NOAA Technical Memorandum NMFS F/NWC-48

Bottom Trawl Survey of Canary Rockfish *(Sebastes pinninger),* Yellowtail Rockfish *(S. flavidus),* Bocaccio *(S. paucispinis),* and Chilipepper (S. *goodei)* off Washington-California, *1980*

by

Thomas A. Dark, Mark E. Wilkins,

and Kathleen Edwards

September **1983**

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

BOTTOM TRAWL SURVEY OF CANARY ROCKFISH (*Sebastes pinninger*), YELLOWTAIL ROCKFISH (S. *flavidus*), BOCACCIO (S. *paucispinis*), AND CHILIPEPPER (S. *goodei*) OFF WASHINGTON-CALIFORNIA, 1980

by

Thomas A. Dark, Mark E. Wilkins, and Kathleen Edwards

Resource Assessment and Conservation Engineering
Northwest and Alaska Fisheries Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112

September 1983

CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

The Northwest and Alaska Fisheries Center conducted a bottom trawl survey during July-October, 1980 off Washington, Oregon, and California as the second in a series of triennial assessments of Pacific whiting and important shelf rockfish resources. Two chartered trawl vessels sampled at 529 preselected stations from Monterey, California to northern Vancouver Island between the depths of 30 and, 200 fathoms. Catch per unit effort data for canary rockfish (*Sebastes pinniger*), yellowtail rockfish (S. *flavidus*), bocaccio (S. *paucispinis*), and chilipepper (S. *goodei*) were compared with data from a 1977 survey and decreases in population densities were observed in most areas. Canary and yellowtail biomass estimates were greatest in the International North Pacific Fishery Commission (INPFC) Vancouver and Columbia areas and about equally distributed between the two areas. Ninety-four and 71 percent of the estimated chilipepper and bocaccio biomass occurred to the south in the INPFC Monterey area. Age and length frequencies are presented by INPFC area. Factors affecting trawl survey estimates and variation in the availability of rockfish to sampling gear are discussed.

INTRODUCTION

Fishery-independent resource surveys have been conducted by the Northwest and Alaska Fisheries Center for a number of years to complement analyses based on fishery data and to provide statistical assessment and biological information not available from other sources. In 1977, the first of a series of triennial west coast groundfish assessment surveys was completed (Gunderson and Sample 1980). The results of that survey were utilized by the Pacific Fishery Management Council in the development of its groundfish management plan.

In 1980, a second comprehensive survey was completed off the coasts of Canada, Washington, Oregon, and California. The 1980 survey was designed to provide current information on the distribution, abundance, and biological characteristics of Pacific whiting (*Merluccius productus*) and shelf rockfish stocks. Special sampling was incorporated to assess the distribution and abundance of canary (*Sebastes flavidus*) and yellowtail rockfish (S. *pinniger*) in two commercially important areas off Washington and Oregon. The purpose of this special sampling was to evaluate optimum yields (OYs) recommended in the Pacific Fishery Management Council's draft West Coast Groundfish Management Plan which were being approached or exceeded by 1978 and 1979 commercial catches of canary and yellowtail rockfish. This report presents information on these key rockfish species based on the bottom trawl survey data. Results of bottom trawl/hydroacoustic surveys for Pacific whiting will be contained in a separate report.

METHODS

Timing and Geographic-bathymetric Coverage

The 1980 Pacific whiting/shelf rockfish survey was conducted during 5 July-1 October. Primary considerations in selecting this study period were that Pacific whiting should be well established in summer feeding areas, an optimum time for determining abundance, and it approximated the timing of the 1977 study to facilitate comparisions between the two surveys. The geographic and depth boundaries of the survey area were established to include the distribution of the commercially available portion of the Pacific whiting resource as well as rockfish areas of major concern. Geographic boundaries were lat. 36°48'N (Monterey Bay, California) on the south and lat. 50°00'N (northern Vancouver Island, B.C.) on the north. Survey depths were from 30 to 200 fathoms (55-366 m).

Vessels and Equipment

Two commercial west coast trawlers, the Pat San Marie and Mary Lou, were chartered for a period of 80 days each to conduct this survey. The Pat San Marie. is a 101-ft (31 m) sternramp trawler powered by an 865-hp main engine. Deck equipment includes hydraulically powered trawl winches, a single net reel mounted above the stern ramp, dual net reels mounted just aft of the pilot house, and lifting winches and tackle mounted on the main boom and a picking boom.

The Mary Lou is an 86-ft (26 m) stern trawler powered by twin main engines providing 700 hp. Deck equipment includes hydraulically powered trawl winches, dual net reels mounted above the stern ramp, and lifting winches and tackle mounted on the main boom and picking boom.

The vessels had similar electronic equipment which included VHF and single sideband radios, dual radars, dual echosounders, sector scanning sonar, net sounders, automatic pilot, and dual Loran C receivers. In addition, the *Pat San Marie* had a third Loran C receiver with a Loran-to-geodetic coordinate converter.

The trawl net used for the demersal survey was the Nor'Eastern bottom trawl equipped with 14- and 18-inch (35.6 and 45.7 cm) rollers on the footrope. This trawl has a headrope of 90 ft (27.4 m) and a footrope of 105 ft (32 m). Construction in the forebody is of S-in (127 m) stretched-mesh web, 3.5-in (89 mm) web in the cod end, and a 1.25-in (32 mm) web liner in the cod end. Each wing was attached to a 5 x 7-ft (1.5 x 2.1 m) steel V-shaped trawl door by three 30 fathom (55 m) dandylines, the bottom one of which was l/2-in (12.5 mm) diameter, and the top two were 3/8-in (9.8 mm) diameter steel cable. The mouth opening dimensions of this net were not measured on either vessel during this survey, but average net mouth dimensions measured aboard similar vessels fishing this gear at a similar speed are 44-ft (13.4 m) wide and 29-ft (8.8 m) high. Because a study to measure relative fishing powers of the two vessels was not practical, every effort was made to rig the nets on each vessel identically and to assure that the vessels utilized similar setting, fishing, and retrieving procedures to provide, as nearly as possible, comparable catch data.

The bottom trawl survey area was stratified latitudinally and bathymetrically based on available information on the distribution of the target species. Greatest sampling intensities were scheduled for areas of highest projected abundance in an effort to reduce the variances of mean catch rates. Intensive sampling was planned in the International North Pacific Fisheries Commission

(INPFC)1/ Columbia area (Fig. 1) where shelf rockfish catches are approaching or had exceeded proposed acceptable biological catches (ABCS). Commercial catch records for the two species of major concern, canary and yellowtail, were used to delineate the rockfish study areas within the Columbia region. One such area was located off Oregon between lat. 42°50'-44°18'N and the second off Washington between lat. 46°10'-47°20'N (Fig. 1). Known bathymetric distributions of these species were used to select sampling strata at 30-100 fathoms (55-183 m) and 101-120 fathoms(184-219 m). Depth strata of 30-100 fathoms (55-183) and 101-200 fathoms (184-366 m) were established for bocaccio (Sebastes paucispinis) and chilipepper (2. goodei).

The process of trawl sample allocation involved establishing tracklines perpendicular to the 30 fathom (55 m) isobath. Trackline spacing directly affected sample density. Trackline intervals and sampling variation from the 1977 survey (Gunderson and Sample 1980) were used to determine the spacing necessary for desired precision in the 1980 survey. In 1977, tracklines in high density rockfish areas were established at 5-nmi intervals and resulting precision varied with species and area. Ninety percent confidence limits for yellowtail and canary rockfish biomass estimates for the Columbia area were +72 and +51% of the point estimate, respectively. Because of the critical management needs for status of stock information in the Columbia area on canary and yellowtail rockfish, trackline intervals were reduced to 3 nmi in 1980 in hope of obtaining better precision in abundance estimates than achieved in 1977. Bocaccio and chilipepper were secondary target species, so no effort was made to provide for especially intense sampling of these species.

l/ INPFC statistical areas were used throughout the development of the survey design and subsequent data analyses because they represent the management areas adopted by the Pacific Fishery Management Council.

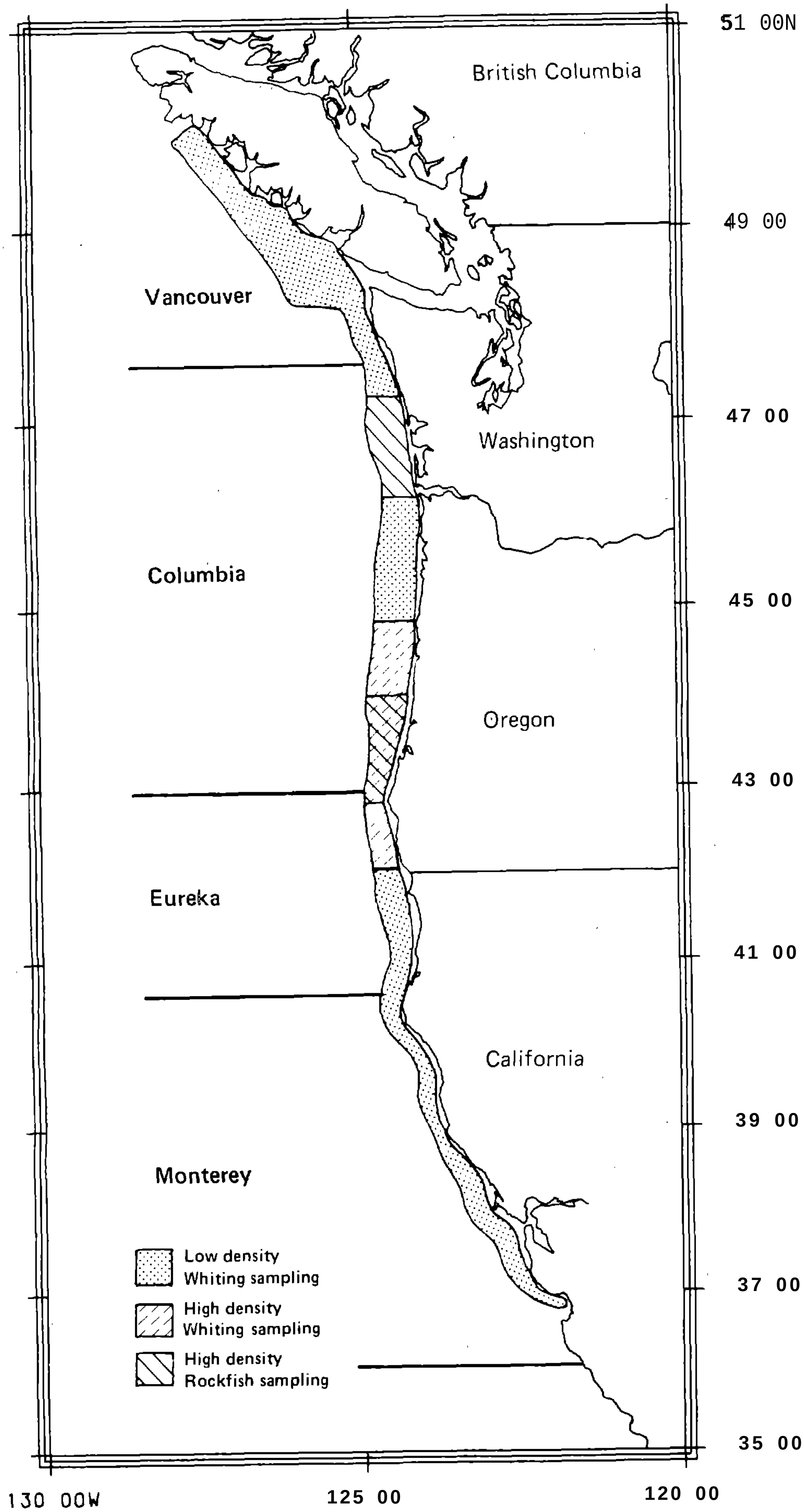

Figure 1.,--The 1980 bottom trawl survey area showing regions of differing station density

