Distribution and Abundance of Rockfish Off Washington, Oregon, and California During 1977

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ABSTRACT—The methods employed during the demersal (bottom trawling) phase of the 1977 rockfish survey and in obtaining catch and biological data during the demersal and pelagic (hydroacoustic-midwater) phases are outlined. Geographic and bathymetric trends in the abundance and species composition of the demersal rockfish community are discussed, and the results of the demersal and pelagic surveys are compared. Biomass estimates (50- to 250-fathom or 91- to 457-m depth zone) are given for the dominant rockfish species in each statistical area of the International North Pacific Fisheries Commission (INPFC).

Canary rockfish, Sebastes pinniger *(26,000 t), yellowtail rockfish,* S. flavidus *(23,000 t), and Pacific ocean perch,* S. alutus *(15,000 t), dominated the rockfish biomass in the Vancouver and Columbia INPFC areas. Rockfish biomass was low in the Eureka area (about 4,000 t in the 50- to 250-fathom zone) but increased again to the south. The rockfish biomass in the Monterey and Conception INPFC areas was dominated by shortbelly rockfish,* S. jordani *(320,000 t), splitnose rockfish,* S. diploproa *(10,000 t), chilipepper,* S. goodei *(9,000 t), stripetail rockfish,* S. saxicola *(7,000 t), and bocaccio,* S. paucispinis *(6,000 t). Shortbelly rockfish were found to be principally pelagic in their distribution; less than 10 percent of the stock was encountered during the demersal survey.*

The precision of most biomass estimates for rockfish was relatively low because of the highly contagious spatial distribution characterizing most of these species.

Introduction

Soon after the enactment of legislation on extended fisheries jurisdiction, serious shortcomings in the quality of the data base on commercial fisheries for rockfish made it apparent that an intensive survey of rockfish resources would be desirable. The problems to be addressed in implementing such a survey were the subject of discussion at a 3-day workshop held at the Northwest and Alaska Fisheries Center, National Marine Fisheries Service (NMFS), in January 1976 (Gunderson[1]).

As a direct result of that workshop, a pilot survey of rockfish in Monterey Bay, Calif., and Queen Charlotte Sound, British Columbia, was conducted in 1976 to examine and improve the techniques used in rockfish surveys (Gunderson and Nelson[2]). A full-scale survey of rockfish resources from Pt. Hueneme, Calif., (lat. 34°00′N), to Cape Flattery, Wash.,[3] (lat. 48°29′N) was subsequently undertaken in 1977. This survey represented a cooperative effort between NMFS, Washington State Department of Fisheries, Oregon Department of Fish and Wildlife, California Department of Fish and Game, Oregon State University, University of Washington, and Polish Sea Fisheries Institute (Gdynia, Poland).

The survey was subdivided into two major task forces, one carrying out a pelagic (hydroacoustic/midwater trawl) survey, while the other conducted a demersal (bottom trawl) survey. The objectives of the survey were to collect data necessary to: 1) Estimate the demersal biomass for the major species taken in bottom trawl hauls; 2) estimate the biomass of pelagic fish aggregations; 3) determine the species composition of pelagic fish aggregations; 4) determine the size composition of key rockfish species, Pacific whiting, *Merluccius productus*, and sablefish, *Anoplopoma fimbria*, in bottom and midwater trawl catches; 5) determine the age composition in the catches of both types of trawls for selected "target" species (Pacific whiting; chilipepper, *Sebastes goodei*; bocaccio, *S. paucispinis*; shortbelly rockfish, *S. jordani*; splitnose rockfish, *S. diploproa*; yellowtail rockfish, *S. flavidus*; canary rockfish, *S. pinniger*; and Pacific ocean perch, *S. alutus*); 6) determine the acoustic target strength of Pacific whiting and selected rockfish species; 7) characterize oceanographic conditions prevailing in the survey area; 8) determine genetic relationships between rockfish stocks in different areas; 9) determine sizes at maturity and length-fecundity relations for selected rockfish species; and 10) examine the distribution and abundance of cephalopods.

A significant amount of work has proceeded along the lines of the basic objectives since the completion of the 1977 rockfish survey and has been summarized in a series of separate reports. This paper describes the basic methodology used during the demersal survey and summarizes the results of that survey.

Methods

The survey was conducted during 4 July-27 September 1977 and began off Pt. Hueneme, Calif. By beginning in the south, the survey off California coincided as closely as possible to the June-mid-August period when chilipepper and bocaccio were reported to

[1]Gunderson, D. R. 1976. Proceedings of the first rockfish survey workshop, January 20-22, 1976. Unpubl. manuscr., 16 p. Northwest and Alaska Fisheries Center, NMFS, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

[2]Gunderson, D. R., and M. O. Nelson. 1977. Preliminary report on an experimental rockfish survey conducted off Monterey, California, and in Queen Charlotte Sound, British Columbia, during August-September 1976. Unpubl. manuscr., 82 p. Northwest and Alaska Fisheries Center, NMFS, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

[3]The United States-Canada equidistant line was taken as the northern boundary of the survey area.

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be most available to commercial trawlers in that area. The survey off Washington and northern Oregon took place during late August-late September, a period when the availability of Pacific ocean perch to bottom trawls is at a peak (Gunderson, 1977).

The survey area was subdivided into 14 geographic strata (Fig. 1) on the basis of historical fisheries patterns. Each of these was further subdivided into four depth strata (50-99, 100-149, 150-199, and 200-250 fathoms or 91-181, 183-272, 274-364, and 366-457 m) since it was known that rockfish abundance, species composition, and size composition all vary with depth. Those areas that were known to produce high catches of rockfish were singled out for intensive, high density sampling (designated by an H in Figure 1). Four untrawable areas (36°00′ - 36°16′ N, 36°30′ - 36°38′ N, 36°46′ - 36°51′ N, and 40°16′ - 40°25′ N) were delineated, and no attempt was made to trawl in those areas or to estimate the biomass of demersal stocks inhabiting them. Thirteen biological sampling strata were designated (Fig. 1) so that the distribution and intensity of sampling of otoliths, tissues for genetic studies, and ovaries for fecundity studies could be specified.

On the basis of an analysis of alternative survey design strategies using data from the 1976 pilot survey (Lenarz[4]), a systematic series of tracklines were selected every 5 nautical miles (9.3 km) in strata selected for high-density sampling and every 10 nautical miles (18.5 km) in other strata. This was done by choosing a single starting point at Cape Flattery, then proceeding south along the 50-fm (91-m) contour at the appropriate intervals. All tracklines were drawn perpendicular to the 50-fm (91-m) contour.

Supplementary tracklines were added in Juan de Fuca and Astoria canyons where the isobaths turned perpendicular to the coast. These were chosen at 5-nautical-mile (9.3-km) intervals, beginning at the point where the deepest contour turned perpendicular to the coast, and ran between 100-fathom (183-m) contours.

Along each trackline, the number of stations to be sampled in each of the four depth strata was chosen by the following rule:

Linear distance along trackline (nautical miles; km)	No. of stations
<5; 9.3	1
5- 9; 9.3-16.7	2
10-14; 18.5-25.9	3
15-19; 27.8-35.2	4
etc.	

