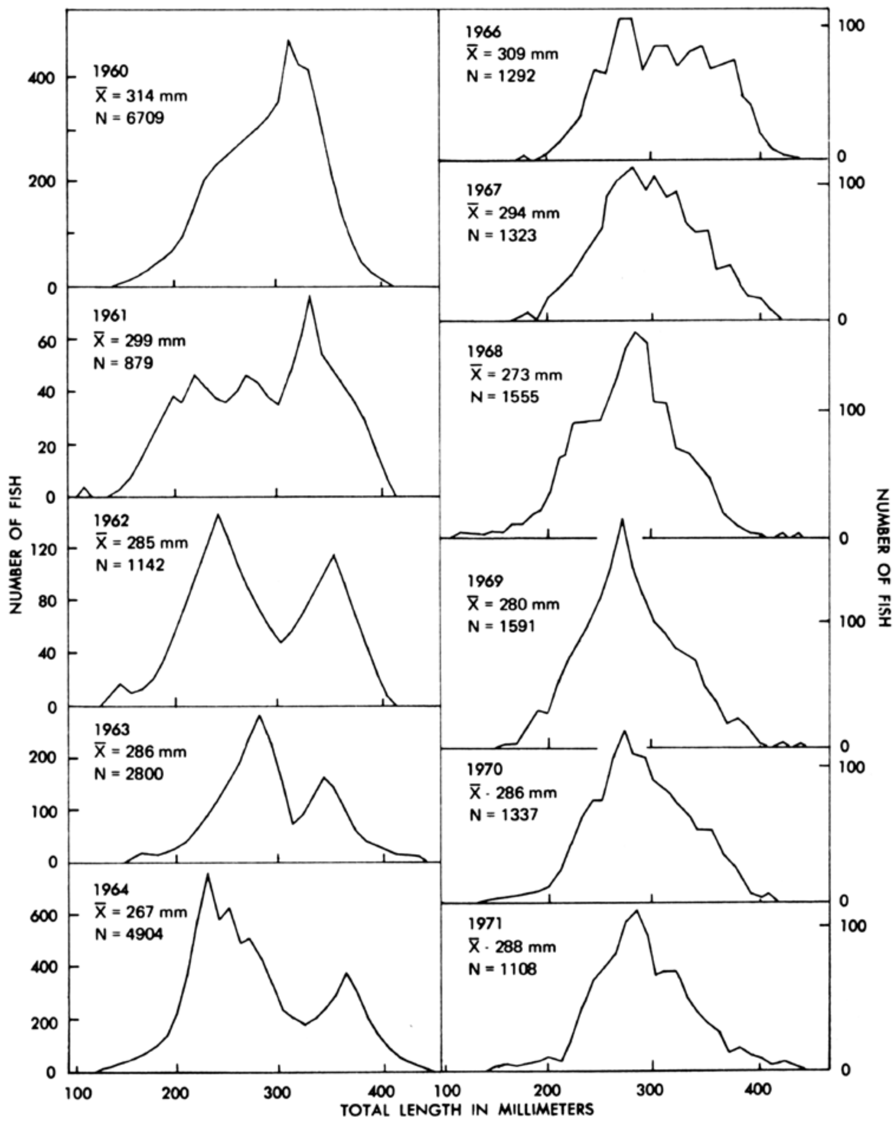

FIGURE 12. Length frequency polygons, mean annual size, and number of blue rockfish, sampled in the Monterey partyboat catch, 1960–1971.

FIGURE 12. Length frequency polygons, mean annual size, and number of blue rockfish, sampled in the Monterey partyboat catch, 1960–1971.

rockfish stocks. The strong bimodal size frequence in the 1962 and 1963 catches indicates poor recruitment for several years previous and, with increased effort on the larger fish, catches of blue rockfish are now dependent upon a steady recruitment of smaller fish (Figure 14).

3.1.11. Avila

Partyboat operators fish in two separate areas, north to Pt. Buchon and south to Pt. Sal. Consequently catch parameters are sporadic with highly fluctuating catch-per-hour values for both total fish and blue rockfish. The

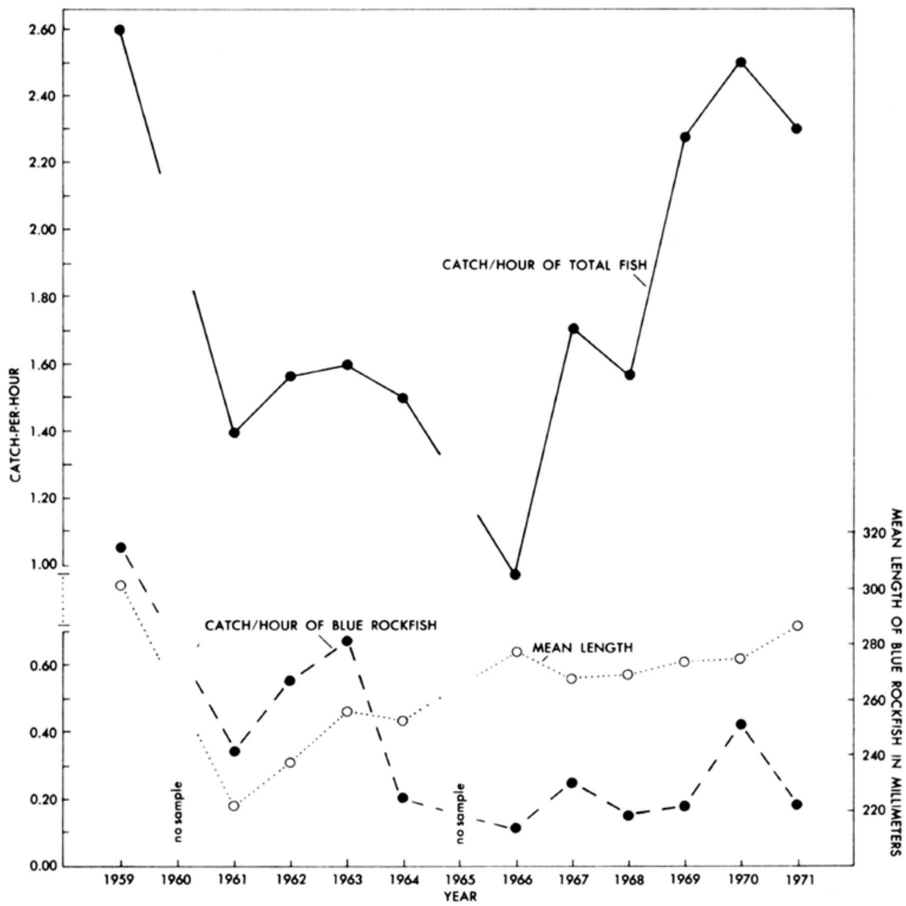

FIGURE 13. Skiff catch-per-hour of total fish and blue rockfish and mean length of blue rockfish at Monterey, 1959–1971.

FIGURE 13. Skiff catch-per-hour of total fish and blue rockfish and mean length of blue rockfish at Monterey, 1959–1971.

only indication of over exploitation is the mean annual size, which has steadily declined since 1960. While the skiff fishery does not depend heavily on blue rockfish, the mean size also has been declining as in the partyboat catch.

3.2. CATCH ANALYSIS SUMMARY

Blue rockfish stocks are not migratory and concentrate in dense schools in kelp bed and rocky reef areas from the surface to depths of around 295 ft. (90 m). These fish are highly available and are vulnerable to overutilization in continually fished areas. The large relatively unfished stocks present throughout central California in the late 1950's were heavily fished from 1956 through the 1960's. This emphasis on blue rockfish effort on shallow inshore reefs was due to a combination of three factors: the shift from trolling to bottomfishing because of the salmon shortage; a possible reduction in stocks of large demersal rockfish at major ports; and the presence of large easily captured blue rockfish throughout central California. These large blue rockfish were heavily utilized at Princeton, Santa Cruz, Monterey,

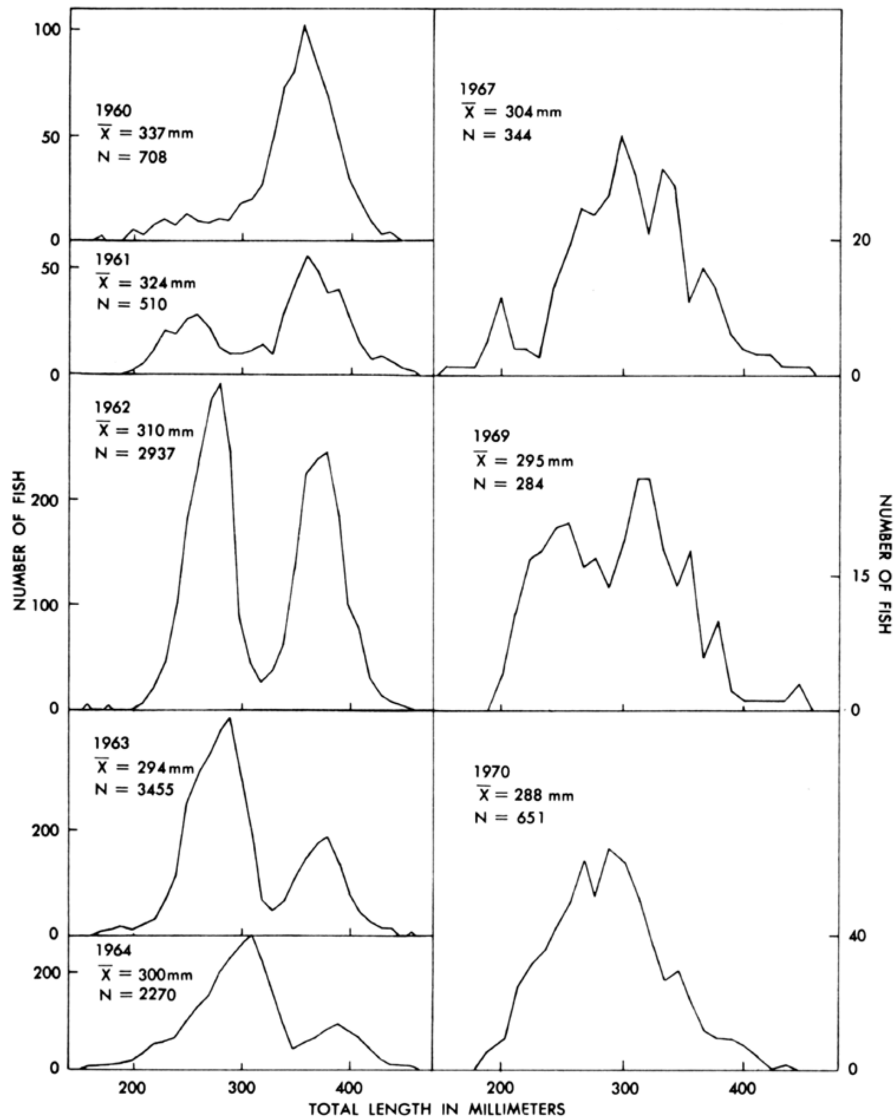

FIGURE 14. Length frequency polygons, mean annual size, and number of blue rockfish sampled in the Morro Bay partyboat catch, 1960–1970.

FIGURE 14. Length frequency polygons, mean annual size, and number of blue rockfish sampled in the Morro Bay partyboat catch, 1960–1970.

Morro Bay, and Avila resulting in progressively decreasing catch-per-hour values and smaller fish. This was especially true for skiff fishermen at Santa Cruz and Monterey, who do not travel long distances and must fish on small populations of local fish. The influx of blue rockfish in 1969 and 1970 indicated increased recruitment of several year classes, but with continued heavy utilization this increase lasted but 1 or 2 seasons. It is interesting to note that this increased abundance first appeared in 1969 at Ano Nuevo but not until 1970 at nearby Santa Cruz. In Monterey blue rockfish catches increased in the partyboat catch in 1969 but not in the skiff catch until 1970. This further substantiates the existence of semi- or totally isolated blue rockfish stocks at each port area, and that skiff and partyboat fisheries at most ports utilize essentially different fishing grounds.

Gotshall (1969), using project tagging and aging data, estimated that the annual survival rate for Monterey area blue rockfish was around 0.77 when computed from age composition and around 0.30 when computed from tag return data. Wide discrepancies of parameters such as this can be expected in a fishery utilizing possibly a dozen or more semi-isolated stocks of fish each year. Gotshall proposed that the principal reasons for this discrepancy in survival rates was tag loss and failure of fishermen to return tags. Our recent findings point out a potentially greater source of error. These stocks are resident to a particular reef and there is disproportionate fishing pressure between reefs which is not in direct ratio to the number of tags released in each area.

3.3. LIFE HISTORY

3.3.1. Movements

From 1961 to 1963 a total of 7,647 blue rockfish was tagged and released from Santa Catalina Island to Fort Ross, Sonoma County. of these, 168 were returned by partyboat and skiff fishermen for a 2.2% return. All tag returns were made within 10 miles (16.1 km) of a port area and fish tagged outside the range of utilization did not apear in the catch accounting for the unexpected low return in such a heavily utilized fishery. The highest return (10.4%) was at Monterey where 18 fish were returned from a single release of 173 fish in 1963. of the fish tagged within a fishery range nearly all were released in areas outside kelp bed areas; the few released in kelp beds were in Pt. Lobos State Reserve area and around the Channel Islands. of the 168 returns, 142 (84.5%) traveled less than 1 mile (1.6 km), 23 (13.8%) traveled from 1 to 6 miles (1.6–9.7 km), and the remaining three moved 7 miles (11.3 km), 12 miles (19.3 km), and 15 miles (24.1 km) from the point of release.

None of the 1,200 fish tagged and released from 1961 to 1963 in the then unfished blue rockfish concentrations between Soberanes Pt. and Pt. Piedras Blancas appeared in catches landed at Monterey, San Simeon, or Morro Bay, demonstrating that these stocks cannot be expected to replenish heavily harvested stocks near these ports. This also demonstrated there were unfished blue rockfish stocks in the area from Yankee Pt. to San Simeon, and soon after this tagging program was completed partyboat operators from Monterey began fishing the area from Soberanes Pt. to Pt. Sur, and boats operating from San Simeon and Morro Bay traveled to as far north as Cape San Martin to obtain large blue rockfish. One tagged fish was returned from the Cape San Martin area in 1963. This fish had been at liberty 1,130 days and was recaptured where released.

In the juvenile blue rockfish study, 1,356 juvenile and adult blue rockfish ranging from 91 to 293 mm TL, caught in traps and by hook-and-line, were tagged and released on the inside or south side of Monterey Breakwater. of these, 399 were recaptured at the point of release, four moved to the outside of the breakwater, and in about 6 months after release five were returned by pier fishermen at Monterey Pier No. 2, a distance of about ¼ mile (0.4 km) from release point. Conclusions derived from this significantly high recapture rate of juveniles is that in the subtidal rocky areas and in the kelp canopy, juvenile rockfish remain within a narrow range and where there is adequate food and cover. Juvenile blue rockfish were found throughout the rocky areas from Pt. Pinos to off Seaside, a distance of about 3 miles (4.8 km). However, within this area there were two areas where juveniles were in relatively dense aggregations: the Monterey Breakwater, and near the fish cleaning table on Monterey Pier No. 2. Food is more abundant in these two areas; at the breakwater in the form of enrichment by fecal material of the 500 to 800 California sea lions, Zalophus californianus, that lay out on the rocks for most of the year, and at the pier by small amounts of fish periodically released into the water at the cleaning table. Juveniles at the pier cleaning table grew at a faster rate and averaged 13 mm TL more in November than those at the breakwater, indicating food can be a critical factor in blue rockfish distribution and can influence growth rates at an early stage. Juvenile rockfish appear to remain close to the area where they settle down after the pelagic stage in the inshore rocky and kelp bed areas, and do not move about more than about 200–300 ft. (approx. 60–90 m) until November or December when winter storms agitate shallow areas. Young blue rockfish seek protected areas in the winter, but are rarely seen deeper than about 130 ft. (approx. 40 m) until they are about 3 or 4 years of age.

The reef ecology study from 1967 through 1971 included an intense tagging program in the kelp bed and shallow reef areas from Pt. Pinos to Seaside. All initial captures and all but eight recaptures were made by project personnel using hook-and-line, and at the end of the study by spearing. Sport skiff fishermen returned six of the tagged fish; skindivers the other two.

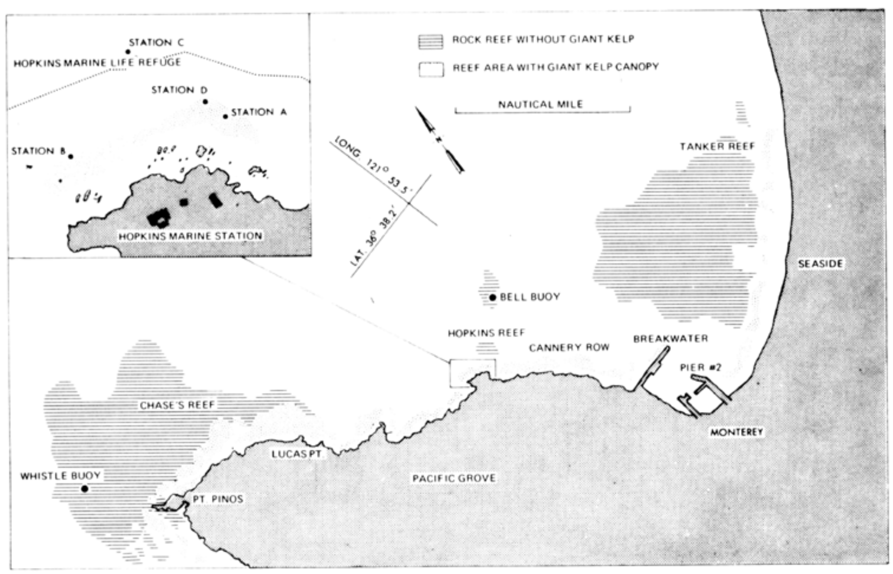

FIGURE 15. Map of reef areas where fish were tagged and released.

FIGURE 15. Map of reef areas where fish were tagged and released.

of the total 2,508 blue rockfish tagged, 2,038 were released in the Hopkins Marine Life Refuge kelp bed area, 328 in nearby kelp beds, and 97 in shallow reef areas outside the kelp bed zone (Figure 15). of the 423 individual blue rockfish recaptured, 305 were recaptured once, 75 twice, 28 were recaptured 3 times, 12 caught 4 times, two 5 times, and one was recaptured 9 times for an accumulated total of 606 recaptures. Movements of blue rockfish in kelp beds and between adjacent kelp beds is quite restricted compared to the wandering movements up to 1 mile (1.3 km) common for fish tagged in deeper reef areas.

Blue rockfish were tagged in Hopkins Marine Life Refuge at three stations within the contiguous growth of giant kelp, Macrocystis pyrifera, encompassing about 12 acres (Figure 15). Tagging was initiated in August 1967 and continued monthly until July 1970. Even though tagging operations were conducted throughout the year, most of the fish were captured during the June through October period when this species was most available.

Fish tagged in Hopkins Marine Life Refuge showed little movement between stations (Figure 15). of the 881 fish released at Station B, three were recovered at Station A, a distance of 1,150 ft. (350 m), and two were recovered at Station D, a distance of 980 ft. (300 m). One of the fish that had moved to A from B (after 109 days at liberty) was recaptured again back at B, 217 days later. of the 520 tagged fish released at Station A, one was recaptured at B (350 m) and six were recaptured at D, 250 ft. (76.3 m) distant from A. of the six captured at D, two were subsequently recaptured at A. of the 485 fish released at Station D, six were recaptured at nearby Station A, and one at B.

of 1,886 fish released at Stations A, B, and D, 22 were recaptured at another station in the kelp bed, and 388 were recaptured at the station of release. There was an additional 197 tagged blue rockfish released in Hopkins Marine Life Refuge with seven returns recorded; however, these fish were released in 1967 before the station release program was established and exact release area within the kelp bed was not recorded. All returns from this series were recaptured in Hopkins Marine Life Refuge.

Movements of tagged blue rockfish at other kelp bed areas show a similar residential behavior except for those released in and near Tanker Reef (Figure 15). of the 149 blue rockfish released at Chase's Reef, one was recaptured at Station A 368 days later, and this fish was recaptured twice more at Station A, 7 and 156 days after first appearing there. We did relatively little recapture fishing at Chase's Reef, accounting for the small percentage of recoveries at that station.

Eight tagged fish were released along Cannery Row with one recapture recorded in the same area. of the 139 blue rockfish tagged and released at Tanker Reef kelp bed area, one was recaptured at Tanker Reef, one at Station A, and two were returned by skiff fishermen fishing in the Pacific Grove area. About half of the Tanker Reef fish were captured and released in open water adjacent to the kelp bed area and these fish apparently followed the pattern demonstrated in the 1961–65 tagging program of occasionally wandering to adjacent reef areas outside kelp bed areas. Kelp canopies on Tanker Reef are subject to considerable swell damage during winter and are nearly nonexistent from November through March. Inasmuch as offshore blue rockfish tend to school in deeper waters over unprotected reef areas during the winter, there appears to be movement of adult blue rockfish from Tanker Reef, resulting in a more distant wandering of the fish in this area.

No homing experiments were conducted on this survey although one release of blue rockfish in 1963 off Santa Catalina Island of fish caught at San Miguel Island, 93 miles (150 km) to the northwest indicated these fish may have been heading back toward San Miguel Island since one was recaptured 7 miles (11.3 km) to the northwest in 22 days and another was captured 2.5 miles (4.0 km) to the northwest in 103 days.

Carlson and Haight (1972) found that yellowtail rockfish exhibited a marked homing instinct, being able to return to their home reef after being displaced up to 21.7 miles (35 km) and over a time span up to 428 days. Other California marine fishes are noted to home to a specific area such as opaleye and wooly sculpin (Williams, 1957). These fishes returned each low tide period to the same tidepool. Hubbs (1921) noted that reef surperch returned to the same pools on successive low tides.

The reasons for the low availability of blue rockfish in kelp beds during January to March are not fully understood. Recaptures were made during each month of the year in Hopkins Marine Life Refuge indicating that not all blue rockfish at each station left the area, and visual sighting on underwater transects revealed the presence of fairly large numbers of blue rockfish, many with tags, on certain days during this relatively unavailable period. However, there was such a wide discrepancy between the hook-and-line catch-per-hour values during the June through November period and the remainder of the year (Figure 16) that other possibilities were investigated.

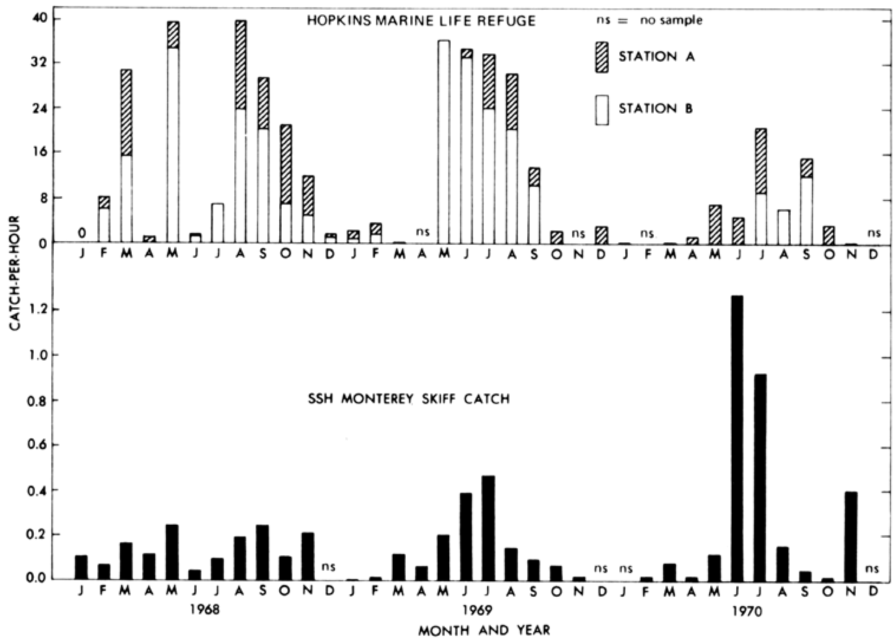

FIGURE 16. Catch-per-hour of blue rockfish taken in time fishing experiments (20 minute intervals) in Hopkins Marine Life Refuge compared to monthly blue rockfish catch-per-hour values in the Monterey skiff catch, 1958–1970.

FIGURE 16. Catch-per-hour of blue rockfish taken in time fishing experiments (20 minute intervals) in Hopkins Marine Life Refuge compared to monthly blue rockfish catch-per-hour values in the Monterey skiff catch, 1958–1970.

Dives were made during the winter period on Hopkins Reef (Figure 15), a rocky and sand area 590 ft. (180 m) adjacent to the Hopkins Marine Life Refuge kelp bed area in from 60–80 ft (18.3–24.3 m) and even though blue rockfish were observed there, none was tagged. Likewise, there was an intensive wintertime commercial gill net fishery off Chase's Reef about 1 mile (1.6 km) distant from Hopkins Marine Life Refuge and none of the 2,000 plus blue rockfish tagged at Hopkins Marine Life Refuge was taken in this operation. Considering that fish tagged at each station rarely moved to another station over a period of at least 3 years, if some fish did move to deeper water outside kelp bed areas during the winter, they homed back to the same location in the kelp bed in which they had spent the previous summer. Our tentative conclusion is that seasonal change in availability to hook-and-line fishing is due primarily to feeding habits rather than to extensive movements, and that most blue rockfish (as well as other species) remain in the kelp bed area but in habitat difficult to census during the period of heavy swell action.

The fact that there were comparable seasonal catch-per-hour fluctuations in both the Monterey skiff catch and at Stations A and B (Figure 16) suggests these seasonal changes occur in all areas and depths, and that feeding behavior is the principal factor. The high catch-per-hour values recorded in our Hopkins Marine Life Refuge time-fishing experiments is due to the efficiency of our hook-and-line operation and because we were fishing in an area not fished by the public. In addition, skiff fishermen effort was inclusive for all species caught, whereas we were in specific quest of blue rockfish.

3.3.2. Age and Growth

Larvae of blue rockfish are about 3.5 mm TL at hatching and remain in the epipelagic zone for several months. In April juveniles at about 45–50 mm TL concentrate in protected shallow rocky areas and in kelp canopies. By June there are large concentrations of these reddish-blue juveniles in protected inshore areas of central California, and by October these young fish range in size from 65 to 90 mm TL. Growth for the first year and a half was documented by size frequency progressions of trapped fish from April 1964 through August 1965 (Figure 17). Observed first year's growth ranged from 65 to 115 mm TL and back-calculated first year's growth of 280 partyboat and skiff caught fish ranged from 57 to 118 mm TL. There was overlapping in size frequencies of 1 and 2 year old fish when slow growing Age I fish (one ring plus the second summer's growth) are the same size as the fastest growing Age 0 fish of the year at approximately 110 mm TL.

Otoliths and scales were tested for use in age determination, and even though otoliths were more reliable than scales for rings 1 through 3, scale readings were chosen for our analysis. There was a comparable percentage of agreements by scales and otoliths in fish over 4 years of age, and scale image projections are more convenient for back-calculations. In spite of occasional negative growth rate in larger individuals during the winter, there are no obvious spawning checks or evidence of resorbtion of scale margins. Annuli are typical bands of narrowed circuli.

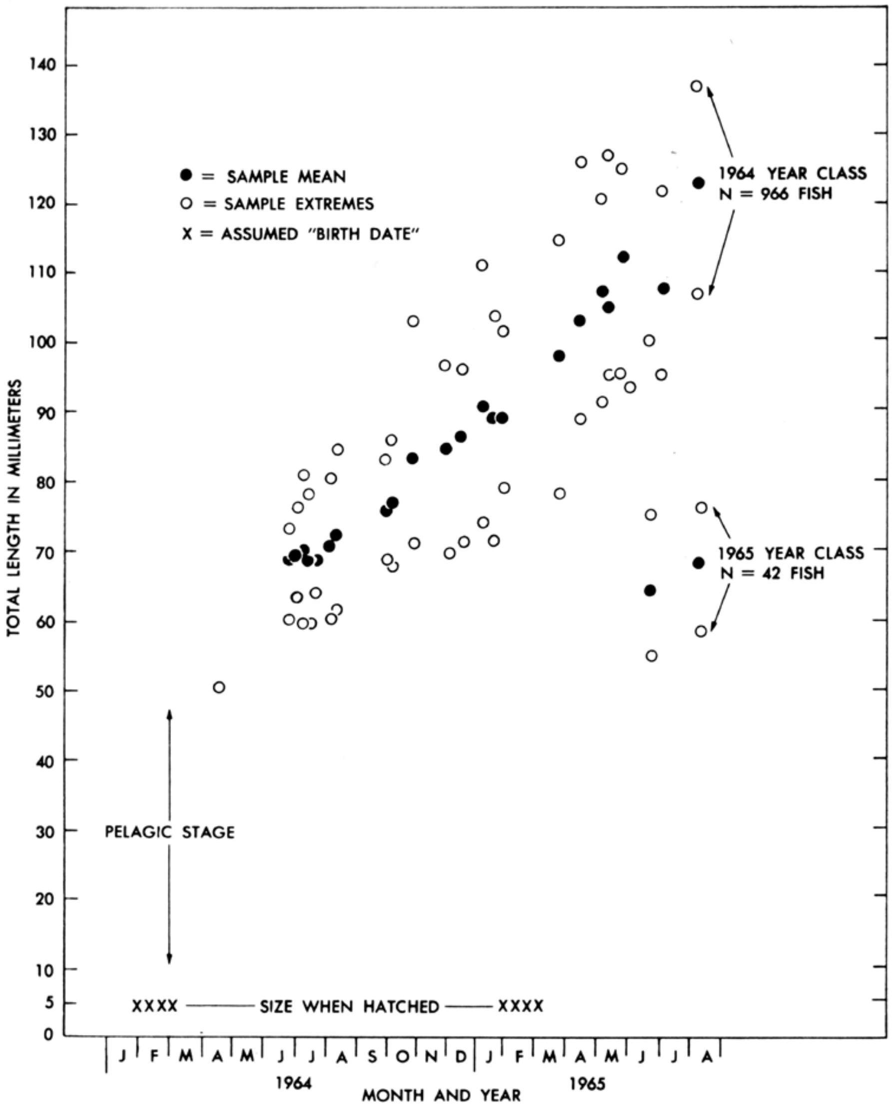

FIGURE 17. Scatter diagram of mean lengths of blue rockfish samples trapped at the Monterey Breakwater and inside Monterey Harbor, 1964–1965.

FIGURE 17. Scatter diagram of mean lengths of blue rockfish samples trapped at the Monterey Breakwater and inside Monterey Harbor, 1964–1965.

In fish over 200 mm TL there was little growth from December to February with growth increment appearing on the scales in late February. By the first of March, 20% of the scales showed new growth and by May 1st, the annual anniversary date, scales from all age groups showed new annular growth. Monthly growth increments from tagging data showed a continued growth from March through November.

There was wide variation in growth between individuals, by sex, between geographical areas, and by depth. These widely varying factors precluded construction of an age-length curve applicable to all ports and depths.

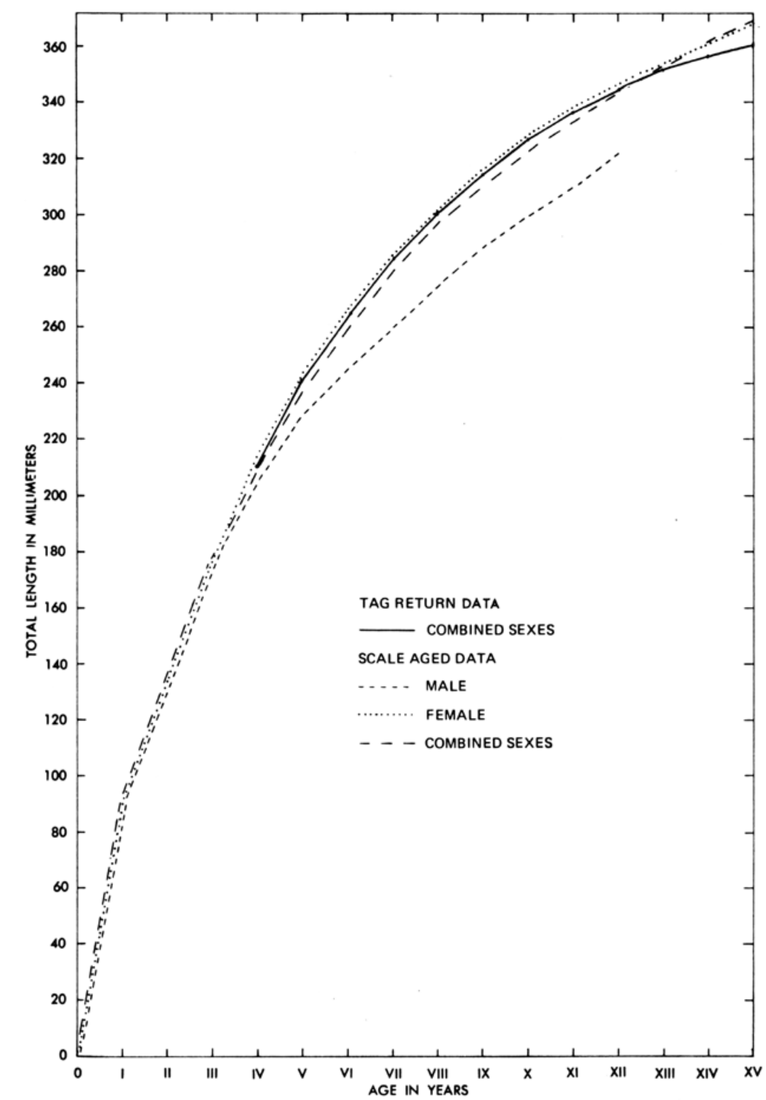

FIGURE 18. Von Bertalanffy growth regressions of partyboat caught blue rockfish compared to a Von Bertalanffy regression of growth increment data derived from tagged blue rockfish at liberty 320–410 days.

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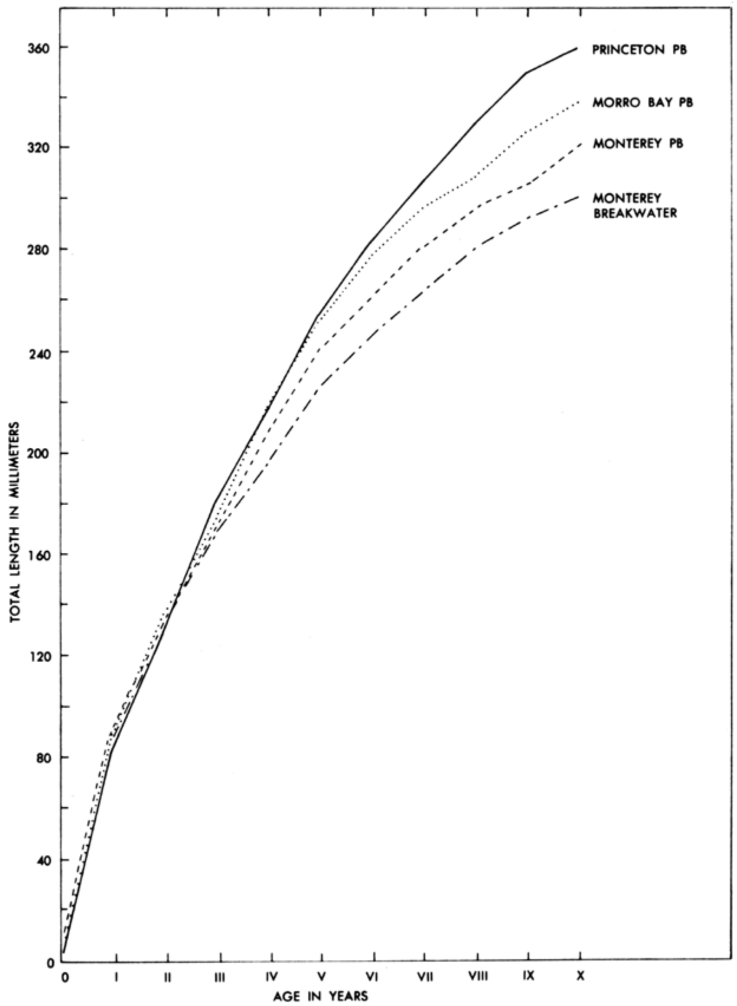


FIGURE 19. Age-length comparisons between Princeton, Morro Bay, and Monterey partyboat caught blue rockfish (sexes combined) compared to blue rockfish captured at Monterey Breakwater.

FIGURE 19. Age-length comparisons between Princeton, Morro Bay, and Monterey partyboat caught blue rockfish (sexes combined) compared to blue rockfish captured at Monterey Breakwater.

Females grow at a more rapid rate than males and attain a longer life span (24 years maximum for females compared to 17 years maximum for males).

Back-calculated growth curves of 180 males, 320 females, and an additional 80 unsexed fish caught by partyboat hook-and-line fishermen at Monterey were fitted by a Von Bertalanffy equation. These curves were than compared to a Von Bertalanffy fitted growth curve using tag recovery data of 572 recaptured fish for which size data were recorded (Figure 18). Plottings of the averaged back-calculated lengths of partyboat caught fish for Ages II through XI were compared for Monterey, Princeton, and Morro Bay, and these were compared to growth of a shallow water stock collected at the Monterey Breakwater (Figure 19). The Monterey partyboat fish grow at a slower rate from Age III on than those at Morro Bay and Princeton. The fitted lengths expressed by Von Bertalanffy curves using scale-age data from Monterey hook-and-line caught fish represent minimal growth parameters for deeper reef stocks of central California partyboat catch; the Monterey Breakwater curve represents a slow growing shallow water stock; and the Von Bertalanffy fitted tag return data represents observed growth of Monterey blue rockfish. Possible reasons for size and growth discrepancies between shallow and deeper water stocks and the slightly higher growth of smaller fish in the tag return data are revealed in analysis of back-calculated size and annual growth increments derived from scale-age and tag recovery data. Reasons for some of these discrepancies are not clear, but seem to involve some of the factors postulated by various workers causing Lee's

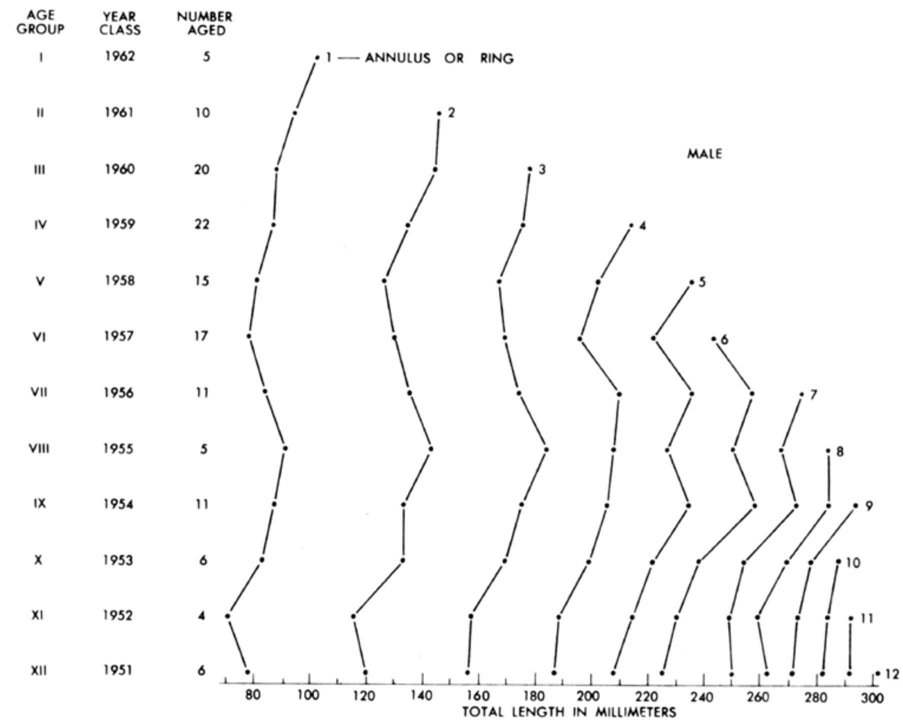


FIGURE 20. Back-calculated total lengths of male blue rockfish at time of formation of annuli 1 through 12 of Age Groups I through XV.

FIGURE 20. Back-calculated total lengths of male blue rockfish at time of formation of annuli 1 through 12 of Age Groups I through XV.

Phenomenon, i.e., when observed sizes of younger fish are larger than back-calculated sizes for the same age.