Trawl stations were located along tracklines randomly but with the condition that one station be provided for each 5 nmi of trackline length with a depth stratum. If a trackline across a depth stratum was less than 5 nmi long, one station was selected for that stratum so that sampling of all depth strata would occur on each trackline. Another constraint was that no two adjacent stations on a trackline could be less than 2 nmi apart. This allocation scheme provided for relatively intense sampling in areas where canary and yellowtail rockfish were expected in greatest abundance and yet allowed for a minimum level of sampling where we anticipated abundance would be lowest.

The survey area was partitioned into 12 biological sampling regions at approximately equal intervals to facilitate the collection of biological data from throughout the entire area. Age structures (otoliths) were to be collected from 300 rockfish of each target species in each depth stratum of a biological sampling area. Attempts were made to accumulate age data from a number of catches spread throughout each biological sampling area. Other biological data collected included length-frequencies, maturity stages, and stomach contents. All length and age samples were random. Biological collections were coordinated between the two vessels to ensure thoroughness of sampling and reduce duplication of effort.

Trawl hauls were made at preselected stations when possible. If the roughness of the seabed precluded bottom trawling at the preselected site, a search was begun for an alternate site within a 1-nmi radius. If none was found within one half hour of searching, that station was considered untrawlable and the vessel proceeded to the next station. Standard trawl hauls were of 30 min duration beginning 3-8 min after setting the winch brakes to allow the net to settle to the bottom. A tow was considered successful and included in the analysis if more than half the tow time was completed and if any irregularities such as snags or tears- occurred that were deemed likely to have a significant effect on the composition or magnitude of the catch. Trawling was conducted only during daylight hours at a vessel speed of approximately 3 kn over the ground. Catch rates were standardized and expressed in terms of kilograms per kilometer of trawling (kg/km).

Data Acquisition, Processing, and Analytical Procedures

Representative sampling of trawl catches requires the application of procedures which not only minimize biases but which are workable under conditions-encountered at sea. The catch sampling program incorporated the methods used by Gunderson and Sample (1980).

All catch and trawl data collected aboard the bottom trawl vessels were transferred from work forms to cassette magnetic tape at sea through the use of portable data logging terminals. Data tapes were returned to the Northwest and Alaska Fisheries Center (NWAFC) where the information was transferred from tape to magnetic disc for computer analyses. All data were further subjected to a number of editing programs for final correction against raw data forms before the first analysis was initiated. All age structures were read at the NWAFC.

A computer program package has been developed at the NWAFC for most standard survey data analyses. The basic program provides for the derivation of catch per unit effort (CPUE) values (means and variances) and biomass and population number estimates. The calculations involved in the analysis are also described by Gunderson and Sample (1980).

The BIOMASS program generates estimated population length-frequencies for each species in a stratum by first weighting individual sample length-frequencies by the appropriate CPUE, summing them, and then expanding the resultant weighted stratum length composition to the estimated numbers in that stratum.

Age compositions are derived through use of age-length keys constructed from age-length samples from each stratum. Age-length keys are applied to strata length compositions defined above. By developing distinct age-length keys for each stratum, we hope to minimize biases which could occur using a single key to generate strata age compositions when the length-age relationship may vary among strata.

RESULTS

Survey-sampling Coverage:

The survey vessels occupied most of the scheduled trawl stations in the survey area. The survey area covered 32,924 km^2 which included 578 scheduled trawl stations. A total of 529 stations were fished, 502 of which were considered usable in the analyses. Figure 2 presents the distribution of bottom trawl hauls and Table 1 shows number of hauls allocated and completed by INPFC area and depth strata. Persistent bad weather forced the vessels to bypass the area between lat. 42°00'-42°50'N in order to maintain the schedule. Prolonged favorable weather for the remainder of the period allowed 43 unscheduled trawls to be completed prior to conclusion of the work. These trawls were used as replicate samples in the rockfish study area off Washington to examine the changes in shelf rockfish availability during a relatively short period.

Age and length samples were routinely taken from target species in all areas where they occurred in adequate numbers. Age and length collections by species, INPFC area, and depth stratum are found in Table 2.

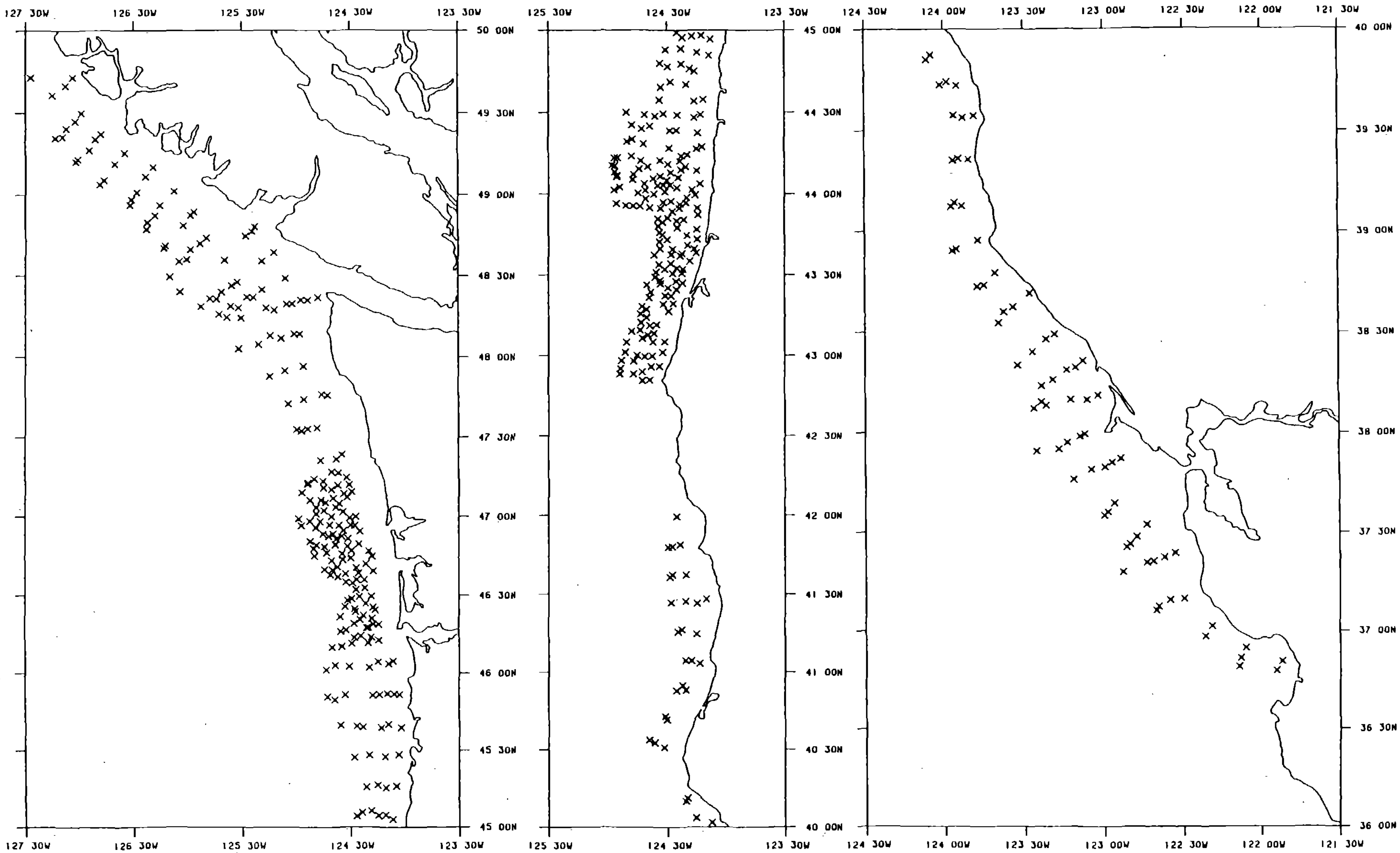

Figure 2.--The distribution of bottom trawl hauls completed during the 1980 survey.

Table 1.--Bottom trawl stations allocated and' completed by International North Pacific Fisheries Commission (INPFC) area and depth strata.

INPFC area and depth (m)	Stations allocated	Stations sampled	Area (km^{2}1	Sampling density (km2)/station)
Vancouver (U. S. Portion)				
55-181	21	17	3,687	217
182-366	12	4		51
Depths combined	33	21		185
Columbia				
55-181	253	249	15,719	63
182-219	39	30	1,204	40
220-366	37	26	2,743	106
Depths combined	329	305	19,666	64
Eureka				
55-181	26	24	2,744	114
182-366	13	12	698	58
Depths combined	39	36	3,442	96
Monterey				
55-181	54	56	8,701	155
182-366	24	20	1,624	81
Depths combined	78	76	10,325	136

Table 2.--Numbers of age and length collections from selected species and by International North Pacific Fisheries Commission (INPFC) area.