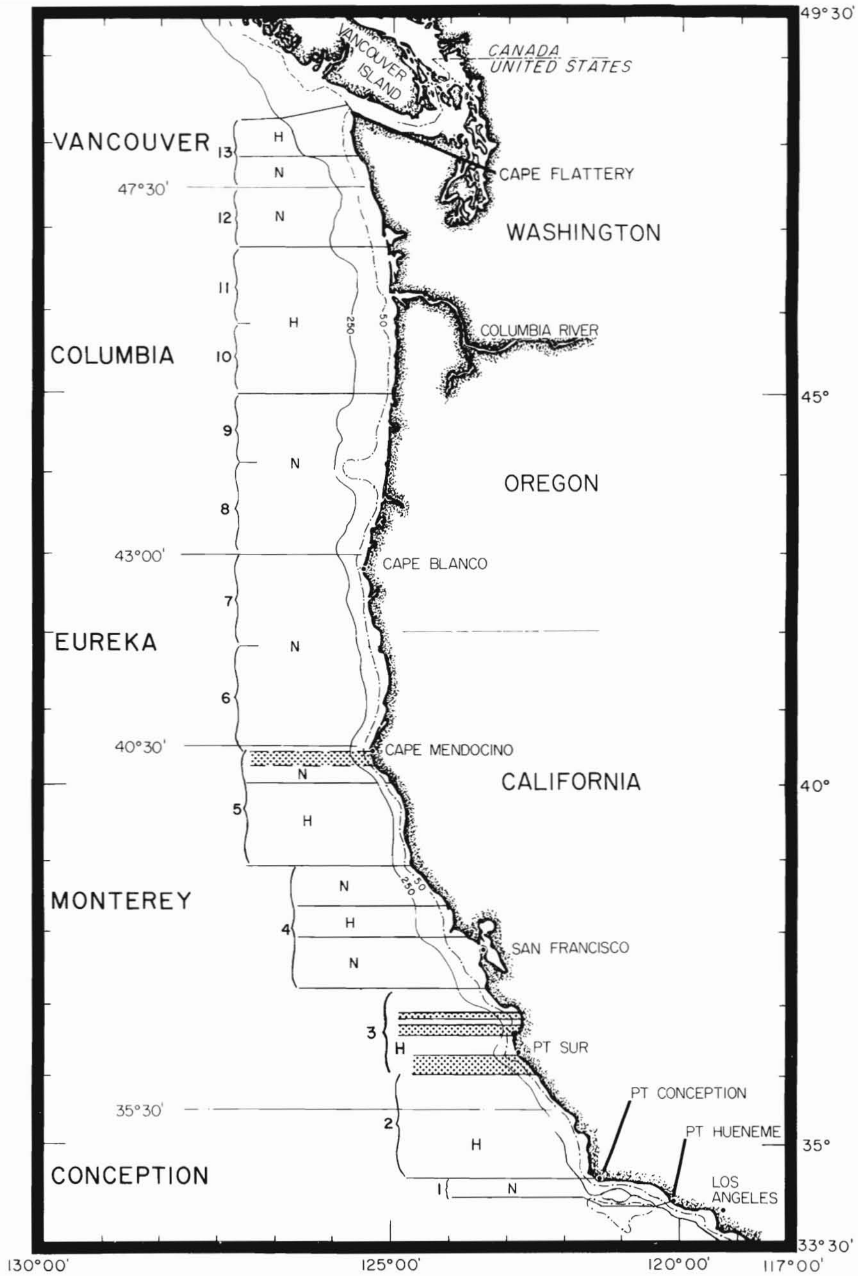

Figure 1.—Geographic sampling strata for the 1977 rockfish survey, N = normal trackline density (10 nautical miles or 18.5 km spacing), H = high trackline density (5 nautical miles or 9.3 km spacing). Stippling denotes untrawlable bottom. Biological sampling strata are indicated by the brackets.

[4]Lenarz, W. H. 1977. Comparison of random, stratified random, and systematic sampling for rockfish. Unpubl. manuscr., 19 p. Southwest Fisheries Center, NMFS, NOAA, 3150 Paradise Drive, Tiburon, CA 94920.

This procedure was repeated whenever a new depth stratum was encountered and concentrated the sampling effort along the continental slope to a far greater extent than a random sampling design (Table 1). The precise location of the stations was chosen by dividing the trackline section into n equal segments and choosing the desired number of stations at random, with the constraint that no two stations be closer than 2 nautical miles (3.7 km). Rockfish are frequently most abundant in marginally trawlable areas, and if there seemed to be even the slightest chance of completing the station, it was included in the survey. A search radius of 1 nautical mile (1.9 km) was allowed around untrawlable stations, but search time was not allowed to exceed 0.5 hour at each station. All survey hauls were 0.5 hour in duration.

Bottom trawling was conducted by the chartered stern trawlers *Pacific Raider*, *Tordenskjold*, and *Commando* and the NOAA research vessel *David Starr Jordan*. Although vessel size and horsepower differed (see following table), all vessels employed similar doors, dandylines, and trawl gear and attempted to maintain a trawling speed of 3 nautical miles per hour (5.6 km/hour).

Vessel	Overall length (ft; m)	Continuous horsepower
Pacific Raider	125; 38.1	750
Tordenskjold	75; 22.9	350
Commando	67; 20.4	365
Jordan	171; 52.1	918

Table 1.—Number of demersal trawl stations occupied during the 1977 rockfish survey by INPFC[1] area and depth stratum.

Depth range (fathoms)	Area (km^2)	No. of usable hauls	Sampling density (km^2 per station)
	Vancouver Area		
50- 99	2,843	32	88.8
100-149	803	17	47.2
150-199	385	14	27.5
200-250	193	7	27.6
50-250	4,224	70	60.3
	Columbia Area		
50- 99	10,547	104	101.4
100-149	2,322	51	45.5
150-199	1,680	33	50.9
200-250	2,193	40	54.8
50-250	16,742	228	73.4
	Eureka Area		
50- 99	2,451	20	122.6
100-149	600	14	42.9
150-199	494	13	38.0
200-250	488	12	40.7
50-250	4,033	59	68.4
	Monterey Area		
50- 99	5,396	78	69.2
100-149	978	43	22.7
150-199	818	44	18.6
200-250	817	41	19.9
50-250	8,009	206	38.9
	Conception Area		
50- 99	1,486	28	53.1
100-149	1,213	29	41.8
150-199	872	19	45.9
200-250	1,159	25	46.4
50-250	4,730	101	46.8

[1]International North Pacific Fisheries Commission.

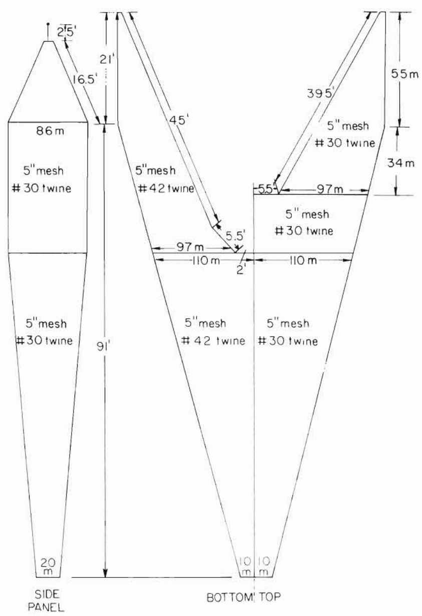

Figure 2.—Nor'Eastern otter trawl (m = meshes). Footrope = 105'; headrope = 90'; circumference = 632 m/5"; intermediate = 3.5" mesh, #60 twine, 105 m around, 60 m long; codend = 3.5" mesh, #96 twine, 105 m around, 120 m long; liner = 1.25" mesh, #18 twine, 300 m long.

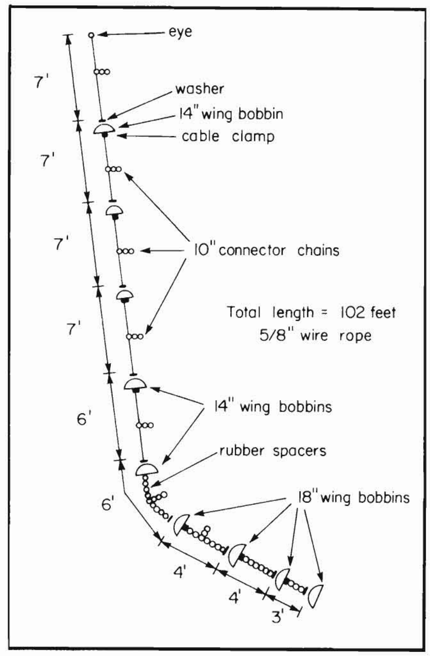

Figure 3.—One-half string of roller gear used for the Nor'Eastern otter trawl.

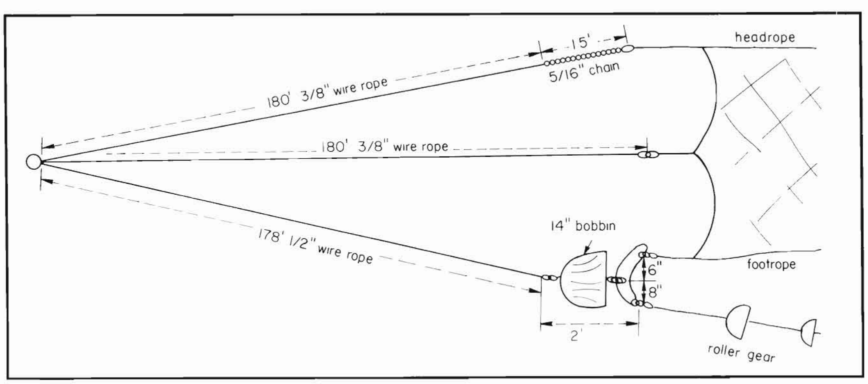

Figure 4.—Dandyline and wing-tip bobbin configuration used on the Nor'Eastern otter trawl.

There were small differences in the weight of the trawl doors employed by the four vessels (1,000-1,250 pounds or 454-567 kg) and in the length of the tail chains/sweeplines used to attach the doors to the dandylines (8-18 feet or 2.4-5.5 m), but other differences were minor. All four vessels employed a Nor'Eastern[5] otter trawl (Fig. 2) with the roller gear and dandyline configuration shown in Figures 3 and 4. Measurements of the operating characteristics of the Nor'Eastern trawl were obtained by using an acoustic measuring device (Wathne, 1977) and indicated that the Nor'Eastern trawl has a horizontal sweep (wing tip to wing tip) of 44 feet (13.4 m) and a vertical opening (at the center of the headrope) of 29 feet (8.8 m) when rigged and towed as it was during the survey.

Processing of a typical trawl catch obtained during the survey is outlined in Figure 5. All catches less than about 2,500 pounds (1,134 kg) were dumped directly from the cod end into a sorting table, then sorted into baskets by species. Up to nine of these baskets were then weighed to the nearest 0.5 pound (0.2 kg) on a platform scale and the total weight caught extrapolated from them. Catches larger than the 2,500-pound sorting table capacity were subsampled using the cargo net system described in Hughes (1976), then processed in a similar fashion.

