Results of the Coastal Pacific Whiting, *Merluccius productus*, Surveys in 1977 and 1980

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Introduction

A major research vessel survey was conducted in 1977 by the National Marine Fisheries Service (NMFS) and cooperating agencies to help assess the status of Pacific whiting, *Merluccius productus*, and other groundfish species, especially important species of rockfish, *Sebastes* spp., in the California to Vancouver Island, B.C., region (Dark et al., 1980; Gunderson and Sample, 1980). This was the first of a triennial series of comprehensive multispecies groundfish surveys, and it was followed by a comparable survey in 1980. Both surveys included bottom trawl and acoustic (echo integrator)-midwater trawl sampling. A primary objective of each year's survey program was to determine the distribution, biomass, and the length-and-age composition of the exploitable portion of the whiting population. This report summarizes methodologies used in those surveys and presents results obtained for Pacific whiting.

Methods

In both years, the surveys were conducted during July through September, a period of the year when Pacific whiting are between their northward feeding migration and southward spawning migration and coastwise movements appear to be relatively localized. In 1977 the survey included the area from Port Hueneme, Calif. (34°08′N) to Kyuquot Sound, Vancouver Island (50°00′N), except that bottom trawl sampling was limited to the area south of Cape Flattery, Wash. (48°30′N). In 1980 the survey began off Santa Cruz, Calif. (36°50′N) and again ended at 50°00′N. The change in geographic range between years was due mainly to changes in the objectives of the rockfish investigations and to the lack of Pacific whiting (other than juvenile fish) south of Santa Cruz. The survey each year included two or more vessels for bottom trawl sampling and a single vessel equipped with echo integrator and midwater trawling systems to sample the off-bottom component of the population. The estimates of abundance generated by the bottom trawl and echo integrator-midwater trawl surveys were considered additive and representative of the total population. Figure 1 shows the survey areas for 1977 and 1980 and International North Pacific Fisheries Commission (INPFC) statistical areas used to summarize the survey data.

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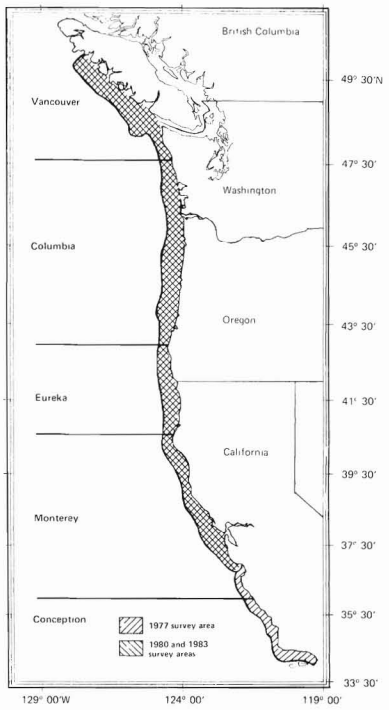

Figure 1.—Areas surveyed in 1977 and 1980, and INPFC statistical areas by which survey data were summarized.

Bottom Trawl Surveys

Methods used in the 1977 bottom trawl surveys are described by Dark et al. (1980) and Gunderson and Sample (1980). The 1980 bottom trawl survey was similar to that conducted in 1977. Sampling effort was again allocated on the basis of target species abundance as indicated by commercial catch statistics, including a special effort to sample whiting most intensively in the area off southern Oregon where the fishery had been focused during 1977-79. Sampling was conducted between depths of 30 and 200 fathoms with stations allocated between two depth strata, 30-99 and 100-200 fathoms. Due to a change in the target rockfish species, sampling of the relatively small 201-260 fathom depth stratum, which had been sampled in 1977, was eliminated; this change was not considered significant because less than 2 percent of the whiting biomass estimate derived from the 1977 bottom trawl survey was located in that depth stratum.

Biomass estimates were calculated by the "area-swept" method (assuming 100 percent trawl efficiency) and length samples were weighted by catch per unit effort (CPUE) to provide estimates of population length compositions by INPFC areas. Age-length keys were derived by INPFC area and applied to area length frequencies to obtain estimates of population age compositions by INPFC area. Details are presented by Dark et al. (1980). The trawl gear, catch sampling methodology, and abundance and biological parameter estimation procedures used in 1980 were identical to those employed in 1977. Requirements for whiting biological samples in 1980 included the collection of at least 200 otoliths from each depth stratum in each of 12 biological sampling areas described by Dark et al. (1983).