	Monterey		Eureka		Columbia		Vancouver		
Species	Shelf	Slope	Shelf	Slope	Shelf	Slope	Shelf	Slope	Total
Canary rockfish									
# length			130		819	58	348		1,355
# age			90		647	20	301		1,058
Yellowtail rockfish									
# length	28		100		1,544	68	500		2,240
# age			87		872		305		1,264
Chilipepper									
# length	581	697	67						1,345
# age	196	324	67	-	-	-			587
Bocaccio									
#length	345	201	26	12	63				647
# age	116	66			14				196

Distribution and Abundance

Average CPUE values for the target species are given in Table 3 along with values from the 1977 survey for comparative purposes. In 1980, canary rockfish CPUE was highest in the Vancouver area2/ (9.3 kg/km)-and lowest in the Monterey area (0.3 kg/km) where the species is usually of minor importance. Yellowtail rockfish catch rates followed a similar pattern. Both of these species were at relatively low densities in the Columbia area, an area where those species traditionally are an important component of the commercial catch. When compared with the 1977 data, the 1980 results showed that canary and yellowtail rockfish decreased in abundance in all areas except Eureka. Substantial decreases occurred in the Vancouver and Columbia areas. Figures 3 and 4 present yellowtail and canary density contours.

Chilipepper is the most southerly distributed species of concern, with CPUE progressively increasing from zero in the Vancouver area to 12.9 kg/km in the Monterey area (Table 3, Fig. 5). Chilipepper abundance was significant only in the Monterey area where there was a very slight decrease in the overall CPUE between 1977 and 1980. Bocaccio were distributed throughout the survey region but were also most dense in the Eureka and Monterey areas (Table 3, Fig. 6). Bocaccio CPUE, like that of yellowtail and canary rockfish, decreased between 1977 and 1980 in all areas except Eureka.

Since trawl catches of round fishes are likely to underrepresent actual abundance, estimates of absolute abundance based on simple expansion of trawl samples ought to be considered minimal and used with caution. Biomass values

2/ Only the U.S. portion of the INPFC Vancouver area is included in these analyses.

Table 3.--Catch per unit effort (kg/km) by International North Pacific Fisheries Commission (INPFC) areas and depth strata in 1977 and 1980.

Species and depth (m)	Vancouver (U.S. portion only)		Columbia		Eureka		Monterey[a]	
	1977[b]	1980	1977[b]	1980	1977[b]	1980	1977[b]	1980
Canary rockfish								
55-183	104.1	9.8	9.9	2.4	0.2	6.2	2.2	0.3
184-219	0.3	0.2	2.8	1.2	0.0	0.0	0.0	0.4
55-219	46.8	9.3	5.2	2.4	0.1	5.7	0.6	0.3
Yellowtail. rockfish,								
55-183	58.2	18.9	15.4	4.4	3.6	2.7	2.2	0.3
184-219	2.0	0.3	1.4	0.9	0.2	0.0	0.0	0.0
55-219	26.9	17.9	7.5	4.3	1.3	2.5	0.8	0.3
Chilipepper								
55-183	0.0	0.0	0.0	0.1	0.6	2.9	13.1	13.1
184-366	0.0	0.0	0.0	0.0	0.0	0.0	21.2	12.1
55-366	0.0	0.0	0.0	0.1	0.2	2.7	14.8	12.9
Pocaccio								
55-183	8.2	0.5	0.9	0.4	0.1	3.3	5.5	4.6
184-366	0.5	0.4	1.1	0.3	0.1	1.7	14.4	6.2
55-366	3.9	0.5	0.9	0.4	0.1	3.0	7.7	4.9

[a] 1977 CPUE is calculated for the entire Monterey area whereas 1980 CPUE is calculated for a major portion.

[b] The shallow stratum was 91-183 m in 1977 so CPUE was calculated over a smaller area than in 1980.

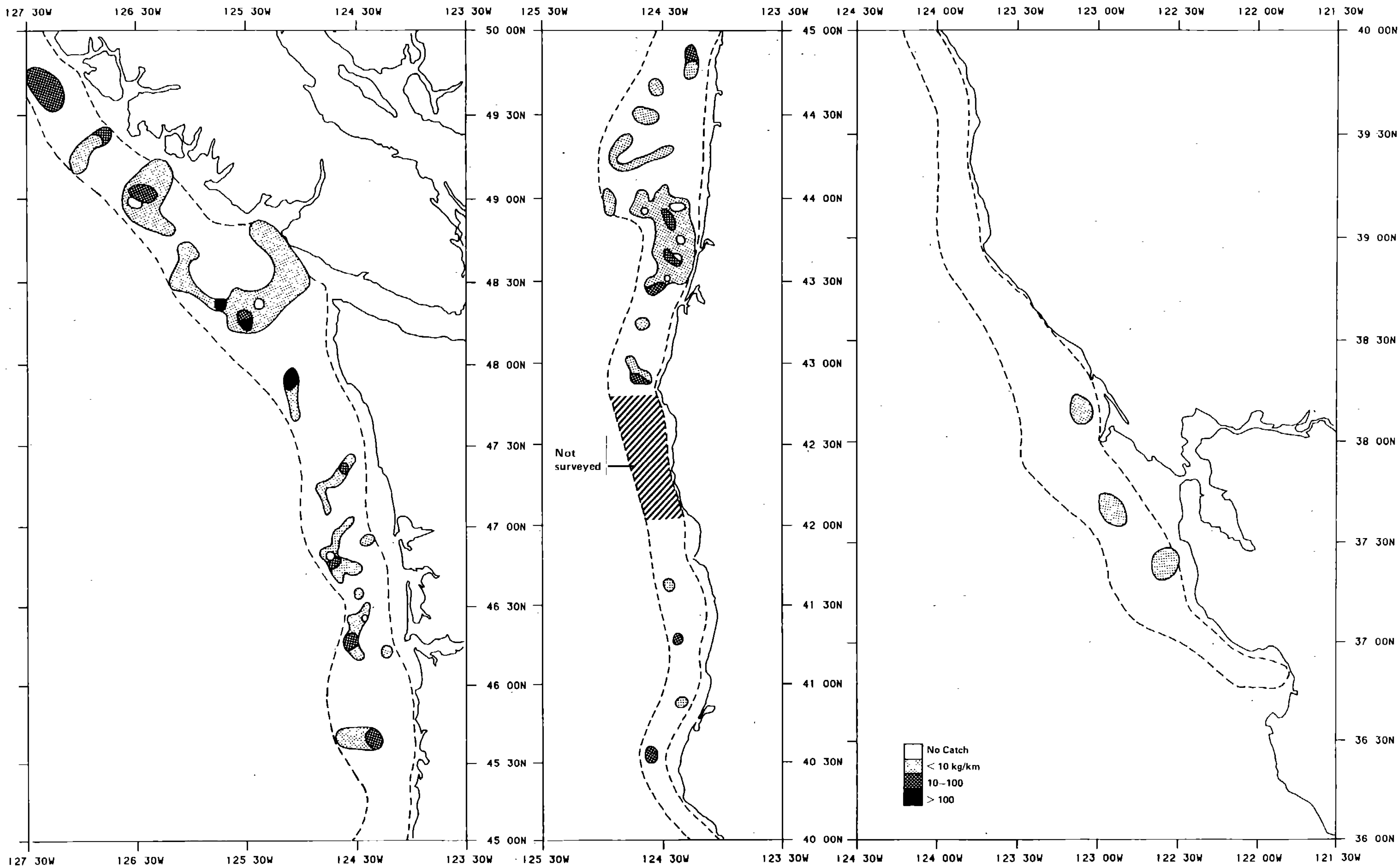

Figure 3.--Yellowtail rockfish densities based on **bottom** trawl CPUE (kg/km) in 1980.

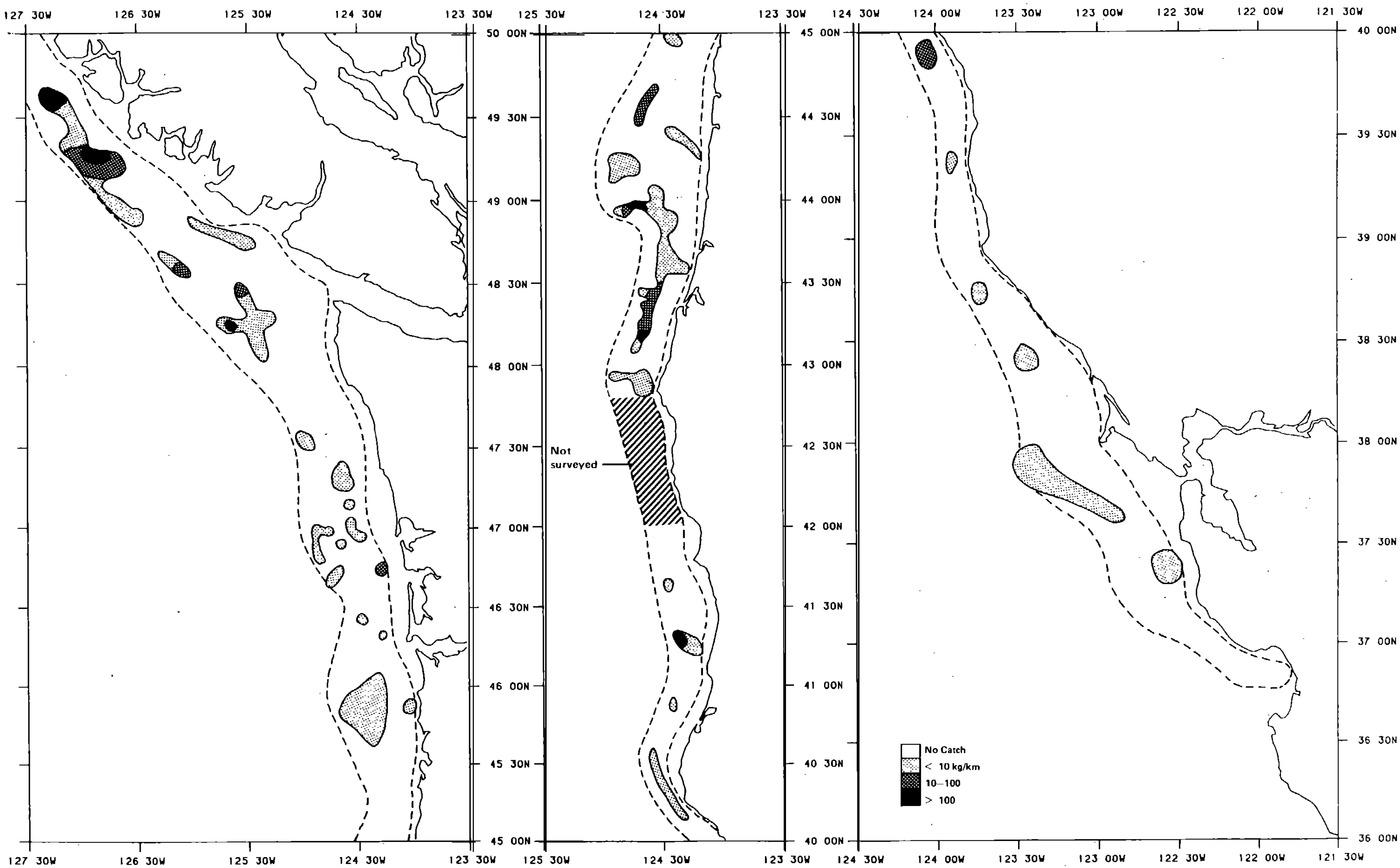

Figure 4.--Canary rockfish densities based on bottom trawl CPUE (kg/km) in 1980.