Once the catch (or the sample of the catch) had been sorted by species, biological samples were obtained to determine the size composition of all "target" species (Pacific whiting; sablefish; bocaccio; chilipepper; shortbelly rockfish; splitnose rockfish; canary rockfish; yellowtail rockfish; darkblotched rockfish, *S. crameri*; silvergray rockfish, *S. brevispinis*; and Pacific ocean perch) by sex. Each biological sample was obtained by taking an equal proportion from the first, middle, and last row of baskets sorted (after Westrheim, 1967) and usually consisted of up to 200 fish. For all

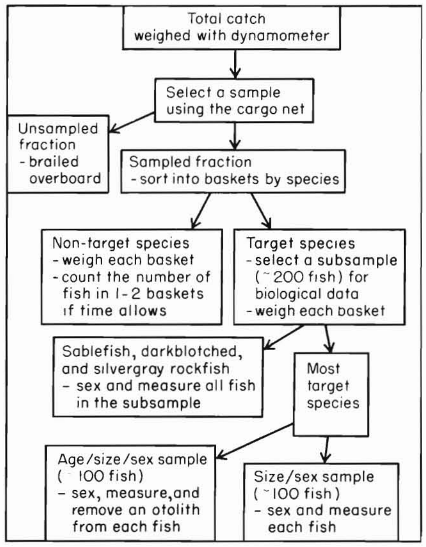

Figure 5.—Typical processing of a catch greater than 2,500 pounds.

species other than sablefish, darkblotched rockfish, and silvergray rockfish, a portion of the biological sample was further sampled for otoliths, as time allowed. This was done either by randomly picking one-half of the baskets in the biological subsample (making certain that an equal number of baskets came from the first, middle, and last portions sorted) or by removing a fixed number of fish from the top of each basket. Otolith collections were usually geared to the size of the catch, with the objective of collecting the bulk of the otoliths for a given species from the largest catches made in the area.

Only a minor amount of effort was spent processing catches of nontarget species, although the number of fish caught was determined for small catches. Mean weight was determined for larger catches as time allowed by counting the number of fish in one or two baskets, then weighing them. The mean weight data were then used to estimate the total number of fish caught for that species.

Estimates of the number caught were almost always obtained for the target species, either by direct count or by extrapolating the mean weight of individuals in the length-frequency sample to the entire catch. Length-frequency data were usually obtained for each target species if 10 or more individuals were caught in a haul.

Biomass estimates for the predominant species in each survey area were obtained by depth and geographic stratum from:

$$\hat{B}_i = \frac{A_i}{a}\,\overline{\mathrm{CPUE}}_i$$

where $\hat{B}_i$ is the estimated biomass in the ith geographic/depth stratum, A_i is the total area within that stratum, a is the area swept per kilometer by a trawl with a 44-foot (13.4-m) horizontal spread, and $\overline{\mathrm{CPUE}}_i$ is the average catch per unit effort (CPUE, kg/km) in the stratum, based on n_i hauls ($\overline{\mathrm{CPUE}}_i = \frac{1}{n_i}\sum_{j=1}^{n_i}\mathrm{CPUE}_{ij}$). These biomass estimates were then summed across all h strata to obtain a biomass estimate $\hat{B}$ for each International North Pacific Fisheries Commission (INPFC) statistical area (Fig. 1) along the Pacific coast. On the assumption that the survey stations within each stratum were randomly distributed with respect to the fish populations and that total biomass estimates are normally distributed around the actual biomass for that area, 90 percent confidence limits for $\hat{B}$ were approximated by:

$$\hat{B} \pm t_{(.90,n_e)}\,(\mathrm{Var}\,\hat{B})^{1/2}$$

where $\mathrm{Var}\,\hat{B} = \sum_{i=1}^{h}\left(\frac{A_i}{a}\right)^2 \mathrm{Var}\,(\overline{\mathrm{CPUE}}_i)$,

$$\mathrm{Var}\,(\overline{\mathrm{CPUE}}_i) = \frac{1}{n_i(n_i-1)}\sum_{j=1}^{n_i}(\mathrm{CPUE}_{ij}-\overline{\mathrm{CPUE}}_i)^2$$

and n_e = number of effective degrees of freedom (Cochran, 1962).

Results

The relative abundance (kilograms caught per kilometer trawled) of the dominant rockfish species encountered during the demersal survey is shown geographically in Figures 6-14, and by INPFC area and depth in Table 2.

Three distinct regions can be used to describe the patterns of demersal rockfish distribution observed during the 1977 survey. The most northern region extended from Cape Flattery to Cape Blanco (Vancouver and Colum-

[5]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

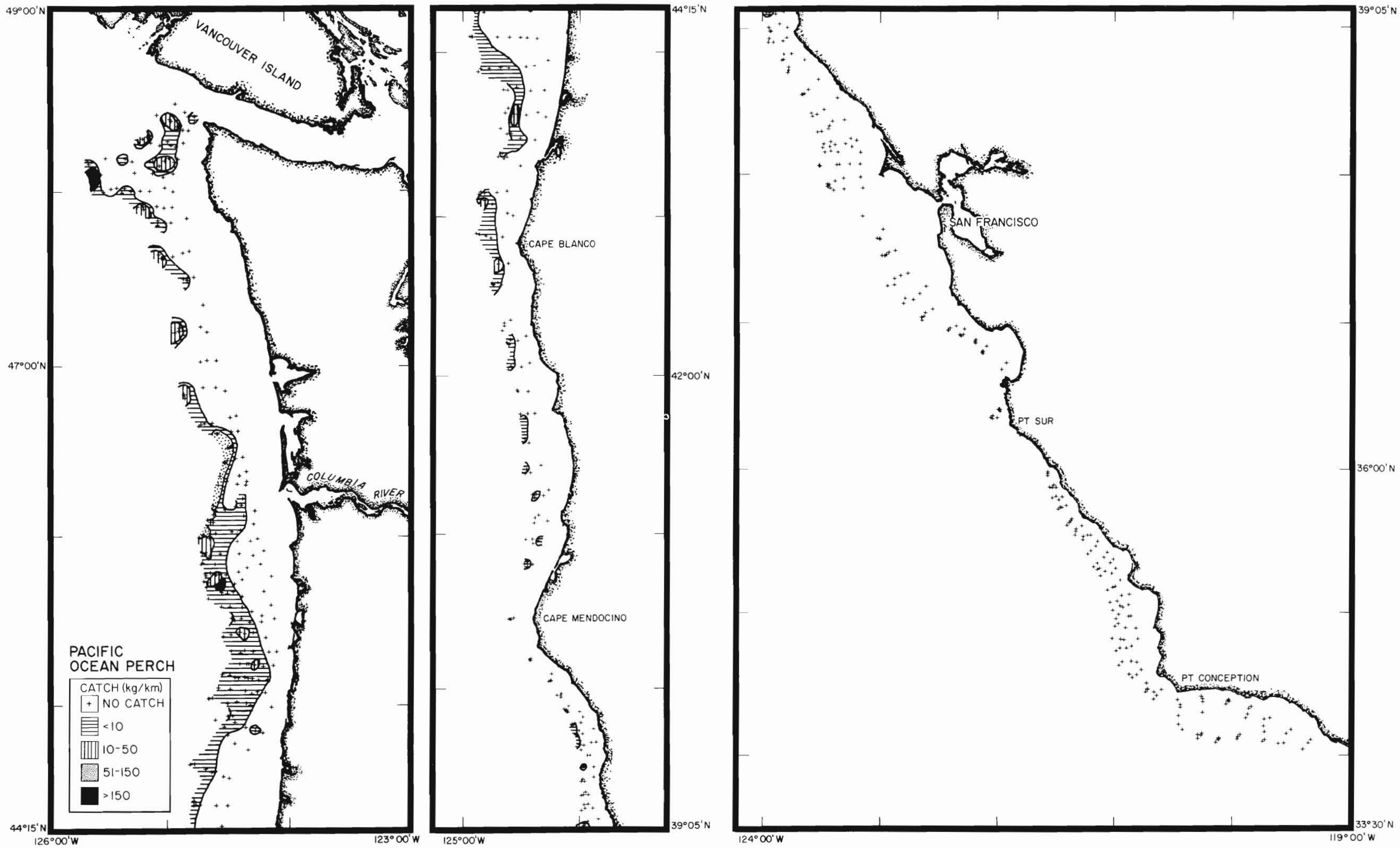

Figure 6.—Distribution and relative abundance of Pacific ocean perch off Washington, Oregon, and California, 1977.