Discrepancies between observed and back-calculated ages are common among fishes, the causes of which are not fully understood for each species but may include factors such as size segregation by migration or schooling, selective removal of faster growing fish by fishing, size dependence mortality, age dependence mortality, or methodological errors in determining age. Zamakhaev (1964) discussed these factors and described the compensatory growth condition in some fishes.

Chen (1971) demonstrated a marked Lee's Phenomenon in honeycomb rockfish in calculating lengths of fish over 7 years of age and concluded the most likely cause was a differential size specific mortality beyond Age VII, with slower growing fish living longer; however, Chen also indicated this increased mortality of older fish may have been age specific rather than size

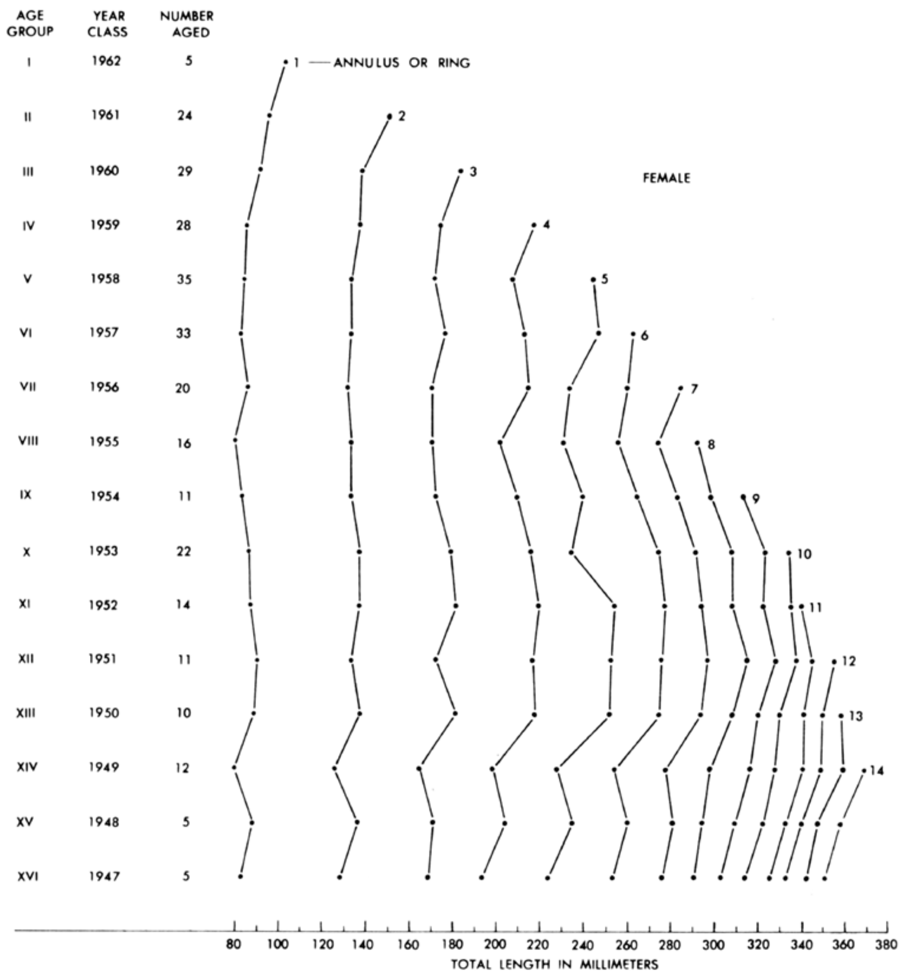


FIGURE 21. Back-calculated total lengths of female blue rockfish at time of formation of annuli 1 through 14 of Age Groups I through XVI.

FIGURE 21. Back-calculated total lengths of female blue rockfish at time of formation of annuli 1 through 14 of Age Groups I through XVI.

specific. Chen found no significant evidence of compensatory growth and disclosed that honeycomb rockfish do not exhibit a growth differential between males and females as do blue rockfish and many other fishes.

To determine presence of Lee's Phenomenon in blue rockfish, back-calculated lengths of 122 males and 280 females chosen at random from the total partyboat scale sample were computed for each age group for which a sufficient number of readings were available. Growth increments between successive age groups for each ring are compared graphically (Figures 20 and 21) and the most obvious characteristic is the wide variance in male and female growth. There are diminishing back-calculated lengths for males beyond Age IX and for females beyond Age XI indicating age dependence mortality and/or emigration of faster growing fish beyond the range of partyboats. Unlike honeycomb rockfish (Chen, 1971), blue rockfish, especially females, show an accelerated growth or an increased availability of faster growing Age IX–XI fish for 3 or 4 years prior to the initiation of decreasing back-calculated sizes. The higher than average back-calculated lengths of rings 1, 2, and 3 for Ages I, II, and III is most likely due to hook size selectivity of larger fish in these younger age groups; however, the possibility exists that the larger fish of these age groups are more available in distribution to partyboat fishermen.

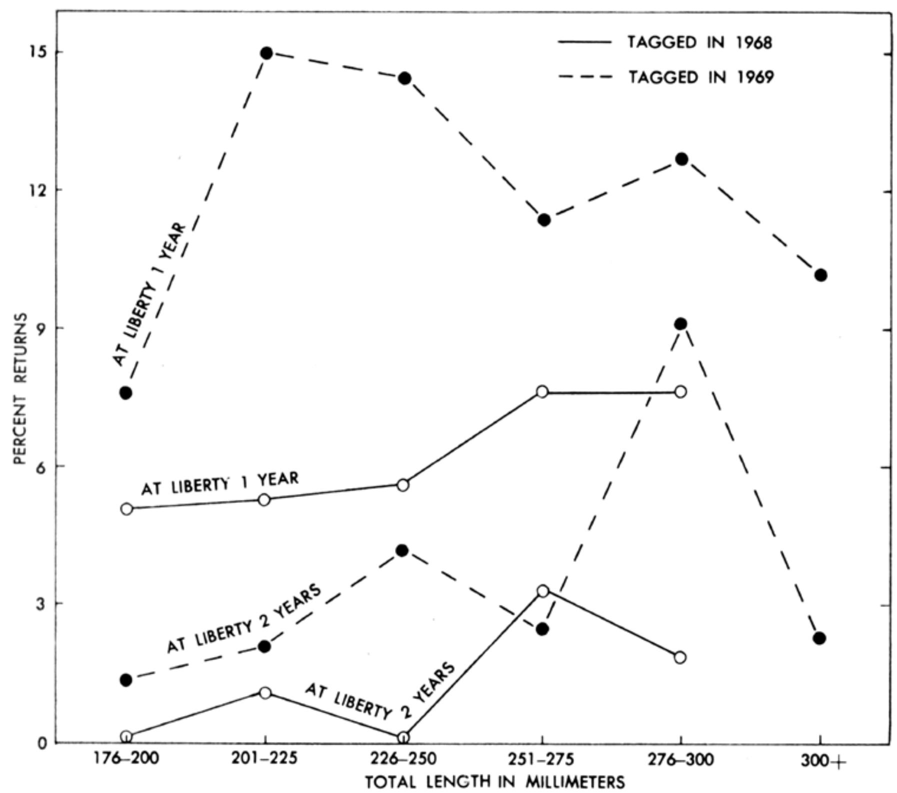


FIGURE 22. Percentage of blue rockfish tagged in 1968 and 1969 in Hopkins Marine Life Refuge recaptured after 1 and 2 years at liberty.

FIGURE 22. Percentage of blue rockfish tagged in 1968 and 1969 in Hopkins Marine Life Refuge recaptured after 1 and 2 years at liberty.

There are data indicating the occurrence of tagging mortality and/or emigration of younger fish from the study area. By comparing the percentage of tagged fish recaptures of individual fish (not including multiple recaptures of the same fish) for 2 years for each 25 mm TL interval for the 1968 and 1969 released fish, there was a constant lower percentage of over-winter returns from the smallest size categories for both the 1 and 2 year at liberty recapture series (Figure 22). The higher recovery rate for the 1969 tagged series was due in part to the large sample of fish speared at the termination of the study and to less tag loss than in the 1968 series.

It is possible there was some mortality of smaller fish tagged since infections were observed in recapture fish; however, there was no significant tagging mortality observed in controlled aquarium studies to determine tag loss and mortality. The ascending percentage of return of older fish indicates residential behavior of older fish in the area, and that the Hopkins Marine Life Refuge area is a nursery ground for young rockfish, most of which leave the area in 2 or 3 years.

Several possible causes of Lee's Phenomenon could thus be operating simultaneously; however, inasmuch as there was an increase of back-calculated sizes in the medium aged females (Ages IV through XI) the effect of possible disproportionate fishing mortality for Age I through V Monterey fish either was not significant or was masked by other transcending growth or behavioral factors.

It is somewhat disquieting that both male and female blue rockfish that live longest are the slowest growing. Females grow faster but live longer than the slower growing males indicating there is a sex related growth factor working in opposition to an age or size related growth pattern. Obviously more needs to be discovered concerning fish growth.

Minor discrepancies in back-calculated lengths appearing throughout Figure 20 could be caused by any combination of factors including insufficient numbers of fish sampled, variation in growth of a particular year class, changes in fishing patterns, and errors in determining age.

Annual growth increments for 25 mm intervals from 76 to 325 mm TL were computed for all series of tag return, modal progression, and scale determined age data (Table 3). Modal progression growth increments were estimated from length frequency polygon data of the Monterey skiff and

TABLE 3

Annual Growth Increment in Millimeters of Blue Rockfish Determined From Tag Return, Modal Progression, and Back-Calculated Scale-Aged Data for Monterey Area

Size Range (mm)	*Tag Return Data*			*Scale-Aged (Back calculated)*	
	1964	*1967–1971*	*Modal Progression*	*Partyboat*	*Monterey Breakwater*
76–100	54			45.0	47.0
101–125	51			44.0	40.5
126–150	47			40.0	37.0
151–175	40			36.5	32.0
176–200		31.8		29.0	28.0
201–225		30.3	30.5	32.0	20.0
226–250		23.2	24.0	22.0	17.0
251–275		22.4	20.0	17.0	12.0
276–300		19.9		12.0	10.5
301–325		8.5		12.0	8.0

*TABLE **3***

Annual Growth Increment in Millimeters of Blue Rockfish Determined From Tag Return, Modal Progression, and Back-Calculated Scale-Aged Data for Monterey Area

partyboat catch. Monterey partyboat and Breakwater growth increments were taken from intervals along the scale-age growth curves. Tagging data growth increments were derived from growth of fish between captures.

The 1967–1971 increment data more closely fit the growth curves derived for partyboat caught fish than the curves derived for breakwater caught fish, indicating breakwater fish were slower growing as was concluded in a previous analysis (Miller, Odemar, and Gotshall, 1967).

In the size ranges from 260 mm TL through 300 mm TL tag return increment slopes show a more rapid growth than those of the scale-aged series, but not more than that expressed by modal progression data indicating there are factors resulting in an anomalous growth curve calculated using scale age-length data. The fact that modal progression and tag return data express an almost identical growth pattern for the center portion of the observed growth curve lends acceptance of the assumption that these two series most accurately represent blue rockfish growth.

One weakness of tag return data is that these fish were not sexed and considering the magnitude of the differential growth between sexes, if scale-aged data vary considerably in sex ratio when compared with tag return data, many of the conclusions would be invalid. At the end of the project a large number of tagged fish were speared and sexed. The sex ratio proved comparable to that of partyboat catches with about twice as many females present as males in the older age groups, but with nearly even sex ratios for juvenile fish.

Sources of scale reading bias and tagged fish error were investigated. Two factors affecting tagging data may be the adverse effects of capture and tagging and the possibility that fish readily taken by hook-and-line may be faster growing. There apparently was no adverse effects due to capture and tagging since the growth of these fish was as great or greater than that computed in other series. Observations of growth of individual fish captured several times at close intervals revealed no marked decrease in growth after each recapture.

TABLE 4

Mean Daily Growth Increment in Millimeters of Tagged Blue Rockfish at Liberty Over 100 Days

Range (TL in mm)	*Recapture Categories* *	*Number*	*Mean Daily Increment* †	*Standard Deviation*	*Standard Error of Mean*	*Range of Daily Increment*
151–200	C2	20	.0946	.0383	.0086	.0507–.1739
	C3	7	.1003	.0599	.0226	.0506–.1989
	C4	1	–	–	–	– –
	C5+	1	–	–	–	– –
	ΣC3+	9	.0955	.0528	.0176	.0506–.1989
201–250	C2	60	.0798	.0447	.0058	.0000–.2521
	C3	11	.0829	.0330	.0099	.0431–.1641
	C4	10	.1284	.0426	.0135	.0995–.2150
	C5+	3	.0964	.0345	.0199	.0566–.1178
	ΣC3+	24	.1034	.0419	.0086	.0431–.2150
251–300	C2	51	.0527	.0348	.0049	.0000–.1393
	C3	5	.0942	.0562	.0251	.0181–.1572
	C4	5	.0688	.0335	.0150	.0237–.1021
	C5+	3	.0821	.0127	.0073	.0688–.0941
	ΣC3+	13	.0817	.0399	.0111	.0181–.1572
301–350	C2	22	.0226	.0160	.0034	.0000–.0735
	ΣC3+	3	.0287	.0173	.0100	.0088–.0405

* First recapture = C2, 2nd recapture = C3, etc.
† Millimeters

*TABLE **4***

Mean Daily Growth Increment in Millimeters of Tagged Blue Rockfish at Liberty Over 100 Days

The possibility that hook-and-line caught fish may be more aggressive or less "hook-shy" and possibly more rapid growing was tested by calculating the daily growth of fish at liberty over 100 days in 50 mm TL categories in each of the recapture strata, i.e., (C2), (C3), etc. (Table 4 and Figure 23). Because of the wide variation in individual growth, standard errors of the means are high for this series; however, it can be concluded that except possibly for the fish in the 176–200 mm TL size category there was no retardation of growth due to tagging and that larger fish certainly were not slower growing individuals. For fish in the 201–250 and 251–300 mm TL categories there was a slightly higher growth rate for most recovery strata beyond the C2 group, indicating these fish may actually be faster growing. This slightly higher growth rate for these fish may have contributed a slight bias to tag return growth curves since they represent 28% of the tag returns.

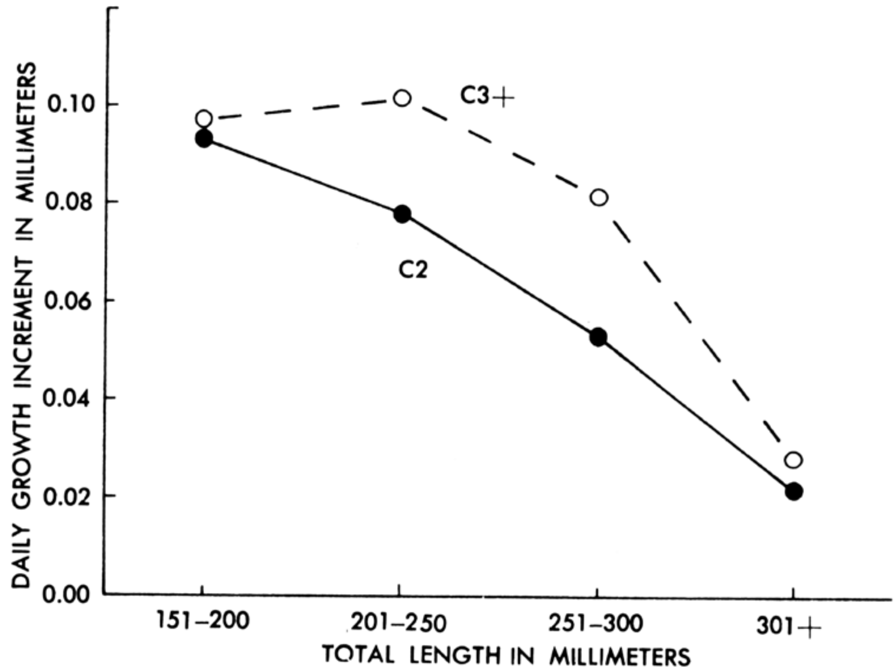


FIGURE 23. Mean daily growth increment of blue rockfish at liberty over 100 days of first recapture (C2) only and second recapture and more (C3+).

FIGURE 23. Mean daily growth increment of blue rockfish at liberty over 100 days of first recapture (C2) only and second recapture and more (C3+).

One of the possible reasons for this slightly faster growth of C3–C9 fish is that these residential fish may have learned to feed on the squid we used for bait. Since barbless hooks were used, bait could be more easily removed from the hook without the fish being caught, and continual fishing for at least 4 and up to 12 days per month over several years possibly could have supplied these particular fish with enough energy to enhance their growth. As was noted earlier, fish of the year at the Monterey Pier fish cleaning table showed a decidedly faster growth than nearby concentrations of fish of the same age.

We next tested to determine if tagged fish tended to take the hook more often than untagged fish, and if repeatedly recaptured fish were caught at progressively shorter intervals indicating a learned behavior to feed on bait. Hook-and-line recapture time intervals were computed between each recapture stratum (C1 to C2, C2 to C3, etc.) and these time intervals were compared to the time at liberty of fish speared at the end of the project. There are high standard errors for this series because of the wide range of days at liberty (1 to 622) between recaptures. In spite of these wide recapture intervals, there was a persistent and significant lessening of time between hook-and-line recaptures after the fish were recaptured once (C2) at each of three Hopkins Marine Life Refuge tagging stations (Table 5) indicating the lessening of time between recaptures for hook and-line fish was due to either learned or an innate behavior. For speared fish, the lessening of time of recapture for areas A and D was not due to fish preference, but was the result of a mathematical function since the time interval recorded prior to spearing at the end of the study was from the last time the fish were recaptured, and for fish recaptured once or twice the interval at liberty before spearing would be shorter than if the fish had not been recaptured in the interim. For hook-and-line fish this mathematical function is not in effect because these fish chose to bite throughout the interval (tag-release time to end of project), and the time between recapture intervals beyond C2 is not related to the first time of capture as is the case with speared fish.

TABLE 5

Mean Days at Liberty of Blue Rockfish Caught by Hook-and-Line and Speared at Three Stations

	Recapture Category *	*Number*	*Mean Days at Liberty*	*Standard Error*	*Range in Days at Liberty*
Hook-and-Line					
Station A	C2	128	120.5	10.61	3–503
	C3	52	97.3	15.72	2–366
	C4	26	95.9	23.19	1–346
	C5	9	80.1	32.37	3–327
	C6	2	175.0	52.32	101–249
	C7	1	53.0	—	—
	C8	1	5.0	—	—
	C9	1	23.0	—	—
Station B	C2	139	106.0	10.85	2–611
	C3	38	83.2	18.26	2–384
	C4	10	56.6	26.39	2–282
	C5	3	22.0	—	7–42
Station D	C2	37	183.5	26.19	2–514
	C3	5	61.4	43.25	5–229
	C4	1	50.0	—	—
Underwater Spearing					
Station A	C2	33	324.6	32.63	110–822
	C3	10	265.4	62.81	34–637
	C4	3	209.0	88.03	117—385
	C5	2	80.5	55.50	25–136
Station B	C2	48	407.0	29.53	30–819
	C3	8	263.3	75.81	20–604
	C4	2	454.5	164.52	290–619
	C5	0	—	—	—
	C6	1	56.0	—	—
Station D	C2	27	324.9	31.44	125–608
	C3	4	335.5	117.64	133—610
	C4	0	—	—	—
	C5	1	110.0	—	—

* First recapture = C2, 2nd recapture = C3, etc.

TABLE ***5***

Mean Days at Liberty of Blue Rockfish Caught by Hook-and-Line and Speared at Three Stations

Spearing data disclosed there was a large number of fish captured only once (C1) that did not take the hook again even though they apparently remained in the immediate vicinity for several years. Hook-and-line recaptures disclosed there was a group of fish that tended to be caught more often and, on the average, at shorter intervals between successive captures.

Underwater observations demonstrated that tagged fish tended to bite more often than untagged fish. Ratios of tagged to untagged fish observed under the boat were compared to the ratio of tagged to untagged fish taken by hook-and-line at the same time at Stations A and B (Table 6), and there was a consistently higher ratio of untagged fish in underwater observations except for the October 1968 and August 1969 series in which the ratios were about the same. There is a possible source of error in the underwater data in that observers may miss seeing the tags protruding from one side under the dorsal fin. This could result in a disproportionately higher ratio of untagged fish. This error, if it exists, is not considered significant in that only a small zone about 30 feet (9 m) in diameter directly under the boat was surveyed.

TABLE 6

Ratios of Tagged to Untagged Blue Rockfish at Stations A and B of Hook-and-Line Captures Compared to Underwater Observations

	Underwater Observed			*Hook-and-Line Recaptures*		
	Number Tagged Fish Observed	*Total Counted*	*Percent Tagged*	*Number Tagged Fish Observed*	*Total Counted*	*Percent Tagged*
1968						
August	10	89	11.2	26	99	26.3
September	70	416	16.8	78	163	47.9
October	44	164	26.8	43	161	26.7
November	89	312	28.5	18	56	32.1
December	25	155	16.1	1	3	(33.3)
1969						
January	16	134	11.9	1	2	(50.0)
June	6	132	4.5	5	55	9.1
July	3	80	3.8	20	136	14.7
August	12	58	20.7	58	334	17.4
September	28	389	7.2	34	106	32.1
October	12	63	19.0	26	79	32.9
Totals	315	1992	15.8	310	1194	25.9

TABLE ***6***

Ratios of Tagged to Untagged Blue Rockfish at Stations A and B of Hook-and-Line Captures Compared to Underwater Observations

In summary, the wide variation between individuals, the residential behavior of this species in shallow water, and relatively slow growth precludes construction of an age-length curve from aging data applicable throughout the geographic range and depth of this species. Females live longer and grow at a more rapid rate than males, and there appears to be an age related dependence mortality for males starting at Age IX and for females at Age XII. The back-calculated scale-aged growth curves show effects of Lee's Phenomenon and express a slower growth rate than do a theoretical observed Von Bertalanffy curve derived from tag return data. Modal progression data indicate tag return growth increment curves are more realistic. Errors in age determination do not preclude age composition determination of age at first maturity.

3.3.3. Population Estimates from Tagging Data

To have established that blue rockfish stocks are primarily residential in shallow areas and that some individuals bite more often than others sheds light on problems encountered when using Petersen (1892), Schnabel (1938), Schumacher and Eschmeyer (1943), and Chapman (1952) methods of estimating population size from tag recovery data. The first three of these standard methods were employed by Kelly and Barker (1961, 1963) in their redfish, Sebastes marinus, studies off Maine. Similarities in behavior of redfish and blue rockfish merit some discussion since both species are readily captured by hook-and-line, are primarily macroplankton feeders, are comparatively slow growing, and exhibit a nonmigratory or residential behavior in shallow rocky areas but tend to move about more randomly in deeper waters. Dissimilarities of the species are that redfish feed actively at night whereas blue rockfish are active in daytime, and redfish growth is materially reduced with tagged fish whereas tagged blue rockfish exhibit a slightly faster growth. There were dissimilarities between the blue rockfish study and redfish study in that the Maine study area was within a linear shoreline zone extending over about 3 miles whereas the reef at Hopkins Marine Life Refuge was an isolated area of about 12 acres supporting a dense growth of giant kelp. of the 6,000 redfish tagged more than 2,400 were recaptured yielding an estimated stock from 6,000 to 20,000 fish, depending upon method used.

Originally we had planned to employ the standard methods listed above and to compare these standard computations with stock estimates derived from underwater transect data. At the onset of our study several conditions necessary for the standard computations were not known for blue rockfish. Conditions for the standard methods are: (1) that there is no tag loss; (2) that mortality is the same for tagged and untagged fish; (3) that tagged fish and untagged fish are randomly mixed in the study area or population; (4) that tagged fish are equally as vulnerable as untagged fish; and (5) that emigrations from and immigrations into the study area are negligible. The first two conditions were determined negligible in the previous blue rockfish survey; however, in late 1968 it was discovered that the plasticizer in the spaghetti tags purchased in 1963 had deteriorated and tags were beginning to break off after they had been in the water about a year, amounting to an unknown tag loss for the 1968 releases. New tags were purchased and used in 1969 and 1970.

Our tagging program indicated conditions 3 and 4 (above) cannot be met with blue rockfish, and that considerable emigration of juveniles (condition 5) from the inshore nursery areas to deeper waters and adjacent rocky reefs occurs each fall. Adult fish in shallow areas either remain as residents, or possibly a few leave during stormy weather but may return to the same area of the kelp bed each spring. As a result, we did not attempt to estimate numbers of blue rockfish from tagging data. The only way this can be done is to randomly tag and recapture fish throughout the study area using grid patterns of the area covered in which each grid is no more than about 100 ft. (30 m) square. The use of standard formulas for hook-and-line caught fish necessitates computation of constants to correct for learned behavior of bait feeding and/or easily recaptured individuals that tend to bite more often than others. We could have made stock size estimates from the data on hand, but since nearly and fish at each tagging station remained within about 200 ft. (60 m) of the release point, computations would reveal only a rough estimate of fish concentrated near each of the three stations and would not yield an estimate of stocks present on the entire reef.

3.3.4. Length-Weight Relationship

Length-weight data for 278 fish were collected in the 1961–1965 survey. Miller, Odemar, and Gotshall (1967) developed a table of constants and standard errors for these relationships (Table 7) as well as plotted a regression for each sex (Figure 24). Fish over 400 mm TL weigh about 2 pounds apiece, with the bulk of the sport catch now averaging a little less than 1 pound.

TABLE 7

Constants and Standard Errors for Weight-Length *
Relationships by Sex for 278 Blue Rockfish

	N	*Log a*	*b*	*Standard error of b*	*Standard error of estimate*
Females	147	−6.99302	2.80779	.06407	.18168
Males	58	−7.47782	2.98849	.08862	.05325
Combined	278	−6.31687	2.53589	.02896	.20015

* Formula = Log W = Log a + b Log L.

TABLE 7

Constants and Standard Errors for Weight-Length Relationships by Sex for 278 Blue Rockfish

3.3.5. Reproduction

The eggs are ovoviviparous, i.e., they are fertilized internally by sperm stored in the ovary from copulation occurring shortly before ovulation (Magnuson, 1955) and develop to yolk-sac stage eyed larvae within the egg capsule in the lumen of the ovary. Incubation or larval development takes around 30 days for blue rockfish, which compares favorably to that of the western Pacific rockfish, Sebastes oblongus, (Fujita, 1958). There is no certainty as to whether the larva breaks from the egg capsule inside the ovary before release or when the capsule enters sea water. Morris (1956) believed rockfish larvae hatched externally. DeLacy, Hitz, and Dryfooz (1964) reported splitnose rockfish in Seattle markets with hatched larvae in the ovaries indicating internal hatching, and Smith (1936) and Eigenmann (1892) also postulated that hatching was internal. On February 2, 1963, a ripe female blue rockfish was speared at the Monterey Breakwater by project personnel and underwater observations lend more evidence for internal hatching, but were still not conclusive. Larvae were observed freely swimming when entering sea water and either must have been hatched internally or immediately upon contact with sea water. No broken capsules were observed along with the escape of free swimming larvae.

A total of 648 blue rockfish ovaries was examined from four port areas. The spawning season consists of the fertilization period, period of larval development, and hatching. Ovaries with maturing but unfertilized ova were observed in October, the first fertilized or developing ova appeared in mid-December, and release of larvae occurred from mid-January to mid-March (Figure 25). Ova over 0.30 mm in diameter were considered maturing,

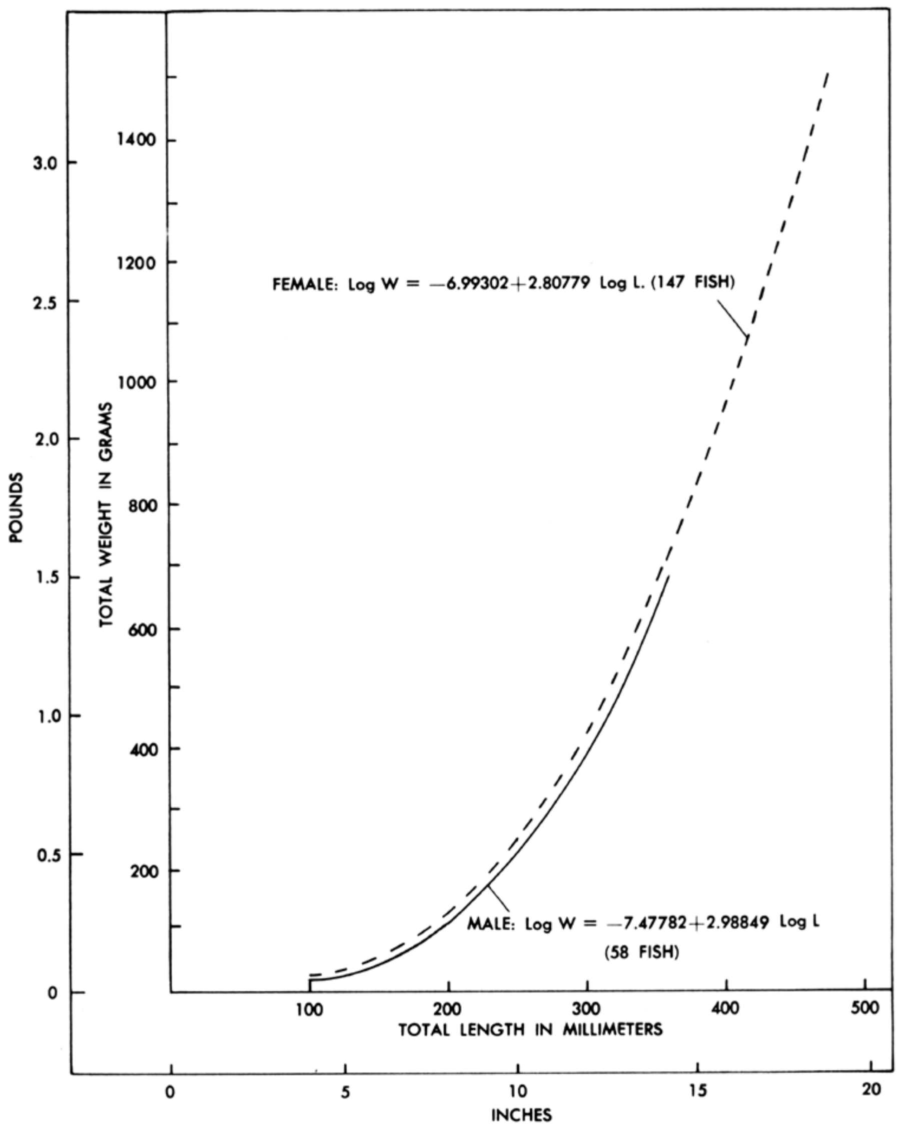


FIGURE 24. Blue rockfish weight-length relationship.

FIGURE 24. Blue rockfish weight-length relationship.

fertilization took place when ova were around 0.90 mm in diameter, and the capsules containing term larvae averaged 1.37 mm in diameter. Moser (1967) and MacGregor (1970) noted that some species of rockfish spawn two separate broods per year, but out of 648 female blue rockfish only one, a 247 mm TL fish, indicated multiple spawnings. This fish contained a mass of unhatched eyed larvae, developing ova ranging from 0.81 to 0.95 mm in diameter, enlarging ova ranging from 0.58 to 0.71 mm in diameter, and immature ova around 0.17 mm in diameter. The occurrence of this one female would indicate this species spawns once yearly but under certain conditions may spawn more than once. There is the possibility that in blue

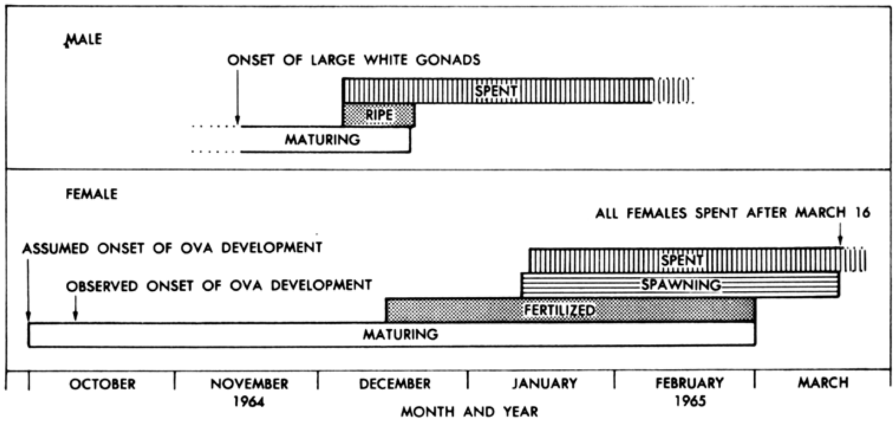


FIGURE 25. Sexual development of mature male and female blue rockfish from onset of gonad development to postspawning, 1964–1965.

FIGURE 25. Sexual development of mature male and female blue rockfish from onset of gonad development to post-spawning, 1964–1965.

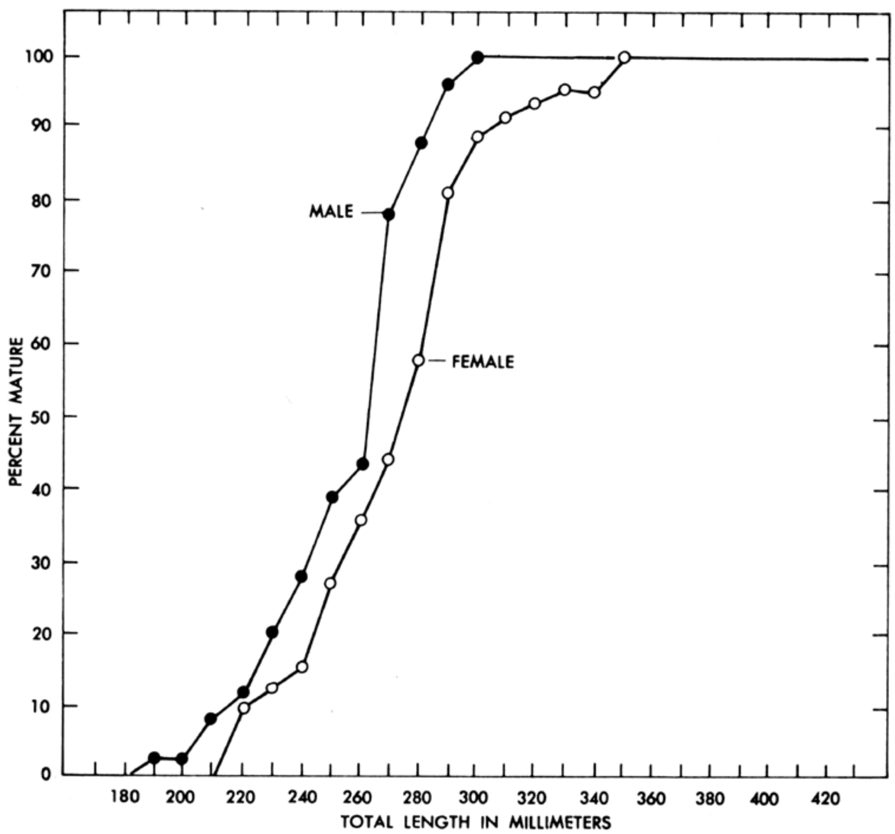


FIGURE 26. Sexual maturity of 648 female and 343 male blue rockfish by length.

FIGURE 26. Sexual maturity of 648 female and 343 male blue rockfish by length.

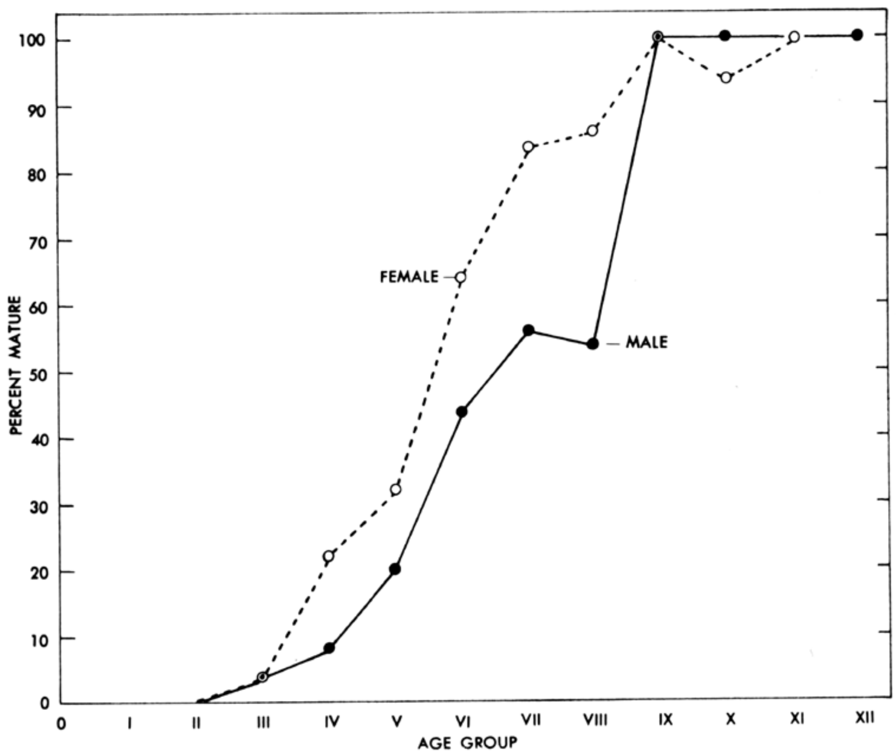


FIGURE 27. Sexual maturity of 399 female and 170 male blue rockfish by age.

FIGURE 27. Sexual maturity of 399 female and 170 male blue rockfish by age.

rockfish secondary modes of developing eggs may not begin maturating except on rare occasions and only after a length of time has elapsed after the first spawning. Since retained larvae may be resorbed quickly a multiple spawning may only be rarely observed. In addition, there are certain fishes that may develop secondary modes but these eggs may not be spawned and are resorbed (Howard and Landa, 1958; MacGregor, 1970). If some blue rockfish do have multiple spawnings, then because of the short fertilization period in December (Figure 25), the viable sperm of one copulation stored within the ovary fertilizes each brood.

Size and age at first maturity vary considerably (Figures 26 and 27). Some females and males begin spawning at Age III, for males this is around 190–200 mm TL, and for females about 200–210 mm TL. Some females may attain 300 mm TL before first spawning and some males may not spawn until reaching 290 mm TL. Not all females are mature until Age X; however, 80% have spawned by 6 years of age.

Blue rockfish spawn from 50,000 to 300,000 eggs per year Figure 28) depending on size. This fecundity rate is based on the assumption that only one brood is produced annually. Computation of fecundity was made by weighing a small portion of the ovary, counting the eggs in this portion, then computing by direct weight ratio the number of eggs in the entire ovary. Only one side of the ovary was used since most of the fish used in this series were speared and often only one ovary was left intact. Most rockfish ovaries are of different sizes on each side, but since these ovaries were collected at random it was assumed that as many smaller ovaries were represented as larger ones.

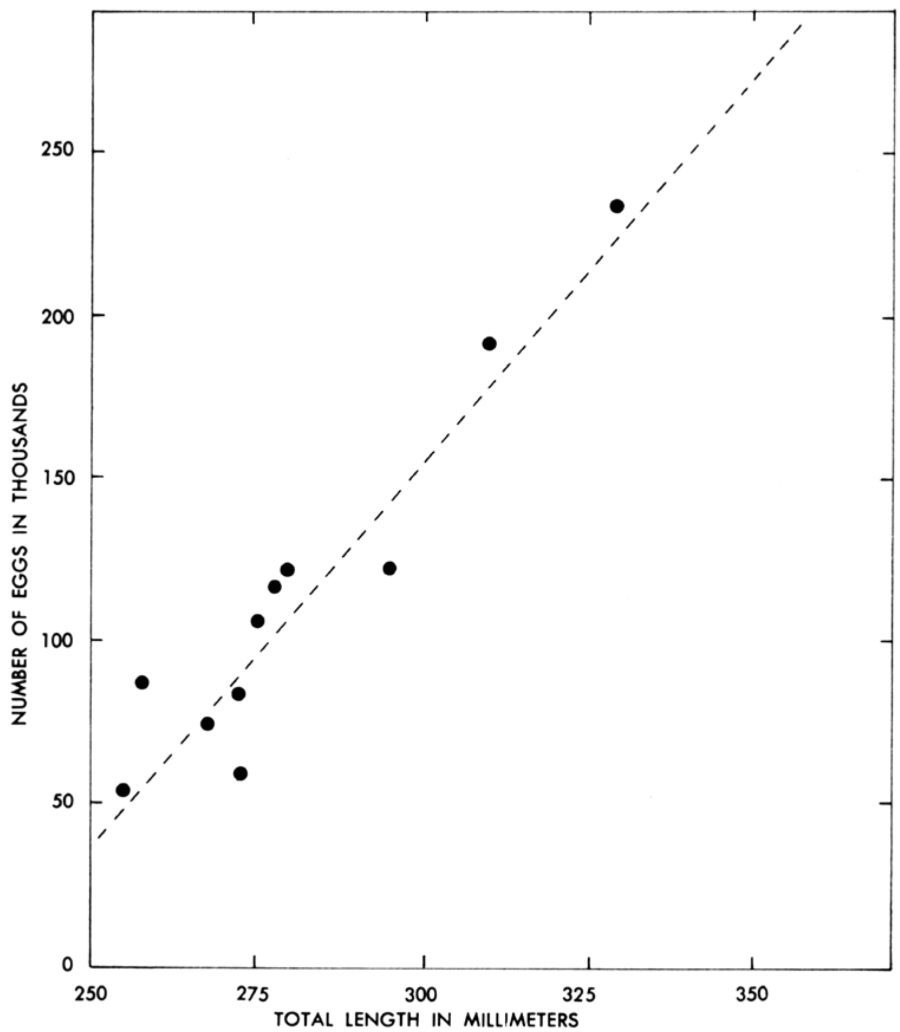


FIGURE 28. Number of eggs in ovaries of eleven blue rockfish ranging fom 256 to 330 mm TL.