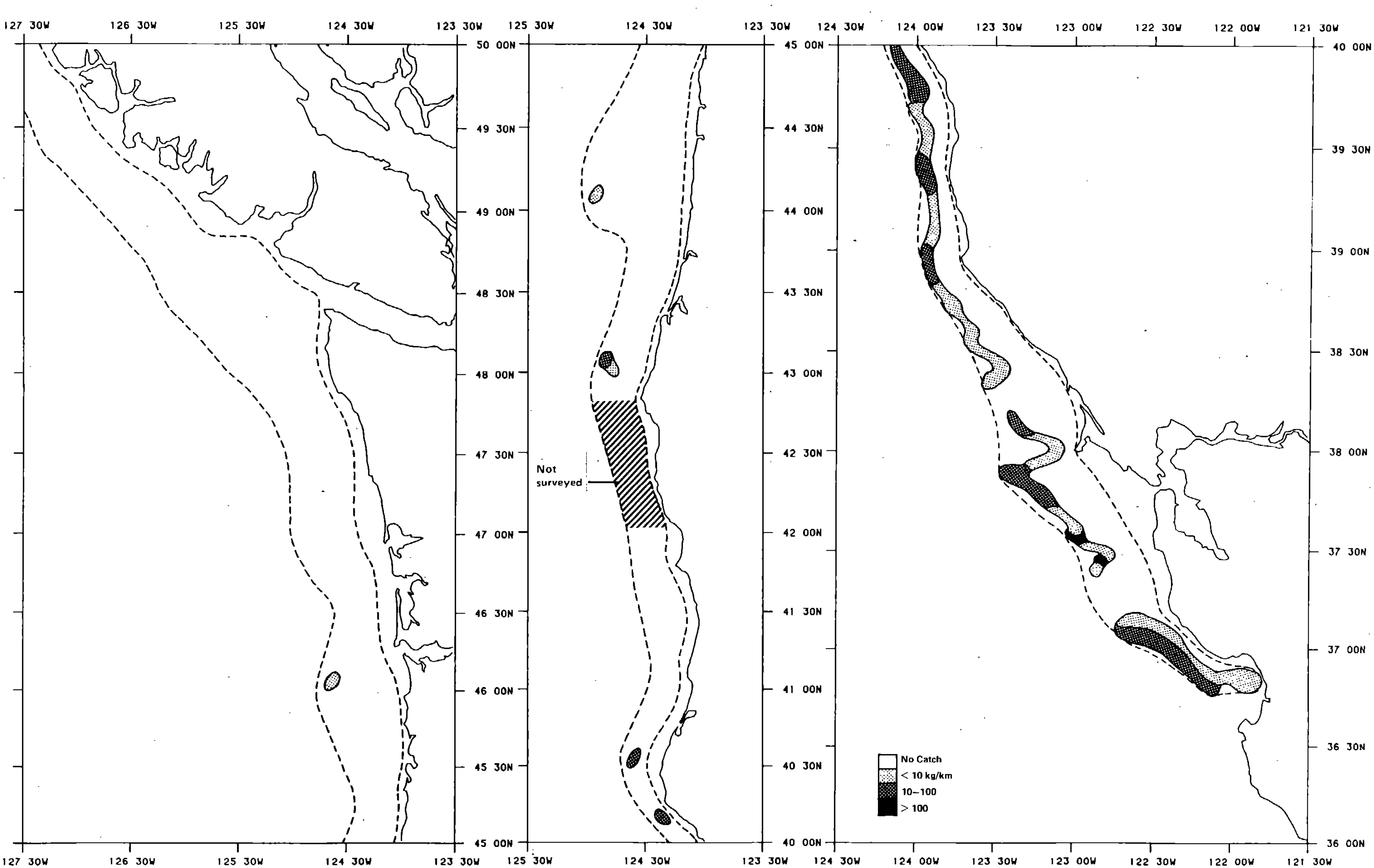

Figure 5.--Chilipepper densities based on bottom trawl CPUE (kg/km) in 1980.

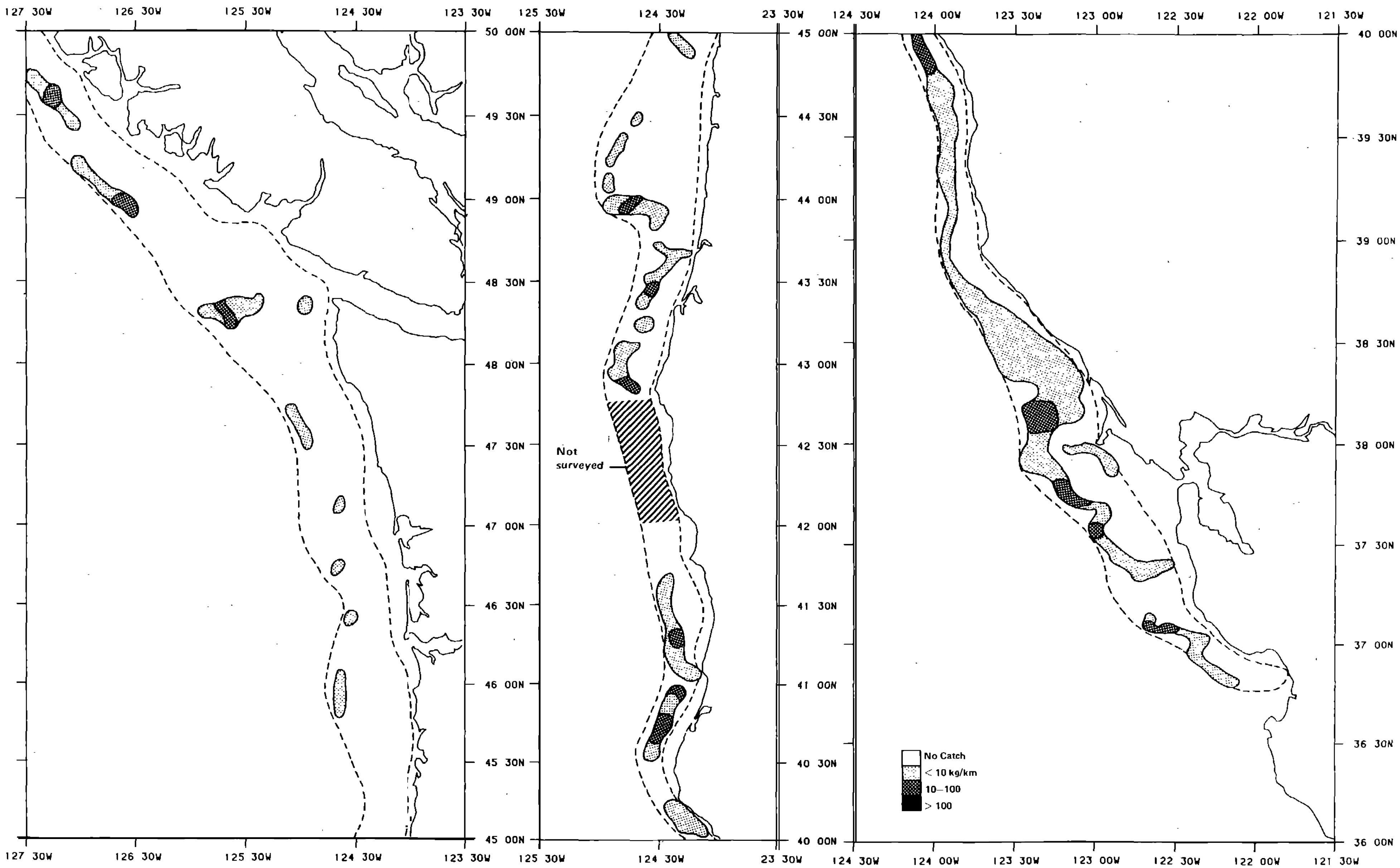

Figure 6.--Bocaccio densities based on bottom trawl CPUE (kg/km) in 1980.

have been included here because management groups often require estimates which can be measured against indicators of absolute resource size derived from other sources, such as analyses of fisheries information. Biomass estimates are presented in Table 4. Estimates from the 1977 survey are not presented because differences in depths surveyed in 1977 and 1980 preclude meaningful comparisons of biomass values.

The estimated biomass of canary and yellowtail rockfish abundance was greatest in the Vancouver and Columbia areas and about equally distributed between the two areas. Densities, however, were over four times greater in the smaller Vancouver area (Table 3). Biomass decreased to the south of the Columbia area and only 3% of the canary and 2% of yellowtail rockfish biomass was located in the Monterey area. As expected; almost the entire estimated biomass occurred over the continental shelf in waters less than 100 fathoms (184 m). Only 2.0% of the canary and 0.5% of the yellowtail rockfish biomass were estimated to be in the l00-120 fathom (184-219 m) zone.

In spite of efforts to increase precision, in the Columbia area through "saturation" sampling, the variance around 1980 biomass estimates was somewhat greater than that observed in 1977. This result reflects the high degree of annual variability in vulnerability and availability of shelf rockfish to bottom trawl gear. Nevertheless, the higher intensity sampling in the Columbia area in 1980 was apparently beneficial because variances were reduced from those in other INPFC areas where sampling was less intensive in the same year.

As expected, chilipepper rockfish did not occur in the Vancouver area, only a trace was found in the Columbia. region, and just under 10,000 t was estimated for the Monterey area. Bocaccio is more prevalent in the northern areas, but it also was most abundant in the, Monterey area. Again most of the estimated biomass was in waters less than 100 fathoms (184 m), but chilipepper

Table 4.--1980 biomass estimates (t) and confidence intervals (CI) for canary rockfish, yellowtail rockfish, chilipepper, and bocaccio by depth and INPFC area.