Echo Integrator-Midwater Trawl Surveys

The 1977 echo integrator-midwater trawl survey design and procedures are described by Dark et al. (1980). The 1980 survey was conducted similarly along a zigzag trackline with transects running obliquely across isobaths. The average distance between adjacent transects was 5 n.mi. in 1977, whereas in 1980 it varied between 5 and 7.5 n.mi., depending primarily on observed population densities. In 1980 the shoreward boundary of the survey area was the 30-fathom isobath as opposed to a 50-fathom boundary in 1977, and in both years the seaward boundary was 250 fathoms. Transects were extended if whiting schools were present at the planned bathymetric limits.

The configuration and use of the echo integration system are described by Traynor and Ehrenberg (1979), Dark et al. (1980), and Traynor and Nelson (1981). Echo sign was sampled to identify acoustic targets by species and to collect biological data by using a midwater trawl with a vertical mouth opening of 18-20 m. Codend mesh sizes (stretched measure) in the trawls were 33 mm (1977) and 46 mm (1980). Each trawl haul was directed at selected fish echo targets using a cable netsounder system. Most trawl hauls were made during the day but some trawling was done at night in conjunction with the collection of whiting target strength data, as well as to provide whiting biological samples from areas inadequately sampled during the day. Biological sampling requirements and procedures used for processing trawl catches for species composition data and biological data were not significantly different from those used on the bottom trawl surveys.

The procedures used to derive biomass estimates were basically the same as those described by Dark et al. (1980). Whiting aggregations were identified from the characteristics of their echo signatures and analysis of trawl species composition data. Aggregation boundaries were delineated by examining the distribution of individual (1 min. interval) density (kg/m^2 surface area) estimates along the survey transects. All the echo integrator data for whiting were scaled to estimates of absolute density by assuming an average target strength (i.e., the target strength of the average scattering cross section) of -35 dB/kg for the length range encountered on the surveys. The variance (due to sampling) of each biomass estimate was calculated using cluster sampling techniques in the manner described by Dark et al. (1980) and Williamson (1982).

The length distributions of whiting, by INPFC area, were estimated by combining unweighted midwater trawl length-frequency samples. Age and length keys based on otolith samples were constructed for each INPFC area and applied to the length distributions to provide percentage age compositions. Procedures for developing age-specific biomass and population estimates are still being developed. In this paper, estimates of biomass by age group and INPFC area are presented for 1980.

Estimation of Total Biomass

Total estimates of whiting biomass were made by summing the bottom trawl survey and acoustic survey estimates. Although the acoustic system was capable of sampling to a depth of about 3 m above bottom, target detection actually varied between 3 and 10 m off the bottom, depending on the bottom gradient and other factors. It is highly unlikely the total estimate was substantially increased by the occurrence of whiting in the small interval sampled by both techniques. While the bottom trawl and acoustic surveys were conducted synoptically to the extent possible, we acknowledge the potential for the exchange of bottom and midwater whiting aggregations which could have resulted in some fish being counted by both surveys. Any inflation of biomass estimates due to the "double counting" problem would tend to be compensated by bottom trawl estimates which are considered to be conservative because 100 percent trawl efficiency is assumed.

Distribution and Abundance

Bottom Trawl Surveys

In 1977, the bottom trawl survey covered 37,700 km^2 and included 666 useful hauls (Fig. 2). In 1980, 502 hauls were successfully completed in a 48,722 km^2 survey area (Fig. 3). Estimates of relative abundance, in terms of kilograms caught per kilometer trawled, are shown geographically in Figures 4 and 5. During the 1977 survey, whiting at low densities (<21 kg/km) were distributed much more uniformly than in 1980, but in both years higher densities were very unevenly distributed. Table 1 gives CPUE values by INPFC area and depth, and the most noticeable features are the reduction in CPUE as depth increased and differences in CPUE among INPFC areas. The highest densities were found on the continental shelf (<100 fathoms) in both years. Densities were highest and similar in the Columbia, Eureka, and Monterey areas in 1977, but maximum densities shifted southward in 1980. The extraordinarily high CPUE in the Monterey area in 1980 was due to the presence of a large proportion