FIGURE 28. Number of eggs in ovaries of eleven blue rockfish ranging fom 256 to 330 mm TL.

3.3.6. Food Habits

This species is primarily a plankton feeder with 59% of the volume of food consisting of jellyfish, crustaceans, and tunicates (Gotshall, Smith and Holbert, 1965). Much of the volume of other materials consumed was algae; however, this plant material appeared to be surrounded by a thick mucoid layer and the cellulose bearing portions of the plant may not actually be digested or contribute materially to energy requirements. On several occasions blue rockfish were observed swimming with kelp thalli trailing from the vent, so at least some of this material is not digested.

Juvenile fish of the year consume large quantities of hydroids during summer months along with algal material, crustaceans, and smaller amounts of jellyfish and tunicates. Fish appeared in stomachs of the larger fish sampled, comprising 15.2% of the food items in fish over 400 mm TL. Seasonal changes in diet occurred. In the spring upwelling period tunicates and crustaceans dominated the planktonic food items, and it was during this period that the highest growth rate occurred. Conversely, this was the time of year when catch-per-hour values were the lowest. Most probably these low catches were due to the presence of readily available food throughout the epipelagic zone since blue rockfish over deeper reefs are noted to school thinly and spread out near the surface during this time. During the fall oceanic and Davidson Current periods, the percentage of empty stomachs increases and algae, jellyfish, and fish make up more of the diet.

3.4. MANAGEMENT CONSIDERATIONS

of all the important bottomfish in central California blue rockfish has the greatest potential of being overfished. The heavy demand for inshore fish by partyboat and skiff fisheries has reduced blue rockfish stocks in numbers and size within 10 miles (16.1 km) of all major ports, and the average size is now less than 1 pound in most areas. Tagging experiments indicate there are no migrations with little wandering over 1 mile (1.6 km) over deeper reefs and over 610 ft. (20.0 m) in kelp bed areas. Thus, unfished stocks in more inaccessible areas between ports do not replenish heavily fished stocks within the range of sport boats. The growth rate is relatively slow for rockfish, requiring 3 to 5 years to attain fishable size as well as age at first maturity.

There is presently a daily sport bag limit of 15 fish per angler. If only rockfish are taken, these 15 fish may be of one species of rockfish or may be of any combination of rockfish (See Fish and Game sportfishing regulations). For blue rockfish this restriction will slow down the exploitation, but if fishing effort continues to expand blue rockfish stocks could be overutilized in spite of a bag limit. Inasmuch as this species is one of the aggregate inshore catch, it is not feasible to impose season closures to reduce the numbers taken. Thus, the only restrictions capable of enhancing blue rockfish catches are imposition of a size limit and a zonal (area closure and reopen) management program.

Minimum size limits could create a more quality fishery of larger fish, but would not necessarily result in more fish being taken. The primary fault with size limits is that there are several similar appearing rockfish in the inshore area and there would be an identification and law enforcement problem. This is especially so with many pier fishermen who at times catch young blue rockfish and actually don't realize they are rockfish. The additional problem of mortality due to air bladder expansion was investigated (Miller, Odemar, and Gotshall, 1967) with the conclusion that a 254 mm (10 inches) TL minimum size would not cause undue mortality (6% of the 1960 catch could have died had there been such a restriction) inasmuch as most of the fish below 10 inches TL school in shallow depths and can descend after being brought to the surface. At this time it is not recommended to impose a size limit on this species.

It may be that aggregate species in the inshore area may be difficult to manage on a species basis, and other management concepts may be necessary. One of these is the concept of zonal management which is discussed later in the section on inshore aggregate management problems.

3.5. LINGCOD CATCH ANALYSIS AND LIFE HISTORY

There have been several lingcod life history, tagging, and population studies conducted in British Columbia and the State of Washington. Phillips (1958) presented a summary of some of these works and included additional information on California lingcod. In 1967–71 California Department of Fish and Game conducted a partial life history study of possible differences in lingcod behavior, growth, and maturity due to geographical variation.

3.6. CATCH

In the 20 year period from 1948 through 1967 there was an average annual commercial take of 10,461,000 pounds of lingcod in California, Oregon, Washington, and British Columbia divided as follows: Canada, 4,538,000 pounds; Washington, 3,911,900 pounds; Oregon, 737,100 pounds; and California with 1,274,000 pounds. The maximum annual catch up to 1968 in Canada was 8,425,000 pounds (1944); in Washington, 8,243,100 pounds (1944); in Oregon, 1,645,800 pounds (1946); and in California, 2,056,100 pounds (1958). Since 1968 in California, however, there has been a marked increase in the lingcod commercial catch with a preliminary 1972 catch of over 3,244,000 pounds. Commercial catch records from British Columbia, Washington, and Oregon demonstrate this marked increase in catch took place only in California with catches declining from 1969 to 1972 in Canada and Washington, and remaining about the same in Oregon.

In California the major commercial port for lingcod has been the Eureka area, which includes landings for Crescent City, Eureka, and Fort Bragg, with progressively smaller landings recorded at all statistical port areas to the south (Table 8). In the Eureka (Crescent City to Fort Bragg) area there was five times as many lingcod landed in 1972 as in 1966, and in the Santa Barbara (Morro Bay to Santa Barbara) area there was over 11 times as many commercial lingcod landed in 1972 as in 1966.

About 85% of the partyboat lingcod catch has been landed north of Pt. Arguello, and 95% of the statewide skiff lingcod catch is taken north of Pt. Arguello. In the 1957–1961 sportfishing assessment survey from Pt. Arguello to Oregon (Miller and Gotshall, 1965) lingcod contributed 3.0% of the total hook-and-line and spearfishing catch by numbers and 9.3% by weight. The total sport catch of lingcod was 51,250 fish (410,000 pounds), 50.2% of which was landed by partyboat fishermen, 35.8% by skiff fishermen, and 5.8, 5.7, and 2.5% by shore fishermen, skindivers, and pier fishermen respectively. The sport catch of lingcod was 22% of the combined sport and commercial catch by weight for central and northern California.

Statewide partyboat landings of lingcod since 1947 have ranged from a low of about 14,000 fish in 1953 to a high of 103,965 fish (approximately 650,000 pounds) in 1972. From 1960 through 1968 there was a gradual decline in lingcod catches at several ports; however, at Monterey and Morro

TABLE 8

California Commercial Lingcod Catch in Pounds by Landing Area, 1966 Through 1972

	Eureka (Crescent City to Fort Bragg)	*San Francisco (Bodega Bay to Princeton)*	*Monterey (Santa Cruz to Monterey)*	*Santa Barbara (Morro Bay to Ventura)*	*Los Angeles (Ventura to Newport)*	*San Diego (San Diego County)*	*Total*
1966	382,383	269,307	92,825	44,380	1,576	489	790,960
1967	576,519	210,788	80,266	53,217	855	323	921,968
1968	758,814	188,337	71,318	50,556	595	427	1,070,047
1969	766,128	168,849	40,164	46,832	91	330	1,022,394
1970	894,423	336,456	179,258	96,906	657	552	1,508,252
1971	1,174,250	429,881	264,299	225,857	3,157	505	2,097,949
1972 *	2,062,353	392,624	272,524	515,599	1,083	257	3,244,440

* Preliminary figures

*TABLE **8***

California Commercial Lingcod Catch in Pounds by Landing Area, 1966 Through 1972

Bay there was an initial decline from 1960 to 1964 followed by an increase in catch per day values due primarily to the expansion of the Morro Bay fishery to San Simeon and Cape San Martin, and of boats out of Monterey operating southward to Pt. Sur. In 1969 there was a sharp decline in lingcod catch-per-day values at nearly all ports followed by an unprecedented increase of the catch from 1969 to 1972 (Figure 29). The 1972 partyboat catch at Monterey (over 36,000 fish) was greater than the total statewide lingcod partyboat catch of 1969 (32,693 fish).

There was an increase in partyboat effort from 1969 through 1972 with new bottomfishing areas being utilized at San Simeon, Pt. Sur, and Cordell Bank off San Francisco; however, the increase in lingcod landings was only partly due to expanded effort. Lingcod landings for the area from Bodega Bay to Avila (excluding San Francisco Bay ports) contributed 92.7% of the partyboat lingcod catch north of Pt. Arguello and 81.6% of the total partyboat catch. The 1969 through 1972 catch in this area was analyzed to determine the relative contribution made by increased angler days and by changes in availability of lingcod. Assignment into catch-per-day and increased angler day categories was done by computing the magnitude of the catch change due to catch-per-day (availability) changes (C/D of 1970—C/D of 1969 X Total Angler Days in 1970) and subtracting this value from the total difference in number of lingcod caught between 1969 and 1970 yielding the change in lingcod landed due to an increase or decrease of angler days expended. For example: There was an increased catch of 1,242 lingcod from 1969 to 1970 at Bodega Bay. The 1970 lingcod catch-per-day was 0.282 and in 1969, 0.160. Total angler days for Bodega Bay in 1970 was 7,097. Thus, 0.282 - 0.160 X 7,097 = 865 lingcod caught in 1970 due to increased availability, leaving 377 lingcod caught due to an increase in angler days between 1969 and 1970. Over the 3 year period there was an increase of 61,932 lingcod at these ports, 82% of which was due to increased availability of lingcod with 18% due to increased fishing effort (Table 9).

The increase of lingcod from 1969 to 1972 was not uniform by port nor between adjacent years. There was a decline in lingcod catch from 1970 to 1971 at most ports in spite of higher catch-per-day values. This decrease was due to a decline in angler days expended from 1970 to 1971 at all ports except San Simeon and Avila. Between 1971 and 1972 effort again increased as well as availability of lingcod, especially at Princeton, Monterey, and Avila. The continued lower catches at Morro Bay can be partly explained by the shift

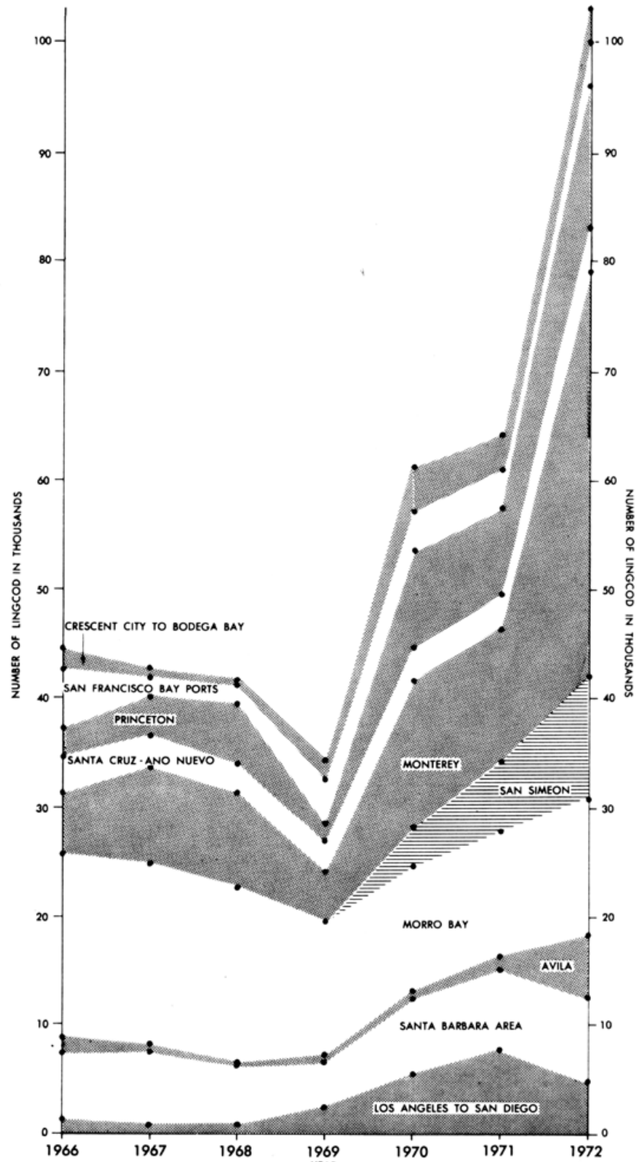


FIGURE 29. Lingcod partyboat catch in numbers by port area, 1966–1972.

FIGURE 29. Lingcod partyboat catch in numbers by port area, 1966–1972.

TABLE 9

Increase or Decrease in Number of Lingcod Due to Changes in Effort and Availability

Port	From 1969 to 1970			From 1970 to 1971			From 1971 to 1972			From 1969 to 1971			From 1969 to 1972		
	Increase or Decrease	*Due to Effort*	*Due to Availability*	*Increase or Decrease*	*Due to Effort*	*Due to Availability*	*Increase or Decrease*	*Due to Effort*	*Due to Availability*	*Increase or Decrease*	*Due to Effort*	*Due to Availability*	*Increase or Decrease*	*Due to Effort*	*Due to Availability*
Bodega Bay	1,242	377	865	−597	−421	−176	275	344	−69	645	148	497	920	375	545
Princeton	7,266	666	6,600	−1,045	−1,375	329	3,853	3,174	679	6,221	311	5,910	10,074	1,754	8,320
Ano Nuevo + Santa Cruz	505	64	441	7	−231	238	928	37	891	512	−115	627	1,440	−112	1,552
Monterey	9,663	831	8,832	−1,618	−301	−1,317	24,534	1,914	22,620	8,045	1,245	6,800	32,579	2,029	30,550
San Simeon	3,790	3,790	0 *	2,505	1,345	1,160	4,304	2,160	2,144	2,505	1,345	1,160	10,599	7,295	3,304
Morro Bay	390	515	−125	−375	−747	372	1,030	1,199	−169	15	−276	291	1,045	−872	1,917
Avila	59	−90	149	449	147	302	4,767	1,037	3,730	508	24	484	5,275	660	4,615
Total	22,915	6,153	16,762	−674	−1,583	908	39,691	9,865	29,826	18,451	2,682	15,769	61,932	11,129	50,803
Percent of Total	100	27	73	—	—	—	100	25	75	100	14	86	100	18	82

* New fishery, no previous catch.

*TABLE **9***

Increase or Decrease in Number of Lingcod Due to Changes in Effort and Availability

of several Morro Bay partyboats to the San Simeon area and subsequent decrease in area covered by the Morro Bay fleet to the north where lingcod are more abundant.

In the total sport catch of central and northern California, there has been a greater percentage of lingcod taken by skiff fishermen over the past 12 years. The 1966 reassessment survey from San Francisco to Yankee Pt., Monterey County (Miller and Odemar, 1968) indicated an overall increase in skiff effort from 1959 to 1966 of 59% which resulted in 32.4% of the total sport caught lingcod being taken by skiff fishermen in 1966 compared to 18.1% in 1959. Catch per unit of effort values were generally about the same or in some areas a little lower than those recorded for the partyboat fishery, except for the special partyboat lingcod excursions to Ano Nuevo Island which averaged much higher than partyboat and skiff catch effort values at other port areas.

TABLE 10

Percentage of Lingcod Under 24 Inches in Skiff and Partyboat Catches, Bodega Bay to Avila, 1959–1970 *

Skiff	*1959 •*	*1961*	*1962*	*1963*	*1964*	*1966*	*1967*	*1968*	*1969*	*1970*
Bodega Bay	61.7	57.1	86.1	67.5	—	—	—	—	—	—
Princeton	17.3	9.1	34.4	29.9	—	38.1	—	—	—	—
Santa Cruz	23.5	23.5	47.2	53.5	51.0	27.5	38.7	35.5	67.4	42.6
Capitola	37.0	16.0	47.9	62.6	63.1	30.0	—	—	—	—
Monterey	41.6	23.1	40.7	66.8	59.2	51.8	58.5	25.0	56.3	57.9
Morro Bay	50.0	—	—	86.9	65.1	—	—	—	—	—
Avila	29.0	—	—	—	75.7	—	33.3	—	—	—
Partyboat	*1960 •*	*1961*	*1962*	*1963*	*1964*	*1966*	*1967*	*1968*	*1969*	*1970*
Bodega Bay	31.0	48.4	25.0	32.4	—	—	—	—	—	—
Farallon Isls.	—	2.8	3.5	17.3	22.2	—	—	—	—	—
Princeton	—	4.8	4.9	6.1	19.3	21.6	—	—	—	50.0
Ano Nuevo	10.5	8.9	17.2	22.6	33.0	18.4	12.0	19.3	31.9	33.3
Santa Cruz	9.0	8.0	16.9	37.9	4.4	23.2	17.7	22.2	44.7	69.6
Monterey	41.9	16.3	36.8	56.5	38.8	42.0	17.3	29.7	26.8	35.6
Pt. Sur	—	—	—	—	—	—	12.5	12.1	0.0	29.4
San Simeon	—	—	—	—	—	—	33.3	22.6	63.6	33.8
Morro Bay	—	39.6	55.0	70.0	69.8	—	39.2	33.3	50.8	65.4
Avila	—	—	44.2	67.8	61.7	—	33.3	—	—	—

• No partyboat sample in 1959; no skiff sample in 1960; no sampling in 1965.

*TABLE **10***

Percentage of Lingcod Under 24 Inches in Skiff and Partyboat Catches, Bodega Bay to Avila, 1959–1970

A useful parameter to represent size composition is the percentage of individuals above and below a certain size interval representing some critical factor in the life history or catch such as size at first maturity, a proposed size limit, etc. We compared the relative size of lingcod catches between ports and years by using the number of lingcod below 22, 23, 24, and 25 inches (559, 585, 610, and 625 mm) TL as indicators of reduction of older fish and/or increase of younger fish. Fish under 24 inches (610 mm) TL have fluctuated widely at some ports such as from under 10% in the Santa Cruz partyboat catch in 1960 and 1961 to nearly 70% in 1970 (Table 10). There is a close relationship between the increase in catch per unit of effort values and increase in percent of fish under 24 inches TL in the partyboat catch at several ports (Figure 30). At ports where lingcod catches are of small magnitude such as in the Santa Cruz local partyboat catch and at Avila before 1970, there was little or no increase in catch per day as lingcod sizes fluctuated. Because of the relatively small number of lingcod in the total aggregate at these ports, a slight increase in lingcod availability could not

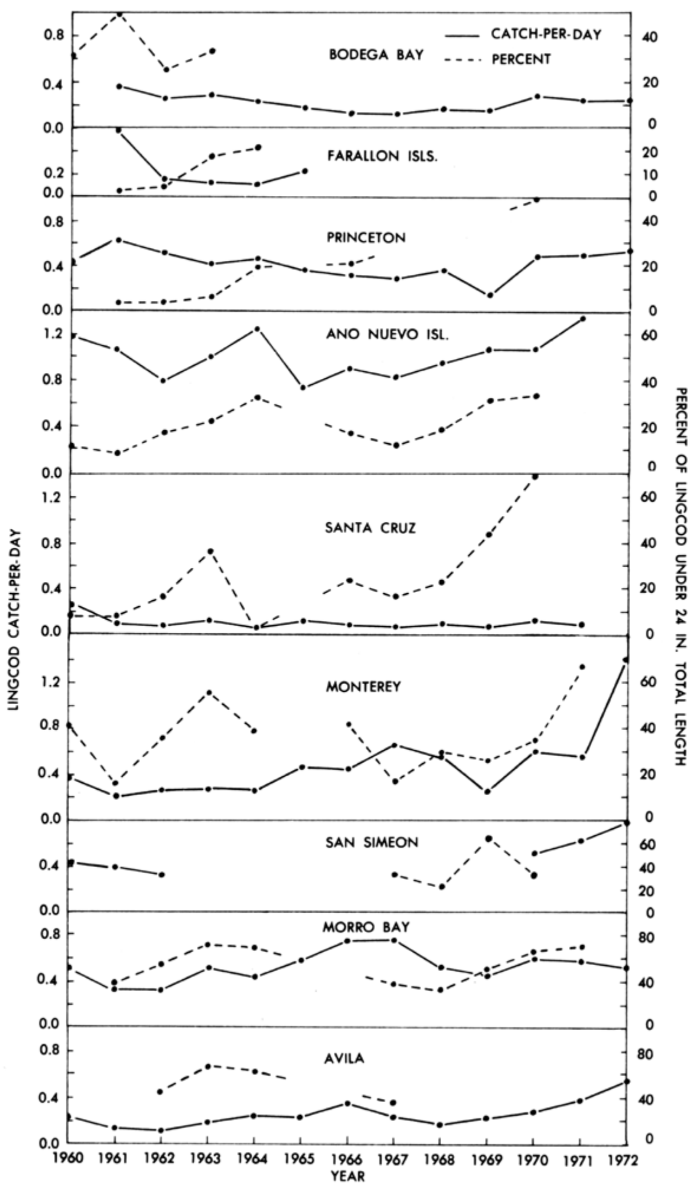


FIGURE 30. Catch-per-day and percent of lingcod under 24 inches (610 mm) TL in the partyboat catch at central California ports, 1960–1972.

FIGURE 30. Catch-per-day and percent of lingcod under 24 inches (610 mm) TL in the partyboat catch at central California ports, 1960–1972.

be detected. In areas where lingcod are specifically sought and make up more of the catch, catch per day values and size composition are good indicators of changes in lingcod availability from year to year.

To demonstrate the effects of different fishing techniques and species emphasis, the monthly partyboat catches of the Ano Nuevo and Monterey areas are compared. The fishery at Ano Nuevo Island is specifically in quest of lingcod and the partyboat operators frequent reefs and portions of reefs most productive for that species. The fishery at Monterey is in quest of large numbers of rockfish in the aggregate catch and the lingcod catch is incidental or merely part of the aggregate for most of the year. At Monterey in fall months, when weather conditions are better and the prespawning larger fish appear, special lingcod trips are made to certain reefs. In the Ano Nuevo Island fishery, partyboats are anchored whereas at Monterey partyboats are allowed to drift while fishing. The number of lingcod caught in the Ano Nuevo fishery is in direct relation to the amount of effort expended (Figure 31); whereas, at Monterey the greatest catches of lingcod are made in the November to March period when weather conditions are better and the influx of spawning fish appears (Figure 32).

Skiff lingcod catches are typically higher in the spring period from February through May when there appears to be an increased postspawning feeding activity in shallow areas. Monthly catch-per-hour values for 3 years at Monterey are compared to depict seasonal variations of skiff fishing (Table 11) using a poor lingcod year (1964), and exceptionally good year (1970) and data representing an average season (1971). When catches are exceptionally high as in 1970, catch-per-hour values remain relatively high throughout the year, yet there is still a springtime increase in fishing success. Thus, regardless of overall abundance, lingcod continue to demonstrate higher availability during the spawning and postspawning period. As will be discussed later, these seasonal catch trends indicate the presence of both residential and migratory lingcod stocks on inshore rocky reefs.

Skindiver's catches are higher during the October to February period for the same reasons the skiff catch increases in this period; i.e., calmer weather (between storms) and higher availability of lingcod in the inshore area. In 1972 about 35% of the skindiver's catch from Pismo Beach to Oregon (Miller, Geibel, and Houk, 1974) was speared during the December through February period. Over 80% of the skindiver's lingcod take are young males and most of these are speared in the fall and winter period.

Lingcod in the commercial catch are taken predominantly in the May through September period (Figure 33) with some shift of the season into late fall in the Eureka area and during the spawning season in San Diego. The Eureka and central California commercial catch is mostly taken by otter trawl nets; whereas, the Los Angeles and San Diego commercial catches are made by hook-and-line.

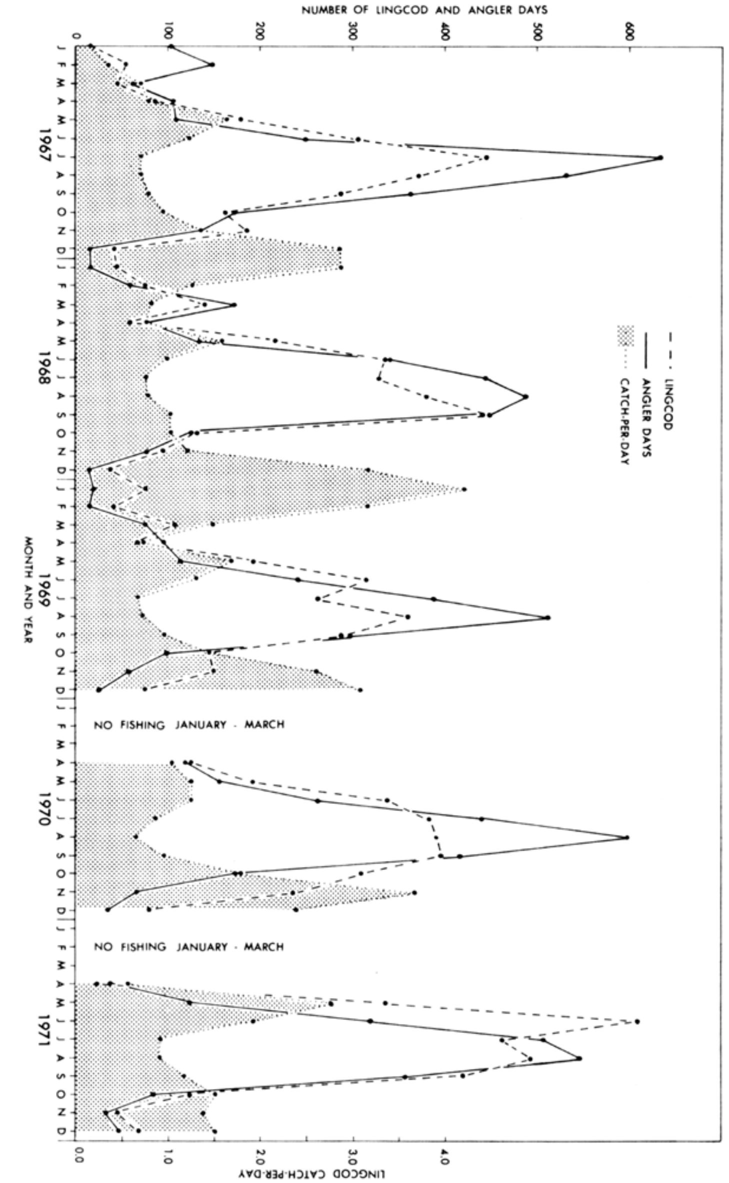


FIGURE 31. Number of lingcod, angler days, and catch-per-day of lingcod by month in the Ano Nuevo Island partyboat catch, 1967–1971.

FIGURE 31. Number of lingcod, angler days, and catch-per-day of lingcod by month in the Ano Nuevo Island party-boat catch, 1967–1971.

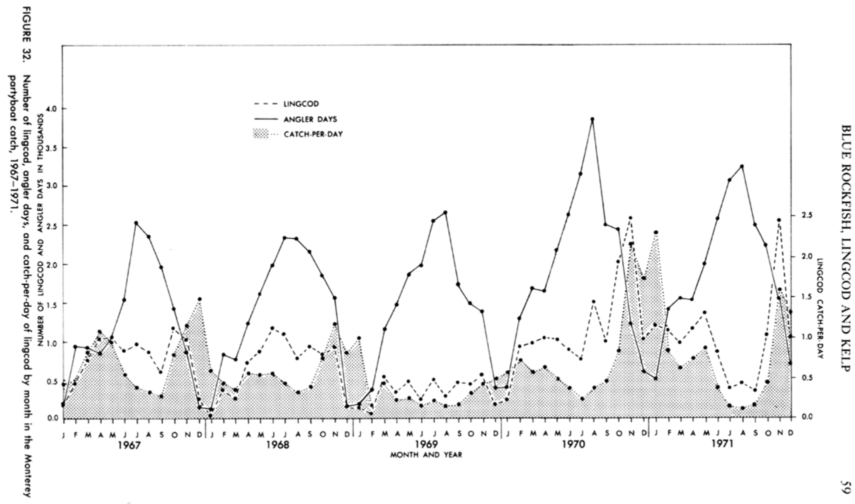


FIGURE 32. Number of lingcod, angler days, and catch-per-day of lingcod by month in the Monterey partyboat catch, 1967–1971.

TABLE 11

Number of Lingcod, Hours Spent Fishing, and Catch-per-hour of Lingcod in the SSH Stratum for the Monterey Skiff Fishery, 1964, 1970, and 1971

Month	*1964* Number Lingcod	*1964* Hours	*1964* Catch/Hour	*1970* Number Lingcod	*1970* Hours	*1970* Catch/Hour	*1971* Number Lingcod	*1971* Hours	*1971* Catch/Hour
January	63	2133	0.03	No Sample	—	—	35	1343	0.03
February	42	915	0.05	279	1861	0.15	135	2249	0.06
March	18	558	0.03	154	857	0.18	268	2101	0.13
April	104	1728	0.06	139	1265	0.11	40	892	0.05
May	100	1825	0.05	450	2498	0.18	226	2052	0.11
June	52	2148	0.02	252	2476	0.10	76	1009	0.08
July	34	2301	0.01	148	2451	0.06	20	4030	0.01
August	34	2138	0.02	430	4540	0.09	149	3526	0.04
September	9	2061	Trace	149	2652	0.06	140	4822	0.03
October	68	2300	0.03	383	2468	0.16	50	2114	0.02
November	15	915	0.02	500	4240	0.12	47	694	0.07
December	0	315	0.00	No Sample	—	—	No Sample	—	—

*TABLE **11***

Number of Lingcod, Hours Spent Fishing, and Catch-per-hour of Lingcod in the SSH Stratum for the Monterey Skiff Fishery, 1964, 1970, and 1971

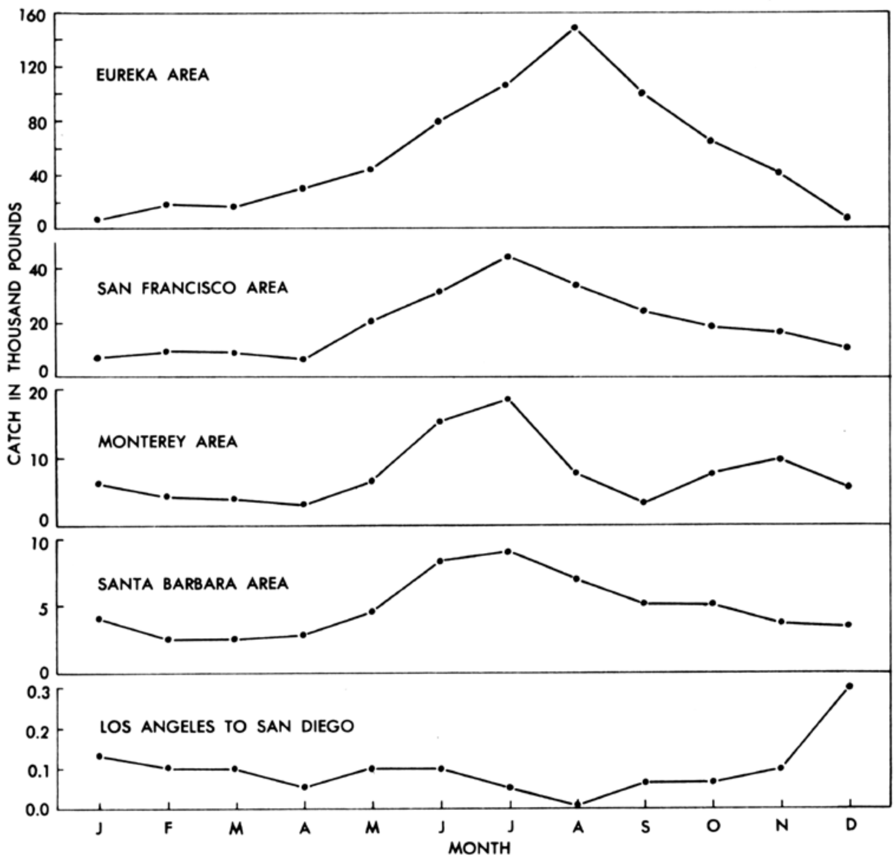


FIGURE 33. Five year average monthly California commercial lingcod catch by area, 1966–1970.

FIGURE 33. Five year average monthly California commercial lingcod catch by area, 1966–1970.

3.7. LIFE HISTORY

3.7.1. Distribution and Movements

Lingcod range over 3,000 miles (4,820 km) of coastline from Pt. San Carlos, Baja California, to Kodiak Isl., Alaska. Larvae are at first sedentary and hide among crevices and vegetation (Wilby, 1937), but soon become epipelagic. Juveniles up to about 70 mm TL are primarily epipelagic and can be taken at the surface at night by dipnet when attracted by light. Larger juveniles frequent a wide range of bottom habitats including eelgrass beds and other shallow vegetative cover in bays and estuaries (Wilby, 1937; Chatwin, 1954), and outside bays have been taken on sandy bottom to at least 200 ft. (60 m). Age 0 lingcod as small as 126 mm TL have been taken in bottom trawl nets in depths to 183 ft. (56 m) off San Francisco (CF&G experimental trawl data), and an Age 0 lingcod at 155 mm TL was taken 180 ft. (55 m) off Pelican Bay, Del Norte County (Stan Katkansky, California Department of Fish and Game, pers. comm.). Ketchen (1950) noted 10 inch (254 mm) TL lingcod were commonly taken in bottom trawl nets off Cape Lago, Vancouver Island.

In California young fish are about 350 mm TL when they first move into the more rugged inshore rocky areas. Underwater observations by project personnel near Monterey disclosed that juveniles from about 200 to 400 mm TL were present in the sandy areas adjacent to rocky reefs but would remain on sandy bottom and rarely venture in rocky areas. Chatwin (1956b) noted that certain reefs seemed to be inhabited only by large fish and suggested that cannibalism by larger fish may suppress movement of young fish into these reefs. Wilby (1937) noted ". . . large females are taken on the tops of the reefs which are from 30 to 40 fathoms below the surface and the smaller males are obtained beside the reef at a slightly greater depth."

Juveniles from about 350 mm TL to 500 mm TL move onto the shallow rocky reef areas; however, there are also large numbers of these juvenile fish in deeper reef and bank areas where they are commonly taken in otter trawl nets. As adults lingcod are found in nearly all bottom habitats from the intertidal zone to at least 1400 feet (427 m); however, most of the hook-and-line sport catches are made on rocky reefs 60 to 200 ft. (18 to 60 m) in depth.

Wilby (1937) and Phillips (1958) as well as other workers, report a seasonal vertical movement of adult lingcod from deeper waters into the sub- and intertidal zones for spawning during the November through March period. This movement has been accepted as fact, but as Chatwin (1956b) and others point out, tagging experiments to date have not confirmed a seasonal mass spawning migration. Inasmuch as this migration is of critical importance in management, in that it involves the possibility of interfishery competition between shallow and deep water fisheries, particular emphasis was placed in our study to confirm this phenomenon.

Ketchen (1954) reported fishing experiments in the Strait of Georgia indicated about 95% of lingcod landed during October to March were taken by hook-and-line in shallower waters, and that trawling was relatively inefficient for lingcod during that time. Forrester (1969) stated that lingcod movements took place for spawning in the Strait of Georgia area, but his conclusions were not based on tagging data. Reeves (1966) demonstrated a markedly reduced number of tag returns from December through April in a tag return study on Forty-mile Bank off Puget Sound; however, he noted the possibility that the decrease in lingcod catches during this period may have been due to a shift of fishing grounds by trawlers in quest of other species and/or because of spiny dogfish abundance on Forty-mile Bank from August to November. Chatwin (1956b) in attempting to determine interfishery competition between the hook-and-line and otter trawl fisheries off Vancouver Island, presented additional indications of restricted movement. Fish tagged in the trawler fishing area were recaptured almost entirely by trawlers, and most of the fish caught and tagged in the area fished by hook-and-line were recaptured in the same area by hook-and-line. Chatwin states: ". . . the small return of all line-tagged fish by trawl gear indicates a low availability to trawlers of lingcod which are already estalished on the rocky banks or reefs." Chatwin concludes, "Tag recaptures subsequent to 1943 confirm the results obtained from the earlier recaptures in that there appears to be no well defined migration pattern." However, his study did not disprove occurrence of vertical spawning migrations since there was no fishery and thus no tag recoveries during a 3 month spawning season closure.

As in the Pacific Northwest, California fishermen and researchers accepted the fact of a seasonal spawning migration inasmuch as there is an increase of larger fish, mostly gravid females, appearing in the inshore catch in fall months prior to and during spawning time. In central California there is no closed season, and there are fisheries operating in all months at all depths and in all habitats frequented by lingcod. Due to limited project operations, we were unable to conduct an extensive tagging program to disclose movements of adult fish between depths and fisheries, so our efforts were expended in observing changes in sex ratio and sizes of lingcod by season and depth in the trawl, partyboat, skiff, and skindiving catches from Avila to the Oregon border. A limited tagging study was conducted to confirm the established findings of Pacific Northwest researchers that there are no horizontal coastal migratory patterns and that there is a minimal wandering behavior of those adult fish resident in rocky areas.

From 1967 through 1971, we tagged 238 lingcod in the inshore Monterey area. of these, 15 were recaptured with two moving from the area of release, one moved 1 mile (1.6 km), the other moved 3 miles (4.8 km). Nineteen lingcod were tagged during 1963–1965 in shallow water at Monterey and of these, two were recaptured; one at the point of release and the other, a 530 mm TL male, was recaptured 438 days later off Capitola. Hart (1943b) concluded that large Canadian lingcod move about less than smaller ones, that there was no indication of difference in movement by sexes, and that ". . . once a fish has found a suitable station, some but not more than 5% of lingcod are more or less migratory during each year." Manzer (1946) reported the longest movement was 80 miles (129 km) of a fish at liberty 128 days. The longest period at liberty was for 12 years 2 months for a fish recaptured where released (Fisheries Research Board of Canada, 1954), and there was some evidence of homing of lingcod released about 6 miles (9.7 km) from point of capture (Chatwin, 1956b). Results of Reeves' (1966) tagging studies indicated a similar pattern of restricted movement of lingcod on Forty-mile Bank with 74% of recaptures made at point of release, 5% were known to move away from Forty-mile Bank, and 21% were of uncertain recapture location. There appears to be little horizontal or coastal movements exhibited by some adult fish that move into a rocky reef or bank area, and only a few tend to wander from reef to reef at the same depths. However, these studies have not disproved existence of a short term vertical seasonal spawning migration of a segment of the adult lingcod population.

One reason a migratory spawning behavior has been assumed is lingcod are reported to spawn in subtidal and lower intertidal areas, thus all spawning fish in deeper waters must migrate shoreward each fall. Jewell (1968) conducted an intensive lingcod egg-nest study at a Seattle breakwater and found nests extending from the lower intertidal zone (5 ft. below a 7 ft. high tide level) to depths of between 30 and 35 ft (9.1–10.7 m) with the lower-most rocks of the jetty extending to depths of 35 ft (10.7 m) below high water. Quast (1968) in a short term kelp bed fish study in southern California reported lingcod from 25 to 125 ft. (7.6–38.1 m) but Limbaugh (1955) made extensive underwater surveys throughout the year in southern California and did not observe lingcod shallower than 65 ft. (about 20 m). Lingcod nesting in southern California most likely occurs below the 65 ft. (20 m) level; however, neither Quast nor Limbaugh reported nesting. Lloyd Austin (University of California at Berkeley) photographed a nest guarding male at about 62 ft. (18.9 m) in Carmel Bay (Figure 34). Don Gotshall (California Department of Fish and Game, pers. comm.) observed an unguarded nest of lingcod sized eggs in 80 ft. (24.4 m) off Hopkins Marine Station, but positive identification as to species is not certain. The maximum depth at which lingcod deposit their eggs is uncertain, so if spawning migrations occur it is not known between which depths these movements take place.