Species and depth (m)		(U.S.) Vancouver	Columbia	Eureka	Monterey	Total
Canary rockfish						
55-183		2,695	2,844	1,212	204	6,955
184-219		3	74	46	12	135
	Total	2,698	2,918	1,258	216	7,090
CI (.90)		0-6,954	1,163-4,676	0-3,287	0-451	1,381-12,799
Yellowtail rockfish						
55-183		5,188	5,207	547	209	11,151
184-219		5	55	0	0	60
	Total	5,193	5,262	547	209	11,211
CI (.90)		0-11,400	208-10,319	14-1,080	0-425	2,024-20,397
Chilipepper						
55-183		0	76	591	8,488	9,155
184-366		0	11	0	1,465	1,476
	Total	0	87	591	9,953	10,631
CI (.90)		-	0-181	0-1,627	1,243-18,663	304-20,958
Bocaccio						
55-183		136	477	682	3,017	4,312
184-366		28	95	89	749	961
	Total	164	572	771	3,766	5,273
CI (.90)		0-336	278-865	263-1279	1,635-5,898	2,660-7,886

and bocaccio tend to be distributed deeper than are yellowtail and canary rockfish with 14 and 18% of the total biomass, respectively, occurring between 101 and 200 fathoms (183 and 366 m). Chilipepper and bocaccio densities on the continental slope. as indicated by catch rates (Table 3) are often comparable to or exceed those on the shelf, but the much smaller area of the, slope results in smaller biomass estimates.,

Ninety percent confidence intervals for biomass estimates of chilipepper ranged from + 88-175% of the point estimate and for bocaccio from + 5l-105%. Precision of the chilipepper biomass estimates was greatest in the Monterey area in both 1977 and 1980 and poor each year in the other areas. The precision of the bocaccio estimates both years was poor in the Vancouver area but good in all other areas.

Length Composition

Mean body lengths by species, sex, depth of capture, and INPFC area are presented in Table 5. Depth related changes in size are not apparent for any of these species. The mean lengths of all species showed some latitudinal cline with values decreasing from north to south.

Figures 7-10 present estimated population length compositions by sex and INPFC area. Length distributions of yellowtail rockfish portray some variability, particularly in the Eureka and Monterey areas where sample sizes were small (Fig. 7). Strong modes were present in all areas, except in the case of females in the Columbia area, where the size distribution is quite broad resulting from the presence of a large number of age groups that were similarly represented. Mean sizes tended to decrease from north to south and yellowtail rockfish in the southern portion of their range (Monterey area) 'were on the

Table 5.--Mean lengths (cm) of canary rockfish, yellowtail rockfish; bocaccio, and chilipepper by sex, depth stratum, and International North Pacific Fisheries Commission (INPFC) area.

Depth (m)	Canary rockfish			Yellowtail rockfish			
	Vancouver	Columbia	Eureka	Vancouver	Columbia	Eureka	Monterey
<u>55-183</u>							
male	47.7	47.5	45.9	46.1	45.1	42.4	38.1
female	49.4	49.6	49.0	46.1	43.9	47.2	37.8
combined	48.3	48.3	46.8	46.1	44.9	44.6	38.0
<u>184-219</u>							
male		48.8			44.1		
female		55.3			42.3		
combined		49.8			43.8		
<u>All depths</u>							
male	47.7	47.5	45.9	46.1	45.1	42.4	38.1
female	49.4	49.6	49.0	46.1	43.9	47.2	37.8
combined	48.3	48.8	46.3	46.1	44.9	44.6	38.0

Depth (m)	Bocaccio			Chilipepper		
	Columbia	Eureka	Monterey	Columbia	Eureka	Monterey
<u>55-183</u>						
male	44.8	39.7	42.5	42.7	35.8	33.8
female	44.8	42.1	42.1	44.3	45.1	40.2
combined	44.8	40.7	42.3	43.2	43.3	37.0
<u>184-366</u>						
male		42.7	41.3			32.9
female		41.0	42.4			39.4
combined		42.2	41.9			36.9
<u>All depths</u>						
male	44.8	40.0	42.3	42.7	35.8	33.7
female	44.8	42.0	42.2	44.3	45.1	40.1
combined	44.8	40.9	42.2	43.2	43.3	37.0

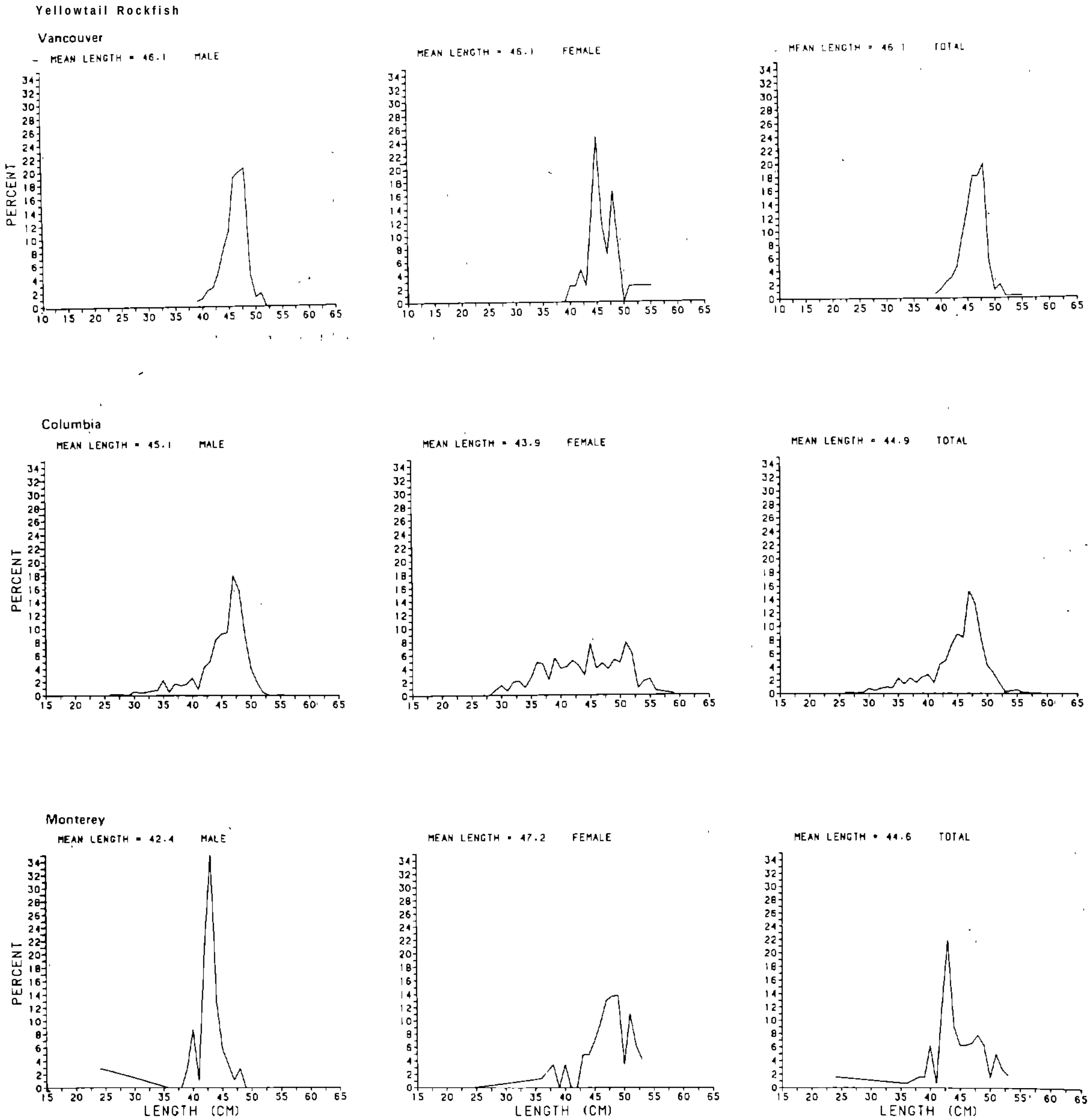

Figure 7.--Estimated yellowtail rockfish population length compositions by sex and International North Pacific Fisheries Commission areas in 1980.

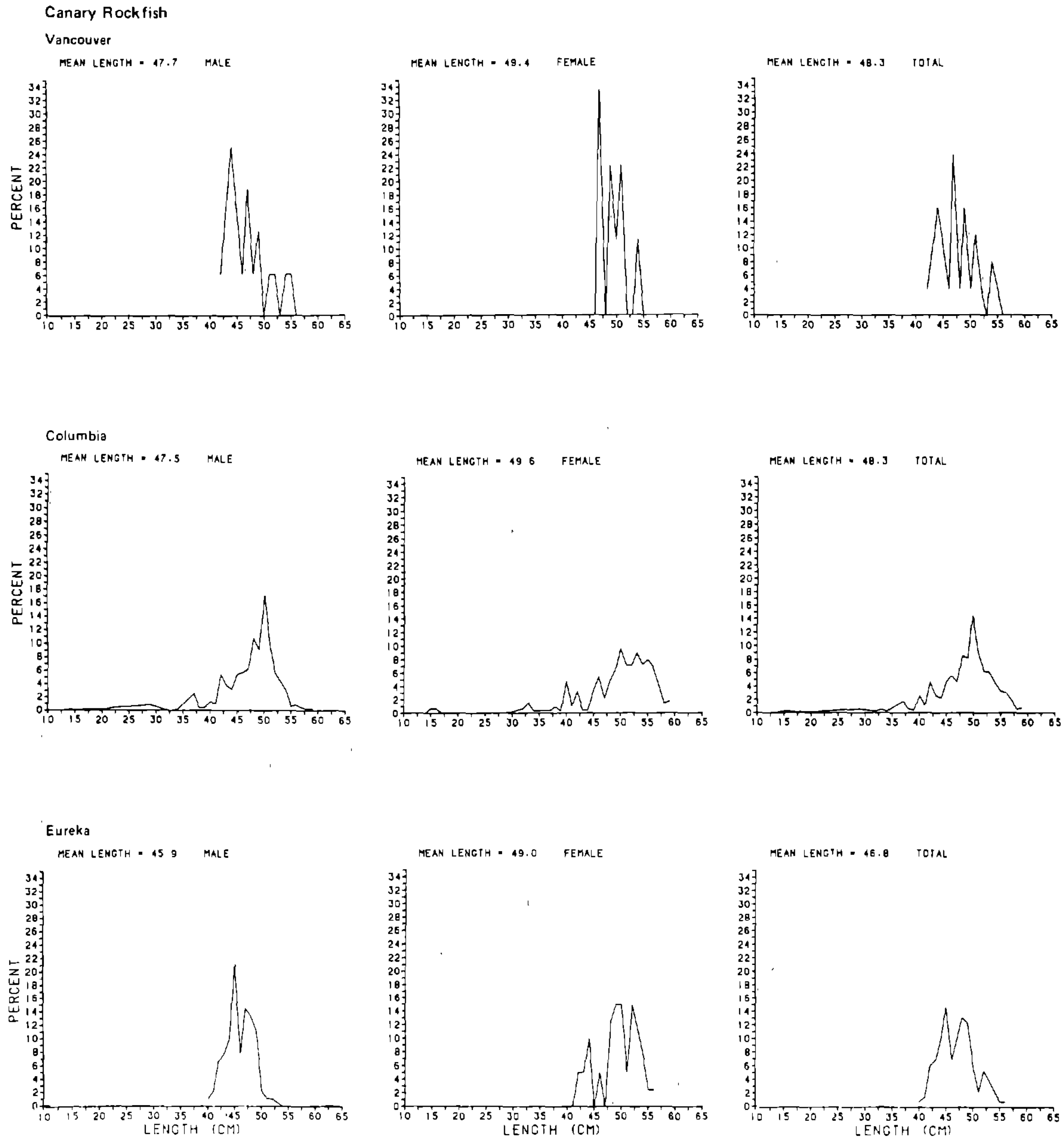

Figure 8.--Estimated canary rockfish population length compositions by sex and International North Pacific Fisheries Commission areas in 1980.