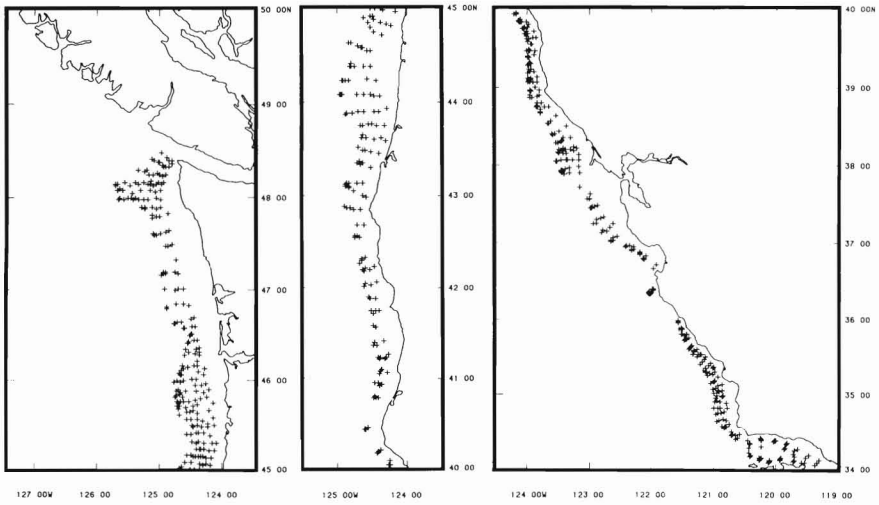

Figure 2.—Geographic distribution of bottom trawl stations in 1977.

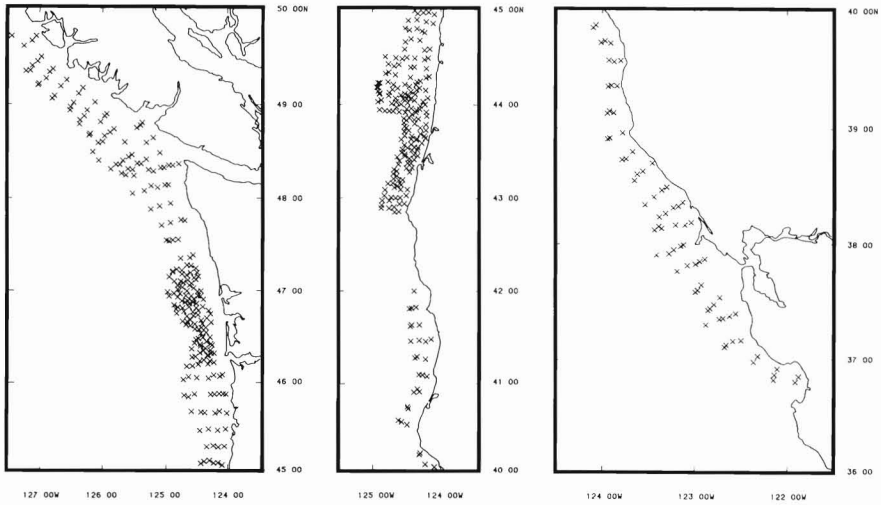

Figure 3.—Geographic distribution of bottom trawl stations in 1980.

Table 1.—The number of bottom trawl hauls and average catch per unit of effort (kg/km) of Pacific whiting by INPFC area and depth stratum for 1977 and 1980.

Year and depth (fathoms)	Vancouver[1]		Columbia		Eureka		Monterey[1]		Conception	
	No. of hauls	kg/km	No. of hauls	kg/km	No. of hauls	kg/km	No. of hauls	kg/km	No. of hauls	kg/km
1977										
50-99	32	19.7	104	42.1	20	48.1	78	36.9	28	7.4
100-149	17	6.9	51	9.0	14	9.0	43	13.8	29	10.5
150-199	14	14.5	33	5.8	13	6.0	44	10.7	19	8.5
200-250	7	2.3	40	5.1	12	1.7	41	4.1	25	1.6
1980										
30-99	65	17.2	249	16.3	24	52.2	56	218.0		
100-200	20	6.1	56	3.6	12	15.2	20	19.6		

[1]As indicated in the text and in Figures 2 and 3, there were significant differences between 1977 and 1980 in the latitudinal extent of the sampling in the Vancouver and Monterey INPFC areas.

of the very abundant 1977 year class. The concentration of these young (age 3) fish in the Monterey area was consistent with the strong tendency for whiting size and age to decrease with latitude.