Catch as well as tagging records show conclusively that not all spawning lingcod migrate from deeper to shallower waters and return to deeper waters. There are always large adult as well as young lingcod in shallow rocky areas, and large resident lingcod, especially females, in kelp bed areas often assume a golden to orange-brown adaptive coloration. Several tagged adult lingcod were observed nearly every month for over 1 year in the Hopkins Marine Life Refuge study area. Thus, as related by Hart (1943b) and Chatwin (1956b), many lingcod remain residential in a restricted area. If there is a vertical migration it must be concluded that only a portion of the lingcod stocks in an area are involved.

TABLE 12

Percent of Male and Female Lingcod in Skindiver, Skiff, Partyboat, and Trawl Catches

	Number Fish in Sample	*Percent Males*	*Percent Females*	*Approx. Depth. (in feet)*
Skindiving	1911	72.7	27.3	0–80
Skiff	4576	59.8	40.2	20–200
Partyboat	7427	55.6	44.4	80–320
Trawl	671	37.6	62.4	200–1400

*TABLE **12***

Percent of Male and Female Lingcod in Skindiver, Skiff, Partyboat, and Trawl Catches

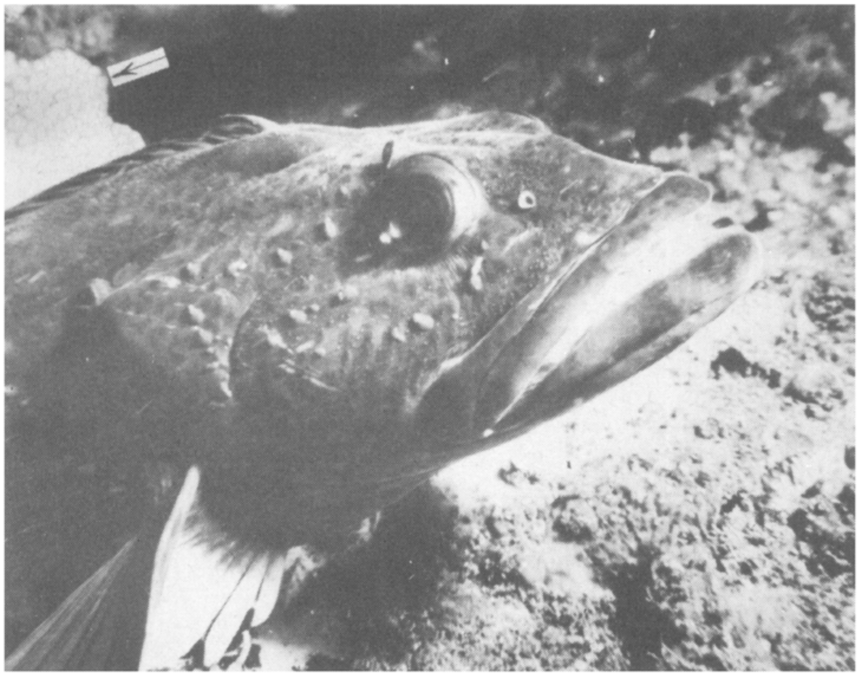


FIGURE 34. Male lingcod guarding next of eggs (arrow) at 62 foot depth in Carmel Bay. Note parasitic copepods, *Lepeophtheirus* sp., on opercular area of fish. Photograph by Lloyd Austin, University of California at Berkeley.

FIGURE 34. Male lingcod guarding next of eggs (arrow) at 62 foot depth in Carmel Bay. Note parasitic copepods, Lepeophtheirus sp., on opercular area of fish. Photograph by Lloyd Austin, University of California at Berkeley.

By comparing sex ratios and sizes of lingcod by season and depth there are good indications that seasonal vertical migrations do occur in central and northern California. There is a striking gradation of the ratio of males to females from shallow depths to waters in excess of 600 ft. (183 m). Over 70% of the skindivers' take is males (Table 12); there is some change by area, with more females present near Monterey and Avila. In the skiff and partyboat catch, which ranges from 10 to 300 ft. (3.3–91.5 m), about 60% of the shallower skiff catch was males whereas about 56% of the deeper partyboat catch was males. Results of trawl catch sampling from 1949 through 1972 show a consistently smaller percentage of males to females, averaging around 38% males over the years. It appears from these series of data that males are more residential in shallower waters than females, and theoretically this should be the case since males must guard the egg nests for 5 to 7 weeks. Females do not take part in nest protection.

Trawl catch records of lingcod in routine box samples (data supplied by Tom Jow, California Department of Fish and Game) demonstrates a definite depth preference by sex and size (Figure 35). There is a gradual decrease in males by depth with a sharp decrease in percentage of males in the trawl catch beyond 600 ft. (183 m). Size or "maturity" comparisons were made by separating the catch into two categories: all fish 600 mm TL and smaller were considered immature fish, and all fish over 600 mm TL were considered adults. All males are mature at 600 mm TL and at least 90% of females in California are mature at this size. If there is a differential movement of immature and mature fish, the percentage of fish in each size

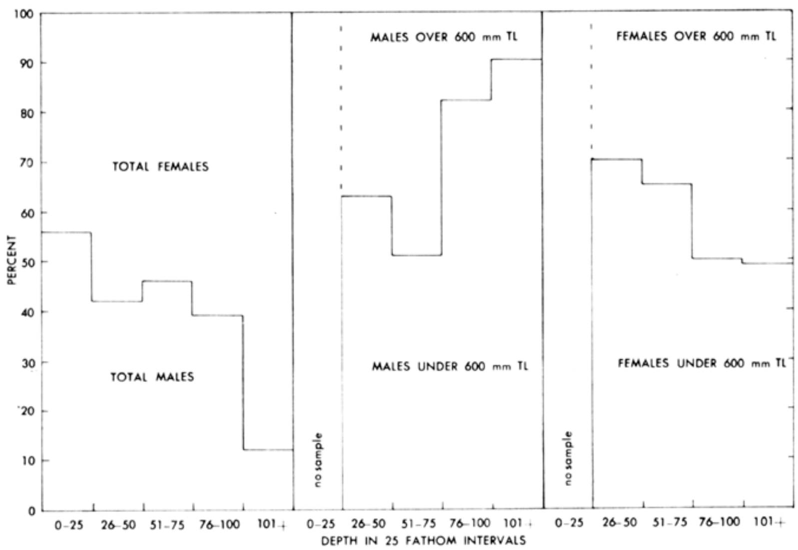


FIGURE 35. Percent of males and females and sex composition in the California trawl catch, 1949–1958, and percent of males and females under and over 600 mm TL by 25 fathom depth intervals. (1 fathom = 6 ft. = 1.83 m).

FIGURE 35. Percent of males and females and sex composition in the California trawl catch, 1949–1958, and percent of males and females under and over 600 mm TL by 25 fathom depth intervals. (1 fathom = 6 ft. = 1.83 m).

category by depth and season should reveal fewer adult fish in deeper water during the spawning period, and such was found to be the case. Over 90% of males in the trawl samples in depths below 600 ft. (183 m) were 600 mm TL and under (Figure 35). Female sizes at these depths demonstrate an opposite trend with larger females increasing in relative numbers in deeper areas. Over 40% of all females in the trawl samples were over 600 mm TL, and over 50% of the females in depths greater than 600 ft. (183 m) were over 600 mm TL. It would thus appear that lingcod stocks in depths in excess of about 200 ft. (61 m) are mostly immature fish, that most adult male lingcod remain in shallow waters, and that adult female lingcod frequent deeper areas than do adult males. This series of data also indicates adult female lingcod move into shallow areas to spawn and return to greater depths than do the relatively smaller number of adult male lingcod that migrate.

Data for all fishing methods were grouped in 4 month intervals (Figure 36) approximating three phases of the annual reproductive cycle: the October through January period of migration, spawning, and peak period of nest guarding; the February through May postspawning period of migration of some females and termination of nest guarding by males; and the July through September period of reproductive inactivity with possible initiation of shoreward migration of deepwater fish.

There was a significantly higher percentage of adults compared to immature fish in the partyboat, skiff, and skindiving catches during the October-January spawning period than in the February-May postspawning interval, and there was a converse disproportionate ratio of adult to immature fish in the trawl samples between these two periods (Figure 36), providing at least circumstantial evidence of a spawning migration of both males and females occurring between these two time intervals. The high percentage

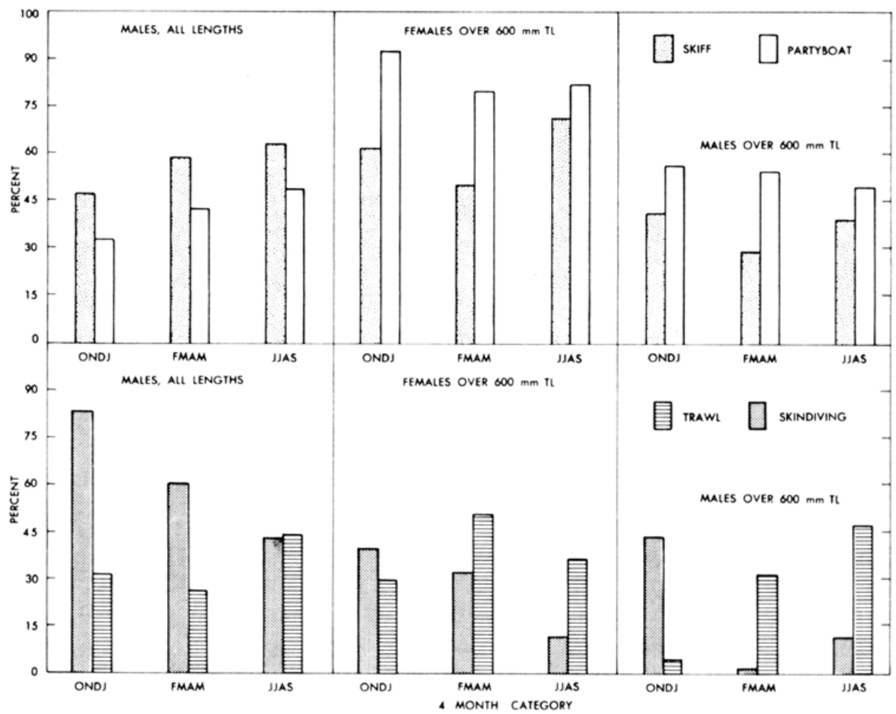


FIGURE 36. Percent of males and percent of females and males over 600 mm TL in the Monterey skiff, partyboat, California trawl, and skindivers catches by 4 month intervals.

FIGURE 36. Percent of males and percent of females and males over 600 mm TL in the Monterey skiff, partyboat, California trawl, and skindivers catches by 4 month intervals.

of males in the skindivers catch during the spawning period is probably due to the ready availability of nest guarding or territorial males to the diver. Females that are not resident may spend only a short time on the reef and move outside the range of divers soon after spawning. By size, the skindivers' take of female lingcod declines considerably during the midsummer period with only 12% of all females speared being over 600 mm TL during the July through September period.

Even though it appears that females migrate more than males, the changes in sizes of males in the skindiving and trawl catches indicate there may also be a substantial movement of larger males between deep and shallow areas each year. During the October-January spawning period only 2.2% of males in the trawler catch were 600 mm TL, whereas in the July-September period nearly half of the trawl caught males were over 600 mm TL.

TABLE 13

Percent Males and Females in Experimental Gill Net Sets from Monterey to Point Sur, November–December 1972

Depth in Meters	*Percent Males*	*Percent Females*
46–55	71.7	28.3
66–75	48.5	51.5
79–85	9.6	90.7

*TABLE **13***

Percent Males and Females in Experimental Gill Net Sets from Monterey to Point Sur, November–December 1972

The ratio of small to large males in the partyboat catch and to some extent in the skiff catch varied only slightly between season intervals, indicating the possibility that many adult lingcod do not leave areas from 60 to 300 ft.

(20 to 60 m) in depth and may actually nest in rocky areas in these moderate depths. A series of gill net samples taken in November-December 1972 (data supplied by Jim Hardwick, California Department of Fish and Game, pers. comm.) demonstrates a significant change in ratio of males and females over and under 600 mm TL at about 210 ft. (60 m) in the Monterey to Pt. sur area (Table 13). In a postspawning gill net experimental cruise in April 1973 (N B SCOFIELD 73-S-2) in the same general area, males contributed to over 80% of the catch in depths less than 180 ft. (55 m), but made up 18% of the catch in depths over 240 ft. (73 m). The overall percentage of males in the samples increased from 33.1% in November-December to 44.2% in April, indicating that some females may have moved out of range of the nets in the postspawning period and/or that some adult males moved into the area from shallower waters. However, this relatively small change in percentage could result from some unknown sampling bias. A sample of partyboat caught fish taken in February, 1970 sheds some light on the composition of lingcod at 300 ft. (90 m) on a rocky reef off Monterey. This sample consisted of 16 lingcod, 14 of which were large spent females (determined by gonad inspection), one immature female, and one immature or possibly spent young male. This sample suggests that nesting does not occur to 240 ft. (90 m) and that all adults at that depth move into shallower areas to spawn, with females returning to deeper water soon after egg deposition.

In summary, small juveniles up to about 70 mm TL are primarily epipelagic, thereafter settling to the bottom. Age 0 fish have been taken from shallow eelgrass beds in bays to depths of over 180 ft. (55 m) in the ocean. Most lingcod less than 350 mm TL tend to remain on sandy bottom adjacent to rocky areas and begin moving onto the reefs at about this size. Fish up to about 600 mm TL tend to move about more randomly than larger fish, the longest recorded movements being 80 miles (129 km) in Canada and 22 miles (35 km) in California. Many adult lingcod of both sexes become residential in rocky reefs; however, there appears to be a segment of the population that frequents depths from 240 ft. (90 m) to over 1200 ft. (360 m) and migrates annually into shallower areas to spawn. Adult males appear to be more residential in the inshore area than females; however, both adult males and females frequent deeper areas to 1400 ft. (427 m). Adult males are seldom taken in depths below 600 ft. (183 m) whereas about half the females deeper than 600 ft. are over 600 mm TL. The maximum depth of nesting is not clearly defined and there appears to be the possibility of nesting to 360 ft. (110 m). So far, however, nesting has been confirmed to 62 ft. (18.9 m) depth with a possibility to 80 ft. (24.4 m). Until an extensive tagging program is undertaken, the magnitude of the population segment that is presumed to be migratory cannot be determined; and underwater observations must prove nesting below 62 ft. (18.9 m).

3.7.2. Reproduction

Spawning. Nesting occurs from November into March and the peak of activity is from late December into the first week of February with larger fish spawning early and most younger fish nesting later in the season. Nests are located in crevices or beneath overhanging rocks and extend from lower intertidal areas to at least 62 ft. (18.9 m) below low tide. In a Seattle study, Jewell (1966) found that of 74 nests only one was between 30 and 35 ft. (9.1–10.6 m), 70 were above the 25 ft. (7.6 m) level, and 10 of the 74 nests were located in the lower intertidal zone, approximately 5 ft. (1.5 m) below the surface during a 7 ft. high tide.

The eggs are about 2.8 mm in diameter when first laid and soon water harden to about 3.5 mm (Wilby, 1937). They are pinkish in color when first laid, turn whitish in a few days, then become yellowish and often greenish-brown due to accumulation of diatoms on the surface of the egg mass. The egg mass becomes dark gray near the end of incubation due to larvae pigmentation. Wilby (1937) described egg deposition and fertilization: "The female extruded the eggs directly upon the chosen spot together with a quantity of transparent yellowish highly viscous secretion which, upon contact with the salt water, formed a strong adhesive for attachment of the eggs to the rocks and to one another. This adhesive was somewhat like albumen in appearance but very stringy and sticky.

"When a layer of several eggs in thickness had been laid the male swam slowly over the mass and fertilized the eggs with short successive jets of milt. The female then returned and continued to add to the egg-mass and each time that eggs were added the male swam over them and covered them with milt, the surrounding water becoming quite white and almost opaque at times."

The larvae are about 12 mm TL when hatching and observations in an aquarium by Wilby indicate newly hatched larvae remain benthic and remain near protective cover. At some early stage, possibly at the end of the yolk sac stage in about 10 days after hatching, postlarvae leave the rocky areas and become epipelagic, reappearing as juveniles at about 70 mm TL in shallow bay areas as well as to at least 180 ft. (55 m) in the ocean on sandy bottom. No larvae or juvenile lingcod were collected in a large series of rocky inter- and subtidal fish poisonings at Diablo Cove, San Luis Obispo County, and Pt. Arena, Mendocino County (Dick Burge and Dan Gotshall, California Department of Fish and Game, pers, comm.).

Males guard the egg nests throughout the incubation period which averaged about 7 weeks near Seattle; however, incubation is expected to be of slightly shorter duration in warmer California waters. Wilby (1937) noted that males not only guard for predators but fan the egg mass with their pectoral fins, although Jewell's study indicated this process may not be vital to egg development. Jewell (1968) observed 74 nests and most, but not all, were guarded by an adult male. Some males were observed guarding from two to four nests, and there were indications that one male could service more than one female. Predation destroyed four of eight nests from which guardian males were removed. Predators included pile surfperch, possibly cabezon, and green sea urchin.

In the Seattle study hatching of larvae took place over 3 to 7 days, and Wilby (1937) noted: "One interesting feature observed in examining an egg-mass which weighed approximately 15 pounds and measured over two and a half feet across was the fact that while the eggs on the outside of the cluster were in such condition that the shells were disintegrating and allowing the young to escape, eggs in a few layers below were in a much less advanced condition and in some cases the eggs in the centre of the mass were still in various stages of development and not nearly ready to hatch."

Fecundity. Hart (1967) developed a regression for egg number to fork length and Phillips (1958) reviewed several published fecundity determinations and presented two additional counts. Counts range from 60,000 eggs for a 762 mm (30 inches) TL female to 518,000 for a 1,041 mm (41 inches) TL fish.

Maturity. Wilby (1937) reported the smallest female found in mature condition in Canada was 768 mm (30.25 inches) TL and all females above this size were mature fish, and for males the minimal size of maturity was

Length in Milli-meters	Female			Male		
	Immature	Mature	Total	Immature	Mature	Total
300	–	–	–	–	–	–
310	2	–	2	1	–	1
320	–	–	–	2	–	2
330	–	–	–	–	–	–
340	–	–	–	–	–	–
350	4	–	4	2	–	2
360	2	–	2	2	–	2
370	3	–	3	1	–	1
380	5	–	5	2	–	2
390	6	–	6	–	3	3
400	5	–	5	4	3	7
410	3	–	3	3	2	5
420	13	–	13	4	3	7
430	5	–	5	–	–	–
440	3	–	3	1	1	2
450	2	–	2	2	1	3
460	2	–	2	1	5	6
470	1	–	1	–	4	4
480	4	–	4	–	–	–
490	3	–	3	1	3	4
500	1	–	1	4	2	6
510	1	1	2	–	5	5
520	4	1	5	1	8	9
530	5	–	5	–	3	3
540	7	1	8	1	1	2
550	4	3	7	–	3	3
560	2	5	7	–	3	3
570	3	–	3	–	2	2
580	–	–	–	–	2	2
590	1	4	5	1	2	3
600	2	3	5	–	1	1
610	1	–	1	–	4	4
620	3	3	6	–	4	4
630	–	1	1	–	1	1
640	1	2	3	–	1	1
650	1	2	3	–	2	2
660	1	3	4	–	2	2
670	1	1	2	–	1	1
680	–	–	–	–	1	1
690	1	2	3	–	–	–
700	–	1	1	–	2	2
710	–	–	–	–	–	–
720	–	2	2	–	1	1
730	–	2	2	–	–	–
740	–	4	4	–	1	1
750	–	1	1	–	–	–
760	1	2	3	–	–	–
770	–	3	3	–	1	1
780	–	–	–	–	–	–
790	–	2	2	–	–	–
800–1000	–	29	29	–	–	–
Total	103	78	181	33	78	111

TABLE ***14***

Number of Mature and Immature Lingcod in the Monterey Partyboat Catch at 520 mm (20.5 inches) TL. Phillips (1958) collected 64 males and 55 female lingcod at Fort Bragg and found that both sexes started to mature at around 585 mm (23 inches) TL, somewhat smaller than those in Canada.

We determined the maturity of 111 males and 180 females ranging from 310 to 960 mm (12.2 to 37.8 inches) TL taken in the Monterey and Morro Bay areas. Inasmuch as some fish may initiate gonadal development but actually not spawn, maturity criteria included only near spawning, spawning, or spent individuals. Samples were taken in late December and early January to include early spawning larger fish, and a series of gonads was collected in mid-February to determine maturity of smaller sized younger fish.

Size at first maturity was considerably smaller than for either the Canadian or Fort Bragg samples, most probably because our February samples contained small first spawning 2 year old fish. Phillips' samples were collected in October and November; however, Wilby's samples extended from December through April, indicating California fish may in fact mature at a smaller size. In our study the smallest spawning female was 510 mm (20 in.) TL and 390 mm TL (15.3 inches) was the length of the smallest spawning male (Table 14). All females were mature beyond 765 mm TL (30 in.), but few over 600 mm TL were immature. All males were mature beyond 590 mm TL (23.2 in.), but a few beyond 500 mm TL were immature.

Ages are determined for 80 lingcod ranging from 365 to 960 mm TL collected for the maturity study (Table 15). Over 60% of the 2 year old males (Age I) were mature, and all but one male were spawning in their fourth year (Age III). Females mature at an older age than males; the first mature female being 3 years of age (Age II) and not all females were spawning until 7 years of age (Age VI).

TABLE 15

Percentage of Mature Female and Male Lingcod by Age Group in the Monterey Partyboat Catch

	Percent Mature	
Age Group	*Female*	*Male*
I	0.0	0.0
II	0.0	62.5
III	12.5	72.7
IV	36.4	100.0
V–VI	69.5	100.0
VII +	100.0	100.0

*TABLE **15***

Percentage of Mature Female and Male Lingcod by Age Group in the Monterey Partyboat Catch

3.7.3. Weight-Length Relationships

Wendler (1953) conducted a study of weight-length relationships for lingcod including total weight to dressed weight, dressed weight to total length, total length to total weight for both males and females, and total length to total weight for males and females combined (Figure 37). Hart (1943a, 1967) determined weight-length relationships for Canadian lingcod, and observed a variation due to sexual maturity which Wendler did not report. The largest lingcod on record is a 105 pound fish taken in British Columbia (John L. Hart, Fisheries Research Board of Canada, pers. comm.), and the largest California lingcod is a 54 pound fish (estimated at about 52 inches TL) reported by Phillips (1958).

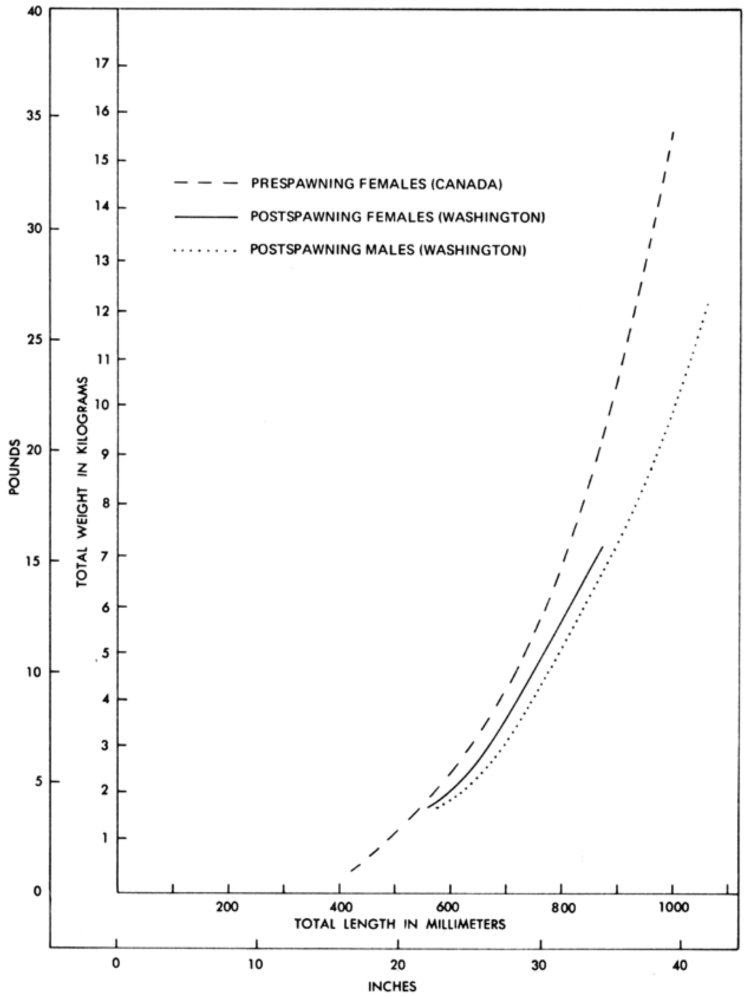


FIGURE 37. Weight-length relationships of male and female lingcod. (Washington data from Wendler, 1953; Canada data from Hart, 1967.)

FIGURE 37. Weight-length relationships of male and female lingcod. (Washington data from Wendler, 1953; Canada data from Hart, 1967.)

3.7.4. Food

Lingcod are primary benthic predators and are well equipped with dentition and mouth size to capture most species present. Wilby (1937) noted the smallest fish examined contained small crustaceans whereas large juveniles feed primarily on young herring and other small fishes. Adults in Canada and Washington feed on a variety of fishes including young lingcod, but rarely on lingcod eggs. Crabs, shrimp and squid also appeared in the adult diet. Quast (1968) recorded almost entirely squid and fish in 17 lingcod stomachs along with an occasional algal fragment which was most probably food of a consumed herbivore prey.

In our study 255 stomachs were examined, 213 were from fish captured by hook-and-line and 42 were from speared fish. Stomachs were collected during all months of the year and from depths ranging from 30 to 220 ft. (9 to 67 m). All fish were large juveniles or adults. Collections were made in the Monterey area, Carmel Bay, Pt. Sur, and off San Simeon. Only qualitative tallies were made of food items in each stomach.

TABLE 16

Percentage by Season of Food Categories in 255 Lingcod Stomachs Collected from Monterey to San Simeon

	Number Stomachs			*Food Categories in Percent*			
	Number Stomachs	*Number Empty*	*Percentage Empty*	*Fish*	*Cephalopods*	*Gastropods*	*Decapods*
Spring (March–May)	22	11	50.0	71	21	8	0
Summer (June–August)	138	40	29.0	77	19	3	1
Autumn (September–November)	81	22	27.2	87	10	0	3
Winter (December–February)	14	5	35.7	70	20	10	0
Totals	255	78	30.6	76.3	17.5	5.2	1.0

*TABLE **16***

Percentage by Season of Food Categories in 255 Lingcod Stomachs Collected from Monterey to San Simeon

Only those fish whose stomachs contained food items (70%) are included here (Table 16). Fishes were the most common food item by frequency (76.3%), followed by cephalopod molluscs (17%). Since both northern anchovy and squid are used as bait by partyboats, these figures may be unnaturally high. Northern anchovy made up 7.8% of identified food fishes, yet did not occur in any speared lingcod. Squid, a natural prey of lingcod, were present in both speared and hook-and-line caught fish.

Juvenile rockfishes, Sebastes spp., (Table 17) were the predominant food fish (73.0%), followed by adult shortbelly rockfish (9.0%). In addition to the identifiable 145 food fish there were remains of 50 fish unidentifiable.

of the cephalopods, half (13) were squid, Loligo opalescens, and half were octopus, 11 Octopus bimaculatus and two O. apollyon. Gastropod molluscs present included the snails Calliostoma, Tegula, and Nassarius. Decapod crustaceans included a small Cancer crab and the shrimp Spirontocaris. Miscellaneous items observed in the stomachs were: rocks, eelgrass, Macrocystis blades, fucoid rockweed, Endocladia (coralline algae) , and a barnacle plate. Ascarid roundworms were frequently seen, as were small orange cysts embedded in the gut wall.

TABLE 17

Composition of Identifiable Fish in 255 Lingcod Collected from Monterey to San Simeon

Species	*Number*	*Percent composition*
Juvenile Rockfishes	106	73.0
Shortbelly Rockfish	13	9.0
Northern Anchovy	11	7.6
Staghorn Sculpin	3	2.1
Blackeye Goby	3	2.1
Spotted Cusk-eel	2	1.4
Sanddab (Unident.)	2	1.4
Pacific Saury	2	1.4
Greenling (Unident.)	1	0.7
California Lizardfish	1	0.7
Viperfish	1	0.7
Total	145	100.1

*TABLE **17***

Composition of Identifiable Fish in 255 Lingcod Collected from Monterey to San Simeon

3.7.5. Age and Growth

Vertebrae have been used to determine age of lingcod (Chatwin, 1954, 1956a) since scales and otoliths failed to yield reliable ages. We compared vertebrae and otoliths for usefulness in aging, and found otoliths to be a better source of age-growth data. Otoliths were rinsed clean in alcohol and placed in number vials containing oil of anise. In anise oil, otoliths change from being nearly entirely opaque to translucent with opaque annuli within 3 to 10 days, depending on size. Otoliths were placed in a black watch glass and examined in anise oil under a dissecting microscope using reflected light. Soaking an otolith in anise oil beyond the optimum time may clear it completely with loss in contrast between hyaline and opaque zones, and if this does occur rings can be made to reappear by drying the otoliths for several days.

When a lingcod otolith is examined under a dissecting scope, many fine alternating opaque and translucent bands are apparent. These bands form the larger opaque summer rings. Since the summer ring is composed of these smaller bands rather than of a single opaque band, reading of lingcod otoliths can be somewhat confusing. To minimize this confusion, several criteria can be used to determine valid annuli.

The summer opaque ring generally forms a continuous band around the otolith, while the individual smaller bands are not continuous and tend to run together. Summer rings increase in width from the first summer ring to the second and from the second to the third. The third summer ring is usually the largest with all successive summer rings becoming increasingly narrower.

In order to determine the formation period of the opaque bands on lingcod otoliths, the reader noted whether the otolith edge was opaque or transparent. From these observations, it appears that any time during the year some otoliths will have an opaque margin, while others will have a translucent margin; however, except for the period when the edge of otoliths are changing from one condition to the other, the greater percentage of opaque rings will be forming in the summer and early fall. Opaque zones were present on the edges of 82% of otoliths in September, while in the winter and spring, when the translucent band will be forming, 17% had opaque edges.

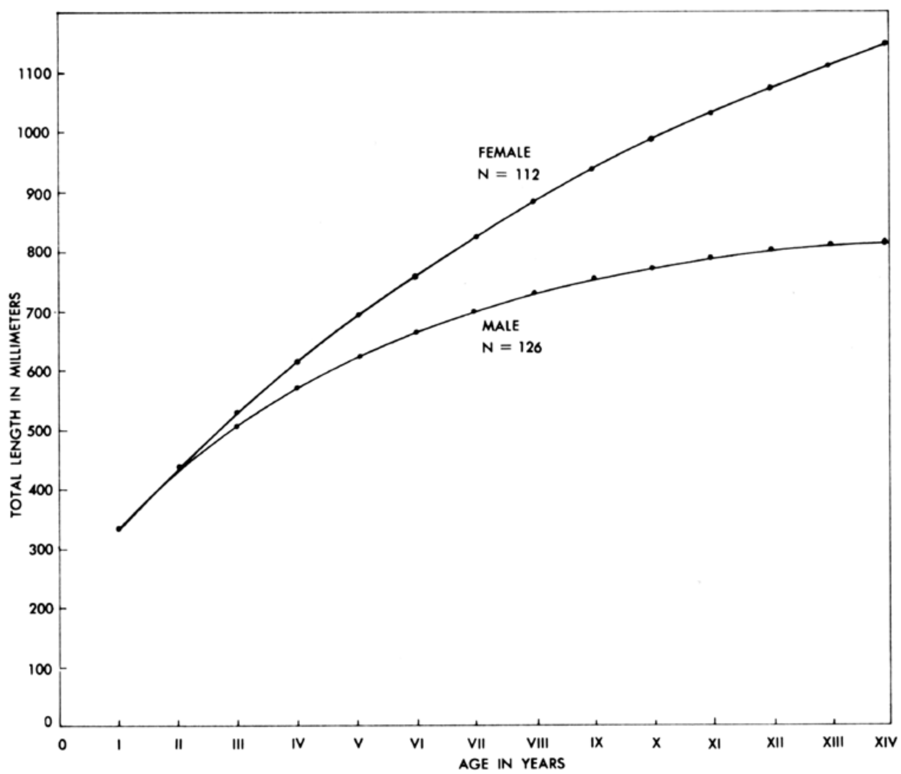


FIGURE 38. Von Bertalanffy growth regressions for California male and female lingcod.

FIGURE 38. Von Bertalanffy growth regressions for California male and female lingcod.

A total of 112 female and 126 male age determinations was made of lingcod collected from Morro Bay to Anchor Bay, Mendocino County. Von Bertalanffy regressions of these observed agings were fitted for males and females (Figure 38). These curves indicate a 3 year old lingcod of either sex averages around 500 mm TL but thereafter a wide divergence in male and female growth patterns becomes apparent. Males rarely reach 915 mm TL (36 inches) and in our sample the oldest male, 11 years of age, was 890 mm TL (35 inches). The oldest female in our sample, 12 years of age, measured 1100 mm TL (43.3 inches). The largest male observed in California is a 1001 mm TL (39.7 inches) fish taken by trawl gear.

Compared to observed growth rates of Canadian lingcod (Hart, 1940; Chatwin, 1956a), California lingcod show a more divergent growth pattern between males and females with males growing at a slower rate than those in Canada and California females growing at a more rapid rate than Canadian lingcod; however, for ages up to 3 years both California males and females apparently grow faster than Canadian fish. Growth of the first 2 years was observed for Canadian fish through size frequency progressions (Chatwin, 1954) with the first year's growth ranging from about 170 to 350 mm TL. Samples containing a total of 1,515 Age 0 lingcod taken near Hunter's Point in San Francisco Bay (deposited in California Academy of Sciences fish collection) revealed a slightly faster progression of lengths than that shown by Chatwin for the April through August period (Table

TABLE 18

Number of Lingcod by Length Taken in Humboldt Bay; at Hunter's Point, San Francisco Bay; and in Experimental Bottom Trawl Gear Off San Francisco and Northern California in Monthly Categories

Length Milli-meters	Humboldt Bay Feb-Mar	Hunter's Pt., San Francisco Bay April	May	June	July	Aug-Sep	Trawl Catch (30+ Meters) * October	Feb-Mar
71-80	4	2	6	2				
81-90		3	145	82	5			
91-100			451	292	12			
101-110		1	88	228	29			
111-120			1	91	23			
121-130				15	14	1	2	
131-140				3	6	1	1	
141-150				4	4			
151-160					2	2	2	
161-170					1	1	2	
171-180							1	
181-190								1
191-200							2	
201-210							3	2
211-220							2	2
221-230								3
231-240								2
241-250								3
251-260								5
261-270								2
271-280								1
281-290								3

* 30+ meters = 98+ feet.

*TABLE **18***

Number of Lingcod by Length Taken in Humboldt Bay; at Hunter's Point, San Francisco Bay; and in Experimental Bottom Trawl Gear off San Francisco and Northern California in Monthly Categories

18). Unfortunately we do not have an adequate series of trawl caught fish from ocean areas, but the small samples available indicate an emigration of Age 0 fish from the bays in fall. Age 0 fish first appeared in bottom trawl catches outside bays in October as 126 to 220 mm TL fish.

3.8. MANAGEMENT CONSIDERATIONS

Lingcod stocks in California are apparently not overutilized at this time although for several years between 1960 and 1969 there was some concern that lingcod stocks at some port areas were being adversely affected by fishing. The percentage of smaller fish in landings was increasing and catch per unit of effort values were declining, indicating a high mortality of older fish. Subsequent to 1969, however, the large influx of young lingcod throughout California has resulted in record high catches at nearly all California ports and in all fisheries. Thus, if there was overutilization at certain ports, the reproductive capacity of the stocks was apparently not impaired. The fact that lingcod stocks are discrete for each port area and that recruitment increased simultaneously throughout California indicates that overall oceanographic conditions resulting in good survival and increased availability transcended any local factors of utilization.

Continued surveillance of catch parameters of sport fisheries and commercial catch is necessary to determine management needs. There are three potential regulations that should be discussed at this time. These are a reduction in the daily sport bag limit (presently 10 fish per day maximum), a size limit, and a spawning season closure.

Reduction of the bag limit will spread the fish available inshore into more daily catches, but in the long run will not be effective if the number of fishermen continues to increase as they have in the past few years. If numbers are to be controlled, curtailment of the commercial catch should be considered inasmuch as about 78% of the total 1972 California lingcod catch was landed by commercial fishermen (Table 19). There is evidence that stocks of adult fish in waters deeper than 240 ft. (73 m) probably migrate into shallower areas each year to spawn and that both the commercial trawlers and sport fishermen are utilizing the same stocks of fish.

TABLE 19

Total Annual Catch and Catch During Lingcod Spawning Season in the Trawl, Partyboat, Skiff, and Skindiving Fisheries

Method	*Total Pounds*	*Percent by Method*	*Poundage Landed in Dec-Feb*	*Percent Landed in Dec-Feb of Total*	*Percent Landed in Dec-Feb Each Method*	*Percent of Fish Landed in Dec-Feb by Method*
	A	A/ΣA	B	B/ΣA	B/A	B/ΣB
Trawl	3,240,000	77.8	275,000	6.6	8.5	78.6
Partyboat	650,000	15.6	38,300	0.9	5.9	10.9
Skiff	250,000	6.0	28,200	0.7	11.3	8.1
Skindiving	24,000	0.6	8.400	0.2	35.0	2.4
Total California	4,164,000	100.0	349,900	8.4	—	100.0

TABLE ***19***

Total Annual Catch and Catch During Lingcod Spawning Season in the Trawl, Partyboat, Skiff, and Skindiving Fisheries

A size limit would create a more quality fishery of larger fish, and since lingcod do not have an air bladder and can be brought up without harm from any depth, this restriction is feasible. Should otter trawling, hook-and-line fishing, and spearfishing continue to expand rapidly, a 610 mm TL (24 inch) size limit or possibly even larger may be necessary to insure capture of large fish. A 610 mm TL fish (about 4.5 pounds) has spawned once if a female and most likely twice if a male, and is still in its period of most rapid growth. If a size limit of 24 inches TL was enacted upwards to 65% of the sport catch at Santa Cruz and Morro Bay would be returned annually. Hence, a gradual progressive size limit starting at 558 mm TL (22 inches) would be necessary to not adversly affect the fisheries economically.

A December through February season closure such as is in effect in some areas in the Pacific Northwest appears to be a valid management tool, yet the effectiveness of this regulation is not known and use of this management scheme is not recommended at this time. The spawning season actually extends over a nearly 5 month period from late November through the first part of March. There is also an influx of prespawning large gravid females in the inshore area from late September into early November, and when these fish with their extended abdomens are viewed at fish markets the public becomes concerned about allowing the take of fish "with eggs." Spawning closures merely to save eggs is of no biological consequence because females are constantly carrying eggs, but these eggs are visible to the naked eye only prior to spawning, and no matter when a fish is caught it is prevented from spawning the next time it was to spawn, whether it is 300 or 3 days from spawning. The significance of these statements in terms of management is not understood by most of the public and fishermen. A spawning closure is only effective and necessary when the spawning adults become highly vulnerable and are in danger of becoming overutilized during this time; for example on giant sea bass spawning concentration in southern California. Inasmuch as only 8.4% by weight of all lingcod taken in California in 1972 were caught during the December through February period, a spawning season closure would save relatively few fish, some of which are actually not spawning fish. There is a mounting concern about skindivers spearing guardian males during winter months, but since the skindivers' catch during the December through February period amounts to only 2.4% of the total fish taken during this 3 month period, it would be of insignificant value to limit skindiving activities but not others during this period. There is the possibility that not all spawning occurs in the intertidal to 62 ft. (18.9 m) zone, and that many more males taken by skiff and partyboat fishermen and hook-and-line and gill net commercial fishermen down to 240 ft. (73 m) also may be nest guardians. Because of the large recruitment possible under existing conditions, as witnessed by the influx of unprecedented numbers of young fish statewide in 1970–1972, spawning stocks are apparently not now being adversely affected.