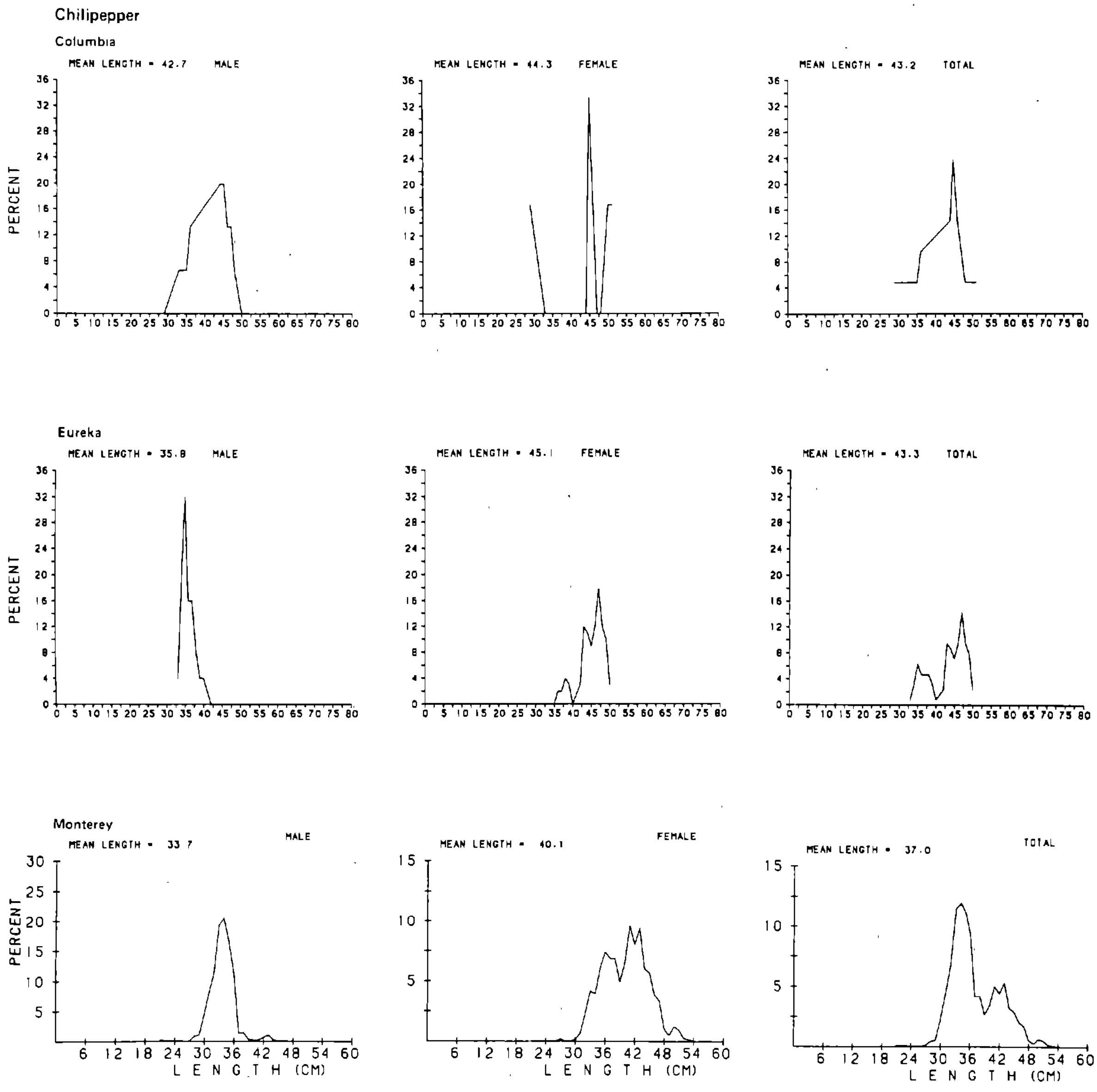

Figure 9.--Estimated chilipepper population length compositions by sex and International North Pacific Fisheries Commission areas in 1980.

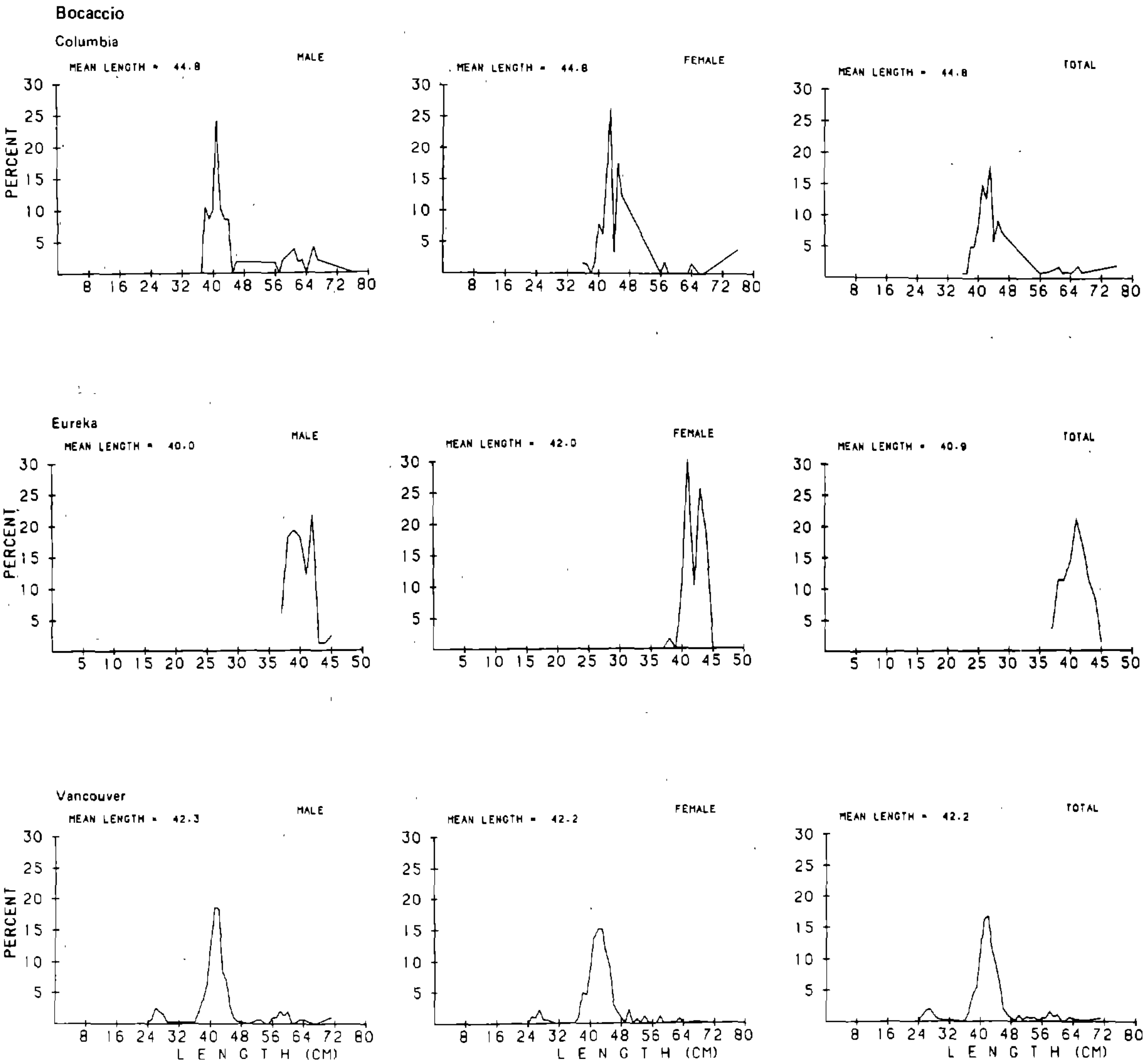

Figure 10.--Estimated bocaccio population length compositions by sex and International North Pacific Fisheries Commission areas in 1980.

average 8 cm shorter than those sampled in the Vancouver area. This tendency was also observed in the 1977 samples (Fraidenburg 1980). The 1977 length distributions were very similar to those in 1980 with the only difference of note being in the Monterey area where yellowtail were on the average slightly larger in 1980.

Small sample sizes also resulted in considerable variability in the length distributions of canary rockfish (Fig. 8). The tendency for smaller fish to be present in the southern part of the range persisted in the case of canary rockfish. Only the 1977 sample from the Columbia area was sufficiently large to be compared with 1980 data. Comparison with the 1977 length data (Boehlert 1980) reveals the presence of fish less than 35 cm in the Columbia area in 1980, a size group which was not present in 1977.

Mean sizes of chilipepper were smaller in the Monterey area (37 cm) than in the Eureka area (43 cm) (Fig. 9). The distributions for sexes combined in these areas are bimodal suggesting the entry of one or two relatively strong, new year-classes. The presence of those new year-classes was most noticeable in the Monterey area. Length samples were only taken in the Monterey area in both 1977 and 1980. The 1977 length distribution was trimodal, with modes at about 23 cm, 35 cm, and 44 cm. The mode at 23 cm was not present in 1980, perhaps suggesting a lesser recruitment of 2- and 3-yr-olds. Sampling variation may also be responsible for changes in length distributions and confirmation of relative year-class strengths require continued monitoring of age and length data.