Between 1977 and 1980, there was a large increase in the biomass of whiting estimated to be available to bottom trawls, and the geographic distribution of biomass changed significantly (Table 2 and Fig. 6). In 1977, the Columbia area contained 47 percent of the estimated biomass; 26 percent of the total was in the Monterey area. The relatively low biomass (6,560 metric tons (t)) in the Vancouver area was partially due to the fact that only a small part of the area was included in the bottom trawl survey. Most of the population in the Conception area was age 0 fish which probably were not sampled representatively. In 1980, 75 percent of the biomass was located in the Monterey area and no other INPFC area contained over 11 percent. In the Monterey area, 77 percent of the estimated population was age 3 fish of the 1977 year class. In both years, most whiting were located on the continental shelf. Only 13 percent and 3 percent of the biomass estimates based on bottom trawl samples for 1977 and 1980, respectively, were found in depths greater than 100 fathoms.

The 95 percent confidence intervals associated with individual INPFC area-depth biomass estimates for 1977 ranged from ± 34 to ± 152 percent of the point estimates and averaged ± 57 percent. In 1980, confidence intervals ranged from ± 45 percent to ± 160 percent with an average of ± 82 percent. The variance of the biomass estimates was higher in 1980 even though the 1980 sampling was designed to increase precision. This is probably largely because the distribution of whiting in 1980 was asynchronous with the survey design, which was based on a predicted distribution derived from fishery statistics.