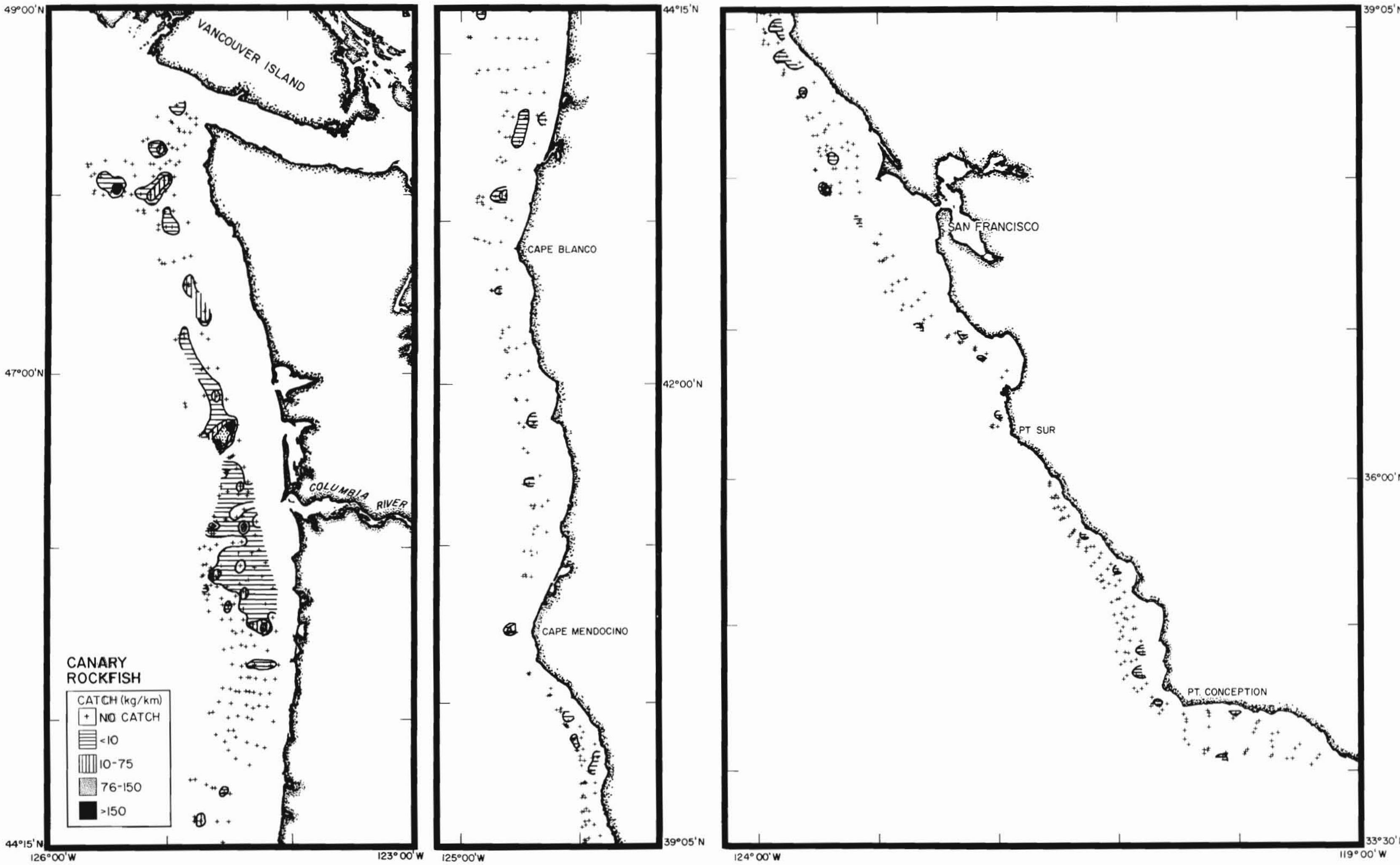

Figure 7.—Distribution and relative abundance of canary rockfish off Washington, Oregon, and California, 1977.

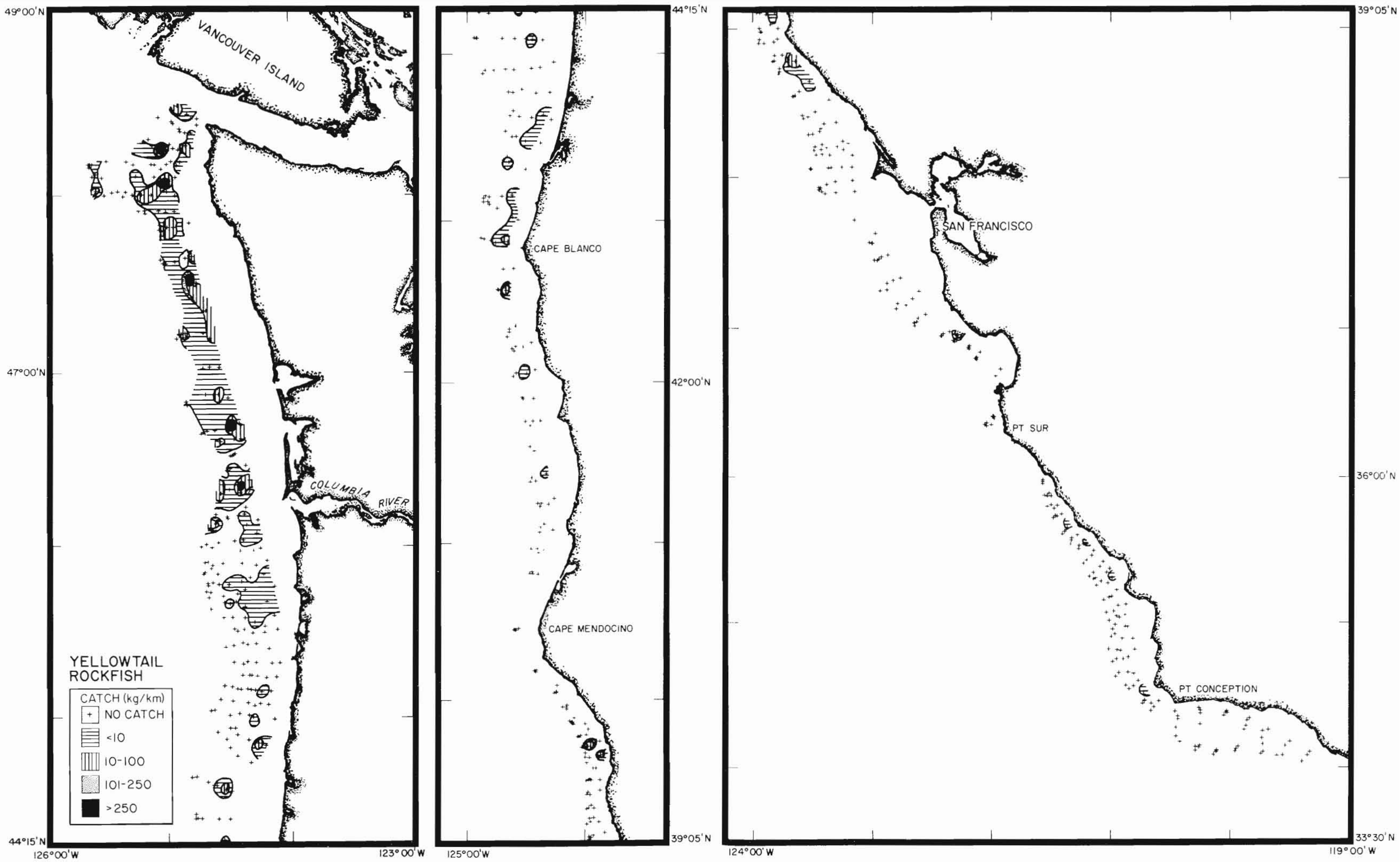

Figure 8.—Distribution and relative abundance of yellowtail rockfish off Washington, Oregon, and California, 1977.

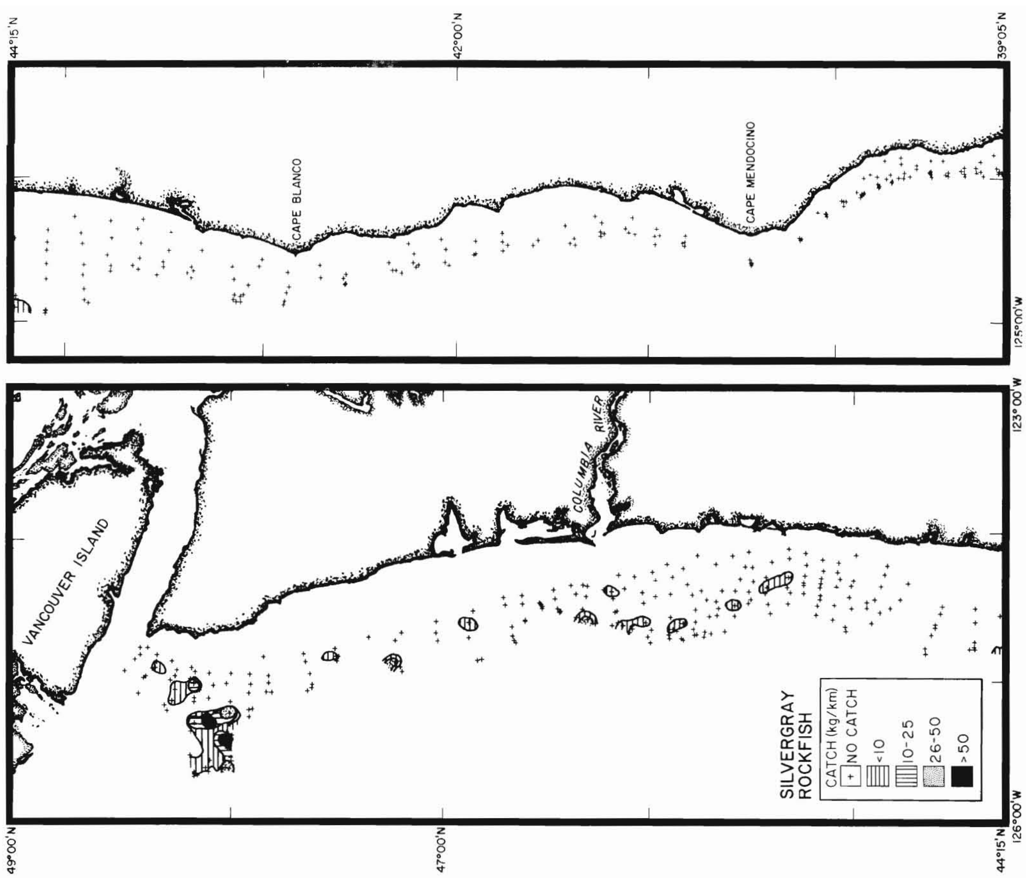

Figure 9.—Distribution and relative abundance of silvergray rockfish off Washington, Oregon, and California, 1977.