As total fishing effort expands in the future, especially in shallower areas, a December through February closure for both commercial and sport fisheries, along with a 24 inch TL size limit, may be desired.

4. REEF ECOLOGY STUDY

Over the past decade inshore research has revealed some behavior patterns and habitat requirements of many species. One of the more significant findings with respect to inshore habitat and fishery management is that nearly all rocky aggregate species are residential or at least non-migratory, and that there may be segments of some populations that migrate between deep and shallow water for spawning such as lingcod, cabezon, and sharp-nose surfperch. Results of studies on artificial reef habitats (Carlisle, Turner, and Ebert, 1964; Turner, Ebert, and Given, 1969), on copper rockfish (Patten, 1973), and in the blue rockfish and lingcod studies show that wandering probably occurs in all inshore species. Species composition uniqueness has been demonstrated for specified habitats and reefs by Limbaugh (1955), Quast (1968), and in the reef ecology study off Monterey, Capitola, and Santa Cruz (Miller, Odemar, and Gotshall, 1967). A characteristic species and size composition was present on each Monterey Bay reef depending upon depth, habitat, and degree of fishing effort expended. The more exposed reefs in clear, turbulent water are optimum habitat areas for blue rockfish, lingcod, olive rockfish, and kelp greenling. The dominant bottom fishes on reefs near Capitola where water conditions are more turbid than on the Monterey side of the bay are brown rockfish, grass rockfish, and surfperches. On sandy bottom from 65 to 213 ft. (20 to 65 m) deep off Monterey, Pacific sanddabs and rock sole are common, whereas off Capitola and Santa Cruz at the same depth on sandy bottom white croaker is the dominant species.

Even though some aspects of life history and distribution of certain fishes have been determined through sport catch sampling and particular life history studies, specifically designed multispecies programs are needed to determine seasonal abundance, distribution, behavior, species interaction, and habitat requirements of aggregate residential populations that are competing for food and habitat. One significant finding of the central California sportfish surveys from 1957 through 1966 is that rocky, heavily vegetated areas may be essential habitat for juveniles of many important commercial and sport species.

In view of the lack of information concerning habitat requirements and population parameters of most fish in the inshore reef areas, an ecological survey was initiated in 1967 to better understand the nature of inshore reef habitats and the dynamics of kelp bed fish populations. Included in this survey was a pilot program to determine the effects of kelp canopy removal on fish populations in central California kelp beds and the effects of harvesting on kelp frond growth and canopy formation.

4.1. METHODS AND DESCRIPTION OF STUDY AREA

Oceanographic parameters and biological data collected were: movements of fish tagged in the study area and on adjoining reefs; underwater transect observations; hook-and-line captures by project personnel to determine catch-per-hour values; secchi disc readings to measure turbidity; water temperatures; dissolved oxygen determinations; and plankton volume and composition. Oceanographic parameters were measured between 0900 and 1100 on each sampling day. In kelp harvesting experiments kelp plants were tagged and growth of individual fronds was determined. At nearby reefs fish were captured for tagging, and at a sandy bottom location, Station C, about 656 ft. (200 m) to the east of Hopkins Marine Life Refuge the above physical parameters were collected and plankton hauls were made. In Hopkins Marine Life Refuge routine collections of all the above parameters were made at Stations A and B, and beyond June 1969 fish were captured for tagging studies at Station D (Figure 39).

Hopkins Marine Life Refuge was set aside by the State of California Fish and Game Commission exclusively as an academic research area under the direction of Stanford University. The rocky reef area from the intertidal zone to about 65 ft. (20 m) encompasses around 18 acres (7.3 hectares), about 12 acres (4.9 hectares) of which are suitable habitat for giant kelp, Macrocystis pyrifera, with a dense understory of other alga, primarily Gigartina, Callophyllis, Rhodymenia, Botrycladia, Microcladia, and Bossiella.

The substrate is dominated by large granodiorite outcroppings and boulders interspersed with coarse sand and shell fragments in the shallow areas grading into finer sand in deeper portions. Out to about 49.2 ft. (15 m) the granitic mass makes up about 80% of the substrate and from 49.2 ft. (15 m) to the edge of the rocky zone at 65 ft. (20 m) there is only an occasional protruding pinnacle. The rock formations are considerably fractured forming crevices, overhangs, and small cave environments with an occasional abrupt relief extending 15 to 20 ft. (5 to 6 m) above the bottom. Because of the hardness of granodiorite the bottom topography is stable. Water currents are minimal in this semiprotected area, and during heavy swell periods there is only negligible sanding of kelp holdfasts and interstices occupied by benthic invertebrates.

The reef area is isolated from nearby reefs by fine sand by distances of about 495 ft. (150 m) to the south (Cannery Row area), 590 ft. (180 m) to the west, and 650 ft. (200 m) to the east. The east or offshore reef is Hopkins Reef consisting of about 85 large granitic outcroppings separated by wide zones of fine sand in from 75 to 95 ft. (23 to 30 m) of water. There is no Macrocystis growing on Hopkins Reef and the predominant invertebrates

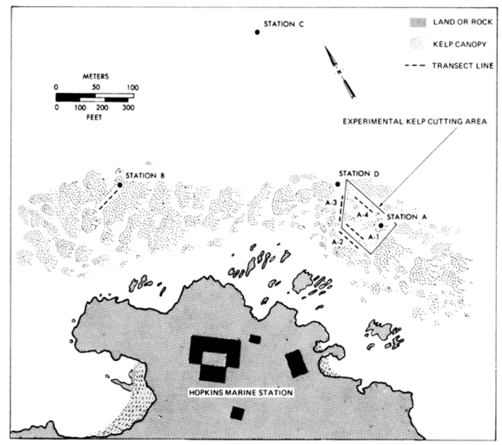


FIGURE 39. Hopkins Marine Life Refuge Study area.

FIGURE 39. Hopkins Marine Life Refuge Study area.

are the white colored anemone, Metridium; sponges; bryozoans; and starfish. There is moderate skiff and spearfishing activity on all nearby reefs but not in the study area. Sea otters began foraging activity in the reserve in late 1964 and have been rafting near Station B since 1968.

Four 98.4 ft. (30 m) permanent transect lines were installed near Station A and one 98.4 ft. (30 m) transect was laid out near Station B. Each transect was marked by a white plastic coated wire clothesline anchored firmly to the substrate at the ends and at intervals along the line. At Station A where kelp canopy removal experiments were conducted, two transects were within the 1.25 acre (about ½ hectare) area from which the canopy was repeatedly removed, and two transects were located in dense kelp growth approximately 33 ft. (10 m) outside the west and north boundaries of the kelp cutting zone. Transect tallies were of fishes only, no benthic inverte-brate studies were made.

Fish transect tallies were made by two divers swimming side by side, each diver counting the fish within a swath extending 3 ft. (1 m) each side of the line in width from the bottom to 6 ft. (2 m) above the bottom. Upon completion of the bottom count one diver would re-traverse the line swimming just under the surface counting all fish in a 6 ft. (2 m) wide swath from the surface to 6 ft. (2 m) depth. Underwater fish counts also were made under our anchored boat at Stations A and B. These boat counts were in an area approximately 26 ft. (8 m) in diameter at the bottom recording the number of tagged and untagged fish.

Hook-and-line catch values were determined at Stations A and B using 1/0 barbless hooks with squid bait for a 40 minute period each sampling day. Fishing was conducted for 20 minutes at the bottom and 20 minutes at middepth. These catches were expanded to catch-per-hour values for each species for both bottom and middepth series. The captured fish were placed in a circulating water holding tank, and at the termination of the time fishing period all fish over 175 mm TL were tagged and released at the point of capture.

Samples of water for dissolved oxygen (D.O.) were taken at the surface, at 16.4 ft. (5 m) and at the bottom. D.O. was determined by the modified Winkler process. Sea temperatures were taken at the surface, 3 m, 5 m, 10 m, 1 m above the bottom, and at the bottom. Secchi disc (8 inch) readings were made vertically from the boat with aid of a glass bottom, watertight box to eliminate surface agitation. Plankton hauls using a # 20 silk 0.25 m net were made from 33 ft. (10 m) to the surface at Stations A, B, and C. In the laboratory plankton samples were allowed to settle in a graduated flask to record a volumetric index, and an alloquate sample was then removed to determine composition by major categories. The research boat OPHIODON was used in our field work. It is a wood 20 ft. (6.5 m) long 8 ft. (2.6 m) beam V-bottom inboard-outboard equipped with a recording fathometer accurate to 3.3 ft. (1 m) resolution, a diving ladder, and a fish holding tank.

4.2. OCEANOGRAPHIC PARAMETERS

Sea temperatures ranged from 9.7°C to 13.2°C at the bottom 33 to 49.5 ft. (10 to 15 m) and from 10.9°C to 15.7°C at the surface with seasonal patterns of upwelling water entering the lower levels starting in March or April

(Figure 40). These values are mean temperatures of from 3 to 5 consecutive days per month. A thermocline developed in June at about 10 to 16.4 ft. (3 to 5 m) persisting until October or November, after which time the water mass remained vertically homogenous until the spring period. The coldest surface temperatures were in the December through March period; however, there was variation between years with the winter sea temperatures at both the surface and at the bottom remaining relatively warmer in 1967–68. There was no significant difference in sea temperatures at all depths between stations except for the bottom temperature at Station C, which averaged about 1°C colder, probably because of the greater depth averaging about 16.4 ft. (5 m) deeper than at the kelp bed stations.

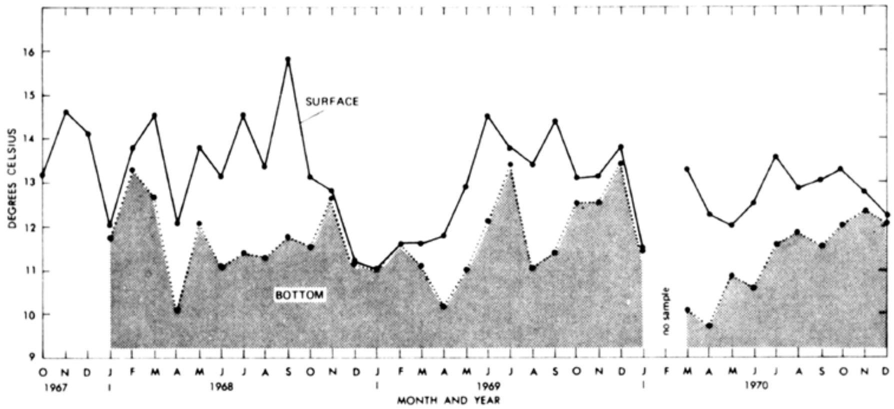


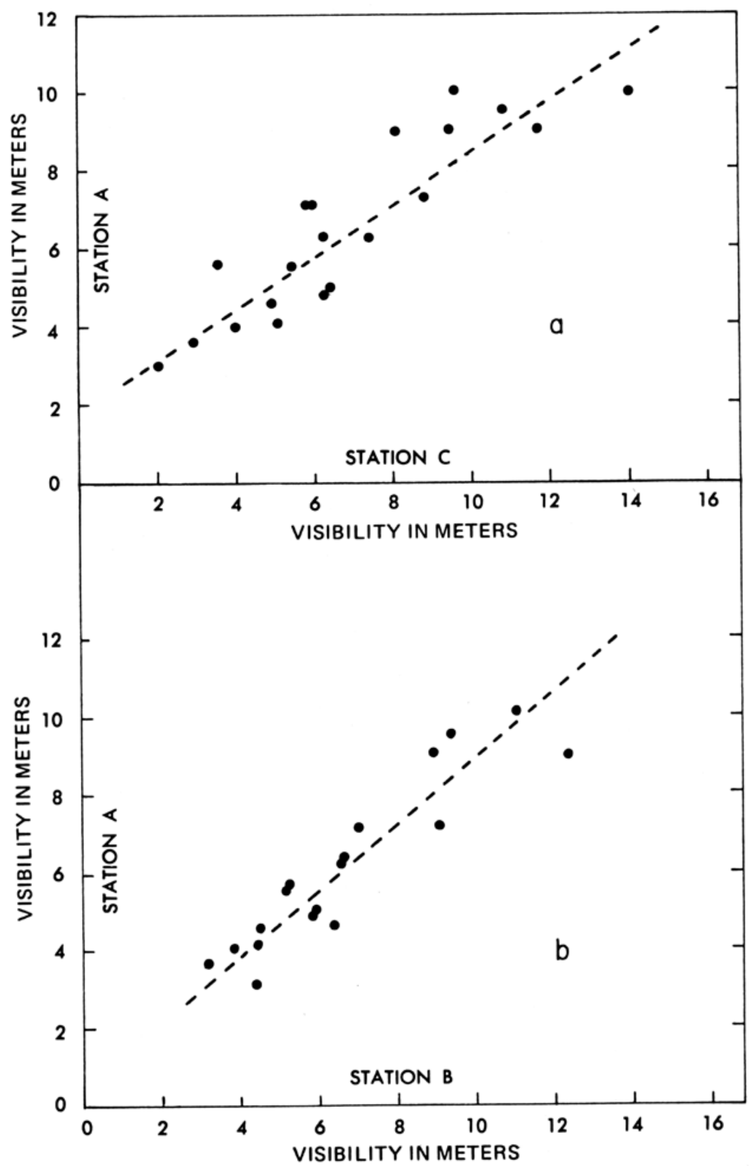
FIGURE 40. Water temperatures recorded during routine monthly sampling periods at Station A, 1967–1970.

FIGURE 40. Water temperatures recorded during routine monthly sampling periods at Station A, 1967–1970.

Turbidity or water visibility as measured by secchi disc readings varied widely. In general the highest visibility was during the winter period from November through February. Periods of extended minimal visibility were during the spring upwelling period when dense blooms of phytoplankton occurred. Occasionally blooms of dynoflagellates would reduce visibility in the warmer fall months for short periods. The maximum visibility was 82 ft. (25 m) recorded in November 1968 at Hopkins Reef and the minimum visibility, 6.2 ft. (1.9 m), was recorded in September 1968 during a Ceratium bloom.

There appeared to be a slight but constant difference in secchi disc readings between Station A in the center of the kelp bed and at Station C outside the reef area (Figure 41a). When visibility was generally low, readings at Station A were higher than at Station C, whereas when visibility was generally high the readings at Station A were slightly lower than at Station C. Secchi disc readings were about the same at Stations A and B; however, averages at Station A were slightly lower during clear water periods than at Station B (Figure 41b).

Dissolved oxygen values were slightly higher at the surface at Station A from July through November than at Station C, but were higher at C during the February through June period (Figure 42). D.O.'s at 16.4 ft. (5 m) showed minor variation between Station A and Station C; however, there



IGURE 41. Relationship of secchi disc readings between (a) Stations A and C, and (b) Stations A and B.

FIGURE 41. Relationship of secchi disc readings between (a) Stations A and C, and (b) Stations A and B.

were fairly constant lower values at the bottom at Station C than at the kelp bed stations, especially during the upwelling period. Surface D.O. values were similar throughout the year at Stations A and B.

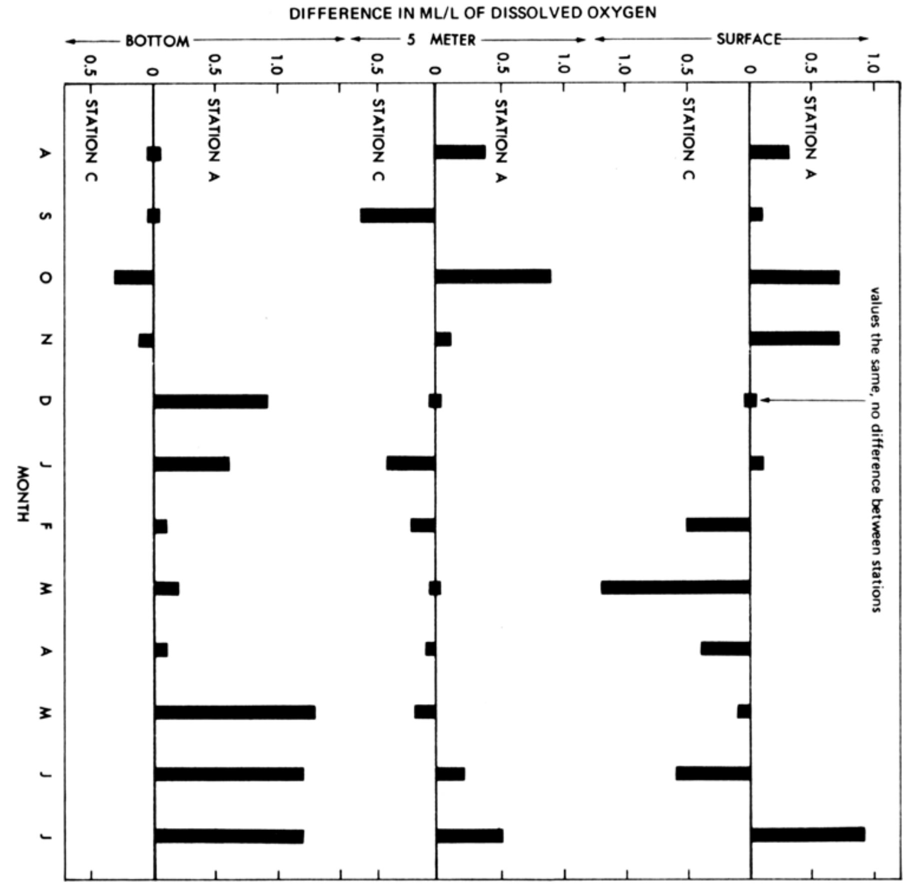


FIGURE 42. Differences between mean dissolved oxygen (D.O.) values at Stations A and C at surface, 5 m, and bottom.

FIGURE 42. Differences between mean dissolved oxygen (D.O.) values at Stations A and C at surface, 5 m, and bottom.

4.3. PLANKTON STUDY

This study was not a standard biomass evaluation but involved a gross estimate of volume by settling, and an estimation of the major items present.

Vertical 33 ft. (10 m) plankton hauls were made using a #20 0.25 m net from August 1968 through July 1969 at Stations A, B, and C. Mean monthly plankton volumes were highest from July through October (Figure 43). There were no significant total volume differences between stations; however, by category there were wide discrepancies between stations between months and even on the same day. It is not known whether these differences were due to kelp bed environmental influences or to normal variations in plankton concentrations. Seven macroplankton categories were used to compare kelp bed plankton composition with that at Station C. These were: small copepods, large copepods, larval gastropods, larval

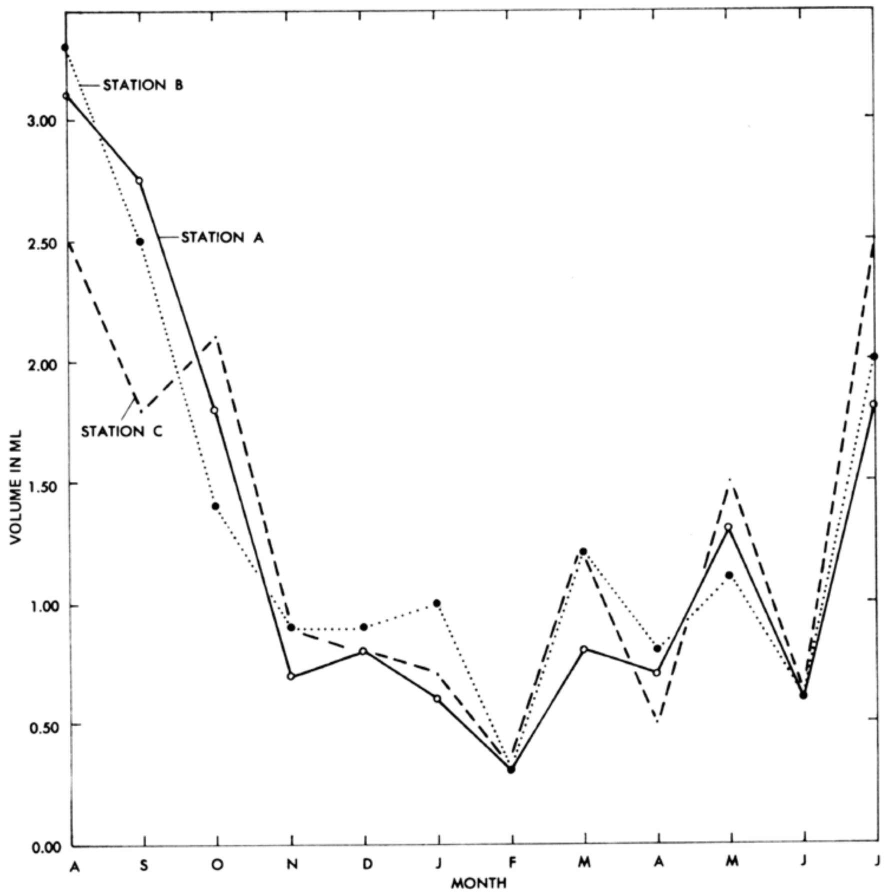


FIGURE 43. Volume (settled measurement) of total plankton at Stations A, B, and C, August 1968 through July 1969.

FIGURE 43. Volume (settled measurement) of total plankton at Stations A, B, and C, August 1968 through July 1969.

pelecypods, crustaceans other than copepods (isopods, decapods, and amphipods), and spionid polychaetes. The diatoms Coscinodiscus and Rhizosolenia were the most commonly observed organisms at all stations. Coscinodiscus were present in small numbers each month, but were exceptionally numerous in November 1968. Rhizosolenia were present in large numbers in all months except February and June and were most numerous in May 1969. There was little variation in occurrence of these two species between stations. Arrow-worms, Sagitta, were fairly common in seven months of the year with the heaviest concentrations in October and December. Plankters observed but not included in this discussion because of their consistently small numbers include: Chaetocerus, Ceratium, Globergerina, Obelia, polychaetes other than spionids, Pleurobranchia, Bipinnaria, auricularians, and fish eggs and larvae.

The large macroplankton volumes from July through October were composed of several organisms each ranging widely in number between months. The most common and those contributing most to the volume as well as affording potential food for juvenile fishes were the tunicate, Oikopleura;

copepods; and crustaceans other than copepods including mysids and caprellid amphipods. Crustaceans were consistently more abundant at Stations A and B than outside the kelp bed area at Station C. This group reached its peak of abundance during the August to October period (Figure 44). In the kelp bed area, isopods and amphipods also contributed to the high concentrations in August, and the October peak was primarily composed of mysids and amphipods, along with copepods.

Copepods were divided into "small" and "large" categories with an inverse abundance of these categories occurring periodically during the July through December period. Other macroplankton contributing to the fall abundance at all stations were juvenile gastropods and pelecypods, spionid polychaetes, and the tunicate, Oikopleura (Figure 45).

Time did not allow for collection of a series of stomachs from juvenile fish to correlate with the plankton hauls. It is interesting to note, however, that the high concentration of macroplankton coincides with the period of juvenile fish abundance in the kelp bed areas. As noted earlier the food of juvenile blue rockfish was primarily sessile hydroids along with planktonic crustaceans, tunicates, and jellyfish. Quast (1968) listed gammarid amphipods usually found on algae as having the highest index of utilization of kelp bed fish food items in southern California followed by crabs, fish, and algae. For smaller fishes and juveniles, Quast noted planktonic shrimp and isopods were of importance. Limbaugh (1955) noted that topsmelt occasionally became abundant in the canopy area and stated: "... their presence probably has a great effect on reducing the number of small organisms that live in the kelp bed or are carried by incoming current..."

In general, data from this study do not indicate reduction of volumes or of a particular group of plankters due to fish foraging in spite of the large number of juvenile rockfish and surfperch in the kelp bed area during peak macroplankton concentration. Small copepods were consistently higher in numbers at Station C from July through October, indicating a possible reduction by foraging at Stations A and B, yet the "large" copepods were actually less abundant at Station C than in the kelp bed zone during this time. Until a more complete series of plankton hauls are made in conjunction with food analysis of juvenile kelp bed fishes no conclusions can be made on the possible reduction of macroplankton by fish foraging in central California kelp beds.

This study demonstrated a coinciding juvenile fish concentration with macroplankton abundance, and revealed the lack of juvenile fish in the kelp bed area during winter and a corresponding reduction in macroplankton entering the canopy zone during the winter months. It also appears that many of the food items of small kelp bed fishes may be residential or associated with inshore vegetation rather than of plankton being carried into the area. Further work is needed to establish this supposition for each species in the kelp bed area.

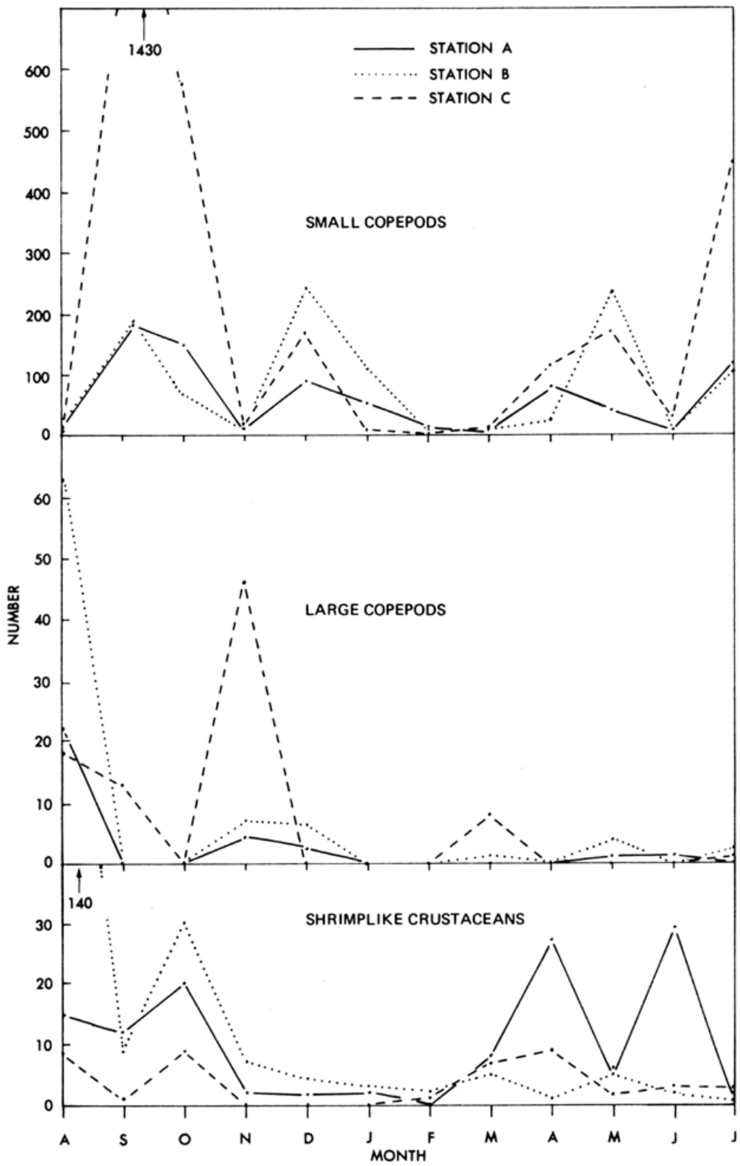


FIGURE 44. Number of crustaceans in alloquots of plankton samples taken at Stations A, B, and C from August 1968 through July 1969.

FIGURE 44. Number of crustaceans in alloquots of plankton samples taken at Stations A, B, and C from August 1968 through July 1969.

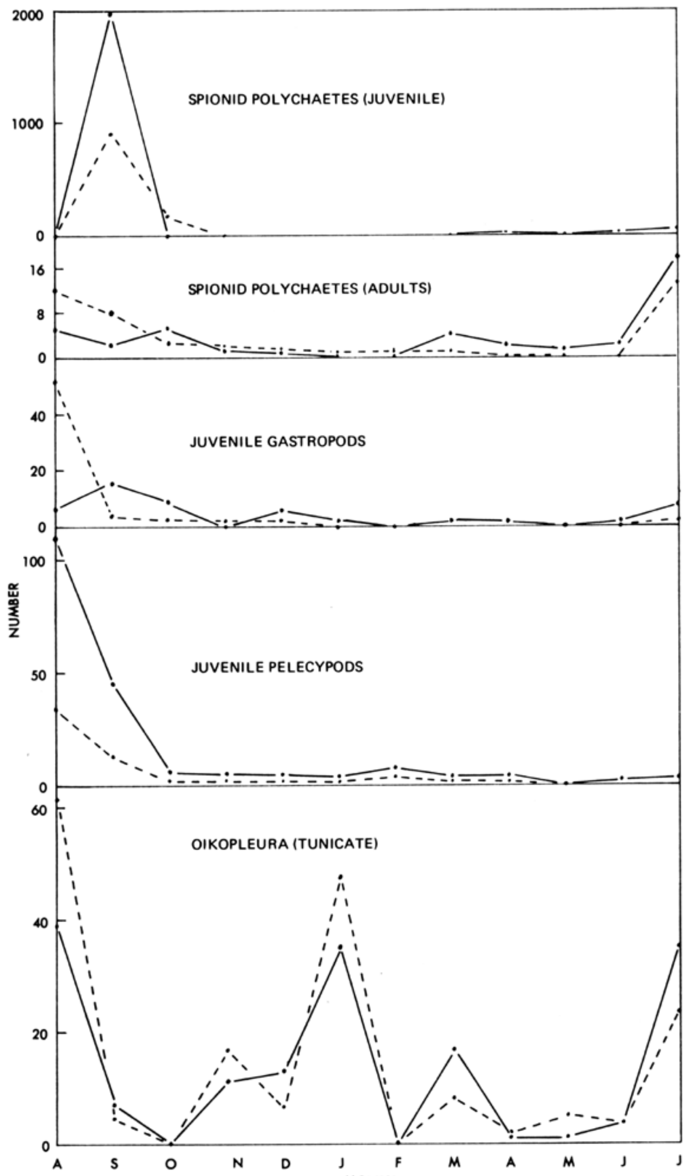


FIGURE 45. Number of polychaetes gastropods, pelcypods, and oikopleura (tunicate) in alloquots of plankton samples taken at Stations A and C, August 1968 through July 1969.

FIGURE 45. Number of polychaetes gastropods, pelcypods, and oikopleura (tunicate) in alloquots of plankton samples taken at Stations A and C, August 1968 through July 1969.

4.4. UNDERWATER TRANSECTS

Studies using underwater transects to determine standing crops of fishes (Brock, 1954; Bardach, 1959; Quast, 1968) have been conducted in southern California or tropical waters where water conditions are less turbid, and on the average less turbulent than in central and northern California. Other basic differences between southern and central California conditions are cooler sea temperatures to the north, a wider range in kelp canopy densities between winter and summer periods, and a distinctly different composition of dominant kelp bed fishes. In southern California kelp bed habitats are typified by kelp bass, halfmoon, opaleye, blacksmith, California sheephead, rock wrasse, senorita, black surfperch, topsmelt, and kelp surfperch. In central California the above species except for kelp and black surfperches are only occasionally or never encountered. Central California kelp bed habitats are dominated by blue rockfish, kelp rockfish, striped surfperch, olive rockfish, and kelp surfperch in the canopy and middepth zones; and by blue rockfish, lingcod, cabezon, kelp greenling, gopher rockfish, black-and-yellow rockfish, and grass rockfish at the bottom. In central California there are dense concentrations of juvenile rockfish and surfperch in shallow vegetative rocky zones and in the kelp canopies from April through November. Limbaugh (1955) and Quast (1968) failed to mention similar juvenile rockfish concentrations in southern California kelp canopies.

Because of the above environmental and biomass differences between central and southern California inshore areas, there was concern about using underwater techniques developed for southern California conditions. The accuracy of underwater observations always has been questioned by divers because of the subjectivity of judging distances and sizes, ability to properly identify similar appearing species, and the behavior of different species to either be attracted to or repelled by the diving operation. Heavy swell action in central California results in considerable change in behavior of inshore species, especially lingcod, greenlings, and rockfishes that tend to remain wedged in deep interstices during storm periods where they are difficult to observe. Quast (1968) noted some of these variables and stated, "Detailed consideration of the belt-transect data has disclosed numerous possible sources of inaccuracy and bias. The foregoing conclusions regarding population densities must be regarded as tentative until further intensive work is conducted on the various species."

Seven random 98.4 ft. (30 m) line transects were made at the onset of this survey in Hopkins Marine Life Refuge and three transects were made in a kelp bed off Chase's Reef 3 miles (4.8 km) to the west to determine the type results to be expected from line transects in this area. These counts were extremely variable in species composition and numbers, with counts of blue rockfish ranging from 0 at four stations and 1, 9, 10, 22, 30, and "several hundred" recorded at the other stations. of the 12 species observed on these 10 transects, seven did not appear at more than one station. At least 20 other species were known to be present in the area, several of which were observed outside the transect zones during the day's operation. Water conditions were ideal in this series and, because of the high variability in counts, a much larger number of random transects would have to be made over the entire extent of the reef to insure that all habitats were represented in a census to arrive at reliable abundance estimates and composition.

The approach to this study was not to attempt computation of the standing crops of fishes for the entire kelp bed through a series of random transects, but to determine daily and seasonal fluctuations along permanent transect stations by species, size, and numbers over several years. Major habitat variables were eliminated and seasonal behavior patterns of each species could be noted for each habitat niche by using permanent transects. Four of these transects were established in 1967 and three additional lines were established in 1969 to detect changes in fish concentration due to kelp canopy removal.

Conditions of good visibility and little turbulence are usually chosen for running transects. In this study, however, the diving days for the entire project were chosen at the onset of the study by choosing a 4 to 5 day diving period spaced 20 to 22 days apart, sometimes shifting a day or two to avoid weekends or holidays. Additional transect counts often were made, and on a few occasions the consecutive 4 day diving series could not be completed due to heavy swell action or reduced visibility.

In all, 142 days were spent in collecting underwater transect data from October 1967 through December 1970. During this period 514 bottom line transects and boat station tallies were made and 213 canopy transect tallies were made for a total of 727 underwater fish tallies recorded in Hopkins Marine Life Refuge. An additional 13 underwater tallies were made on Hopkins Reef, and five tallies were made at Chase's Reef.

Underwater transect data demonstrated high variability in concentrations of fish between different kelp bed zones and between seasons for most species, especially schooling and aggregating species. Solitary, demersal forms were less abundant throughout the area but were routinely encountered in their particular niche or territory. Except for kelp surfperch, sharpnose surfperch, and to some extent senorita, all species were oriented more to the bottom than to the canopy. Juvenile rockfishes were observed throughout the kelp forest, at times utilizing the lower rockweed growths, rocky interstices, and holdfast areas, and at other times were densely aggregated in the canopy and mid-depth zones.

4.4.1. Effects of Canopy Removal on Kelp Bed Fishes

Comparisons were made between tallies along two transect lines within the cutting area (lines A1 and A4) and tallies were made along two lines outside the cutting area (lines A2 and A3). Five cuttings were made removing all the canopy from the 1.25 acre (0.5 hectare) area. Because the after cutting tallies following the April 30, 1970, cutting were not made until a month after cutting, these data are not included in this analysis.

There were no significant effects of canopy removal as represented by changes in numbers between the transect tallies within and outside the canopy removal area for adult rockfishes and all other species (Table 20). The sometimes erratic variations between cut and uncut tallies were not significantly greater than those recorded between days and months at Station B, the control, or between daily and monthly counts at each of the four Station A lines.

Counts of juvenile rockfishes were quite similar in the canopy and at the bottom in the uncut section before and after each canopy removal; however, in the cut section juvenile rockfish variation between canopy and bottom tallies was considerably higher in magnitude than that recorded in any control tally (Table 20). The June 20 and September 16 cuttings produced a much higher magnitude in shift of numbers of juvenile rockfish between the canopy and bottom in the cut section than in the uncut section. These data suggest that after surface canopy removal juvenile rockfishes frequenting the canopy area went to the bottom in the cut area rather than move horizontally to nearby uncut surface fronds.

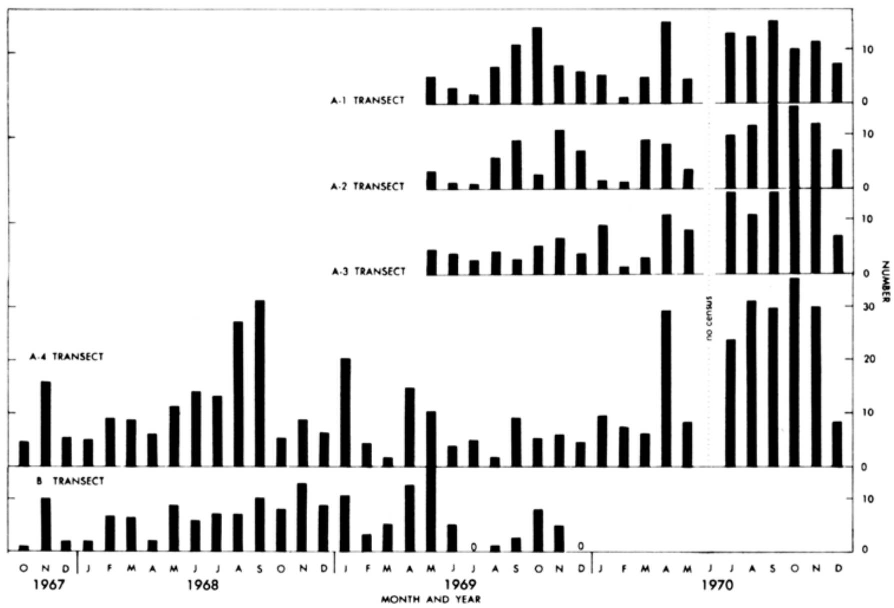


FIGURE 46. Number of striped surfperch by month along five transect lines, 1967–1970. Surveys of transects A1, A2, and A3 were initiated in May 1969. No surveys were conducted in 1970 along B transect.

FIGURE 46. Number of striped surfperch by month along five transect lines, 1967–1970. Surveys of transects A1, A2, and A3 were initiated in May 1969. No surveys were conducted in 1970 along B transect.

Because of the high variability between seasons and particular niche preference by each species, analysis of transect data to disclose effects of canopy removal is difficult. For instance, if there were only minimal effects on fish distribution due to canopy removal these effects may have been masked by multiple natural changes affecting each species in different ways. Line A4 was in an area of relatively high density for nearly all species compared to lines A1, A2, and A3. Thus, natural variations on the disproportionate large numbers of fish at line A4 may have numerically buried any minor changes in fish abundance tallied at the other three station A lines that may have been due to canopy removal. Monthly tallies indicate striped surfperch was a species not affected by our experimental cutting, not particularly more abundant at any one transect line, and was a species demonstrating a high degree of correlation in monthly abundance between all transect lines (Figure 46). Similar month to month changes at line A4 and at Station B line transect were observed from October 1967 to November 1969, indicating availability changes occurring simultaneously throughout

TABLE 20

Differences in Number of Fish Per 30 Meter Bottom Transect and Number of Juvenile Rockfish in the Canopy After Canopy Removal in the Cut Section *

	June 20, 1969		*Sept. 16, 1969*		*Feb. 4, 1970*		*August 5, 1970*	
Species	*CUT*	*UNCUT*	*CUT*	*UNCUT*	*CUT*	*UNCUT*	*CUT*	*UNCUT*
Juvenile rockfishes **								
canopy	+111.3	−10.0	−132.4	+81.5	–	–	Not counted	
bottom	+1,534.0	−11.8	+134.5	+72.2	–	−2.0	−82.5	+317.5
Rockfish								
Blue	−10.5	+6.8	−6.8	−1.1	+3.7	+2.5	+4.5	−2.5
Black-and-yellow	–	–	+0.1	–	−0.2	–	–	−0.5
Copper	+0.3	–	+0.6	–	−0.5	–	–	–
Kelp	0.0	+2.7	−0.6	−0.4	−0.2	−0.5	−6.5	+0.5
Greenlings								
Kelp greenling	0.0	−1.0	+0.7	+0.2	0.0	−0.5	−1.5	−2.0
Lingcod	−1.3	−0.2	+0.3	–	+0.2	−0.5	−1.0	0.0
Cabezon	+0.2	0.0	–	–	–	–	+0.5	+0.5
Kelp Bass	+9.7	–	−11.6	+0.1	−3.0	−2.0	+9.0	−5.5
Opaleye	+16.0	−0.5	−0.4	–	−0.2	+0.8	+1.0	–
Surfperch								
Black	−0.7	+1.2	+0.1	−0.2	+1.0	+0.3	−4.5	+3.0
Pile	−3.5	−2.9	+2.0	+1.5	−1.7	−0.2	−2.0	+2.5
Rainbow	−0.6	−0.6	+2.2	+1.5	−1.0	−1.3	−7.5	−9.5
Rubberlip	−0.8	−0.5	−0.6	–	+0.2	+2.2	−0.5	0.0
Striped	−3.5	−2.0	+1.0	+0.2	0.0	+1.3	−4.0	+2.5
Senorita	+0.2	+0.8	+1.0	–	−174.8	−100.0	+4.0	+5.0

* Lines A1 and A4, and the Uncut Section, Lines A2 and A3 (0.0 = fish observed but no change in numbers; – = no fish observed).
** Juvenile rockfishes not identified.