Modes at about 40 cm were evident in all areas for bocaccio (Fig. 10). A small mode at about 27 cm in the Monterey area suggests the presence of a relatively strong year-class which was just becoming available to our sampling gear. While a latitudinal trend in size is not so obvious in bocaccio, the greatest mean length again was found in the most northern area (Columbia) sampled for lengths. Bocaccio length distributions in 1977 and 1980 from the Monterey area are quite distinct in that a significant portion of the population in 1977 was composed of large fish between 48 and 73 cm, while there was only a trace of that group in 1980. This difference might be attributed to sampling error because in 1977 the 38-48 cm group was well represented and by 1980 many of those fish should have grown l0-12 cm (Wilkins 1980). Length distributions in the other INPFC areas are not compared because small sample sizes resulted in high variability.

Age Composition

Sufficient otolith samples were available for estimating population age compositions for all species except bocaccio. Age compositions for the other species were based on 1,026 canary rockfish, 1,139 yellowtail rockfish, and 587 chilipepper otoliths.

Canary rockfish age compositions differed among areas with the modal age increasing from south to north (Fig. 11). Ages younger than 11 yr were prominent in the Eureka and Columbia areas but were almost completely absent in the Vancouver area. It is not known whether the recruitment pattern was different in the Vancouver area or there has been a succession of very weak year-classes in this area. Age data for the Vancouver area were not sufficient in 1977 to determine if this difference occurred in another year. The 1977 age distribution in the Columbia area (Boehlert 1980) was bimodal with ages 9-11 comprising the younger mode. The 1980 age distribution in the Columbia area was unimodal with the 9-11 age groups the major contributors.

The yellowtail rockfish age distribution in the Eureka area is dominated by 10-yr-olds of the 1970 year-class (Fig. 11). Age distributions in the

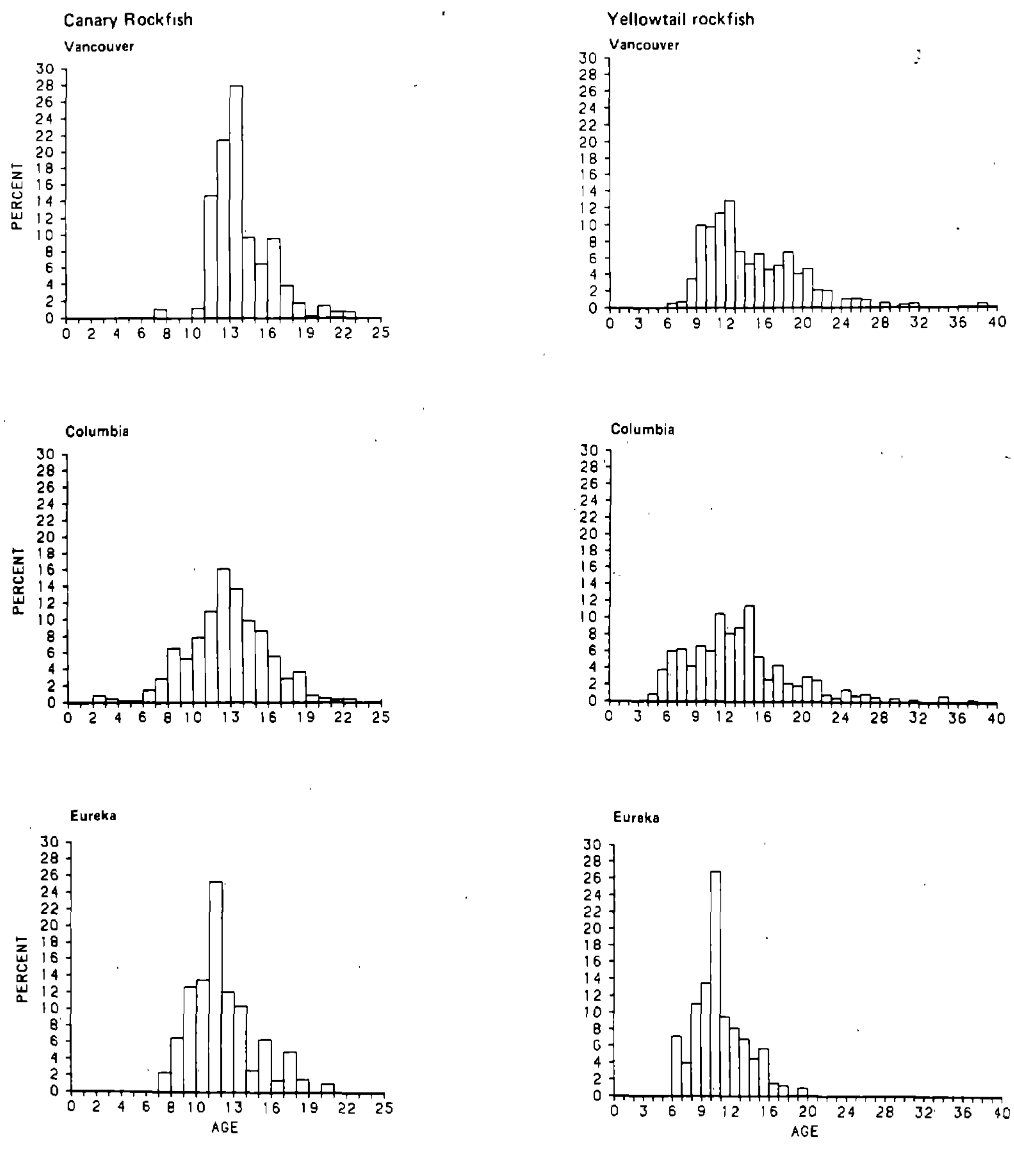

Figure 11 .--Estimated canary and yellowtail rockfish population age compositions by International North Pacific Fisheries Commission areas in 1980.

Columbia and Vancouver areas, however, do not reflect the presence of an extraordinarily strong year-class and are characterized by a large number of year-classes of similar size. As was the case with canary rockfish, the youngest 2 or 3 age groups recruited to the sampling gear in the Eureka and Columbia areas are missing or are present only in trace amounts in the Vancouver area. In 1977, the 9-yr-olds (1968 year-class) were relatively strong in most areas (Fraidenburg 1980), but this year-class was not particularly abundant as 12-yr-olds in 1980. Only in the Vancouver area did 12-yr-olds appear as a relatively abundant age group. In 1977, age distributions in most areas were bimodal, showing a mode of younger and a mode of older age groups. Only the mode of older age groups was evident in 1980 suggesting that recently recruited year-classes are of lower relative abundance than they were in 1977.

The age composition of chilipepper in the Monterey area differed noticeably from that in the Eureka area (Fig. 12). Represented in the Monterey area but hardly significant in the Eureka area were 4- and 5-yr-old fish. Conversely, 10- and ll-yr-olds which were prominent in the Eureka area were minor components in the Monterey area. The 1977 age composition in the Monterey area (Wilkins 1980) resembled that in 1980 with 5-yr-olds predominating and progressively fewer fish in the older age groups. The 1975 year-class was relatively strong as 2-yr-olds in 1977 in the Monterey area and amounted to over 24% of the population as 5-yr-olds in 1980. As with other species of rockfish, recruitment patterns of chilipepper seem to vary latitudinally with fish recruiting at a younger age in the more southern portions of the survey area. The lower proportions of older chilipepper in the southern areas is unexplained. Possible factors include sampling variability, distributional variability among age grows, or juvenescence due to relatively higher rates of fishing mortality.

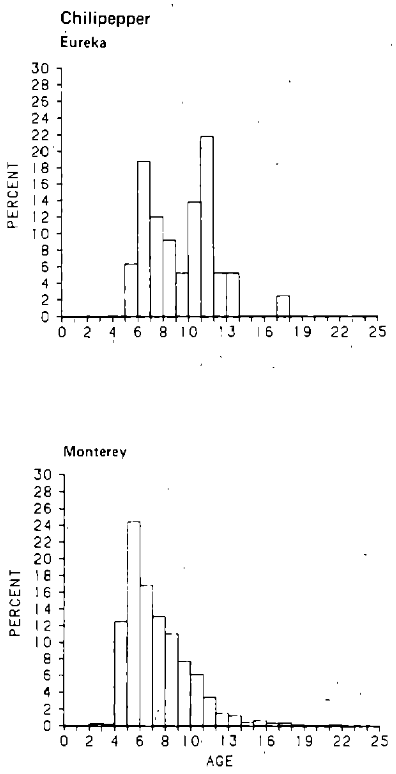

Figure 12.--Estimated chilipepper population age compositions by International Pacific Fisheries Commission areas in 1980.

SUMMARY AND CONCLUSIONS

Canary and yellowtail rockfish densities tend to be highest in the northern portion of-the survey area and decline rather steadily in areas to the south. When mean CPUE's from 1977 and 1980 survey data are compared, population densities for both species appear to have declined in all INPFC areas except Eureka. Reductions in CPUE ranged from 50% in the Monterey area to 80% in the Vancouver area for canary rockfish and from 33% in the Vancouver area to 62% in the Monterey area for yellowtail rockfish. The primary concern is the apparent major reductions of yellowtail and canary rockfish populations in the Vancouver and Columbia areas where they are traditionally important to the commercial trawl fishery.

Chilipepper and bocaccio have a more southern distribution with highest densities in the Monterey and Eureka areas. Chilipepper abundance was highest in the Monterey area where there was only a slight decrease in mean CPUE between the 1977 and 1980 surveys.

The mean CPUE for bocaccio decreased in all areas, except Eureka, from 36% in the Monterey area to 87% in the Vancouver area. Again, these apparent reductions of a major commercial species are reason for concern and for further evaluation.

Canary and yellowtail biomass estimates in 1980 were greatest in the Vancouver and Columbia areas and about equally distributed between the two areas. The U.S. portion of the Vancouver area is only about 20% as large as the Columbia area so rockfish densities were considerably greater there. Abundance decreased southward with only 3 and 2% of the canary and yellowtail rockfish biomass, respectively, occurring in the Monterey area.

Chilipepper and bocaccio abundance was distributed mainly in 'the south with 94 and 71% of the estimated biomass, respectively, occurring in the Monterey area. Most of the biomass occurred in waters less than 100 fathoms (184 m), but these species tend to be more abundant in deeper waters than do yellowtail and canary rockfish.