bia INPFC areas) and was characterized by a canary-yellowtail-silvergray assemblage in 50-99 fathoms (91-181 m), a Pacific ocean perch assemblage in 100-199 fathoms (183-364 m), and a Pacific ocean perch-rougheye, *S. aleutianus*-shortspine thornyhead, *Sebastolobus alascanus*, assemblage in 200-260 fathoms (366-475 m). Silvergray rockfish were confined to the most northerly portions of the survey area, and were most abundant in the Vancouver area.

The Cape Blanco-Cape Mendocino region (Eureka INPFC area) was a region of very low rockfish abundance. Yellowtail and stripetail, *S. saxicola*, rockfish dominated the rockfish assemblage in the 50- to 99-fathom (91- to 181-m) zone, while darkblotched and splitnose rockfish dominated from 100 to 260 fathoms.

The third region, Cape Mendocino to Pt. Hueneme (Monterey and Conception INPFC areas) was characterized by a shortbelly-chilipepper-bocaccio-stripetail assemblage in the 50- to 99-fathom (91- to 181-m) zone and a splitnose assemblage in the 200- to 260-fathom (366- to 475-m) zone. The intermediate depth zone (100-199 fathoms or 183-364 m) seemed to be an area where the splitnose assemblage gradually replaced the assemblage inhabiting the continental shelf. The abundance of rockfish varied substantially within this region, with catch rates being much higher in the Monterey INPFC area than they were to the south (Table 2).

Although shortbelly rockfish dominated the demersal biomass of rockfish in the Monterey area, results from the hydroacoustic survey indicate that the bulk of this stock is found in midwater. The area between Monterey Bay and San Francisco Bay (Fig. 12) was clearly indicated as the area containing the most significant concentrations of shortbelly rockfish during the demersal and pelagic surveys, but the estimated midwater biomass in this area (295,000 t) (Northwest and Alaska Fisheries Center[6]) was over 10 times greater than the demersal biomass for the entire Monterey area (Table 3).

Biomass estimates for the dominant rockfish species encountered during the 1977 survey are shown in Table 3. In addition to the species mentioned previously, several additional species made up a major portion of the biomass in certain areas. Widow rockfish, *Sebastes entomelas*, redstripe rockfish, *S. proriger*, and bocaccio made up a significant portion of the biomass in the Cape Flattery-Cape Blanco region (Vancouver and Columbia INPFC areas), and were most abundant in the 50- to 99-fathom (91- to 181-m) zone. Darkblotched and sharpchin rockfish, *S. zacentrus*, contributed significantly

[6]Northwest and Alaska Fisheries Center. 1978. Cruise results, NOAA R/V *Miller Freeman*, Cruise No. MF-77-02, July 12-September 30, 1977. Unpubl. rep., 19 p. Northwest and Alaska Fisheries Center, NMFS, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

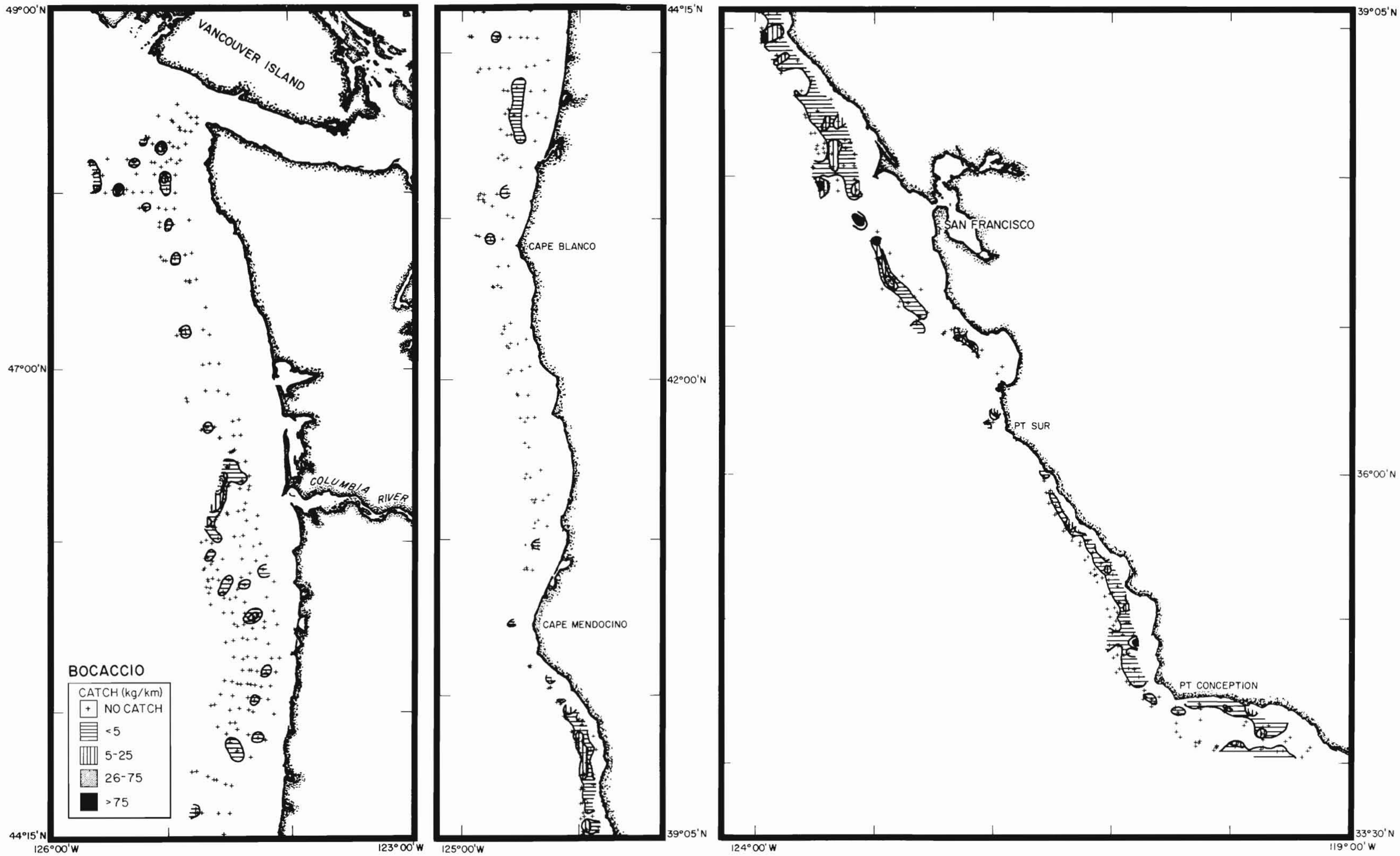

Figure 10.—Distribution and relative abundance of bocaccio off Washington, Oregon, and California, 1977.