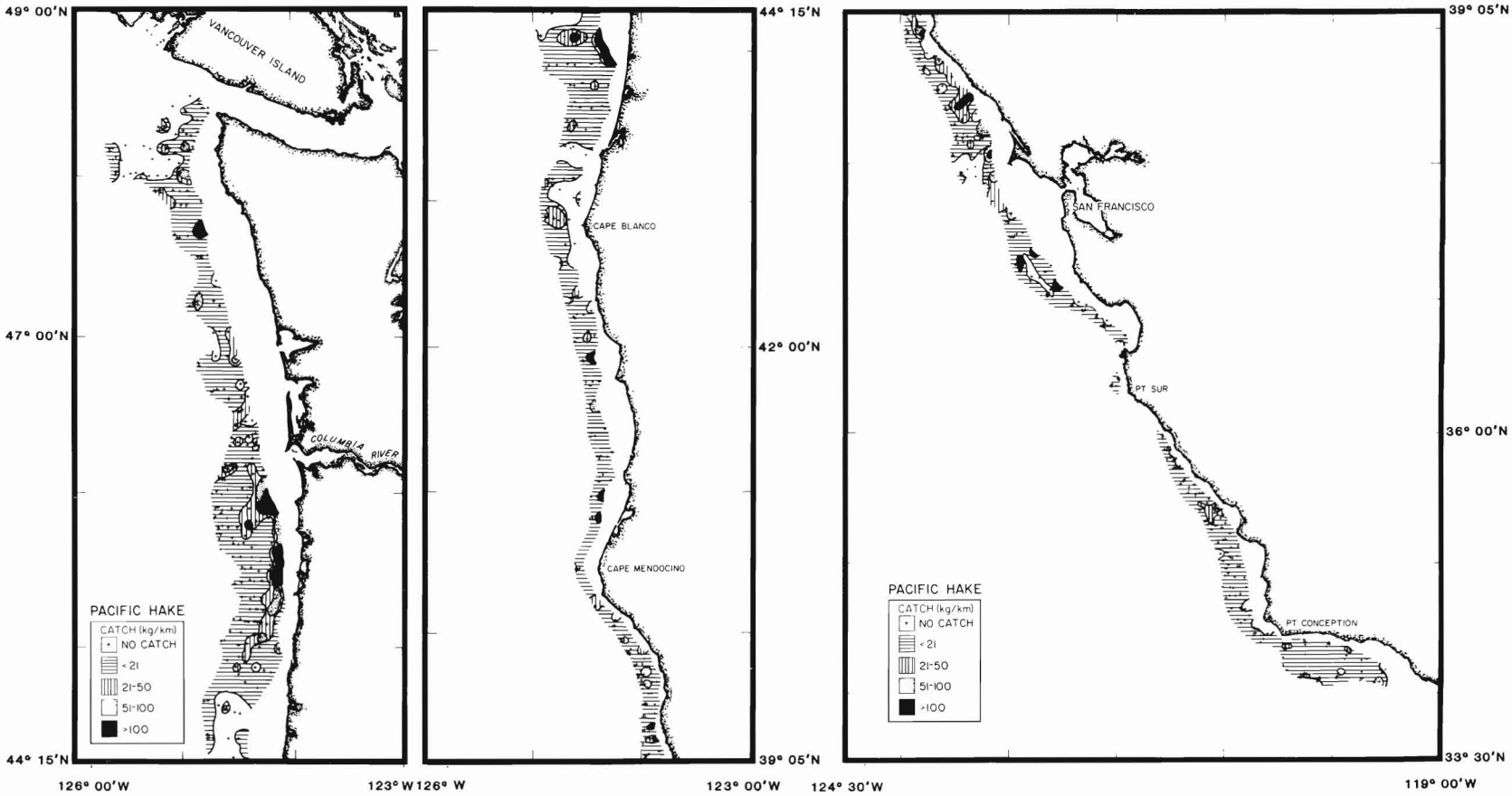

Figure 4.—Pacific whiting density (kg/km) contours as determined from the 1977 bottom trawl survey.