Length and age data for all four 3/ species show a consistent tendency for the smaller, younger members of the population to occupy the southern portions of the survey region. There is some indication that rockfish recruitment patterns vary latitudinally with availability to survey trawls occurring at a younger age in the more southern areas. Canary and yellowtail rockfish length compositions were similar for most areas in 1977 and 1980, but the age compositions in 1977 were generally bimodal while in 1980 they were unimodal. It is assumed that unimodality has resulted from the younger age groups in the left-hand mode in 1977 moving through the population and the older fish in the right-hand mode becoming less abundant in 1980 due to fishing and natural mortality. It is suggested then that recently recruited year-classes are of lower relative abundance than they were in 1977. Chilipepper mean size was smaller in the Monterey area than the Eureka area in 1980 and age data revealed a prominent 4- and 5-yr-old component in the Monterey area which was only of minor significance in the Eureka area. The age composition for the Monterey area was similar in 1977 with 5-yr-olds predominating and progressively fewer older fish. Age data was not available for bocaccio but a small mode at 27 cm in the length distribution from the Monterey area may

3/ Only length data was available for bocaccio rockfish.

announce the presence of a relatively strong year-class which was just becoming available to our sampling gear. Comparison of 1977 and 1980 length compositions was difficult because small sample sizes resulted in high variability.

An important objective associated with building a time-series data base for monitoring population trends is to improve the quality of that data base. Survey procedures and results are under constant review and evaluation so that valid comparisons can be made and to promote a better understanding of inherent strengths and weaknesses. A discussion of data accuracy and precision is presented in the following paragraphs.

Factors Affecting Estimates of Population Length and Age Composition

Length samples are collected to account for any latitudinal or bathymetric stratification of sizes and weighted by the relative contribution of size groups in samples to construct estimated population length compositions. The validity of these estimates is likely to be most affected by improper weighting due to imprecise estimates of the relative abundance of size groups and unequal vulnerability of size groups to the sampling gear.

The accuracy of estimates of numbers or proportions by age group are unknown, but several procedures are routinely applied to minimize the effects of commonly recognized pitfalls. Because many species are known to exhibit latitudinal clines in length and age composition, our sampling designs have included the designation of biological sampling strata that promote uniform' biological sampling over wide latitudinal and bathymetric ranges. Individual sample length frequencies are weighted by CPUE to establish their relative contribution to strata length frequencies. Distinct age-length keys for each stratum are applied to length frequencies for the corresponding stratum when estimating age compositions with the intent of reducing the effects of any changes among areas in the age-length relationship such as those observed by Westrheim and Ricker (1978) and Kimura (1977).

While biological data collected during research surveys may be subject to the errors and biases mentioned above, we believe the age and length data presently available provides a reasonable characterization of the target populations within the survey zone. These data should be considerably more representative than data derived from commercial landings which are often the product of at-sea-culling and specific harvesting strategies aimed at capturing the most marketable components of the population. Future enhancement of sampling programs should involve the spatial and temporal allocation of sampling effort in the study of special issues such as recruitment patterns, seasonal variation, and stock identification.

Variation in Availability of Certain Shelf Rockfishes

Accurate and precise estimates of shelf rockfish abundance and distribution are quite elusive due to imprecise knowledge of their habitat and behavior, and the species tendency to aggregate in relatively small and scattered schools. We have attempted to reduce sampling error and variability by sampling intensively in general areas of abundance as indicated by commercial fishery statistics. Ninety percent confidence intervals for 1977 estimates of canary and yellowtail rockfish abundance ranged from + 51-168 and t 71-114 percent of the point estimates, respectively. In spite of efforts to reduce variances in 1980 by sampling even more intensively, there was no improvement, This cannot be readily explained, but perhaps it occurred as a result of differing availability and vulnerability of shelf rockfish to the sampling gear from year to year.

such unpredictability emphasizes the very dynamic behavior of rockfish populations and the major demands placed on experimental designs.

Not only do annual variations in distribution and abundance render it difficult to design sampling schemes which promote suitable accuracy and precision, but short-term changes in availability can have an impact. Changes in availability created by behavioral patterns and variations in trawl fishing efficiency are a constant concern to those conducting assessment studies, but are not well understood and, therefore, are not usually addressed in experimental designs. After the scheduled survey stations were completed in September 1980, 43 stations were replicated in a small region off Grays Harbor, Washington, about 2 weeks after they were first sampled. Canary rockfish CPUE increased from 1.2 to 3.9 kg/km and yellowtail rockfish CPUE increased from 1.0 to 16.8 kg/km when the stations were replicated. Canary and yellowtail rockfish CPUE values were significantly higher during the second period ($t_{0.95}$ = 5.15 and $t_{0.95}$ = 11.30 for canary and yellowtail, respectively). It is not known whether the difference in mean CPUE's represents a real change in abundance or a change in availability to the trawl. During the first sampling of the northern rockfish study area, it was observed that catches consisted of very few fish and large quantities of jellyfish. The catch of jellyfish was 57 times greater during the first sampling of the replicate stations than during the second sampling. Trawl vessel captains have remarked that rockfish catches often decrease when jellyfish are extremely abundant. One view is that jellyfish clog the meshes of the trawl reducing its efficiency. These changes in CPUE could also reflect changes in availability resulting from short-term behaviorial differences. In both cases, the implication is that slightly different survey periods could produce quite distinct population estimates for reasons other than an actual change in population size.

Variable availability, contagious distribution, and the species tendency to aggregate in poorly defined, very small areas are factors affecting the accuracy and precision of estimates which are not easily overcome at practical levels of sampling effort. Directed trawling and testimony by experienced fishermen suggest variable availability even in those locations known to attract shelf rockfish. Eleven directed trawls were made during the second sampling period at sites chosen by the captain of one of the vessels to compare yellowtail and canary rockfish catch rates resulting from predesignated survey tows and tows using commercial fishing strategies. The captain made directed tows using electronic navigational aids coupled with his knowledge of the grounds and experience in targeting on canary and yellowtail rockfish. The only constraint placed on the captain was that his tows had to be made within five 12 nmi^2 areas. The target species were caught consistently in directed tows ; 10 of the 11 tows (91%) contained one or both rockfish species. Sixty-eight percent (25 of 37) of the corresponding predesignated survey tows made in the same area contained the target species. This suggests that the captain had some ability to successfully direct his effort at these two rockfish species. On the other hand, mean catch rates for directed tows were lower than for predesignated tows in some sections, but were higher in others (Table 6) which would indicate that even directed fishing by an experienced captain will not consistently produce larger catches than those resulting from sampling in a rather intense but systematic random manner. This must be largely due to varying availability and vulnerability of shelf rockfish even in areas known to aggregate such schooling species.

Clearly availability, vulnerability, and other factors affecting sample representativeness are very difficult issues requiring long study. An interim approach to improving area-swept shelf rockfish surveys, in particular,

Table 6.--Catch rates (kg/km) for yellowtail and canary rockfish based on catches at predesignated survey stations and at sites where an experienced fisherman directed tows at the two species.

	Predesignated tows			Directed tows		
		CPUE			CPUE	
Area	No tows	yellowtail	canary	No tows	yellowtail	canary
D	4	101.6	1.2	1	2.8	0.0
E	13	11.8	0.4	3	3.9	2.6
F	3	0.0	0.1	1	0.0	2.3
H	9	19.1	17.7	5	31.6	3.4
I	8	0.4	0.3	1	125.4	0.0

would be to utilize recently improved commercial fishery data to more accurately describe shelf rockfish habitat so the survey area could be stratified in a more effective manner. The same data base could be used to explore trends in availability which might be associated with season, tidal cycles, temperatures, and maturation so the periods of greatest availability might be predicted and surveys scheduled accordingly.

As more information becomes available and new studies are completed the opportunities for measuring the effectiveness of resource surveys in estimating population change are increased. Recently, virtual population (VPA) and stock reduction analyses were completed (Tagart 1982) for yellowtail rockfish in the INPFC Vancouver and Columbia areas for the 1976-1980 period. When these results and CPUE trends were compared with the population trends indicated by the 1977/80 trawl surveys, we found that in the Vancouver area VPA and CPUE indicated a rather stable population with some slight increase between 1977 and 1980, but the survey data indicated a 55% reduction in population size. In the Columbia area, all 4 indicators produced similar results, pointing to population reductions of approximately 44-70% between 1977 and 1980. These results suggest that abundance estimates from areas where the survey was not specifically designed to enhance precision (i.e., the Vancouver Area) may be of limited value and ought be used only with a great deal of caution. On the other hand, in areas where the study was designed to deal with the high variability associated with rockfish distributions, results are corroborated by other indices of relative abundance. In those instances, it appears that research surveys will track population trends as well as any means available. Estimates of absolute abundance on the Columbia area derived from the trawl surveys were 27-59% less than those derived from VPA and stock reduction analyses. This is not surprising because trawls are expected to be less than 100% efficient for capturing rockfish and absolute abundance estimates are viewed as being conservative. Perhaps such future comparisons can be used to establish the general magnitude of trawl efficiency (i.e. catch ability coefficient).

In our view, properly conceived trawl surveys can provide useful information on periodic changes in the relative abundance of some rockfish species. Certain species will be more difficult to monitor than others and it behooves us to utilize a growing body of knowledge about variations in availability, distribution, and behavior to enhance our ability to implement suitable experimental designs. While we can expect to remove some of the imprecision and inaccuracies, there will always be some error associated with survey data. It would be unrealistic to expect otherwise. Other measures of absolute or relative abundance are subject to errors which may be of comparable magnitude. Because all methods share this weakness, there is a strong argument for continuing fishery-independent studies and utilizing resulting data with information from application of other approaches to assess status of stocks.

LITERATURE CITED

Boehlert, George W.

1980. Size composition, age composition, and growth of canary rockfish, Sebates pinniger, and splitnose rockfish, S. diploproa, from the 1977 rockfish survey. Mar. Fish. Rev. 42(3-4):7-63.

Fraidenburg, Michael E.

1980. Yellowtail rockfish, Sebastes flavidus, length and age composition off California, Oregon, and Washington in 1977. Mar. Fish. Rev. 42(3-4): 54-56.

Gunderson, Donald R., and Terrance M. Sample.

1980. Distribution and abundance of rockfish off Washington, Oregon, and California during 1977. Mar. Fish. Rev. 42(3-4):2-16.

Kimura, D. K.

1977. Statistical assessments of the age-length key. J. Fish. Res. Board Can. 34:317-324.

Tagart, J. V.

1982. Status of the yellowtail rockfish (Sebastes flavidus) fishery. Wash. Dep. of Fish., Tech. Rep. 71, 64 p.

Westrheim, S. J., and W. E. Ricker.

1978. Bias in using an age-length key to estimate age-frequency distributions. J. Fish. Res. Board Can. 35:184-189.

Wilkins, Mark E.

1980. Size composition, age composition, and growth of chilipepper, Sebastes goodei and bocaccio, S. paucispinis, from the 1977 rockfish survey. Mar. Eish.Rev. 42(3-4):48-53.