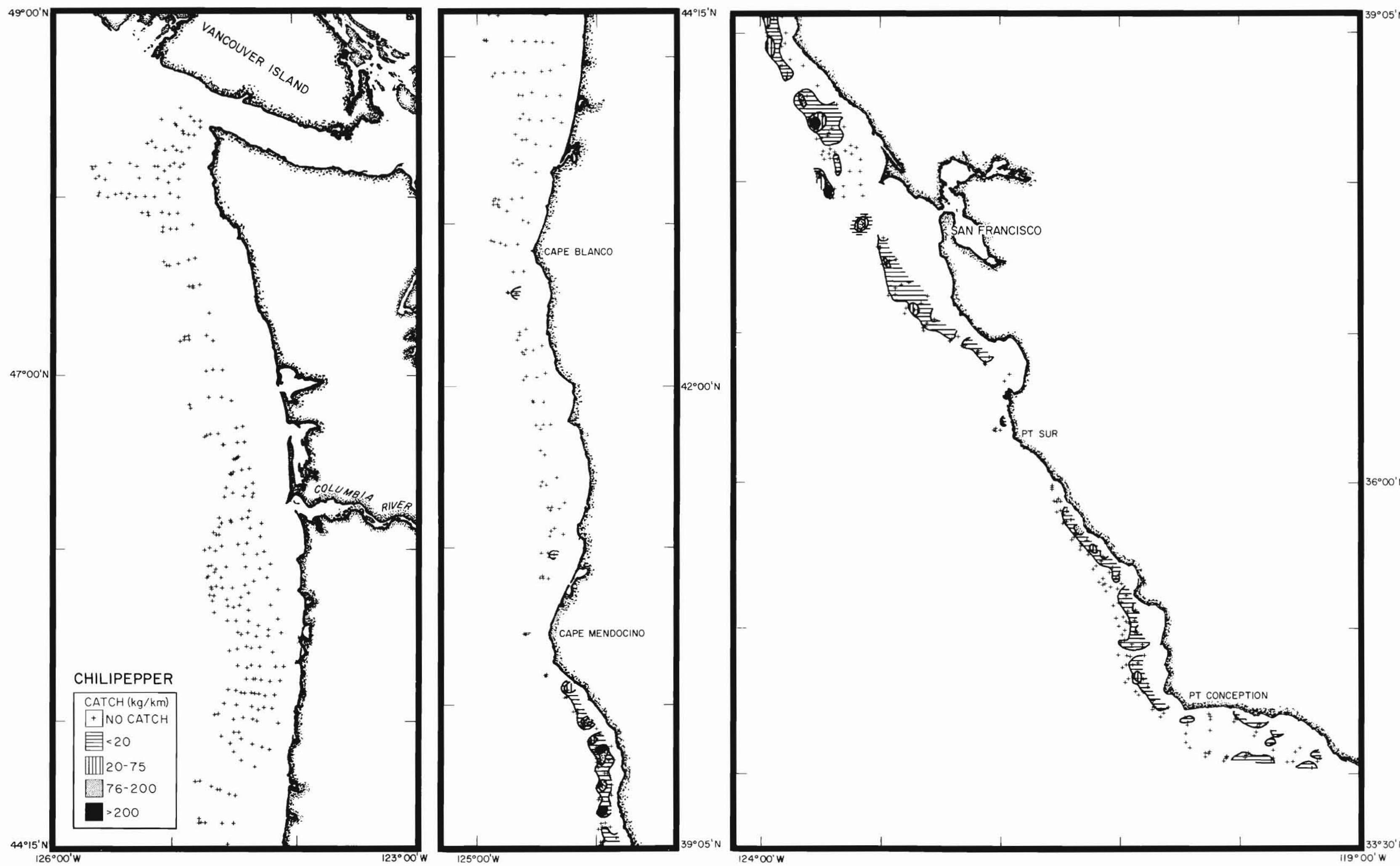

Figure 11.—Distribution and relative abundance of chilipepper off Washington, Oregon, and California, 1977.

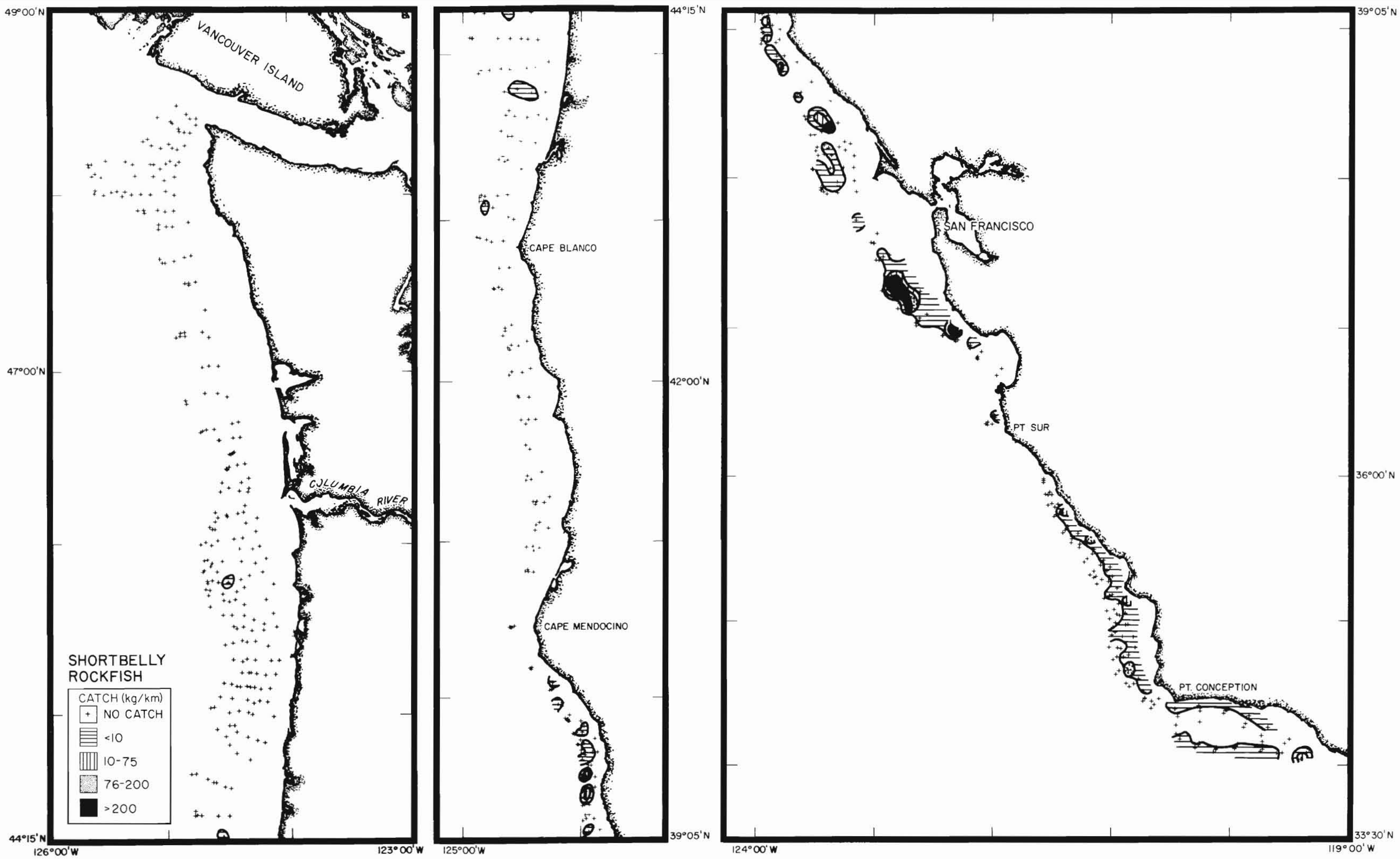

Figure 12.—Distribution and relative abundance of shortbelly rockfish off Washington, Oregon, and California, 1977.