*TABLE **20***

Differences in Number of Fish Per 30 Meter Bottom Transect and Number of Juvenile Rockfish in the Canopy After Canopy Removal in the Cut Section

the kelp bed area. These same abundance trends were not noted for other species, rejecting the possibility that visibility or swell action resulted in comparable diver bias throughout the kelp bed. Tagging studies indicate this species to be more or less residential, as was concluded by Morgan (1961), and varying counts were probably due to fish behavior patterns. The significance here is that underwater observers are able to detect these minor availability changes at each station. This points out the reliability of underwater observations to record fish behavior and abundance changes along stationary transect lines.

Juvenile rockfish tallies resulted in an entirely different seasonal pattern compared to striped surfperch (Figure 47). Juveniles of most solitary, demersal forms such as black-and-yellow rockfish and gopher rockfish remain at the bottom but are rarely observed because of their solitary, cryptic nature. Copper rockfish as adults are solitary, demersal species; however, juveniles up to about 70 mm TL are commonly taken in the canopy as well as at the bottom. Juveniles ranging from 50 mm to 130 mm TL of schooling or aggregating rockfishes including blue rockfish, bocaccio, olive rockfish, yellowtail rockfish, widow rockfish, and shortbelly rockfish were abundant in the kelp bed areas from April through November each year. Blue rockfish dominated this group of fishes, but large numbers of juvenile shortbelly rockfish appeared in August and September 1969.

Counts of juvenile rockfishes in the canopy were highly variable. These fish behave more erratically than adults and tend to be more easily frightened at times and yet are easily attracted at other times. Turbidity creates a major observational variable with these small fish, since they are difficult to observe when water visibility drops below 10 ft. (3 m). Juveniles are more variable in vertical distribution and at any given time may be scattered at varying depths throughout the kelp bed. Underwater observers became increasingly doubtful of the value of canopy juvenile rockfish counts as our studies progressed. Observations from the anchored diving boat at Station A confirmed the erratic behavior of these fish in the canopy and noted their tendency to remain at least 12 to 15 ft. (4 to 5 m) distant from divers moving through the water near the surface. On several occasions the boat observer estimated the number of juveniles near the surface between certain kelp plants before the divers returned, and these counts were compared to diver counts in the same area. On one occasion 200 to 300 juveniles were observed near the boat, but only about 20 were reported by the diver when he swam through the area. Boat observations revealed on several occasions that as the divers progressed through the concentrations of juvenile rockfishes a vacuity of from 10 to 12 ft. (3 to 4 m) would form around the diver with most of the fish remaining beyond the range of underwater visibility. Surface observation from the boat revealed that after each cutting there was only an occasional juvenile rockfish seen near the surface but as the canopy reformed these fluctuating concentrations would reappear.

The major drawback of these canopy harvesting experiments is the small size of the cutting zone which is surrounded by a thick canopy affording refuge habitat. This small scale experiment did not yield fish distribution variation data directly applicable to an extensive commercial harvesting operation in which a major portion or possibly all the canopy would be removed in each cutting operation. It does appear adult fishes probably are not affected by the canopy removal as was concluded by Quast (1968) for southern California kelp beds; however, there is some concern about the environmental changes of a large commercial operation possibly adversely affecting summertime juvenile fish concentrations in central California.

4.4.2. Fish Standing Crop Estimates

Estimates were made of the standing crop of kelp bed fishes present in 1969 and 1970 using May through December data for the four Station A transects (Tables 21 and 22). There were 106 transect counts made in 1969 and 73 in 1970 in the May through December series. Only fishes counted in the bottom transects are included in these estimates. A bottom transect is 98.4 ft. (30 m) long, 6 ft. (2 m) wide, and from the bottom to 6 ft. (2 m) above the bottom.

Compared to published standing crop estimates of southern California kelp bed fishes (Quast, 1968) those represented by the Station A line transects are exceptionally high. Quast estimated standing crops ranging from 99 to 406 pounds per acre when using a wall net, and data from 50 belt transects yielded estimates of 298, 307, and 335 pounds per acre. We did not attempt to estimate the size of adult fish underwater, but used a rough average of the size of hook-and-line caught fish from the study area. This average was about ½ pound per fish for those included in this analysis. Estimates from bottom transect counts of 1,267.7 adult fish per acre for 1969 and 2,042.2 adult fish per acre for 1970 approximate 630 and 1000 pounds

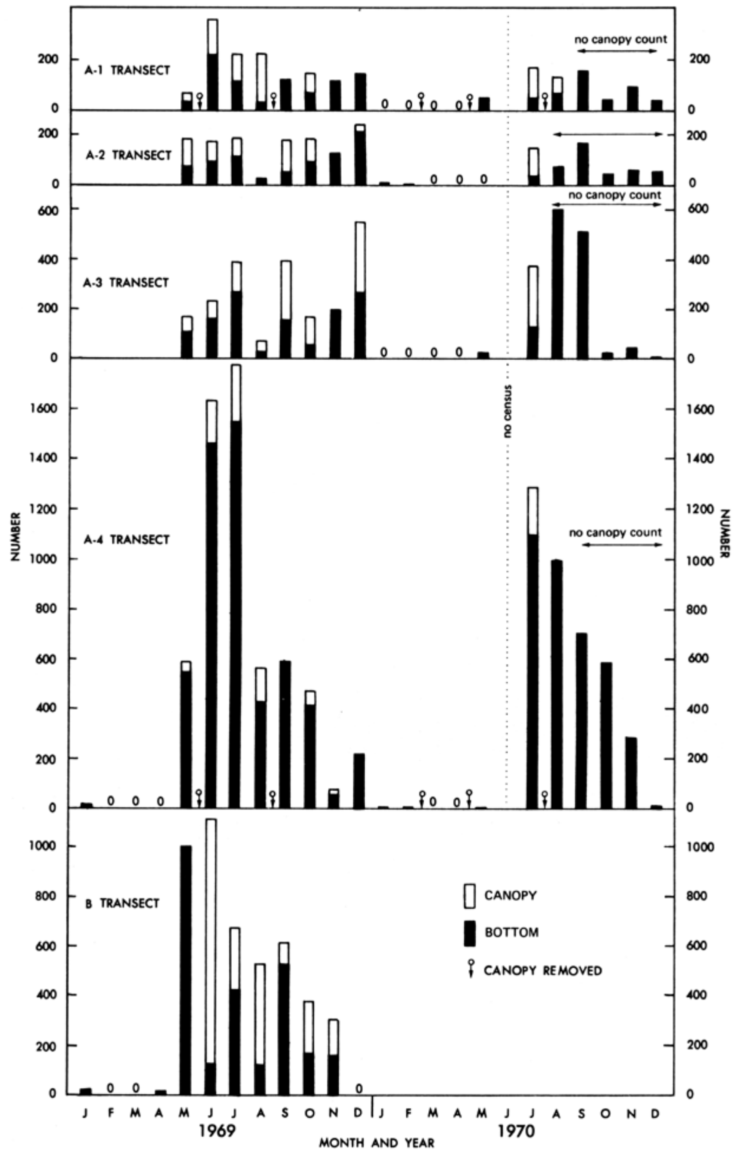


FIGURE 47. Number of juvenile rockfish by month along five transect lines, 1969 and 1970. The 1969 surveys were initiated in May. No surveys were conducted in 1970 along B transect.

FIGURE 47. Number of juvenile rockfish by month along five transect lines, 1969 and 1970. The 1969 surveys were initiated in May. No surveys were conducted in 1970 along B transect.

TABLE 21

Mean Number of Fish Per Bottom Transect Line, Percent Frequency of Occurrence, Maximum on a Transect Line, and Estimated Density from May through December 1969 Near Station A

Species	*Mean Number Per 30 m Transect*	*Percent Frequency Occurrence of 106 Counts*	*Maximum No. on a Transect*	*Fish Per Acre*	*Fish Per Hectare*
Juvenile Rockfishes	283.0	92.4	2,500	18,786.6	46,421.7
Rockfish					
Blue	4.06	46.0	30	269.5	666.0
Black-and-yellow	0.04	3.7	1	2.5	6.1
Copper	0.13	9.4	3	8.6	21.3
Kelp	1.01	47.3	10	66.3	163.6
Olive	0.28	15.0	9	18.6	45.9
Greenlings					
Kelp greenling	0.37	26.4	2	24.6	60.7
Lingcod	0.23	18.8	3	15.3	37.7
Cabezon	0.06	4.7	3	3.7	9.2
Kelp bass	4.12	48.1	50	278.8	689.0
Opaleye	1.45	21.6	50	96.3	237.9
Surfperch					
Black	0.49	33.0	4	32.5	80.4
Kelp	0.09	5.6	3	6.2	15.4
Pile	1.68	64.1	13	111.5	275.6
Rainbow	1.18	42.4	16	78.3	193.6
Rubberlip	0.40	11.3	17	26.6	65.6
Sharpnose	0.12	6.7	30	8.0	20.0
Striped	1.27	54.7	11	84.3	208.3
Senorita	2.05	9.4	90	136.1	336.3
Total Adult	19.2	—	—	1,267.7	3,132.6

*TABLE **21***

Mean Number of Fish Per Bottom Transect Line, Percent Frequency of Occurrence, Maximum on a Transect Line, and Estimated Density from May through December 1969 Near Station A

TABLE 22

Mean Number of Fish Per Bottom Transect Line, Percent Frequency of Occurrence, Maximum Observed on a Transect Line, and Estimated Density from May through December 1970 Near Station A

Species	*Mean Number Per 30 m Transect*	*Percent Frequency Occurrence of 73 Counts*	*Maximum Number on a Transect Count*	*Fish Per Acre*	*Fish Per Hectare*
Juvenile Rockfishes	284.4	93.1	1,700	18,880.2	46,653.0
Rockfishes					
Blue	5.09	60.2	50	337.9	835.0
Black-and-yellow	0.25	17.8	3	16.6	41.0
Copper	0.11	6.8	3	7.3	18.0
Kelp	1.64	63.0	4	108.7	268.3
Olive	0.05	4.1	2	3.6	8.9
Greenlings					
Kelp greenling	1.16	60.1	6	77.0	190.3
Lingcod	0.84	43.8	9	55.8	137.8
Cabezon	0.25	20.5	2	16.6	41.0
Kelp bass	2.36	45.2	27	156.0	385.5
Opaleye	0.36	6.8	20	23.9	59.1
Surfperch					
Black	1.94	72.6	8	128.8	318.2
Kelp	0.19	8.2	5	12.6	31.2
Pile	3.42	87.6	19	227.0	561.0
Rainbow	4.79	80.8	20	317.3	784.1
Rubberlip	0.74	45.2	4	49.1	121.4
Sharpnose	0.43	13.6	7	28.6	70.5
Striped	4.52	90.4	17	300.1	741.5
Senorita	2.64	27.3	50	175.3	433.1
Total Adult	30.78	-	-	2,042.2	5,045.9

*TABLE **22***

Mean Number of Fish Per Bottom Transect Line, Percent Frequency of Occurrence, Maximum Observed on a Transect Line, and Estimated Density from May through December 1970 Near Station A

per acre respectively. If all middepth and canopy fishes had been included the estimated total standing crop of fishes near Station A probably would have exceeded ½ ton per acre (1,120 kg/ha) during the May through December period in 1969 and 1970. This is not counting the mass of juvenile rockfish usually present during the summer months. In 1969 bottom estimates were 18,787 juveniles per acre and in 1970, 18,880 juveniles per acre within 6 ft. (2 m) of the bottom for the May to December period. It appears that a larger standing crop of fishes is present in central California kelp beds than in southern California although it is difficult to equate underwater techniques employed in southern California with ours. Results of transects run in southern California to determine effects of canopy removal are not directly applicable to central California kelp beds because of basic differences in the biomass between the two areas. These differences include different species composition and fish behavior, the large number of juvenile rockfishes in central California, and an apparently larger standing crop of fishes in central California. Additional work is needed to determine a more representative estimate of the standing crop of kelp bed fishes for central California by surveying more kelp beds, including Nereocystis canopies.

Much of the data collected in our 727 transect tallies will not be presented here partly because of space limitations and partly because additional information is being gathered in central California species that will add to our present knowledge of their behavior and habitat requirements. A brief summary of our tagging results, underwater observations, and catch-perhour studies is given for several of the more important sport species. Most of the blue rockfish and lingcod results have been presented, but some additional information is included here.

TABLE 23

Mean Number of Blue Rockfish Per Bottom Transect Line, Percent Frequency of Occurrence, Maximum Observed on a Transect Line and Estimated Density in 1969 and 1970 Near Station A

Survey	*Number Counts*	*Mean Number Per 30 m Transect*	*Percent Frequency of Occurrence*	*Maximum No. on a Transect Count*	*Fish Per Acre*	*Fish Per Hectare*
1969						
A1	27	1.85	29.6	20	122.8	303.5
A2	24	0.46	20.8	4	30.6	75.5
A3	26	3.16	46.3	30	209.9	518.4
A4	29	9.91	82.8	42	658.2	1,625.6
Totals	106	—	—	42	—	—
Mean	—	4.06	46.0	—	269.5	666.0
1970						
A1	18	1.17	61.0	3	77.7	191.9
A2	18	1.72	55.5	6	114.2	282.2
A3	18	1.72	44.4	8	114.2	282.2
A4	19	15.20	79.0	50	1,009.1	2,493.4
Totals	73	—	—	50	—	—
Mean	—	5.09	60.2	—	337.9	835.0

TABLE ***23***

Mean Number of Blue Rockfish Per Bottom Transect Line, Percent Frequency of Occurrence, Maximum Observed on a Transect Line and Estimated Density in 1969 and 1970 Near Station A

4.4.2.1. Blue Rockfish.

This species was the most common fish in the area at all stations and depths. Estimates of 270 and 338 fish per acre within 6 ft. (2 m) of the bottom were estimated in 1969 and 1970 respectively. The highest concentrations were at line A4 (Table 23 and Figure 48). This species is primarily a schooling species but individuals often wander short distances in kelp bed areas. In 1969 this species was observed in 82.8% of the line transect counts at line A4 but only in 20.8% of the tallies at line A2 indicating preference of certain habitat requirements present at A4 not equally present at A2. There is more sand area and less vertical relief along A2, and A4 is nearer the edge of the kelp bed, which may account for some of the differences. There was a poor correlation between hook-and-line time fishing catches and underwater observations (Figures 48 and 49). For instance, in June 1968 there was a high underwater count of adult blue rockfish near the bottom under the boat at Stations A and B but only a few fish were caught by hook-and-line. Over the years, nevertheless, the pattern of decreased numbers observed underwater during the winter period corresponded well with the lower catch-per-hour values during the February and March period.

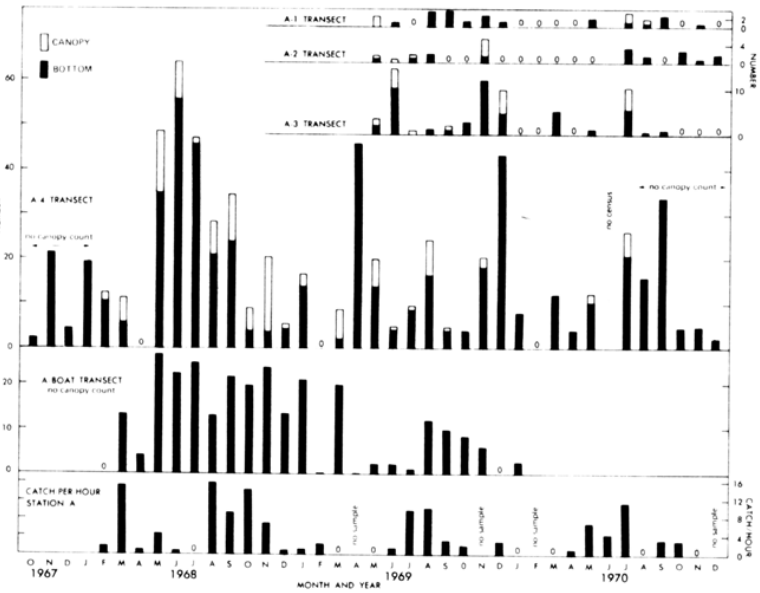


FIGURE 48. Number of blue rockfish by month along five transect lines near Station A and catch-per-hour at Station A, 1967–1970. Surveys of transects A1, A2, and A3 were initiated in May 1969. A boat transect was initiated in February 1968 and terminated in January 1970. Collection of catch-per-hour data began in February 1968.

FIGURE 48. Number of blue rockfish by month along five transect lines near Station A and catch-per-hour at Station A, 1967–1970. Surveys of transects A1, A2, and A3 were initiated in May 1969. A boat transect was initiated in February 1968 and terminated in January 1970. Collection of catch-per-hour data began in February 1968.

4.4.2.2. Black-and-Yellow Rockfish.

This species is a shallow water solitary demersal form that appeared in 3.7% and 17.8% of the transect counts in 1969 and 1970 respectively. Standing crop values were 2.5 and 16.6 fish per acre within 6 ft. (2m) of the bottom in 1969 and 1970 respectively. This species was observed at all stations but mostly at Station B line transect. None was observed under the boat at Station A, but four were caught by hook-and-line at that station. These four fish plus four others released in the Hopkins study area were not recaptured. In all, 54 black-and-yellow rockfish were tagged, eight in Hopkins study area, 41 at Chase's Reef, two at Tanker Reef, and four at Lucas Pt., Pacific Grove. Only one of these, a 293 mm TL fish,

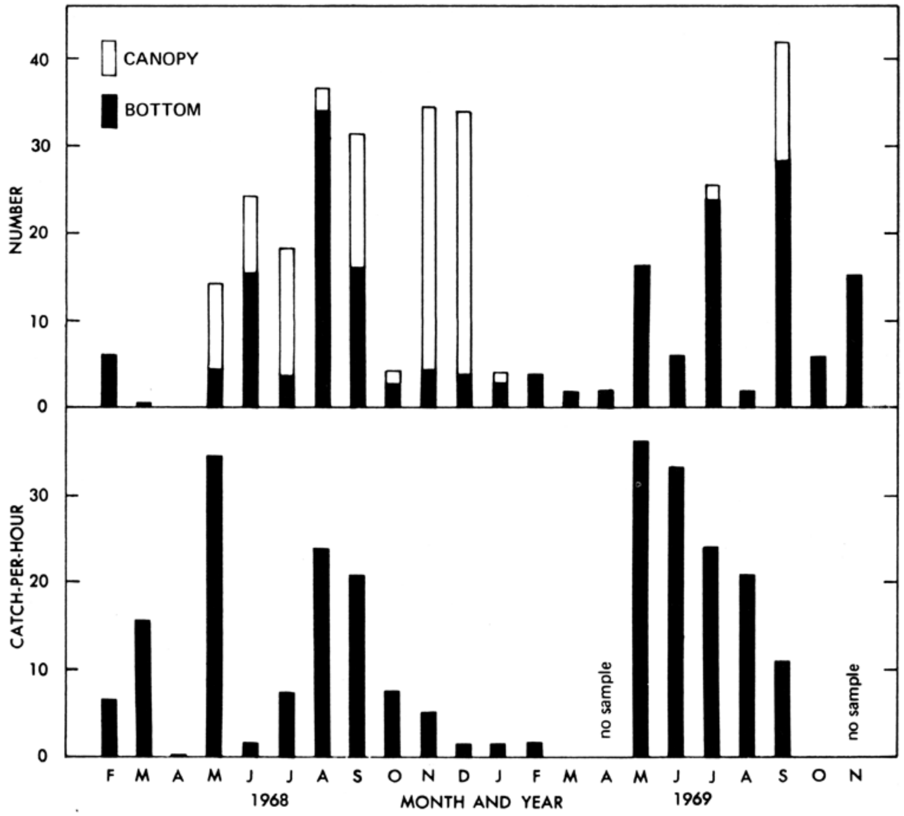


FIGURE 49. Number of blue rockfish by month at Station B transect compared to catch-per-hour values at Station B, 1968 and 1969.

FIGURE 49. Number of blue rockfish by month at Station B transect compared to catch-per-hour values at Station B, 1968 and 1969.

was recaptured. This fish had been at liberty on Chase's Reef 710 days, grew 1 mm in length, and was recaptured where released.

4.4.2.3. Copper Rockfish.

This species demonstrated a particular preference to certain areas throughout the study area. Most were seen along line A4 in rocky areas but near sand. They appeared in 34.4% of the tallies, but none was observed along lines A1, A2, and A3 in 1969 nor along lines A1 and A2 in 1970. In the Hopkins study area estimates of fish per acre within 6 ft. (2 m) of the bottom were 8.6 and 7.3 fish in 1969 and 1970 respectively. There was no season of the year in which this species was consistently more abundant. A total of 279 was tagged, 49 of which were recaptured at least once with a total of 65 recaptures. One fish was recaptured eight times by hook-and-line at Station A apparently not moving over the 2 year period in which it was being caught. In spite of this one stationary individual, members of this species wandered about more than any other rockfishes in the area. Eighty-four percent of those recaptured was at the point of release with four of the 49 recaptured moving to another reef area and four moving to an adjacent station in the Hopkins study area. The longest movement was about 1.5 miles, from Tanker Reef to Bell Buoy reef. This fish had been at liberty 6 months. Copper rockfish are relatively fast growing compared to other demersal rockfishes. Fish around 200 mm TL grew about 70 mm in a year, and a 232 mm TL fish grew 80 mm in 14 months. A 320 mm TL fish grew 22 mm in 9 months, and a 280 mm TL fish at liberty 1,100 days had grown 75 mm TL.

4.4.2.4. Kelp Rockfish.

This species is a resident fish that is seldom found outside of a kelp bed area. It is often solitary but on occasion will form aggregations in the middepth area. The maximum number seen along a 98.4 ft. (30 m) transect line was 10, and ranged from 66.3 to 108.7 fish per acre within 6 ft. (2 m) of the bottom in 1969 and 1970 respectively. Hook-and-line captures were very low, indicating this species is relatively unavailable to sport fishermen. Spearfishermen, on the other hand, find this a desirable, easily captured fish. More kelp rockfish were observed during the summer period, nevertheless, this species was observed in all months of the year and at all stations. A total of 176 was tagged of which 17 were recaptured: two by hook-and-line and 15 speared at the end of the study. None had moved to another reef, and two had moved to another station in the Hopkins study area.

4.4.2.5. Olive Rockfish.

This species was surprisingly scarce in the Hopkins study area and showed a considerable decline in abundance from 1969 to 1970. It appeared in 15.0% of the line transects in 1969 but in only 4.1% in 1970. It was observed almost entirely at line A4 and at Station B line transect. A total of 41 was tagged, none of which was recaptured. Adequate data are not at hand to determine residential or wandering behavior of this species. Those observed at line A4 were more abundant during the February to September period.

4.4.2.6. Juvenile Rockfishes.

Concentrations of these fish appeared in April and May each year and remained densely aggregated in the kelp bed area until the advent of winter storms. Blue rockfish is usually the dominant species with large numbers of juvenile shortbelly rockfish and olive rockfish occasionally present. Rockfishes identified in these juvenile aggregations besides the above species are widow rockfish, yellowtail rockfish, canary rockfish, copper rockfish, black rockfish, and speckled rockfish. Erratic movements of this mass of fish between different areas of the kelp forest are noted, but the reasons for these changes in vertical distribution and behavior are not known. Because of less variable underwater observation conditions at the bottom, data from bottom transects are more reliable than observations made on the canopy transects. Habitat preferences, whatever they are, are apparently more optimum along line A4 as there were consistently more juveniles along this line than at any other transect line (Figure 47). A total of 47,000 fish per acre within 6.5 ft. (2 m) of the bottom was estimated from line A4 counts in 1969, with the average fish per acre from all four Station A lines at 19,000 fish per acre within 6.5 ft. (2 m) of the bottom from May through December (Table 24). If these fish were distributed evenly between the surface and bottom, estimates of standing crop of juvenile rockfish in the water mass over each acre would be around 90,000 fish. Underwater observations indicate denser concentrations near the bottom and just under the surface canopy than in middepth, thus a more realistic estimate of the standing crop of these fishes near Station A would be from 50,000 to 60,000 per acre from May through December. Dives in other kelp bed areas in central California indicate the Hopkins study area may have a higher concentration of these juveniles than other areas except possibly the

Monterey breakwater kelp bed. Further work is needed to attain more representative standing crop estimates of these mass aggregations throughout central California.

TABLE 24

Mean Number of Juvenile Rockfishes Per Bottom Transect Line, Percent Frequency of Occurrence, Maximum Observed on a Transect Line, and Estimated Density, May through December in 1969 and 1970 Near Station A

Survey	*Number Counts*	*Mean Number Per 30 m Transect*	*Percent Frequency of Occurrence*	*Maximum No. on a Transect Count*	*Fish Per Acre*	*Fish Per Hectare*
1969						
A1	27	111.4	100.0	415	7,393.4	18,269.1
A2	24	83.8	95.8	283	5,565.1	13,751.5
A3	26	169.4	84.6	440	11,244.5	27,785.1
A4	29	709.5	89.6	2,500	47,097.6	116,378.2
Totals	106	—	—	2,500	—	—
Mean	—	283.0	92.4	—	18,786.6	46,421.7
1970						
A1	18	71.2	88.8	327	4,724.7	11,674.7
A2	18	74.8	100.0	220	4,964.4	12,266.9
A3	18	262.6	94.4	580	17,430.3	43,070.3
A4	19	705.7	89.4	1,700	46,847.3	115,759.8
Totals	73	—	—	1,700	—	—
Mean	—	284.4	93.1	—	18,880.2	46,653.0

*TABLE **24***

Mean Number of Juvenile Rockfishes Per Bottom Transect Line, Percent Frequency of Occurrence, Maximum Observed on a Transect Line, and Estimated Density, May through December in 1969 and 1970 Near Station A

4.4.2.7. *Kelp Greenling*.

While this species was one of the more commonly observed demersal species, it was not abundant. There was an apparent increase in numbers of this species from 1969 to 1970 with 24.6 and 77.0 fish per acre within 6.5 ft. (2 m) of the bottom estimated for 1969 and 1970 respectively. There were never more than six individuals observed along any of the 98.4 ft. (30 m) transect lines, and they appeared in 26.4% and 60.1% of the transect counts in 1969 and 1970 respectively. A total of 63 was tagged, three of which were recaptured. The returns were from the 27 released in Hopkins study area. A fish released at 195 mm TL at liberty 144 days grew 35 mm; a 350 mm TL fish at liberty 670 days grew 20 mm; and a 303 mm TL fish at liberty 1,163 days grew 61 mm. The latter fish was a male, 6 years of age when recaptured. There was a significant increase in numbers sighted along line A4 during the August through January period.

4.4.2.8. *Lingcod.*

The residential as well as migratory behavior of this species has been described in the lingcod section. As indicated by both commercial and sport catches, there was a significant increase in lingcod numbers in 1970 with nearly four times as many observed in the Hopkins study area in 1970 as in 1969 (Table 25). The heaviest concentrations appeared along line A4 with an average of 91 lingcod per acre estimated in 1970. At line A4 residential lingcod were sighted in all months of the year but an influx appeared from September to January. No egg-nests were observed along the transect lines. Tagging results are discussed in the lingcod section.

4.4.2.9. *Cabezon.*

This solitary, demersal species was one of the more uncommon species encountered along the transects, appearing in only 4.7 and 20.5% of the transect tallies in 1969 and 1970 respectively. A total of 86 cabezon was tagged, nine of which were recaptured. Thirty of these tag releases were in the Hopkins study area and of these, seven were recaptured

TABLE 25

Mean Number of Lingcod Per Bottom Transect Line, Percent Frequency of Occurrence, Maximum Observed on a Transect Line, and Estimated Density, in 1969 and 1970 Near Station A

Survey	Number Counts	Mean Number Per 30 m Transect	Percent Frequency of Occurrence	Maximum No. on a Transect Count	Fish Per Acre	Fish Per Hectare
1969						
A1	27	0.22	22.2	1	14.6	36.1
A2	24	0.08	8.3	1	5.5	13.6
A3	26	0.08	7.6	1	5.1	12.5
A4	29	0.48	34.4	3	31.9	78.7
Totals	106	—	—	3	—	—
Mean	—	0.23	18.8	—	15.3	37.7
1970						
A1	18	0.44	22.2	5	29.2	72.2
A2	18	1.00	55.5	3	66.4	164.0
A3	18	0.50	38.8	2	29.9	82.0
A4	19	1.37	57.8	9	91.0	224.7
Totals	73	—	—	9	—	—
Mean	—	0.84	43.8	—	55.8	137.8

*TABLE **25** Mean Number of Lingcod Per Bottom Transect Line, Percent Frequency of Occurrence, Maximum Observed on a Transect Line, and Estimated Density, in 1969 and 1970 Near Station A*

at the point of release and one moved from Station A to Station D. Divers repeatedly observed tagged individuals at the same locations month after month, indicating a strong residential behavior of adults. There were no apparent seasonal fluctuations along any of the transect lines as was noted for lingcod, although greater numbers of cabezon were observed in the fall of 1970.

4.4.2.10. *Kelp Bass.*

The highest fish per acre value within 6.5 ft. (2 m) of the bottom of 1969 for the Station A area transects was for kelp bass. This estimation is probably disproportionately high and may not represent the population density throughout the kelp bed. Underwater observations in many areas in central California and throughout the Hopkins study area have not revealed a concentration of kelp bass comparable to that along line A4. A few individuals have been noted off Santa Cruz and along Cannery Row but not in numbers observed near Station A. Consistent observation of this small aggregation lends evidence that this fish is also nonmigratory and is more or less residential as was noted by Young (1963) and Limbaugh (1955). Even though it is felt these fish are residents of the Hopkins study area, only a few individuals were observed from February through April each year. A total of 43 kelp bass was tagged in the Hopkins study area and one was tagged at Tanker Reef. One was recaptured in the Hopkins study area at the point of release that had been at liberty about 1 month.

4.4.2.11. *Opaleye.*

This typically southern California herbivore was also relatively abundant in the Hopkins study area. As with kelp bass, opaleye appears to be more abundant in our study area than elsewhere in Central California, although skindivers occasionally take this species along Cannery Row. Only three were tagged at Station A and none was recaptured. There was no evidence of kelp grazing in areas where these fish were concentrated. Our estimates of 96.3 fish per acre within 6.5 ft. (2 m) of the bottom in 1969 and 23.9 fish per acre in 1970 indicate a relatively high concentration, surpassing several southern California estimates. Quast (1968) estimated from 0.4 to 66.5 opaleye per acre in his southern California kelp bed experiments.

4.4.2.12. *Black Surfperch.*

This species is usually solitary but often forms aggregations in certain areas. It appears to be strongly residential and was observed throughout the year at most transects. This is one of the few species that was not more abundant at line A4, with the largest counts made at line A1. A total of 48 tagged fish was released in the Hopkins study area, four of which were recaptured at the point of release. A fish at liberty 304 days grew from 217 mm TL to 247 mm TL, and a 315 mm TL fish at liberty 325 days grew only 5 mm indicating a relatively slow growth rate. There was a slight increase in numbers observed during the fall period; however, there was not a significant decrease in winter observations as with most other kelp bed fishes. This was one of the more common species encountered with 32.5 and 128.8 fish per acre within 6.5 ft. (2 m) of the bottom estimated for 1969 and 1970 respectively (Table 26).

TABLE 26

Mean Number of Black Surfperch Per Bottom Transect Line, Percent Frequency of Occurrence, Maximum Observed on a Transect Line, and Estimated Density in 1969 and 1970 Near Station A

Survey	*Number Counts*	*Mean Number Per 30 m Transect*	*Percent Frequency of Occurrence*	*Maximum No. on a Transect Count*	*Fish Per Acre*	*Fish Per Hectare*
1969						
A1	27	0.70	48.2	3	46.5	114.8
A2	24	0.37	25.0	2	24.6	60.7
A3	26	0.42	26.9	4	27.9	68.9
A4	29	0.45	31.0	4	29.9	73.8
Totals	106	—	—	4	—	—
Mean	—	0.49	33.0	—	32.5	80.4
1970						
A1	18	2.56	83.3	7	170.0	419.9
A2	18	2.56	66.6	8	170.0	419.9
A3	18	1.36	72.2	6	90.3	223.1
A4	19	1.37	68.4	4	91.0	224.7
Totals	73	—	—	8	—	—
Mean	—	1.94	72.6	—	128.8	318.2

*TABLE **26***

Mean Number of Black Surfperch Per Bottom Transect Line, Percent Frequency of Occurrence, Maximum Observed on a Transect Line, and Estimated Density in 1969 and 1970 Near Station A

4.4.2.13. *Kelp Surfperch.*

This is the only surfperch observed on the transect lines that is typically a canopy dwelling species. Only a few were observed on the bottom transects with the highest concentrations appearing during the September to November period. These fish were too small to tag.

4.4.2.14. *Pile Surfperch.*

This is primarily a residential fish that is oriented more to the bottom than to the surface canopy. It is relatively unavailable to hook-and-line fishermen but is commonly taken by spearfishermen. Underwater sightings were made of this species throughout the year with a slight increase in abundance from August through October. Pile surfperch is one of the more abundant kelp bed fishes, with estimates of 111.5 and 227.0 fish per acre within 6.5 ft. (2 m) of the bottom in 1969 and 1970 respectively. A total of 29 was tagged, one of which was recaptured at the point of release 8 months later. This species aggregates in the fall months but is often solitary or in small groups of from three to 50 individuals. The maximum observed in any 98.4 ft. (30 m) transect was 19.

4.4.2.15. *Rainbow Surfperch.*

This species is almost entirely restricted to the bottom where it is commonly found around kelp holdfasts. This species showed a marked increase in numbers from 1969 to 1970 with 78.3 and 317.3 fish per acre within 6.5 ft. (2 m) of the bottom estimated for 1969 and 1970 respectively. As with black surfperch, rainbow surfperch was not more abundant at line A4, being more or less evenly distributed over the entire understory area. There were significantly more observed from July through November at all transect lines. A total of 24 was tagged but none was recaptured.

4.4.2.16. *Rubberlip Surfperch.*

This large surfperch appeared erratically at all transect lines and trends were not evident. Most of the observations were along lines A2 and A3 and ranged from 26.6 per acre within 6.5 ft. (2 m) of the bottom in 1969 to 49.1 fish per acre in 1970. None was observed at Station B transect line thus the Station A transect estimates are probably higher than would be representative for the entire reef area. of the seven tagged, none was recaptured. Hook-and-line captures in the Moss Landing Harbor area indicate a seasonal migration into the inshore area during the springtime spawning period. This strong seasonal change was not noted in our observations at the Hopkins study area, suggesting it may not be an important spawning area, although juvenile rubberlip surfperch were observed there.

4.4.2.17. *Sharpnose Surfperch.*

This species was observed only two times in 1968 but appeared during nine months of the year in 1969 and during 5 months of 1970. In our 1958–61 assessment survey this species was rarely seen but in the 1966 assessment survey it was one of the more common species in the Monterey pier catch. Lea (1972) included our project findings in his summary of the apparent "return" of this species that was reported to be common in the late 1800's in California but was rarely seen for many years until the 1960's. Apparently this increased abundance is occurring in the Hopkins study area as well. This species is typically a deeper water species that migrates each year into shallower waters to spawn. In the kelp bed areas it was more commonly observed near the surface canopy with bottom estimates ranging from 8.0 fish per acre within 6.5 ft. (2 m) of the bottom in 1969 to 7.8 fish per acre in 1970. Twenty were tagged but none was recaptured.

TABLE 27

Mean Number of Striped Surfperch Per Bottom Transect Line, Percent Frequency of Occurrence, Maximum Observed on a Transect Line, and Estimated Density in 1969 and 1970 Near Station A

Survey	*Number Counts*	*Mean Number Per 30 m Transect*	*Percent Frequency of Occurrence*	*Maximum No. on a Transect Count*	*Fish Per Acre*	*Fish Per Hectare*
1969						
A1	27	1.04	52.0	4	69.0	170.6
A2	24	0.46	20.8	3	30.5	75.5
A3	26	1.23	65.5	4	81.7	201.8
A4	29	2.21	75.8	11	146.7	362.8
Totals	106	—	—	11	—	—
Mean	—	1.27	54.7	—	84.3	208.3
1970						
A1	18	4.00	94.4	14	265.5	656.2
A2	18	3.83	83.5	10	254.3	628.3
A3	18	3.94	88.9	9	261.6	646.3
A4	19	6.20	94.7	17	411.6	1,017.1
Totals	73	—	—	17	—	—
Mean	—	4.52	90.4	—	300.1	741.5

*TABLE **27***

Mean Number of Striped Surfperch Per Bottom Transect Line, Percent Frequency of Occurrence, Maximum Observed on a Transect Line, and Estimated Density in 1969 and 1970 Near Station A

4.4.2.18. *Striped Surfperch.*

This was the most consistently observed surfperch in the study area ranking third in abundance of all fishes observed in 1970, with an estimated 84.3 and 300.1 fish per acre within 6.5 ft. (2 m) of the bottom in 1969 and 1970 respectively (Table 27). Monthly counts depict changing behavior patterns discernible at all transect lines (Figure 46). Tagging data indicate this species is primarily residential. A total of 231 was tagged, of which 28 individual fish were recaptured a total of 38 times. None had moved to nearby reefs and only three of the 28 individual fish moved between stations, two from Station D to Station A, and one from Station B to Station A. There is a spring spawning period (March through May); however, more were observed during fall months, indicating spawning may have been in areas shallower than the depth of our transect lines. Hook-and-line fishermen from shore commonly catch this species during the spring spawning period, indicating a local movement of this species into shallower subtidal areas during the spawning period and returning to the deeper kelp bed and rocky zones during the rest of the year. Growth rates indicated by tagging data appear to be quite slow; in fact, 11 of the 28 recaptures were shorter than when originally released indicating some anomalous growth due to tagging or because of some possible seasonal total length variation.

4.4.2.19. *Senorita.*

This species is another southern California form that occurs in large numbers in the Monterey and Santa Cruz areas. It is primarily a canopy species but will on occasion remain near the bottom. Sightings were quite erratic, indicating dense schooling and rapid movements. Five senorita were tagged, none of which was recaptured.

4.4.2.20. *Other Species.*

Other species observed were black rockfish, brown rockfish, grass rockfish, canary rockfish, vermilion rockfish, bocaccio, chilipepper, China rockfish, jacksmelt, painted greenling, blacksmith, halfmoon, wolf-eel, monkeyface-eel, pipefishes, and Pacific bonito. Some of these were tagged (Table 28), and a list of all species observed is given in Appendix II. These were present in relatively small numbers, and insufficient observations or tagging data are available to relate in detail here. of the five Pacific bonito released off Pacific Grove on September 30, 1970, one was recaptured off Ventura 100 days later.

5. GIANT KELP, MACROCYSTIS, EXPERIMENTS

Research on Macrocystis has yielded taxonomic studies (Setchell, 1932; Womersley, 1954; Neushul, 1959), growth and other physiological studies (Brandt, 1923; Moore, 1943; Haxo and Neushul, 1958; Neushul, 1959; Clendenning, 1960; Neushul and Haxo, 1963; North and Hubbs, 1968; North, 1971), and enumeration of organisms in kelp beds and some of the ecological relationships of these organisms (Andrews, 1945; Smith, 1944; Limbaugh, 1955; Ghelardi, 1960; McLean, 1962; Carlisle, Turner, and Ebert, 1964; North and Hubbs, 1968; North, 1971). Studies were conducted on the effects of canopy removal in southern California fish distribution (Quast, 1968; Davies, 1968) and Clendenning (1968) investigated the general relationship of kelp harvesting and density of canopies in southern California. Several important aspects of kelp growth and interactions of fish and invertebrates in the canopy area remain unknown. These include the effects of periodic canopy removal on the growth of haptera and consequent

TABLE 28

Number of Fish Tagged and Recaptured Near Monterey, 1967–1971

Species	*Hopkins Marine Life Refuge*	*Cannery Row*	*Hopkins Reef*	*Chase's Reef*	*Tanker Reef*	*Other Reefs*	*Total Tagged*	*Number Recaptured*
Jacksmelt	8	—	—	—	7	—	15	0
Rockfish								
Black	32	1	7	76	22	2	140	3
Black-and-Yellow	7	—	—	41	2	4	54	1
Blue	2,083	27	81	149	139	29	2,508	423
Bocaccio	1	—	—	3	—	5	9	0
Brown	—	1	—	—	7	—	8	1
Canary	—	—	—	—	10	2	12	1
Chilipepper	—	—	—	—	—	1	1	0
China	—	—	—	1	—	—	1	0
Copper	108	40	31	[illegible]	78	11	279	49
Gopher	4	—	3		2	1	24	0
Kelp	135	5	19		2	4	176	17
Olive	16	—	5	20	—	—	41	0
Vermilion	1	—	—	1	8	—	10	1
Yellowtail	8	—	—	—	2	—	10	0
Greenlings								
Kelp greenling	27	2	4	22	3	5	63	2
Lingcod	122	—	29	35	41	31	258	14
Sculpins								
Brown Irish lord	—	—	—	—	1	—	1	0
Buffalo sculpin	1	—	—	—	—	—	1	0
Cabezon	39	—	3	28	13	3	86	9
Kelp bass	41	—	2	—	1	—	44	1
Ocean whitefish	—	—	—	—	1	—	1	0
Opaleye	3	—	—	—	—	—	3	0
Surfperch								
Black	45	—	—	2	1	—	48	4
Pile	18	—	10	1	—	—	29	1
Rainbow	23	1	—	—	—	—	24	0
Rubberlip	7	—	—	—	—	—	7	0
Sharpnose	19	—	—	1	—	—	20	0
Striped	205	—	—	19	3	4	231	28
White	2	—	—	—	—	—	2	0
Blacksmith	7	—	—	—	—	—	7	0
Senorita	4	—	—	1	—	—	5	0
Wolf-eel	1	—	1	—	1	—	3	0
Monkeyface-eel	1	—	—	—	—	—	1	0
Pacific bonito	—	—	—	—	—	5	5	1
Rock sole	—	—	—	—	—	1	1	0
Totals	2,968	77	195	436	344	108	4,128	556

TABLE ***28***

Number of Fish Tagged and Recaptured Near Monterey, 1967–1971

changes in efficiency of the holdfast, the possible change in size or age composition of giant kelp plants due to canopy removal, and the changes in species composition of the various kelp plants in a shallow rocky reef due to man's activities. The effect of natural and artificial canopy removal on vertical and horizontal movements of fish, especially those in the canopy, has been only superficially investigated in southern California and in our central California pilot study presented in the previous section.

In view of our lack of knowledge of the above parameters and in response to the onset of routine commercial kelp harvesting north of Pt. Conception in 1968, a pilot study was initiated in 1969 to determine whether some of the little known conditions mentioned above could result in ecological and environmental damage to central California kelp beds. This study was not designed to incorporate the long term and detailed physiological and life history studies conducted in southern California, but was designed to determine, in the period of 2 years, whether canopy harvesting would result in any obvious disbalance of kelp bed ecology. Unexpected results of the first 2 years' work necessitated additional research in 1971 on haptera growth. An interesting ecological interaction has recently been reported involving the alleged increase in Macrocystis growth due to sea otter predation on benthic invertebrate herbivores (McLean, 1962; North, 1965, 1971; Leighton, Jones and North, 1965; Ebert, 1968a; Faro, 1969). A review of these interactions is presented.

5.1. KELP BEDS OF CENTRAL CALIFORNIA

Three or possibly four species of large brown algae form dense surface canopies in central California. The most easily recognized and most extensive north of Monterey is the annual bull kelp, Nereocystis luetkeana, which is endemic along the west coast of North America from Pt. Conception to Shumagin Isl., Alaska. There are two or possibly three species of Macrocystis in central California. M. integrifolia is found from Monterey to Sitka, Alaska, but the large giant kelp canopies from Half Moon Bay southward are of the giant kelp, M. pyrifera, or possibly M. angustifolia. The taxonomic separation of M. pyrifera and M. angustifolia is subtle, involving holdfast structure, and for the purposes of this discussion all central California Macrocystis other than M. integrifolia is considered M. pyrifera since no plants assignable to M. angustifolia were encountered in our study area. M. integrifolia also is found off Peru (Neushul, 1971), and M. pyrifera is found on both coasts of southern South America, New Zealand and South Africa.

In central California giant kelp beds are typically sharply defined, especially on the seaward edges, forming narrow bands paralleling the shoreline due to the general steepness of the shoreline limiting kelp growth to a relatively narrow euphotic rocky zone. In contrast, off southern California, and in particular from Ventura to Pt. Arguello, shallow rocky shelf and stabilized sandy bottom areas extend well offshore, creating conditions for extensive Macrocystis growth.

There are approximately 70 miles^2 (112.7 km^2) of giant kelp canopy from the Mexican border to Half Moon Bay. of this, 15.5 miles^2 (25 km^2), or 22.4% of the total, are north of Pt. Arguello. of the total 70 miles^2 (112.7 km^2) about 50 (80.5 km^2), 72%, are in areas set aside for exclusive leasing by individual commercial kelp harvesting companies.

The remaining 20 miles^2 (32.2 km^2), or 28% of the total, are in "open" areas that may be harvested by any company possessing a kelp harvesting permit. The principal kelp harvesting restrictions (Title 14, Sec. 165, Fish and Game Commission) for Macrocystis are: a commercial harvester must obtain a permit issued by the Fish and Game Commission, the cutting blades cannot be lower than 4 ft. (1.2 m) below the surface, all kelp cut during a harvesting operation must be taken aboard the harvesting vessel, and drift kelp may be harvested. One of the restrictions imposed on areas leased north of Pt. Arguello is that no more than 5% Nereocystis can be present in any load of kelp cut in the leased harvesting beds. There are no restrictions other than the general harvesting restrictions listed above for open harvesting beds north of Pt. Arguello. There is a tonnage fee submitted to the state for each ton of kelp harvested as well as leasing fees for each harvesting lease, and each company submits a report of the tonnage removed from each kelp harvesting bed. Kelp harvesting beds are delineated by geographic boundaries and may contain several large individual kelp beds. There are no restrictions on the tonnage that can be removed each year from each harvesting bed nor are there restrictions on the frequency of cutting or the amount that can be taken above 4 ft. (1.2 m) from any individual kelp bed, i.e., a contiguous growth of kelp.

Our study area was located in the isolated kelp bed covering about 12 acres (4.9 ha) in the Hopkins Marine Life Refuge (Figure 38). Intensive fish tagging and underwater transect data were initiated in 1967, thus considerable information on the substrate and distribution of fish was known before kelp cutting experiments were initiated. There were four studies completed: (1) determination of growth rates of individual fronds; (2) effect on haptera growth by canopy removal; (3) a listing and estimate of numbers per ton of macro-organisms collected in the kelp canopy; and (4) changes in numbers and distribution of fish due to canopy removal. Results of the latter study are given in the previous section on underwater transect results.

5.2. GROWTH OF MACROCYSTIS FRONDS

Kelp tagging studies were conducted to determine the seasonal growth rates of individual Macrocystis fronds, to determine if fronds from an area with a naturally developing canopy grew at a different rate than fronds in an area where the canopy was periodically cut, and to assess the amount of growth of cut fronds.

Numbered tags were made of white or yellow plastic cut to about 2 inches square. A small hole was punched in one corner of the tag and a 0.5 by 3 inch (1.22 by 7.6 cm) piece of innertube rubber was then looped around the base of a stipe and the plastic tag passed through a slit in the rubber forming a loose loop around the stipe. No injuries attributable to kelp tagging were noted on the stipes.

Kelp plants to be tagged were first located near a familiar underwater landmark. From this landmark, a white plastic clothesline was run to the holdfasts of each plant. This procedure seemed advisable after the first tagging attempt, when several plants with tagged fronds could not be relocated. The clothesline simplified relocation of the tagged fronds, especially when visibility was low.

Frond measuring was conducted at the holdfast by SCUBA divers using a 50 ft. (15.2 m) plastic clothesline marked at 6 inch (15.2 cm) intervals. A brass clip attached at the beginning of the line was fastened to the kelp holdfast. The other end of the line floated to the surface and the line and the frond were pulled down together and measurements recorded. There was no pressure injury to the canopy pneumatocysts being submerged to 30 ft. (9.1 m) depth for this short period of time.

Beginning in September 1969 and continuing through August 1970, four series of kelp tagging experiments were conducted. Prior to each series of kelp taggings, except for the third series, about 1.25 acres (0.51 ha) of the kelp canopy were removed. Fronds were tagged in the cut and uncut areas. In the first two series about half of the fronds tagged in the cut area were uncut fronds. In series three and four, only fronds with apical blades (uncut) were tagged in both cut and uncut sections of the kelp bed. An additional series of 20 fronds that had been cut near the surface was tagged to check for possible regeneration of cut fronds.

Kelp fronds increase in length by intercalary growth. The apical growing tip is the most important feature of the kelp frond for it furnishes the material for future growth. There is continual elongation of a growing kelp stipe, especially near the growing tip. The amount of elongation decreases with the distance from the growing tip as well as with the increase in age of the kelp frond. As a result, when the canopy is cut, only a small percentage of the new canopy will be composed of cut fronds that continued to elongate. Elongation of cut fronds averaged around 1 inch (2.54 cm) per day for a short period after cutting. After a cutting, the new, dense canopy is subsequently composed of young fronds that were below the level of cutting. Regeneration of injured fronds has been observed in Macrocystis in New Zealand (Moore, 1943), however, no regeneration of cut fronds was observed in our study nor in the southern California investigations (North and Hubbs, 1968).

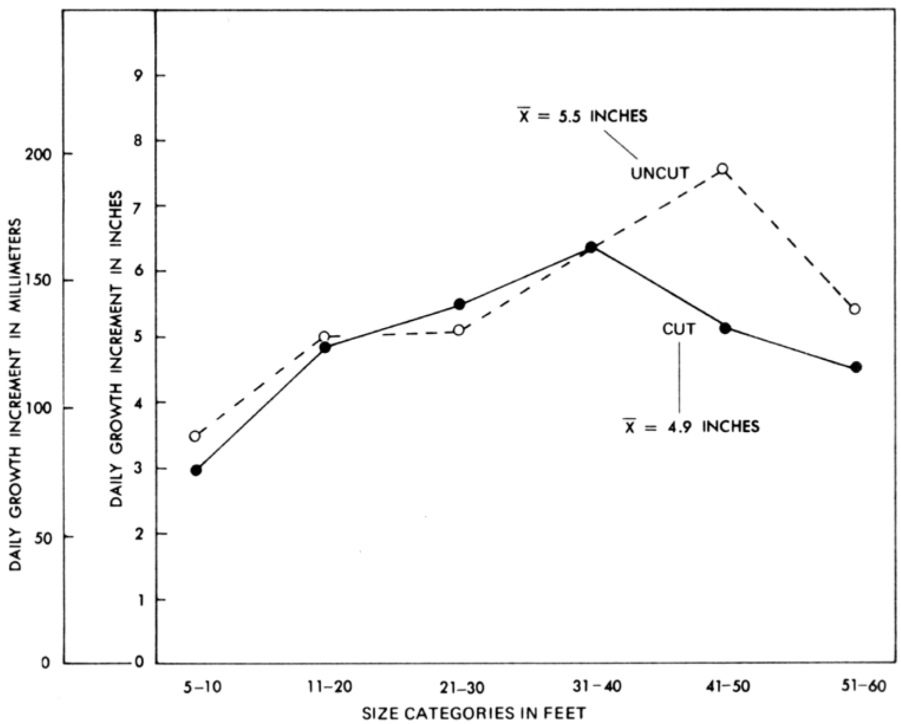


FIGURE 50. Average daily growth of kelp fronds by 10 ft. (3.05 m) intervals in uncut and cut areas of the study area.

FIGURE 50. Average daily growth of kelp fronds by 10 ft. (3.05 m) intervals in uncut and cut areas of the study area.

Although measurements of kelp fronds in some size classes are limited, they are still sufficient to show overall trends. The growth rate of fronds, in both cut and uncut areas, increased until the fronds reached about 50 ft. (15.2 m) in length, after which growth became slower (Tables 29 and 30; Figure 50). As the fronds increase in length the blades also increase in size. In older fronds many of the basal blades were missing, and from our observations it seems that when the growing tip of a tagged frond became senescent it was only a short time before the frond began to deteriorate. The smallest fronds which we tagged were 4 ft. (1.2 m) in length, and it took about 4 months for these fronds to reach their maximum length during the fast growing period. Total maximum life of a Macrocystis frond in the Monterey Bay area is within the 6 month maximum for Macrocystis fronds in southern California (North and Hubbs, 1968).

Macrocystis growth rates varied considerably during the period of our kelp tagging. In general, kelp fronds grew fastest during the spring, summer, and early fall months and slowest in late fall and winter (Tables 29 and 30). From April through September the mean growth rate of tagged fronds in the uncut area was greater than 5 inches (12.7 cm) per day. In November

TABLE 29

Mean Growth Rate in Inches per Day of Giant Kelp by Size Group and Period in Uncut Area of Kelp Bed

Period	*Size Group in Feet*					
	5–10	*10.5–20*	*20.5–30*	*30.5–40*	*40.5–50*	*50.5–60*
Sep. 26–Oct. 20	2.8 (1) •	4.6 (2)	4.8 (2)	5.8 (1)		
Oct. 20–Nov. 19		4.0 (1)	3.2 (2)	5.0 (1)		
Nov. 19–Dec. 4			3.0 (2)			
Feb. 11–Mar. 19	3.9 (2)	3.7 (7)	3.2 (5)			
Mar. 19–Apr. 16			5.6 (5)			
Apr. 17–Apr. 28	4.0 (7)	6.0 (8)	7.5 (3)	8.2 (1)		
Apr. 28–May 11	3.2 (1)	4.8 (10)	6.1 (5)	7.4 (2)		
May 11–May 27		5.1 (5)	6.1 (8)	6.3 (4)	5.6 (1)	
May 27–June 18			6.0 (6)	5.7 (4)	7.9 (4)	6.5 (1)
June 18–July 7				6.6 (3)	9.8 (6)	4.4 (6)
Aug. 28–Sep. 15	3.6 (14)	5.3 (6)	5.8 (2)	5.3 (1)		
Sep. 15–Sep. 29	3.6 (2)	5.9 (13)	5.5 (4)	9.0 (1)	4.3 (1)	
Sep. 29–Oct. 16		5.9 (6)	4.5 (10)	5.8 (3)	4.9 (2)	
Oct. 16–Oct. 29			4.8 (9)	5.1 (8)	5.5 (1)	

• Figure in parentheses is the number of measurements used to determine the mean growth rate.

*TABLE **29***

Mean Growth Rate in Inches per Day of Giant Kelp by Size Group and Period in Uncut Area of Kelp Bed

TABLE 30

Mean Growth Rate in Inches per Day of Giant Kelp by Size Group and Period in Cut Area of Kelp Bed

Period	*Size Group in Feet*					
	5–10	*10.5–20*	*20.5–30*	*30.5–40*	*40.5–50*	*50.5–60*
Sep. 18–Sep. 26	2.2 (1) •		5.3 (2)	6.3 (3)		
Sep. 26–Oct. 21		6.8 (2)		8.6 (1)	7.3 (3)	
Oct. 21–Nov. 10			6.9 (2)	6.6 (1)	4.5 (1)	4.5 (1)
Nov. 10–Dec. 4				3.1 (2)	0.8 (1)	
Feb. 10–Mar. 19	2.4 (1)	5.0 (5)	3.4 (4)	3.8 (2)		
Mar. 19–Apr. 6			7.3 (4)	6.9 (3)		
Apr. 6–Apr. 16				12.8 (3)		
Apr. 17–Apr. 27	3.4 (5)	6.1 (7)	6.2 (4)	7.2 (4)		
Apr. 27–May 11		4.4 (8)	4.3 (3)			
May 11–May 27		3.0 (2)	4.9 (5)	2.0 (2)		
May 27–June 17		2.9 (1)	5.4 (5)	6.1 (2)		
June 17–July 7				5.5 (4)	8.0 (2)	
Aug. 27–Sep. 15	4.2 (8)	7.6 (9)	6.8 (6)	6.6 (1)		
Sep. 15–Sep. 29		7.0 (8)	6.7 (9)	7.5 (5)	6.0 (1)	
Sep. 29–Oct. 16		1.1 (1)	6.2 (8)	7.5 (6)	5.8 (5)	
Oct. 16–Oct. 29			2.8 (1)	4.8 (2)	3.7 (4)	

• Figure in parentheses is the number of measurements used to determine the mean growth rate.

*TABLE **30***

Mean Growth Rate in Inches per Day of Giant Kelp by Size Group and Period in Cut Area of Kelp Bed

the mean growth rate dropped to 3 inches (7.6 cm) per day. No measurements were taken from December 4, 1969, until February 11, 1970, but the mean growth rate would probably be somewhere between 1 and 3 inches (2.54–7.6 cm) per day during this period. From February 11 to March 19, 1970, the mean growth rate was 3.6 inches (9.1 cm) per day (Table 29). Growth rates of tagged fronds increased rapidly through March, with the fastest growth rates measured in April.

Macrocystis growth rates in the cut area followed the same general rate of fronds in the uncut section except that in the cut area growth rates were more variable (Figure 51). Both the maximum mean growth rate of a single frond, 12.8 inches (32.5 cm) per day, and the minimum mean growth rate, 1.1 inches (2.8 cm) per day, were recorded in the cut area. Overall, there appeared to be little difference in the growth rate of Macrocystis fronds in the cut or uncut areas.

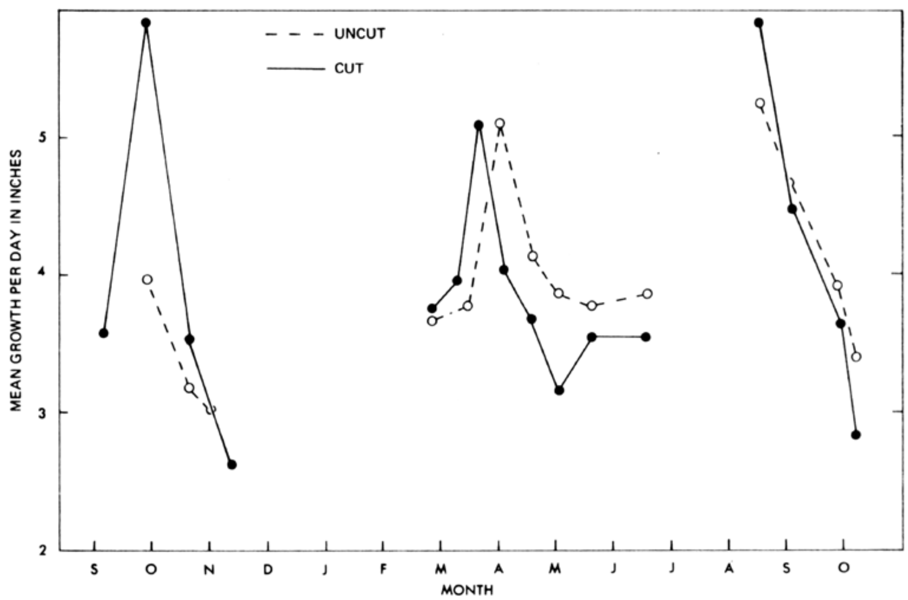


FIGURE 51. Average daily growth in inches by month in cut and uncut areas, September 1969 through October 1970.

FIGURE 51. Average daily growth in inches by month in cut and uncut areas, September 1969 through October 1970.

Few fronds that were mature in fall in the Monterey Bay area survive to springtime. Winter storms and slower growth rates result in a depletion of much of the kelp canopy, depending upon degree of exposure to heavy swells. During winter months few if any senescent fronds can be found on plants in exposed areas. of the 50 kelp fronds tagged in February, only 24 were left after 5 weeks. Only nine of these 24 tagged fronds remained another 4 weeks. Losses of tagged fronds decreased considerably from mid-April through September. When a frond became senescent the lower blades deteriorated first and were lost, and when there were insufficient pneumatocysts to keep it afloat, the stipe would sink to the bottom to decompose. Occasionally a senescent stipe would break near the bottom and float away, and during heavy storms entire kelp plants would be uprooted and floated away.

Little if any loss of tagged fronds resulted from grazing of fish or invertebrates. Sea urchins were sparse in the area and were almost entirely in deep interstices where they feed primarily on drift kelp. The older blades of some fronds become encrusted with bryozoans, and an isopod, Idothea resecata, was abundant but appeared to have little effect on kelp plants.

5.3. ESTIMATES OF MACRO-ORGANISMS PER TON OF KELP CANOPY

An estimation of the number of macro-organisms (larger than about 10 mm in length or diameter) per ton and per acre of kelp canopy was determined by collecting all fish and invertebrates from a section of the canopy cut at about 10 ft. (3 m) below the surface. This mass of kelp was gently floated or allowed to drift over a 20 X 30 foot (6 X 9 m) burlap blanket. One side of the blanket was attached to the boat and the other three sides were attached to poles suspended above the water on floats preventing mobile organisms from escaping. The mass of floating kelp fronds was held in the blanket while each frond was removed and inspected. In calm weather nearly all but the largest fish and a few snails that dropped off during the cutting operation were captured, but when operating the blanket in choppy seas more organisms may have escaped.

Each frond was closely examined for invertebrates and clingfishes, and after all fronds were removed all remaining organisms were gleaned from the blanket. Weight of each sample of kelp fronds was estimated by weighing three equal sized containers of kelp and multiplying the average weight of these filled containers by the total number of containers filled in each series. Three pairs of blanket samples were taken (February 9, April 30, and August 5, 1970) and estimates were made of the number of each species per ton and acre of kelp at the time of cutting. In each pair of samples one sample was taken from the experimental harvesting area immediately before or during a routine canopy removal and the other sample was taken in a previously unaltered section of the kelp canopy near the cutting area.

The isopod, Idothea resecata, far outnumbered all other macro-organisms, but molluscs as a group made up the largest bulk of the invertebrate mass (Tables 31 and 32). A surprisingly large number of fishes were taken with sculpins, gunnels, and rockfishes the primary groups. The largest fish was a 250 mm TL penpoint gunnel. The kelpfishes, Gibbonsia sp., were represented by juveniles from 55 to 61 mm TL, and rockfishes were juveniles up to 56 mm TL in size. An average of 3,697 Calliostoma and Tegula (6 species), 1,032 fishes, and 302 kelp crabs (Pugettia) per acre were estimated for the three series in the cut area. These fish estimates are much lower than estimated from underwater transect tallies in which about 19,000 per acre (46,930/ha) were estimated in the zone within 6.5 ft. (2 m) of the bottom. Most of the fish taken in the blanket series were small canopy forms not observed in bottom transects. These included kelpfishes (genus Gibbonsia) , penpoint gunnel, kelp gunnel, rockweed gunnel, kelp clingfish, and saddleback sculpin. The only fishes observed near the bottom that appeared in the blanket samples were pipefishes and juvenile rockfishes. Obviously the more mobile schooling rockfishes and surfperches were disturbed by the cutting operation before the blanket had surrounded the sample.

TABLE 31

Estimates of Certain Organisms Per Ton and Acre in the Experimental Canopy Removal Area in 1970

Species	February 9 No. Per Ton	February 9 No. Per Acre	April 30 No. Per Ton	April 30 No. Per Acre	August 5 No. Per Ton	August 5 No. Per Acre	Mean Individuals Per Acre
Mollusca							
Acmaea sp.	—	—	—	—	45	665	222
Calliostoma annulatum	74	237	—	—	47	696	311
Calliostoma canaliculatum	154	495	15	180	35	518	398
Calliostoma ligatum	11	35	—	—	—	—	12
Ischnochiton mertensii	—	—	—	—	2	30	10
Littorina scutulata	—	—	—	—	105	1,555	518
Tegula brunnea	45	144	15	180	30	445	256
Tegula montereyi	32	102	69	828	287	4,250	1,727
Tegula pulligo	39	125	65	780	140	2,075	993
Arthropoda							
Balanus glandula	—	—	—	—	45	665	222
Balanus tintinnabulum	—	—	19	228	5	74	101
Idothea resecata	*	*	1,143	13,370	105	1,555	7,462
Pugettia producta	4	13	19	228	45	665	302
Spirontocaris sp.	—	—	—	—	37	546	182
Vertebrata (Pisces)							
Apodichthys flavidus	3	10	—	—	2	30	—
Gibbonsia metzi	—	—	4	48	15	222	90
Oligocottus rimensis	—	—	38	456	92	1,360	605
Rimicola muscarum	—	—	15	180	—	—	60
Sebastes spp. (Juvenile)	—	—	—	—	15	222	74
Syngnathus sp.	1	3	—	—	—	—	1
Ulvicola sanctaerosae	—	—	8	96	12	178	91
Xererpes fucorum	—	—	8	96	12	178	91

* Present but not recorded.

*TABLE **31***

Estimates of Certain Organisms Per Ton and Acre in the Experimental Canopy Removal Area in 1970

TABLE 32

Estimates of Certain Organisms Per Ton and Acre in an Uncut Canopy Area off Hopkins Marine Station in 1970

Species	February 4 No. Per Ton	February 4 No. Per Acre	April 30 No. Per Ton	April 30 No. Per Acre	August 5 No. Per Ton	August 5 No. Per Acre	Mean Per Acre
Cnidaria							
Eucopella sp.	—	—	—	—	*	*	*
Mollusca							
Acmaea mitra	—	—	—	—	4	59	20
Calliostoma annulatum	46	147	—	—	75	1,110	419
Calliostoma canaliculatum	208	665	13	156	20	196	339
Calliostoma ligatum	7	22	—	—	—	—	7
Hancockia californica	—	—	—	—	*	*	*
Tegula brunnea	23	74	7	84	—	—	53
Tegula montereyi	7	22	3	36	—	—	19
Tegula pulligo	12	38	5	60	4	59	52
Arthropoda							
Idothea resecata	*	*	35	420	41	607	513
Pugettia producta	2	6	15	180	4	59	82
Spirontocaris sp.	—	—	—	—	4	59	20
Vertebrata (Pisces)							
Gibbonsia metzi	—	—	—	—	12	178	59
Oligocottus rimensis	—	—	—	—	12	178	59
Rimicola muscarum	41	131	3	36	—	—	56
Sebastes spp. (Juvenile)	—	—	—	—	4	59	20
Xererpes fucorum	—	—	—	—	4	59	20

* Present but not recorded.

*TABLE **32***

Estimates of Certain Organisms Per Ton and Acre in an Uncut Canopy Area off Hopkins Marine Station in 1970

Fish samples taken aboard commercial kelp harvesters in Carmel Bay and off Granite Canyon, Monterey County, in 1972 indicate larger individuals of the same species present in both series and more species of fish remain in the kelp fronds taken aboard the harvester than in our blanket samples (CF&G unpublished data). Three dominant canopy species collected on the harvester in Carmel Bay were not present in the Hopkins study area. These were the northern clingfish, tidepool snailfish, and manacled sculpin. Kelp gunnels were taken at Granite Canyon, in Carmel Bay, and in our study area. Prior to these collections this species had not been collected north of Pt. Conception, indicating the previous lack of research on kelp canopies in central California.

Differences between the estimates in the cut and uncut areas appear to be highly significant (Table 31), but these differences are probably due more to methodology and natural fluctuations of density of organisms than to effects of cutting. There are three major factors causing these discrepancies. One is that in February both samples were taken in calm morning period on 2 separate days before winds could interfere with the blanket operations. In the April and August samples where there was a wide difference between cut and uncut areas, the cut area was sampled during the morning, whereas the uncut area was sampled in the afternoon of the same day. The weather difference between the two periods may have contributed to a change in behavior of organisms and there also may be a difference in distribution between morning and afternoon of certain animals, although no studies were conducted to disclose such behavior. Another factor, and probably the most significant, is that the uncut sample in February was taken from the periphery of the kelp bed, whereas the April and August uncut samples were taken from the inner portions of the kelp bed on the south edge of the harvesting area. The wide variation in distribution of organisms in a kelp bed alone can account for some of the differences encountered in our samples. All the cut area samples were taken in approximately the same location and consequently variation in numbers of most organisms is less than in the uncut section. To adequately test the effects of canopy harvesting on canopy organisms a much larger series should be taken.

The data do show that canopy removal, at least for the small area, does not permanently reduce the kinds of species present or their numbers. However, a commercial harvesting operation removes a much larger segment of the canopy (or even all of the canopy in small beds) and there would be less or no chance of certain organisms moving into the cut area from adjoining uncut canopy areas as the new canopy reforms. A commercial operation removes more of the organisms present than did our blanket samples as was shown by sampling the commercial harvesting operation in Carmel Bay.

Size composition of the organisms collected in the cut and uncut areas does appear to be significantly different and may be due to canopy removal. Except for Calliostoma canaliculatum in the April series, all organisms averaged larger size in the uncut area than in the cut area (Table 33). Methods of measurements of the different groups were: total length for fishes, length of the body of Idothea, lateral width between the horns of a

Pugettia carapace, and snail measurements were of the greatest diameter of the base measured by placing the snail, operculum downward, on a mm scale.

TABLE 33

Size Comparison of Certain Organisms in the Cut and Uncut Canopy Areas in February and April Samples

Species	*CUT AREA* Number	Range in Size (mm)	Mean	Standard Deviation	*UNCUT AREA* Number	Range in Size (mm)	Mean	Standard Deviation	SE of Difference of means of cut and Uncut Areas
February 1970									
Mollusca									
Calliostoma annulatum	55	13–26	18.74	3.01	26	18–28	22.73	2.57	0.65
Calliostoma canaliculatum	114	12–33	21.30	4.16	117	16–36	28.61	3.76	0.52
Calliostoma ligatum	8	16–20	17.88	1.36	4	21–23	22.25	0.96	0.68
Tegula brunnea	35	15–28	22.77	3.38	13	22–27	23.31	1.44	0.70
Tegula montereyi	24	16–32	22.67	4.07	4	28–29	28.75	0.50	0.83
Tegula pulligo	29	14–27	21.17	2.96	7	23–26	24.43	1.40	0.76
April 1970									
Mollusca									
Calliostoma canaliculatum	4	13–30	22.25	7.41	5	15–25	19.20	3.90	4.10
Tegula brunnea	4	18–26	22.75	3.40	3	22–28	25.67	3.21	2.52
Tegula montereyi	18	18–30	24.44	3.07	1	30	—	—	—
Tegula pulligo	17	20–25	21.88	1.80	2	23–24	23.50	—	—
Arthopoda									
Idothea resecata	20	7–20	14.15	4.20	14	9–25	16.29	4.05	1.44
Pugettia producta	5	19–42	32.00	8.80	6	28–42	35.20	4.78	4.39

*TABLE **33***

Size Comparison of Certain Organisms in the Cut and Uncut Canopy Areas in February and April Samples

Even though these data are inconclusive because of sampling inaccuracies and unknown behavior of most of the organisms, it may be concluded that the kelp canopy in Hopkins Marine Life Refuge was not inhabited by several species of fishes present in the more exposed Carmel Bay beds, that there is no obvious decrease in species or numbers due to previous canopy removal, and that there appeared to be a reduction in average size of some invertebrates in the cut area.

5.4. EFFECTS OF CANOPY REMOVAL ON KELP PLANTS

This experiment was designed to detect effects of a maximum harvesting of the canopy on the recovery ability of kelp plants. Cuttings were made when many of the surface fronds of each plant had matured and began cessation of growth. At this stage a canopy achieves a temporary balance between new growth and deterioration of old fronds and is relatively stable until heavy swells or high temperatures occur. The interval between cuttings varied by season. During the fastest growing period from February 4 to April 30 a full mature canopy, indistinguishable from the adjacent uncut areas, was formed in 85 days or approximately 3 months (Table 34). After the September 16, 1969, cutting it required approximately 140 days or around 4.5 months for the fronds to attain maximum length and form a surface canopy dense enough to cut economically. Our harvesting approximated a heavy commercial cutting with canopy removals spaced an average of 102 days (3.5 months) apart including two cuttings in 1969 and three in 1970 (Table 34). For sake of discussion this cutting rate approximates a heavy, maximum harvesting of three cuttings of the same plants within a calendar year. Cuttings averaged 4 to 6 ft. (1.3–2 m) below mean tide.

TABLE 34

Weight of *Macrocystis* Removed from 1.25 Acres of Canopy off Hopkins Marine Station, 1969–1970

Date	*Days Between Cuttings*	*Tons Removed*	*Tons Per Acre*	*Metric Tons Per Hectare*
June 20, 1969	—	15.0	12.0	24.3
September 16, 1969	88	20.0	16.0	32.4
February 4, 1970	140	4.0	3.2	6.5
April 30, 1970	84	15.0	12.0	24.3
August 5, 1970	96	18.5	14.8	30.0

*TABLE **34***

Weight of Macrocystis Removed from 1.25 Acres of Canopy off Hopkins Marine Station, 1969–1970

In the 408 days between the first and last cuttings, 46 tons of kelp per acre were removed for an average daily increment of 0.112 tons per acre (40.5 tons per year). This kelp bed was more dense throughout the year than most other central California kelp beds because of its semi-protected location; however, the estimate of 40.5 tons per acre per year is disproportionately high for this kelp bed since the fastest growing periods of two adjacent calendar years are averaged with only one slow growing period. A more realistic average annual yield is expressed by the February 4th, April 30, and August 5th cuttings totalling 30 tons removed over a 321 day growing period from September 1969 to August 1970. This period includes one slow winter period and one rapid spring and summer growing period.

Productivity of this kelp bed between September 1969 and August 1970 was 34.1 wet tons per acre per year (76.4 wet metric tons per hectare per year) at the level of cutting the canopy three times per year. As previously pointed out growth of individual fronds compared favorably with growth measured in southern California experiments. Quast (1968) concluded in his southern California experiments on the effects of canopy harvesting on fish that fish populations were not harmed by canopy removal and that a "routine or normal harvesting" is one in which "not over one-half of the kelp plant (linear dimension) is taken by the harvester and no single bed is harvested more than three times a year." North (1968b) concluded that harvesting operations in southern California were apparently not injuring the kelp beds or the fish populations within them but that some overcutting can occur. North states: “"This does not mean that cutting cannot harm plants nor should harvesting operations be conducted without surveillance. Changing environmental influences may cause a decline in a given bed, altering effects of cutting. North's model predicts that under certain circumstances cutting may produce considerable losses in photosynthetic capacity. Instances have been studied in the field where cutting has probably been excessive and damaging. . . . Beds harvested four times per year showed a decreasing yield in contrast to beds harvested less frequently (Brandt, 1923). These examples undoubtedly represent a more severe cutting than is practiced currently, but it is well to keep in mind that 'overcutting' can occur."”

Upon termination of our cutting experiments the data were viewed in terms of southern California studies and it appeared at first that harvesting three times a year in central California did not adversely affect the yield from the repeatedly cut area. Frond growth rates and standing crop estimates corresponded well with southern California findings.

All routine studies were terminated in December 1970 and the data were analyzed. In March 1971 we returned to the experimental area to spear remaining tagged fish to discover that there was no kelp canopy in the cut area, but the uncut zones around the cut area contained a dense canopy comparable to that of previous years. Inasmuch as the actual borders of the cut area were discernible and there was no canopy inside the four edges of the study area, the causes of this deterioration must have been from effects of our experimental canopy removal. Subsequent underwater observations disclosed that nearly all plants older than about 6 to 8 months, those with mature fronds extending over the surface, had disappeared. Dense growth of red algae, primarily Gigartina, appeared on the bottom and young Macrocystis plants were present but few fronds of these young plants reached the surface in March.

Michael Neushul (University of California at Santa Barbara, pers. comm.) theorized that repeated canopy removal of fronds from older plants reduced the steady translocation of nutrients to the holdfast area to the degree that growth of haptera was inhibited. This created a gradual disbalance between the growth of new haptera needed to increase the efficiency of the holdfast and the continuous deterioration of the center of the holdfast. Nicholson (1970) reported a retardation of Nereocystis holdfast growth due to blade removal and reduced productivity of the blades: “"—shorter days and low fall light intensities may reduce the productivity of the blades and thereby reduce holdfast growth, so new haptera for attachment do not adequately replace old decaying haptera. Natural deblading of plants effectively removes a plant from the reproducing population and halts holdfast growth,—"” Thus, as Neushul suggested, holdfasts of older, cut Macrocystis plants would become relatively less efficient than those of mature plants in the uncut area, and during winter storms these weakened holdfasts would be more readily torn loose from the substrate.

Since no experiments had been conducted in southern California or by us to substantiate such a possibility, we initiated a short term study to test this theory. Ten plants were chosen in an area where the kelp canopy was thin and intermittent allowing light to penetrate to young fronds below. Stipes of five of the plants were cut at 4 ft. (1.2 m) below the surface and five plants were left uncut. A white clothesline was interwoven among the peripheral haptera of each holdfast and the number of haptera growing over this line were counted about every 2 weeks over a 3 month period. At the same time, the number of fronds extending at least 4 ft. (1.2 m) above the bottom were counted on each plant. At first, as the surface fronds of the uncut plants continued to elongate and those of the cut plants were subsurface, there may have been a small amount of shading of some of the young fronds on the cut plants. However, within 2 weeks several new fronds of the cut plants reached the surface and what little shading had occurred could no longer be a possible factor in growth retardation of the cut plants.

There was significant retardation in haptera growth on each of the five cut plants (Figure 52), and the number of stipes per cut plant remained fewer than on the uncut plants (Figure 53). The number of haptera crossing

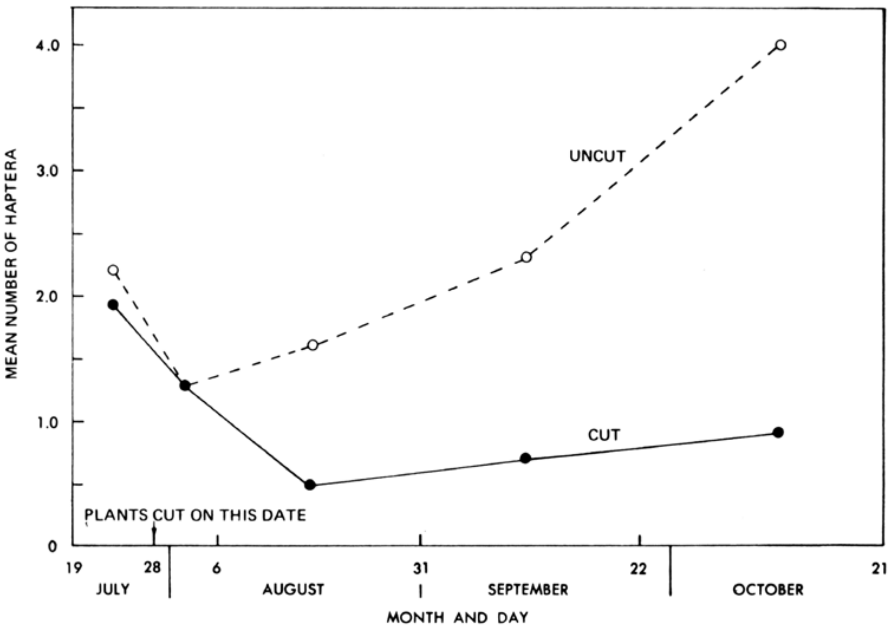


FIGURE 52. Average number of haptera crossing a peripheral line per day on five cut and five uncut *Macrocystis* plants, July through October 1971.

FIGURE 52. Average number of haptera crossing a peripheral line per day on five cut and five uncut Macrocystis plants, July through October 1971.

the line per day declined rapidly in the cut series and only slowly increased in rate a month after the cutting. The sharp drop in rate of haptera growth in both the uncut and cut series between July 28 and August 6 (the average is plotted midway between the two dates) was presumed to be caused by environmental factors since a heavy plankton bloom occurred during this period. The number of fronds per cut plant remained significantly lower each month after cutting than in the uncut series. By October, evidence of seasonal attrition of mature fronds on both series was indicated. At the end of the study in October the cut plants were removed from the substrate and condition of the holdfasts and number and condition of the fronds were noted. A surprising larger number of senescent fronds cut in July were still attached to the holdfast but were almost entirely devoid of blades even though there were enough pneumatocysts present to hold the stipe vertical. Thus, the difference in number of fronds between cut and uncut plants was primarily due to a decrease in formation of new fronds from the upper portion of the holdfast rather than from loss due to deterioration of cut fronds. In October, however, cut plants did have as many new fronds from 1 to 5 feet (0.3 to 1.5 m) long as did uncut plants, indicating the initial adverse effects of cutting had been overcome as far as new frond production was concerned.