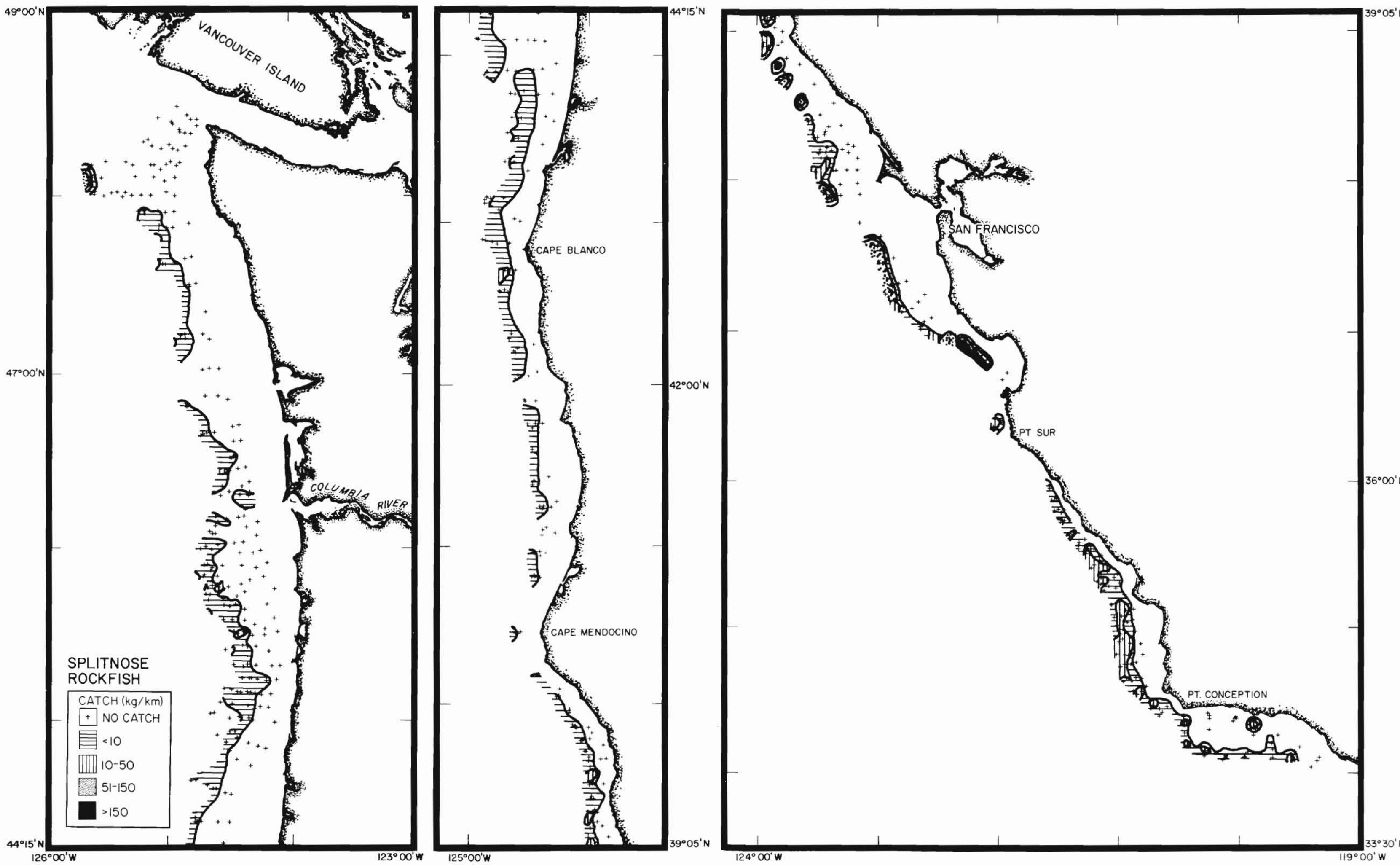

Figure 13.—Distribution and relative abundance of splitnose rockfish off Washington, Oregon, and California, 1977.

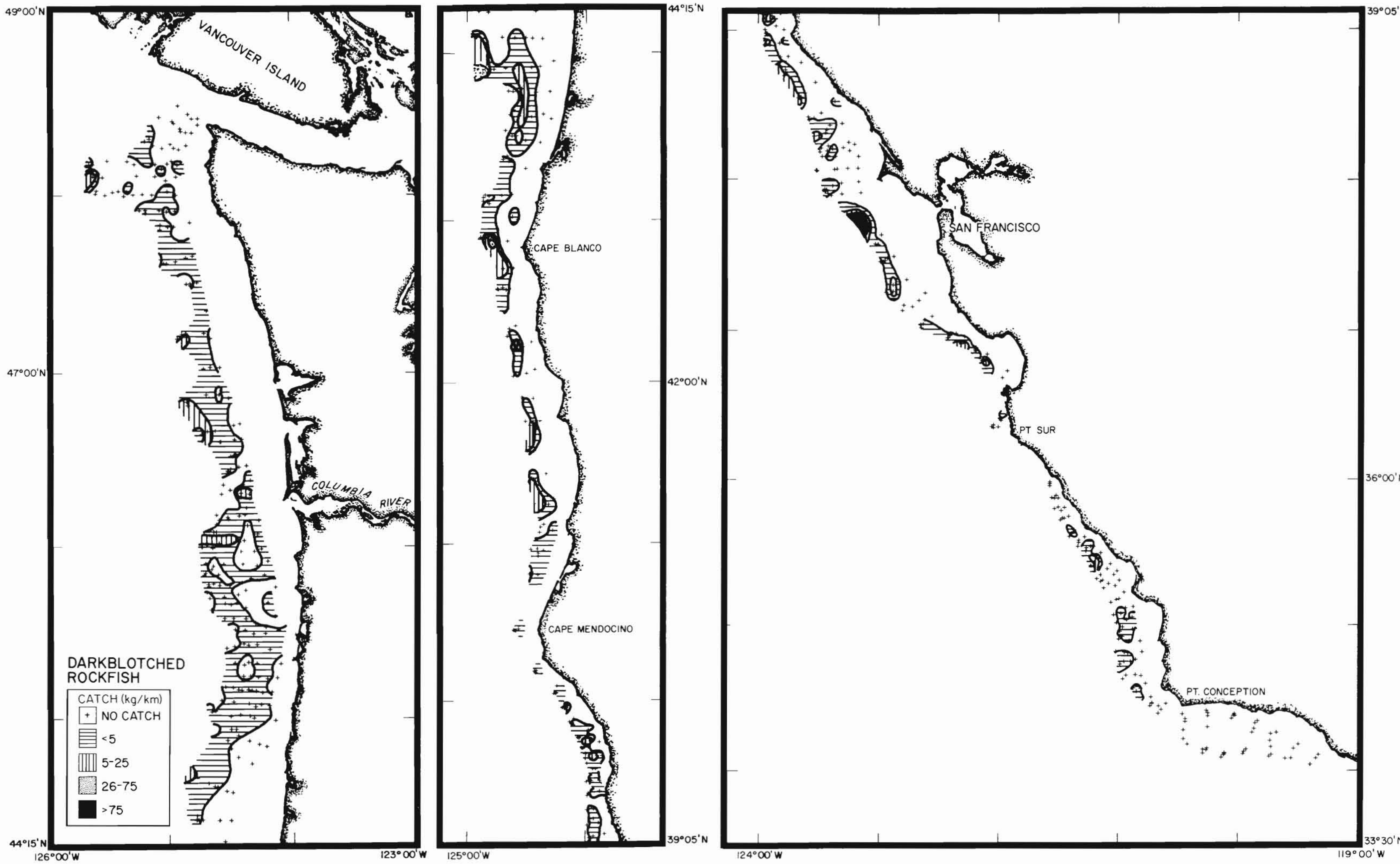

Figure 14.—Distribution and relative abundance of darkblotched rockfish off Washington, Oregon, and California, 1977.

Table 2.—Catch per unit effort (kg/km) obtained during the 1977 rockfish survey by INPFC[1] area and depth zone (fathoms). Quantities less than 0.1 kg/km are not shown.

Principal species of commercial importance	Vancouver Area				All depths comb.	Columbia Area				All depths comb.	Eureka Area				All depths comb.
	50-99	100-149	150-199	200-260		50-99	100-149	150-199	200-260		50-99	100-149	150-199	200-260	
Pacific ocean perch	0.9	101.2	45.0	9.0	35.4	1.5	26.5	16.6	3.1	9.6	0.1	3.2	2.2	0.1	1.3
Yellowtail rockfish[2]	58.2	3.0			26.9	15.4	2.2	0.2		7.5	3.6	0.3			1.3
Canary rockfish	104.1	0.1			46.8	9.9	2.8	0.2		5.2	0.2				0.1
Silvergray rockfish	71.4	7.2			33.9	0.1	2.1			0.5					
Darkblotched rockfish	0.2	0.3	3.7	0.8	1.0	1.0	4.5	3.4	1.3	2.2		7.4	4.1	0.9	2.8
Shortspine thornyhead		2.0	3.3	3.8	1.5	0.9	2.7	5.5	3.0	2.3		1.5	0.4	0.3	0.5
Bocaccio	8.2	0.8			3.9	0.9	1.9	0.1		0.9	0.1	0.2			0.1
Chilipepper											0.6				0.2
Subtotal	243.0	114.6	52.0	13.6	149.4	29.7	42.7	26.0	7.4	28.2	4.6	12.6	6.7	1.3	6.3
Percent of total rockfish catch	(89.5)	(86.3)	(67.4)	(51.1)	(86.4)	(76.2)	(69.8)	(72.2)	(56.5)	(72.5)	(54.8)	(76.8)	(35.8)	(48.1)	(55.3)
Other prominent rockfish															
Splitnose rockfish	0.2	1.1	19.0		4.2	0.1	3.1	3.8	0.6	1.4		2.5	11.0	0.3	3.1
Shortbelly rockfish[2]															
Stripetail rockfish						0.2	0.5			0.2	3.6	0.6			1.4
Sharpchin rockfish	1.1	5.9	0.2		2.0	1.1	10.0	1.2		2.9					
Redstripe rockfish	9.9	2.6			5.1	5.3	1.0			2.6					
Widow rockfish[2]	15.2	2.8			7.5	0.2	0.8	0.3		0.3	0.1	0.1			0.1
Rougheye rockfish	0.1	0.9	3.1	7.5	1.6	0.2	0.2	1.7	3.5	1.0			0.2		
Subtotal	26.5	13.3	22.3	7.5	20.4	7.1	15.6	7.0	4.1	8.4	3.7	3.2	11.2	0.3	4.6
Percent of total rockfish catch	(9.8)	(10.0)	(28.9)	(28.2)	(11.8)	(18.2)	(25.5)	(19.4)	(31.3)	(21.6)	(44.0)	(19.5)	(59.9)	(11.1)	(40.4)
All rockfish comb.	271.6	132.8	77.2	26.6	172.9	39.0	61.2	36.0	13.1	38.9	8.4	16.4	18.7	2.7	11.4