Inasmuch as this amount of growth retardation was caused by but one canopy removal, the theory of decreased holdfast efficiency of older plants appears applicable. It appears that "overutilization" of a kelp canopy can affect productivity through at least two possible processes: (1) the photosynthetic reduction of the entire plant resulting in lower yield through less biomass being produced (North, 1968a); and (2) possibly by inhibiting haptera growth lessening holdfast efficiency resulting in premature loss of plants due to storm damage. The latter process must still be tested in different seasons, on varying substrates, and in several geographic areas before acceptance as a primary cause of increased mortality of harvested plants.

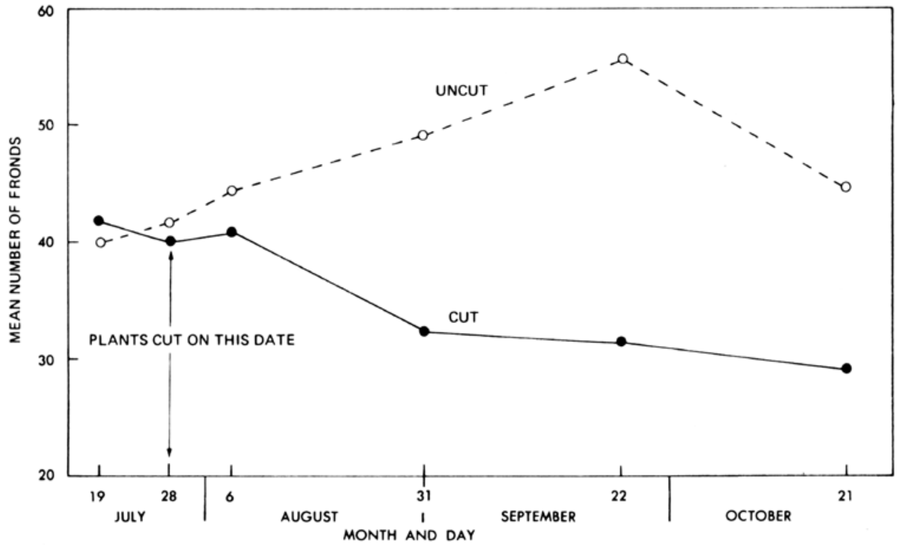


FIGURE 53. Average number of fronds on five cut and five uncut *Macrocystis* plants, July through October 1971.

FIGURE 53. Average number of fronds on five cut and five uncut Macrocystis plants, July through October 1971.

5.5. KELP BED—INVERTEBRATE—SEA OTTER INTERACTIONS

Kelp canopies are important as protective cover for fish and sea otters, as substrate or food for small organisms that may be eaten by larger kelp bed residents, and the canopy supplies food to benthic herbivores when deteriorated fronds or broken blades settle to the bottom. In central California a major realignment of benthic invertebrate distribution and biomass in kelp beds has resulted from the foraging habits of the sea otter, Enhydra lutris. The Department has been collecting underwater data on the effects of sea otter predation (Ebert, 1968a, 1968b; Richard Burge and Paul Wild, California Department of Fish and Game, unpubl. data) Faro (1969) recorded evidence of sea otter predation at Pt. Pinos; and Minter (1971) in his kelp bed study near Monterey noted: “"Though no observations were made during this study of what otters were eating in the Del Monte kelp beds, divers found ample evidence to indicate that a once extensive abalone population had been annihilated. Numerous shells of the Red Abalone (Haliotis rufescens) were observed littering the bottom, yet not a single living animal was seen. In addition, no living specimens of the red urchin, Strongylocentrotus franciscanus, and very few of the smaller purple urchin, S. purpuratus, were observed."” The latter study was conducted in a siltstone area with few deep interstices, but as pointed out by underwater observers (McLean, 1962; North, 1965; Ebert, 1968a, 1968b; Faro, 1969; and Richard Burge, California Department of Fish and Game unpubl. data) and from our underwater observations in Hopkins Marine Life Refuge, populations of sea urchins and abalone do exist within the concentrated range of the sea otter. These abalone are smaller in size, and both abalone and urchins are fewer in number than in most areas outside the sea otter's range and are almost entirely restricted to deep, narrow interstices where sea otters cannot remove them. Results of the 1972 skindiving survey (Miller, Geibel, and Houk, 1974) established that predation by sea otters throughout the area from Seaside to Pt. Estero has reduced the populations of sea urchins, abalone, and red and rock crabs to a level where there is virtually no take of these species by skindivers (7500 red abalone were taken by skindivers in this area in 1960 compared to 75 in 1972), and the take of red and rock crabs by Monterey pier and skiff fishermen is now limited to animals too small to be utilized. Outside the range of the sea otter there has been a continual yield of the above species with healthy populations of abalone present in exposed areas where favorable environmental conditions exist. Large numbers of legal sized abalone are present in many exposed areas outside the sea otter's range where utilization is light, such as along the coast from San Francisco north. However, in heavily utilized areas outside the range of the sea otter the annual take of abalone is primarily the animals that attain legal size each year.

Superimposed upon these invertebrate biomass changes resulting from sea otter predation is an apparent decrease in Nereocystis abundance and an increase in Macrocystis distribution and canopy density in central California. A decrease in Nereocystis beds has been noted by field biologists for several years; however, the only published evidence of this change is for the area from Pt. Pinos to the Monterey breakwater. Andrews (1945) noted pure stands of Nereocystis off Monterey pier and at Pt. Pinos, a mixed Macrocystis-Nereocystis bed off Lover's Point, Pacific Grove, and a pure stand of Macrocystis in the Hopkins Marine Life Refuge area. In our blue rockfish survey in 1962–1964 it was noted that the kelp beds near Monterey pier and breakwater and at Lover's Point were pure stands of Macrocystis and the kelp bed at Pt. Pinos was mixed Macrocystis-Nereocystis. Thus, between 1945 and 1962–1964 a major decline in Nereocystis had taken place in the Monterey area. Unpublished information recorded by Earl Ebert (California Department of Fish and Game, pers. comm.) indicated this Nereocystis-Macrocystis species composition interaction may have been taking place even before 1945. Ebert reports: "Abalone fishermen have reported a long-term (dating back more than 30 years) of giant kelp encroaching upon bull kelp." Ebert further noted this change while conducting research on abalone: "In 1967 giant kelp appeared in the once 'pure stands' of bull kelp near Pt. Estero. Since then the giant kelp has steadily exhibited a canopy increase. Similarly, giant kelp established in 1969 in the once 'pure' bull kelp beds between Pt. Buchon and Pt. San Luis." Isabella Abbott (Hopkins Marine Station, Stanford University, pers. comm.) collected a single young Nereocystis sporophyte in Monterey boat harbor in 1964 but no Nereocystis has been collected in the harbor area since. In our 1967–1972 study the distribution of Nereocystis between Pt. Pinos and Seaside was essentially that observed in 1962–1964 with Nereocystis present only at Pt. Pinos.

The increase in Macrocystis noted by Ebert has been observed by several workers in central California in recent years; however, there are no aerial photographs or sonar profiles to document this expansion. Isabella Abbott (Hopkins Marine Station, pers. comm.) noted an increase in Macrocystis densities on the Monterey Peninsula immediately after the warm water years of 1957 and 1958 and that Macrocystis canopies have remained relatively dense since that date. The senior author observed increases in Macrocystis canopy densities from Yankee Pt. to Half Moon Bay while conducting low level sportfishing and sea otter censusing aerial flights in 1960 and 1966. Unfortunately no aerial photographs were taken to record this phenomenon. In 1964 and again in 1966 project personnel noted Macrocystis growth off Santa Cruz increased to the point where scattered plants were interfering with pier fishing at Santa Cruz pier.

North (1965) noted an increase in Macrocystis densities from shore observations between 1963 and 1964 in the Monterey area and north to Ano Nuevo Island and suggested this increase may have been due to effects of sea uchin removal by sea otters. It has been established that urchin removal results in increased vegetative growth (Leighton, Jones, and North, 1965; Ebert, 1968a; Estes and Smith, 1973); however, the increase in Macrocystis observed by North (1965) in central California occurred outside of as well as within the established foraging range of sea otters. Any major increase in Macrocystis canopy densities due solely to sea otter predation on benthic herbivores can take place only in the transitional zone in which changing interactions between all organisms continue until the sea otter dominated ecosystem becomes stabilized. Increased canopy densities from 1963 to 1964 from Hopkins Marine Station along the coast north to Ano Nuevo Island were not due to sea otter predation on benthic herbivores. The zones where sea otter predation may have contributed to increased Macrocystis densities were from Pt. Pinos to Lover's Pt. and near San Simeon; however, no data were collected in these zones to assign the degree of kelp enhancement to sea otter predation or to favorable environmental conditions. In the area from Cypress Pt. to Pt. Piedras Blancas where sea otters had been well established prior to 1963, continuous sea otter predation on kelp herbivores may have created an ecosystem in which Macrocystis reproduction and growth may more quickly respond to favorable environmental factors. This theoretical condition has not been substantiated by field studies.

North based his supposition that sea otter predation may have been solely responsible for this kelp increase due to verbal reports of two sea otters observed at Ano Nuevo Island in July 1963 as representing the northern limit of sea otter foraging, whereas the actual foraging limit in 1962 was south of Pt. Pinos and in 1963 was at Pt. Pinos. This rare sea otter sighting at Ano Nuevo Island was published by Orr and Poulter (1964). Except on rare occasions there was no sea otter foraging on the Santa Cruz side of the bay until 1971, after which time up to eight sea otters have been observed in the Capitola to Natural Bridges State Beach area. In April 1963, there was a sighting of 75 sea otters just inside Monterey Bay near Pt. Pinos (Bissell and Hubbard, 1968) but they did not forage extensively in Hopkins Marine Life Refuge until 1965 and off Seaside until 1968. North (1965) observed the increased growth in Macrocystis from 1963 to 1964 north to as far as Ano Nuevo Island as did other field investigators, but these changes from Hopkins Marine Station to Ano Nuevo Island where there was essentially no sea otter foraging and from about San Simeon to Cypress Pt. where sea otters had been established at least since 1958 probably were due to widespread environmental factors.

These growth influences may have been operative as far south as Pt. Loma, San Diego. Leighton, Jones, and North (1965) noted that the increase of Macrocystis growth in the Pt. Loma kelp bed treated with quicklime in 1963 extended far beyond the area treated. They state: “"The existing kelp patches expanded first into those areas treated with quicklime and subsequently over a much greater area . . . . At the beginning of fall, 1963, the nearby City of San Diego altered its method of sewage disposal which may have influenced the ecology of the region. The amount of kelp harvested from Point Loma has increased markedly from the time the bed started to improve."” In this example of Macrocystis recovery in southern California there is the possibility of at least three factors operating concurrently; i.e., quicklime treatment, reduction of adverse effects of pollution, and possible widespread favorable environmental influences.

In southern California a documented rapid return of a Macrocystis bed without either quicklime treatment or sea otter predation on urchins was reported by Milton Love (Unv. of Calif. at Santa Barbara, pers. comm.) who observed a nearly nonexistent Macrocystis bed in 1967 on Naples Reef, Santa Barbara County increase to a dense extensive bed by 1970. A California Department of Fish and Game survey of Naples Reef by Charles Turner and Earl Ebert revealed that Macrocystis was not present in 1963. Michael Neushul (University of California at Santa Barbara, pers. comm.), using sonar profiles, recorded a dramatic natural fluctuation of a kelp bed at Anacapa Island. The bed was very thick in 1964 and 1965, was gone in 1966, and was recovering in 1967, demonstrating changes that can take place in a single kelp bed within 3 years' time.

Urchin removal increases vegetative growth, but the degree of Macrocystis enhancement due to uchin removal by sea otters in relation to increases in Macrocystis since 1958 in central California is not known. McLean (1962) reported increased vegetative growth due to sea otter predation, but review of his observations off Granite Creek, Monterey Co., is inconclusive. McLean (1962) wrote: “"Apparently the otters are permitting luxurient development of the Nereocystis-Pterygophora association by their predation upon urchins and, to a lesser extent, abalones. The otters do not range into Monterey Bay."” Macrocystis growth was not referred to in McLean's paper, and as noted previously, Nereocystis growth has not increased in the Monterey area as McLean postulated would happen. Recent kelp growth patterns off Monterey point out the continued effects of unknown growth factors. The Macrocystis canopies from Pt. Pinos to Seaside were less dense in 1972 than in 1971 (determined from boat observations). There are no apparent reasons for this decline which started after the winter storms were over, where water temperatures remained well below the critical level throughout the year, where there was no commercial harvesting, and in an area that has been devoid of abalone and sea urchins except in deep interstices since 1966.

This subject has been discussed in detail to relate that dynamic fluctuations in kelp growth can occur over an extensive geographical area as well as in an individual kelp bed and that there are factors other than destructive winter storms, warm water, herbivore grazing, and commercial canopy harvesting that can cause major changes in kelp canopy density and distribution. Obviously more research is needed to understand the dynamics of kelp bed densities in relation to the interactions of sea otters and benthic herbivores. This is not to say the interactions of sea otters and abalone and urchins is not understood. Evidence is conclusive that there is virtually no human consumption of abalone and urchins within the heavy foraging range of the sea otter. In 1972 this foraging range was from Seaside south to Cayucos. What has not been empirically documented is the enhancement of Macrocystis beds resulting from urchin removal by sea otters.

6. DISCUSSION

Sport catch sampling at major central California ports since 1957 has yielded information on numbers of fishermen in each sport fishery, kinds and numbers of fishes being caught, relative importance of each species by numbers and weight, trends of sport fisheries in terms of expansion and shift of interest, and evidence of overutilization of highly available stocks of fish. Life history studies of blue rockfish and lingcod also have revealed the nature of specific fisheries for these species as well as providing information upon which to formulate catch restrictions should they be needed in the future.

6.1. INSHORE BOTTOMFISH SPECIES MANAGEMENT

A minimum size limit of 24 inches (61 cm) total length for lingcod in certain areas can bring about a more quality fishery, but should overutilization result in a serious decline of a particular local lingcod stock other restrictions may be necessary. These include restrictions on the commercial fishery inasmuch as 78% of the lingcod are taken by otter trawlers, long liners, and gill netters. Possible restrictions might include a reduced sport bag limit, season closures, and geographical area closures. Lingcod stocks are in a healthy state at this time, but our research indicates there is a potential overfishing problem with this species as with practically all inshore aggregate species.

Blue rockfish are now being overutilized at several port areas, but because of enforcement problems due to identification difficulties and the fact that there is a mortality of fish because of expanding gas bladder, no size limit restrictions such as a 10 inch (254 mm) total length is recommended at this time. Because of the schooling behavior of many bottomfish, several species can be caught at the same time and place and it is difficult to find areas where blue rockfish will not be taken in shallower areas. It also is difficult to avoid capturing small individuals which would have to be thrown back if there were for example a minimum size limit of 10 inches total length.

Our inshore reef ecology studies yielded partial life history data on many species of sport and commercial fishes, and tagging studies disclosed behavioral patterns of several inshore aggregate species. There is a similarity of behavior of schooling or aggregating species such as yellowtail rockfish, olive rockfish, and widow rockfish indicating overfishing similar to that of blue rockfish is possible with these species as fishing effort increases. None of the important inshore bottom aggregate species we studied in the shallow Hopkins Marine Life Refuge area are migratory, except possibly for seasonal spawning migrations of sharpnose surfperch, jacksmelt, and a portion of the lingcod population. Because of the nonmigratory behavior of these bottomfish, each port area represents a separate stock of bottomfish, and overutilization of one or several species may exist at one port but not at another. On the other hand, the influx of lingcod at all port areas from San Diego to Crescent City from 1969 to 1972 demonstrates there are coastal widespread conditions causing population changes to take place in all subpopulations simultaneously that can transcend local environmental and fishing pressure variables affecting local stocks. Blue rockfish stocks have shown widespread annual changes in availability; however, these changes were not as uniform at all ports as lingcod, indicating that effects of local fishing pressure and environmental influences may be of greater magnitude than effects of widespread oceanic conditions.

Our tagging studies in which 37 species were tagged not only disclosed the residential behavior of most bottomfish, but that a few individuals of each species wander to some degree. Habitat improvement studies conducted in southern California revealed this wandering phenomenon several years ago and our studies yielded information on the extent of these wanderings in central California. Along Cannery Row and in the reef area off Santa Cruz wandering recruitment was not sufficient to maintain adequate fishing stocks. The small 12 acre reef off Hopkins Marine Station, Pacific Grove, where there was essentially no take of fish, contained a high density aggregate of local species as well as unique populations of more typical southern California species such as kelp bass, opaleye, and senorita. Wandering recruitment from the Hopkins area did not materially contribute to the stocks in the heavily fished stocks off Cannery Row, a short distance away. Residential behavior of kelp bed fishes resulted in a fairly constant high level in an unfished area, and wandering was at such a low rate that nearby reefs were not enhanced by fish emigrating from Hopkins Marine Life Refuge. Over the 3 year study only four of the 2,968 fish tagged and released in the Hopkins study area were recaptured in an adjacent reef. On the other hand, a rocky area adjacent to the skindiving or shore fishing access that is lightly utilized may be constantly replenished by wandering large fish from contiguous rocky areas as well as by annual juvenile recruitment spawned in the immediate area or drifting in on the currents. For instance, the reef area in and adjacent to Van Damme State Beach, Mendocino County, is lightly utilized by spearfishermen throughout the year except for on 1 day in late July each year. Since 1956, a large spearfishing competition meet has been held here each year resulting in removal of up to 1,000 fish in a 4 hour period. The principal species speared are kelp greenling, blue rockfish, lingcod, and surfperches. Wandering large fish from contiguous rocky areas over the remainder of the year apparently replenish these stocks since the size of fish and catch-per-hour's dive has not declined over the years; in fact, they have been increasing over the past several years.

Fish behavior in a central California kelp bed area follows this generalized pattern. There are from 30 to 40 species large enough to be utilized by hook-and-line fishermen, spearfishmen, and commercial gill netters. Rockfishes and surfperches are the dominant schooling and aggregating species with several species of rockfishes, lingcod, cabezon, and kelp greenling the principal solitary, demersal forms. Adults of all species except for some seasonally migratory lingcod, sharpnose surfperch, and jacksmelt are residential with some wandering between areas in the reef but only occasional emigration to an adjacent reef. Recruitment consists of two sources, the annual production of juvenile fish and wandering recruitment of fish immigrating from nearby comparable habitat. Annual reproduction of surfperches is from adults present in the kelp beds since these fish are viviparous with their precocious young remaining in the vicinity where they are hatched. Larvae and postlarvae of rockfishes, lingcod, and kelp greenling are epipelagic for several months after hatching. Larvae released within a particular area may not remain there, and juveniles that settle into the area may not have been spawned in the kelp bed but may have drifted from varying distances into the area, however, no studies have been conducted to document these movements.

The inshore rocky reef and kelp bed areas are juvenile nursery grounds for all residential species except the lingcod. Young lingcod tend to avoid rocky areas until about 13 or 14 inches total length. There is a wide seasonal fluctuation of juvenile rockfishes and surfperches commencing in April and May and continuing until the first heavy winter storms. During the winter a few remain in the canopy area but most juveniles are in the more protected bottom habitats. Second year fish are much less abundant in the kelp bed area indicating a high mortality from predation and/or emigration to deeper areas. A few fish of the year will remain as adult residents as long as suitable food and habitat are available.

In heavily fished areas annual recruitment is probably of greater importance than immigrants in replenishing the stocks. The characteristic small average size in heavily fished areas is indication that wandering recruitment cannot maintain a high yield, quality fishery, especially if there are no nearby reefs or if nearby reefs are also heavily fished.

In view of the above conditions, management of the inshore bottom aggregate becomes quite complex because of the differential exploitation of the many semi-isolated stocks of fish near each port area. For instance, a spawning season closure to protect a local stock of lingcod on reefs near Santa Cruz may be of little value in saving fish along the northern California coast where over 90% of the lingcod catch is made by commercial trawlers during the nonspawning period. Size limits can yield a quality fishery, yet minimum sizes are difficult to enforce and some fish thrown back may die. Daily bag limits are of value only as long as the economic point of no return is not surpassed, i.e., when the daily catch is reduced in either size or numbers below that which a fisherman is willing to pay.

Future possible management procedures for the central California inshore aggregate should include port censusing programs in which all fisheries are periodically monitored yielding information to manage on a local, port area level. The possibility of an alternating zonal opening and closure, permitting a segment of the fishing grounds near each port area to be protected from fishing for certain groups of fishes for several years should be investigated. This zonal opening and closing in central California would include rockfishes, surfperches, sculpins, and greenlings, but not salmon, striped bass, flatfishes, white croaker, and silversides. The objective of management by rotating zonal closures is to allow a segment of the bottom demersal forms within the range of skiffs and partyboats to attain larger size and increase in numbers through full protection in a continuous coastal band extending to at least 240 ft. depth. By alternating three or more zones in each port area there will always be a zone in which no fishing is taking place and zones where fishing has been taking place over varying periods of time. The ultimate purpose is to produce a more quality fishery consisting of larger fish rather than maintenance of a stabilized low level catch of small fish over the entire range of boats from each port such as is the case at several overutilized reefs. Conditions at this time in central California do not warrant such an intricate management program; but eventually this management plan may be necessary.

There are many problems with alternating open and closed fishing zones, especially in enforcement; nevertheless, inshore aggregate species research and port sampling procedures should be oriented to investigate the feasibility of such a program. Some problems are already realized. For example, the need to retain a constantly open zone within at least 2 miles of each port so as to not completely preclude fishermen using small boats that must stay near port. The closure should be from the subtidal zone to at least 240 ft. (73 m) depth and should include both commercial and sport operations. Shore fishermen catch insignificant numbers of fish from rocky areas and may be exempted in the closure; however, spearfishermen may be included in the prohibition. Extent of time period of closure must be experimentally determined. Considering the slow growth rate of many rockfishes and surfperches, it may take from 3 to 5 years for the fish in a heavily fished area to develop into a large population of larger fish through annual recruitment, depending upon the dominant species in each area.

6.2. ECOLOGICAL PRESERVES

Certain areas should be set aside as ecological preserves to maintain a natural base community of organisms unaffected by man's activities. These areas are necessary for scientists and managers to determine possible long term natural trends or changes which may be taking place in an ocean environment. In areas affected by man, it is not known whether a significant change is due to natural causes outside of man's activities or due to human alteration of environmental parameters. If these changes do not occur within a series of well chosen fully protected preserves representing various habitat biosystems, then the ecological changes taking place where man is altering the habitat is most likely not due to some overall natural shift of conditions. There is presently an excellent example of this phenomenon involving evaluation of the effects of sea otter foraging on invertebrates. The key point of controversy in proposing sea otter management has been determination of how much of the depletion of red abalone populations within the sea otter's range was due to commercial and sport harvesting and to sea otter foraging. The invertebrate composition within Pt. Lobos State Reserve has been fully protected from human exploitation for over 40 years. Prior to the mid-1950's there was a dense population of large exposed red abalone throughout the protected Pt. Lobos area. Within a few years after sea otters moved in, these abalone were reduced to a low population density of small (mostly all under legal size) abalone which are restricted almost entirely to deep interstices where sea otters cannot remove them. This is the condition that exists throughout the heavy foraging range of the sea otter (in 1972 from Seaside to Cayucos) thus resolving the effects of human consumption vs. sea otter predation. There can be virtually no human consumption of abalone where sea otters forage, whereas outside the sea otter's range there are abundant stocks of sublegal abalone in exposed areas with suitable habitat conditions. In heavily utilized areas these sublegal abalone are harvested as they reach legal size and management operates on a sustained annual yield basis. Knowledge of the invertebrate size and species composition in Pt. Lobos Ecological Preserve will be an important factor in development of a sea otter management program that will insure maintenance of certain invertebrate populations for human use.

Other values of ecological preserves include use by underwater nature observers and photographers. In a total preserve, fish are not as wary as in areas where they are pursued for spearing, and a complete natural biomass can be observed since all plant and invertebrate populations are not disturbed. Another value might be to establish an ecological preserve to protect a certain endangered or rare species. It is often not enough to merely place a prohibition on the take or possession of an endangered species; a completely protected habitat and natural food supply also may be essential.

Ecological preserves are described here because of the importance of these protected areas to evaluate fisheries trends, effects of environmental change due to waste disposal, and warming of ocean water from thermal effluents. A recent survey of skindivers in central and northern California (Miller, Geibel, and Houk, 1974) showed a 540 percent increase of skindivers from Pismo Beach to Oregon from 1960 to 1972. New equipment enabling long distance travel (up to 3 miles) from access points affords opportunity to utilize invertebrates and spear fish in areas that up to now have been natural preserves because of their inaccessibility. Increased use of skiff and chartered partyboats by skindivers and hook-and-line fishermen also is enabling exploitation of previously nonutilized areas inaccessible from shore.

Results of our reef ecology survey revealed that an ecological preserve in central California can be maintained, but only if hook-and-line fishing is not allowed in the area. We have found that most of the adult fish in the area are residents and that there is emigration of juveniles from rocky inshore areas at the end of the first year. Fishing on nearby reefs even less than a mile away will not alter the species or size composition of fish in the preserve as none of the species in central and northern rocky areas and kelp beds exhibit a horizontal or latitudinal migration, and individual wandering over a mile is negligible. Since most fish in these areas are primarily invertebrate feeders, the removal of but one adult cabezon or kelp greenling (the principal species taken by shore fishermen) would alter the natural balance of organisms in the area for the number of years that individual fish would have lived had it not been removed by man. Constant removal of fish would create an unnatural balance among remaining invertebrate and fish species and the purposes of the ecological preserve would be precluded. Ecological preserves for inshore rocky reefs and kelp beds can be maintained only by preventing the removal of all living organisms, by creating these areas where sewage effluent does not affect the environment, and where there is constant surveillance to prevent fishing, collecting, and destruction of habitat.

6.3. KELP HARVESTING

The use of marine algae for extraction of chemical products is continuing to expand. Giant kelp canopies are being harvested for alginic acid and several of the smaller understory kelps are being harvested for agar. There are many unknowns concerning interactions of fishes and kelp and accelerated research is needed to reveal possible effects of commercial kelp harvesting on fishes concentrated in these areas, primarily juvenile rockfish concentrations in the central California area. Experiments on giant kelp in southern California were not designed to determine effects of canopy removal on juvenile fish concentrations. The southern California experiments did not include effects of canopy removal on possible age-size composition change of kelp plants, nor on possible change in species composition of various kelp plants present when one species is repeatedly harvested. Experiments on reduction of holdfast efficiency due to canopy removal were conducted in our kelp bed pilot study showing a decided retardation of haptera growth, but this experiment must be conducted more extensively in varying physical and oceanographic conditions.

Our Hopkins study area experiments showed that central California adult fish are probably not affected by canopy removal; however, there is some concern for the large concentrations of juvenile rockfish frequenting the canopy area from April through November each year. None of the experiments conducted on giant kelp in southern California or in our study have adequately determined the optimum number of times a canopy can be removed each year from each kelp bed as to not adversely affect the kelp plants or the juvenile fishes and other organisms frequenting the area. Tentative conclusions of southern California experiments indicated three cuttings per year were maximum, but our study indicated three cuttings per year is excessive. At this time there are no controls limiting the number of times a kelp bed (a contiguous growth of kelp plants) may be cut each year. Investigation of the above problems is needed for the central California area.

6.4. LIFE HISTORY STUDIES

Complete life history studies are needed for most species present in central California kelp bed and inshore rocky areas. Results of blue rockfish and lingcod life history studies revealed the necessity to apply a broad ecological approach by collecting data on organisms associated with the bottom aggregate species being emphasized. Food chain complexity, predator-prey relationships, and habitat requirements of phases of the life history should be noted along with routine maturity, fecundity, age, length-weight, and food studies. Surveillance of sport and commercial catches in the coastal area being surveyed should be included in life history studies. Length frequency, age, and species composition are essential parameters in inshore bottomfish life history studies. Species most in need of research are kelp greenling, yellowtail rockfish, striped surfperch, white croaker, and copper rockfish. There are some life history aspects of species previously studied in need of further research. These include egg-nest habitat requirements of lingcod and cabezon. We know lingcod nest from the lower intertidal zone down to at least 62 ft. (18.9 m) and there are indications that they may spawn even deeper. The importance of establishing the depth range of egg-nest location is vitally important in considering possible spawning season closure for lingcod. If all nest guarding males are within the range of spearfishermen, restrictions on skindivers may be necessary some day. However, if only a portion of lingcod nesting is within 60 ft. (18.3 m) of the surface then such a restriction may not be necessary.

An important but difficult task is to determine the origin of juvenile fish in the inshore area. It has never been established whether lingcod, rockfish, and cabezon larvae hatched in a given kelp bed actually remain in the area where hatched or whether recruitment is from widespread distribution of larvae and postlarvae drifting throughout the inshore area. The latter appears to be the case for lingcod as juveniles from about 2 inches (5.1 cm) total length and larger are found scattered over sandy and mud bottoms throughout bays and along the outer coastal areas at least to 200 ft. (61 m) depth. Postlarval lingcod and rockfishes are epipelagic for a short period and we can theorize that they swim to the bottom at a certain time or are carried into kelp beds or inshore rocky areas and survive if the habitat they arrive in is suitable. At this time it is not known where recruitment of a particular area is spawned and what the habitat requirements are for postlarvae and juveniles of our inshore bottomfish species.

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APPENDIX I

Common and Scientific Names of Fishes

Albacore	Thunnus alalunga
Anchovy, northern	Engraulis mordax
Bass, kelp	Paralabrax clathratus
striped	Roccus saxatilis
Blacksmith	Chromis punctipinnis
Bocaccio	Sebastes paucispinis
Bonito, Pacific	Sarda chiliensis
Cabezon	Scorpaenichthys marmoratus
Chilipepper	Sebastes goodei
Clingfish, kelp	Rimicola muscarum
northern	Gobiesox maeandricus
Cowcod	Sebastes levis
Croaker, white	Genyonemus lineatus
Cusk-eel, spotted	Chilara taylori
Eel, monkeyface	Cebidichthys violaceus
wolf-	Anarrhichthys ocellatus
Flatfishes	Bothidae and Pleuronectidae
Flounder, starry	Platichthys stellatus
Goby, blackeye	Coryphopterus nicholsii
Greenling, kelp	Hexagrammos decagrammus
Greenlings	Hexagrammidae
Gunnel, kelp	Ulvicola sanctaerosae
penpoint	Apodichthys flavidus
rockweed	Xererpes fucorum
Halfmoon	Medialuna californiensis
Halibut, California	Paralichthys californicus
Irish lord, brown	Hemilepidotus spinosus
Jacksmelt	Atherinopsis californiensis
Kelpfishes	Clinidae
Lingcod	Ophiodon elongatus
Lizardfish, California	Synodus lucioceps
Mackerel, Pacific	Scomber japonicus
Opaleye	Girella nigricans
Pipefishes	Syngnathidae
Prickleback, ribbon	Phytichthys chirus
rock	Xiphister mucosus
Rockfish, black	Sebastes melanops
black-and-yellow	Sebastes chrysomelas
blue	Sebastes mystinus
brown	Sebastes auriculatus
canary	Sebastes pinniger
China	Sebastes nebulosus
copper	Sebastes caurinus
gopher	Sebastes carnatus
grass	Sebastes rastrelliger
greenspotted	Sebastes chlorostictus
honeycomb	Sebastes umbrosus
kelp	Sebastes atrovirens
olive	Sebastes serranoides
rosy	Sebastes rosaceus
shortbelly	Sebastes jordani
speckled	Sebastes ovalis
starry	Sebastes constellatus
vermilion	Sebastes miniatus
widow	Sebastes entomelas
yellowtail	Sebastes flavidus
Rockfishes	Sebastes spp.
Sablefish	Anoplopoma fimbria
Salmon	Salmonidae
Salmon, king	Oncorhynchus tshawytscha
silver	Oncorhynchus kisutch
Sanddab, Pacific	Citharichthys sordidus
Sanddabs	Citharichthys spp.
Sculpin, buffalo	Enophrys bison
manacled	Synchirus gilli
saddleback	Oligocottus rimensis
wooly	Clinocottus analis
Sculpins	Cottidae
Senorita	Oxyjulis californica
Sheephead, California	Pimelometopon pulchrum
Silversides	Atherinidae
Sole, English	Parophrys vetulus
petrale	Eopsetta jordani
rock	Lepidopsetta bilineata
sand	Psettichthys melanostictus
Snailfish, tidepool	Liparis florae
Surfperch, barred	Amphistichus argenteus
black	Embiotoca jacksoni
Surfperch, kelp	Brachyistius frenatus
pile	Damalichthys vacca
rainbow	Hypsurus caryi

redtail	Amphistichus rhodoterus
reef	Micrometrus aurora
rubberlip	Rhacochilus toxotes
sharpnose	Phanerodon atripes
shiner	Cymatogaster aggregata
silver	Hyperprosopon ellipticum
striped	Embiotoca lateralis
walleye	Hyperprosopon argenteum
Topsmelt	Atherinops affinis
Whitefish, ocean	Caulolatilus princeps
Wrasse, rock	Halichoeres semicinctus

APPENDIX II

Species of Fish Observed or Captured in the Hopkins Marine Life Refuge Kelp Bed, 1967 through 1971, with Additional Species Taken in Kelp Canopies from Monterey to San Simeon Not Appearing at Hopkins Marine Station

Species	Bottom*	Canopy*	Remarks
Engraulididae			
Engraulis mordax	—	J	Occ. in large schools, not resident
Salmonidae			
Oncorhynchus tshawytscha	—	A	Several are taken each year in the kelp beds off Pacific Grove and Monterey Pier.
Salmo gairdnerii	—	A	Occ. appear in canopy near Monterey Pier.
Gobiesocidae			
Gobiesox maeandricus	—	A + J	Common, attached to blades.
Rimicola muscarum	—	A + J	Common, attached to blades.
Atherinidae			
** Atherinops affinis	—	A	Appear each fall near Monterey Harbor; a schooling fish.
Atherinopsis californiensis	A	A	Occ. in summer and fall; sparse schools.
Syngnathidae			
Syngnathus californiensis	A	A + J	Uncommon, scattered in canopy.
Scorpaenidae			
Sebastes atrovirens	A + J	A + J	Large concentrations in canopy to bottom; associated with kelp.
Sebastes carnatus	A + J	—	Solitary on bottom, no heavy concentrations.
Sebastes caurinus	A + J	J	Common but not numerous; resident as well as wanderer; concentrates in certain areas.
Sebastes chrysomelas	A + J	—	Shallow rocky areas; solitary.
Sebastes entomelas	J	J	Summer month juvenile concentration, scattered as well as in schools.
Sebastes flavidus	J	J	Summer month juvenile concentration; usually schooled, mostly in canopy.
Sebastes goodei	J	J	Summer month juvenile concentration; usually scattered.
Sebastes jordani	J	J	Occurs in dense schools, mostly in canopy; summer visitor, erratic in distribution.
Sebastes melanops	A + J	A + J	Resident inshore reef; scattered but occ. concentrates in certain areas; common.
Sebastes mystinus	A + J	A + J	Dominant fish in kelp bed areas of central Calif.; juveniles appear in April and concentrate until about November; some remain resident, others emigrate to deeper rocky reefs.
Sebastes nebulosus	A	—	Occ. on bottom in deeper parts of inshore area.
Sebastes ovalis	—	J	Scattered in canopy in summer months.
Sebastes paucispinnis	J	J	Remain in inshore area for year to 1½ years, scattered in canopy; adults migrate to deep waters.
Sebastes pinniger	J	J	Scattered throughout kelp bed; summer months; migrate to deeper water as adults.
Sebastes rastrelliger	A + J	—	Resident in shallow areas, solitary.
Sebastes serranoides	A + J	A + J	Resident and wanderer in inshore areas; juv. remain throughout summer months; occ. in large schools.
Sebastes (unidentified)	J	J	Juveniles in summer months too small to identify, often in large numbers.
Hexagrammidae			
Hexagrammos decagrammus	A + J	J	Common resident but not numerous; solitary.
Hexagrammos superciliosus	A	—	One adult observed.
Ophiodon elongatus	A	A	Common resident and wanderer; solitary.
Oxylebius pictus	A + J	—	Common in shallower areas; solitary.
Cottidae			
** Clinocottus recalvus	—	A + J	Commonly scattered in canopy from Carmel Bay to San Simeon.
Nautichthys oculofasciatus	A	—	One collected near holdfast.
Oligocottus rimensis	—	A + J	Common in canopy; scattered.
Scorpaenichthys marmoratus	A + J	A + J	Common resident; adults usually on bottom; juv. from tidepools into canopy and on bottom; scattered and solitary.
** Synchirus gilli	—	A + J	One of the most common kelp canopy species from Carmel to San Simeon; scattered throughout the canopy and along stipes to near bottom.
** Liparididae			
Liparis florae	—	A + J	Commonly scattered in canopies from Carmel Bay to San Simeon.
Serranidae			
Paralabrax clathratus	A	A	Resident aggregations.
** Branchiostegidae			
Caulolatilus princeps	A	A	Several have been taken by hook-and-line at Monterey breakwater.
** Carangidae			
Trachurus symmetricus	J	J	A densely schooling fish occ. entering kelp beds near Monterey Pier and along Cannery Row.

* A = Adults J = Juveniles

** Species taken in canopies from Monterey to San Simeon, not recorded at Hopkins Marine Life Refuge.

Girellidae			
Girella nigricans	A	A	Resident; scattered in shallower areas; uncommon.
Clinidae			
Gibbonsia metzi	A	A + J	Scattered, usually in canopy area.
Gibbonsia montereyensis	A	A	Scattered, solitary in shallow rocky areas.
** Heterostichus rostratus	—	A + J	Scattered in canopy but not numerous; off Cannery Row and Pacific Grove.
Cebidichthyidae			
Cebidichthys violaceus	A	—	Occ. seen near holdfasts in shallower areas.
Stichaeidae			
Phytichthys chirus	A + J	—	In and around holdfasts; uncommon; solitary.
Xiphister atropurpureus	A + J	—	In and around holdfasts and in shalllower rocky areas; uncommon; solitary.
Pholididae			
Apodichthys flavidus	A	A + J	Scattered, mostly in canopy; associated with kelp.
Ulvicola sanctaerosae	—	A + J	Scattered in canopy; uncommon; taken only from Monterey to Granite Creek in central California.
Xererpes fucorum	A	A + J	Scattered from canopy into intertidal zone; solitary, occ. common.
Gobiidae			
Coryphopterus nicholsii	A + J	—	Scattered on bottom, usually on sandy areas between rocks; common.
Scombridae			
Sarda chiliensis	—	A	Pelagic migrant into area in fall; occ. enters kelp bed area; schooling fish.
Bothidae			
Cithariththys stigmaeus	A + J	—	Common in sand near edge of kelp bed.
Scorpididae			
Medialuna californiensis	A	A	Rarely appear; mainly in summer months.
Embiotocidae			
Brachyistius frenatus	A + J	A + J	Abundant throughout kelp bed; closely assoc. with kelp; solitary as well as schooled.
Cymatogaster aggregata	A + J	A + J	Scattered in canopy in spring and summer.
Damalichthys vacca	A + J	A + J	Scattered during winter; dense schools, mostly near bottom in summer; occ. numerous.
Embiotoca jacksoni	A + J	A + J	Usually solitary as adults; juveniles schooled; not numerous.
Embiotoca lateralis	A + J	A + J	Common in spring spawning concentrations; scattered throughout remainder of year.
** Hyperprosopon argenteum	A + J	A + J	Common in canopy areas near Monterey Harbor and the piers.
Hypsurus caryi	A + J	A + J	Resident, scattered; mostly near bottom.
Phanerodon atripes	A + J	A + J	Common in May to July spawning period; migrate to deeper waters in winter; a schooling fish.
Phanerodon furcatus	A	A	Uncommon, few observed in summer months.
Rhacochilus toxotes	A + J	A + J	Concentrate in spring spawning period; scattered during remainder of year.
Pomacentridae			
Chromis punctipinnis	A	A	Small resident population; usually schooling.
Labridae			
Pimelometopon pulchrum	A	A	Few scattered adults present; resident.
Oxyjulis californica	A + J	A + J	Resident population; occ. in large concentrations near surface.
Anarhichadidae			
Anarrhichthys ocellatus	A	—	Occ. seen wandering through bottom area.
Molidae			
Mola mola	—	A	Wanderer from offshore; uncommon.