Principal species of commercial importance	Monterey Area				All depths comb.	Conception Area				All depths comb.
	50-99	100-149	150-199	200-260		50-99	100-149	150-199	200-260	
Pacific ocean perch										
Yellowtail rockfish	2.2				0.8					
Canary rockfish	1.0	1.0			0.6	0.3				0.1
Silvergray rockfish										
Darkblotched rockfish	1.3	4.5	6.5	0.8	3.0			0.6		0.1
Shortspine thornyhead		0.5	1.5	1.1	0.6		0.1	0.3	0.6	0.3
Bocaccio	5.5	26.0	0.6		7.6	5.9	2.3			2.3
Chilipepper	13.1	38.9	7.8		14.8	0.6	1.5			0.6
Subtotal	23.1	70.9	16.4	1.9	27.4	6.8	3.9	0.9	0.6	3.4
Percent of total rockfish catch	(28.3)	(45.2)	(19.9)	(6.6)	(31.5)	(28.0)	(12.6)	(3.4)	(4.2)	(14.2)
Other prominent rockfish										
Splitnose rockfish		21.0	58.6	20.7	21.0	0.1	13.7	24.0	11.0	11.2
Shortbelly rockfish[2]	51.8	26.9	1.1		25.2	3.1	3.0			1.7
Stripetail rockfish	5.3	33.4	1.3	0.1	9.3	12.4	9.5			6.2
Sharpchin rockfish		0.4			0.1					
Redstripe rockfish										
Widow rockfish	0.2	0.9	0.1		0.3	1.0	0.1			0.3
Rougheye rockfish				0.1					0.2	
Subtotal	57.3	82.6	61.1	20.9	55.9	16.6	26.3	24.0	11.2	19.4
Percent of total rockfish catch	(70.1)	(52.6)	(74.1)	(73.1)	(64.3)	(68.3)	(85.1)	(91.6)	(78.3)	(80.8)
All rockfish comb.	81.7	156.9	82.5	28.6	86.9	24.3	30.9	26.2	14.3	24.0

[1]International North Pacific Fisheries Commission.
[2]Significant quantities of this species were found in midwater

to the rockfish biomass in the 100- to 200-fathom (183- to 366-m) zone in the same region (Table 2), particularly in the Columbia area.

Judging from midwater trawl catches made during the hydroacoustic survey (Dark et al., 1980) and incidental rockfish catches made during the Soviet-Polish midwater fishery for Pacific whiting (French et al.[7]), a significant portion of the widow rockfish stock in the Vancouver-Columbia area appears to exist in midwater, and the biomass estimates in Table 3 probably underestimate the actual biomass substantially. Some midwater concentrations of yellowtail rockfish were also encountered during the hydroacoustic survey, but they were far less abundant than widow rockfish. This is substantiated by data on incidental rockfish catches made in the 1977 midwater trawl fishery for Pacific whiting in the Columbia area, since U.S. observers reported that widow rockfish made up 69 percent of these catches while yellowtail rockfish made up only 2 percent (French et al., footnote 7). No large (>225 kg) midwater catches of rockfish other than shortbelly rockfish, widow rockfish, or yellowtail rockfish were made during the hydroacoustic survey (Dark et al., 1980), and shortbelly rockfish was the only species that was plentiful enough to allow estimates of pelagic biomass to be made.

Shortspine thornyheads are known to extend out to about 500 fathoms (914 m) (Alton, 1972) in significant quantities, and the region surveyed in 1977 covered only the shallowest portions of

[7]French, R., R. Nelson, J. Wall, and D. Hennick. 1978. Data from the observations of foreign fishing fleets off the coast of California, Oregon and Washington, 1977. Unpubl. manuscr., 21 p. Northwest and Alaska Fisheries Center, NMFS, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

their bathymetric range. The biomass estimates in Table 3 substantially underestimate their total biomass as a result. Catch rates for the 50- to 250-fathom (91- to 457-m) survey area were highest in the Cape Flattery-Cape Blanco region, although the largest commercial landings of this species (Fraidenburg et al., 1977) occur in the Eureka area.

Table 3.—Estimated demersal biomass ($\hat{B}$) of key rockfish species in the 50- to 250-fathom (91- to 457-m) depth zone, as determined from 1977 rockfish survey data.

INPFC[1] area and species	$\hat{B}$ (t)	90% Confidence limits Lower	Upper
S. Vancouver[2]			
Pacific ocean perch	7,730	0	16,370
Canary	19,940	0	53,350
Yellowtail	11,480	140	22,820
Silvergray	3,100	0	7,860
Bocaccio	1,620	0	4,080
Darkblotched	190	50	330
Splitnose	640	10	1,280
Rougheye	270	120	410
Widow[3]	3,040	0	7,050
Sharpchin	590	200	980
Redstripe	2,050	0	4,120
Shortspine thornyhead[4]	290	210	370
Total	50,940		
Columbia			
Pacific ocean perch	7,100	4,300	9,910
Canary	6,290	3,080	9,510
Yellowtail	11,950	3,370	20,540
Silvergray	550	0	2,460
Bocaccio	920	370	1,470
Darkblotched	2,100	1,530	2,670
Splitnose	1,180	790	1,560
Rougheye	820	550	1,100
Widow[3]	330	180	490
Sharpchin	2,180	850	3,520
Redstripe	3,720	0	7,940
Shortspine thornyhead[4]	2,020	1,650	2,390
Total	39,160		
Eureka[5]			
Pacific ocean perch	220	80	360
Canary	490	0	1,280
Yellowtail	640	0	1,370
Bocaccio	40	10	70
Chilipepper	110	0	280
Darkblotched	540	290	780
Splitnose	530	100	950
Stripetail	670	0	1,570
Shortspine thornyhead[4]	140	30	240
Total	3,380		
Monterey			
Bocaccio	4,980	1,960	8,000
Chilipepper	9,280	5,490	13,070
Yellowtail	650	20	1,280
Canary	220	60	380
Darkblotched	1,410	270	2,550
Splitnose	6,840	4,210	9,470
Shortbelly[3]	24,340	7,710	40,980
Stripetail	4,990	2,570	7,420
Shortspine thornyhead[4]	190	120	250
Total	52,900		
N. Conception			
Bocaccio	830	90	1,580
Chilipepper	200	60	340
Splitnose	3,610	2,660	4,560
Shortbelly[3]	610	60	1,160
Stripetail	2,170	1,000	3,330
Shortspine thornyhead[4]	80	60	110
Total	7,500		

[1]International North Pacific Fisheries Commission.
[2]South of the United States-Canada equidistant line.
[3]A substantial proportion of this stock is known to exist in midwater, and this should not be interpreted as an estimate of total biomass.
[4]A substantial proportion of this stock lies deeper than 250 fathoms, and this should not be interpreted as an estimate of total biomass.
[5]Including the area between lat. 40°25′ and 40°30′N.

Discussion

Results from the 1976 pilot survey (Adams[8]; Gunderson and Nelson, footnote 2) showed that most species of rockfish are characterized by a highly contagious spatial distribution, resulting in a high degree of sampling variability in trawl survey data. Dense, tightly-clustered aggregations were periodically encountered during the survey, and the results from a single large trawl catch can significantly increase both the biomass estimate for a given species and its variance.

Ninety percent confidence intervals around biomass estimates obtained in 1977 typically ranged from ±30 to 150 percent (Table 3), reflecting the same order of variability encountered during the pilot survey, although the extreme ranges obtained for bank rockfish, *S. rufus*, (±233 percent) and blackgill rockfish, *S. melanostomus*, (±213 percent) in 1976 were seldom encountered. The broadest ranges encompassed by 90 percent confidence intervals were around biomass estimates for canary rockfish in the Vancouver and Eureka areas (±168 percent and ±161 percent, respectively), silvergray rockfish in the Vancouver and Columbia areas (±154 percent and ±347 percent, respectively) and chilipepper in the Eureka area (±155 percent).

Estimates of Pacific ocean perch biomass in the Vancouver and Columbia area (±112 percent and ±40 percent, respectively) and yellowtail rockfish in the same areas (±99 percent and ±72 percent) were of intermediate precision, and a recent cohort analysis of Pacific ocean perch stocks (Gunderson[9]) suggests that the point estimates in Table 3 are realistic. Biomass estimates for bocaccio and chilipepper rockfish in the Monterey area are also intermediate in their precision (±61 percent and ±41 percent, respectively) and should be useful in the management of these stocks.

Most estimates of rockfish biomass obtained through demersal trawling are relatively imprecise. Such estimates are valuable at present, when no alternative sources of stock assessment data are available, but will become less valuable as data on commercial catches, CPUE, and age composition become available.

A substantial effort should be made in the future to examine alternative survey strategies for rockfish and to determine the degree of sampling effort required to produce more precise biomass estimates. At present, it seems that more precise estimates could be obtained by reducing the extent of the survey area, using the 1977 survey results to concentrate sampling effort in the most important geographic-bathymetric areas and increasing the number of hauls made within them. The variance within such "index" areas would be lower than that encountered during the 1977 survey, but could still be quite high given the contagious nature of rockfish distributions.

[8]Adams, P. B. 1977. The effect of spatial patterns of rockfish (genus *Sebastes*) on sampling strategies. Unpubl. manuscr., 19 p. Southwest Fisheries Center, NMFS, NOAA, 3150 Paradise Drive, Tiburon, CA 94920.

[9]Gunderson, D. R. 1978. Results of cohort analysis for Pacific ocean perch stocks off British Columbia, Washington, and Oregon, and an evaluation of alternative rebuilding strategies for these stocks. Unpubl. manuscr., 20 p. Northwest and Alaska Fisheries Center, NMFS, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

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