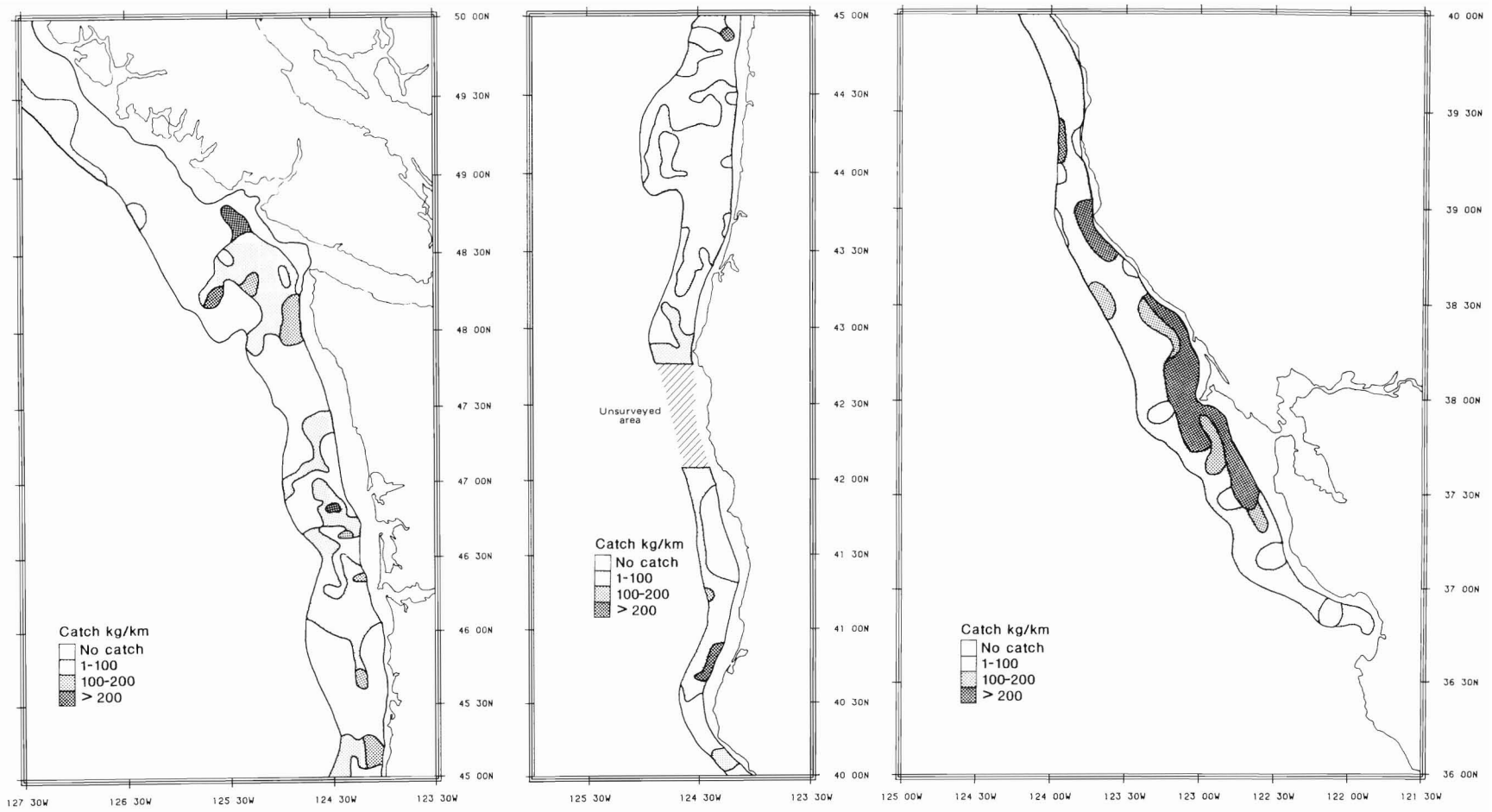

Figure 5.—Pacific whiting density (kg/km) contours as determined from the 1980 bottom trawl survey.

Table 2.—Estimated biomass (metric tons) and associated 95 percent confidence intervals of Pacific whiting from bottom trawl surveys of 1977 and 1980 by INPFC area and depth stratum.

Year and depth (fathom)	Biomass (t)					
	Vancouver	Columbia	Eureka	Monterey	Conception	Total
1977						
0-99	5,680 ± 5,572 (98%)	29,703 ± 12,767 (43%)	8,792 ± 10,019 (114%)	15,546 ± 9,521 (61%)	780 ± 410 (53%)	60,501 ± 19,251 (32%)
100-149	420 ± 310 (74%)	1,592 ± 1,072 (67%)	416 ± 221 (53%)	1,707 ± 2,603 (152%)	953 ± 450 (47%)	5,088 ± 2,818 (55%
150-199	423 ± 281 (66%)	800 ± 482 (60%)	227 ± 175 (77%)	758 ± 656 (87%)	540 ± 247 (46%)	2,748 ± 879 (32%)
200-250	37 ± 30 (81%)	822 ± 326 (40%)	66 ± 70 (106%)	255 ± 86 (34%)	123 ± 90 (73%)	1,303 ± 348 (27%)
Total	6,560 ± 7,873 (120%)	32,917 ± 12,951 (39%)	9,501 ± 10,223 (105%)	18,266 ± 10,036 (55%)	2,396 ± 652 (27%)	69,640 ± 16,313 (23%)
1980						
30-99	15,976 ± 12,157 (76%)	19,093 ± 8,550 (45%)	10,689 ± 12,059 (113%)	141,449 ± 82,624 (58%)		187,207 + 84,724 (45%)
100-200	1,310 ± 1,205 (92%)	1,063 ± 563 (53%)	792 ± 1,192 (151%)	2,375 ± 1,526 (64%)		5,540 + 2,216 (40%)
Total	17,286 ± 12,191 (71%)	20,156 + 8,631 (43%)	11,481 ± 12,171 (106%)	143,824 ± 82,855		192,747 ± 84,754 (44%)

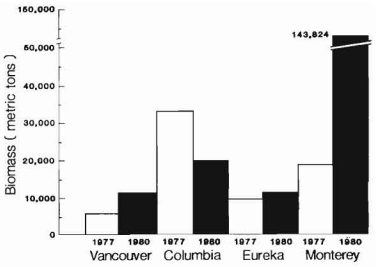

Figure 6.—Bottom trawl survey estimates of Pacific whiting biomass by INPFC area for 1970 and 1980.

Acoustic-Midwater Trawl Surveys

The total distances of the acoustic survey tracklines (Fig. 7, 8) were 6,464 km in 1977 and 4,445 km in 1980. The trackline was shorter in 1980 mainly because of the reductions in geographic coverage and average transect

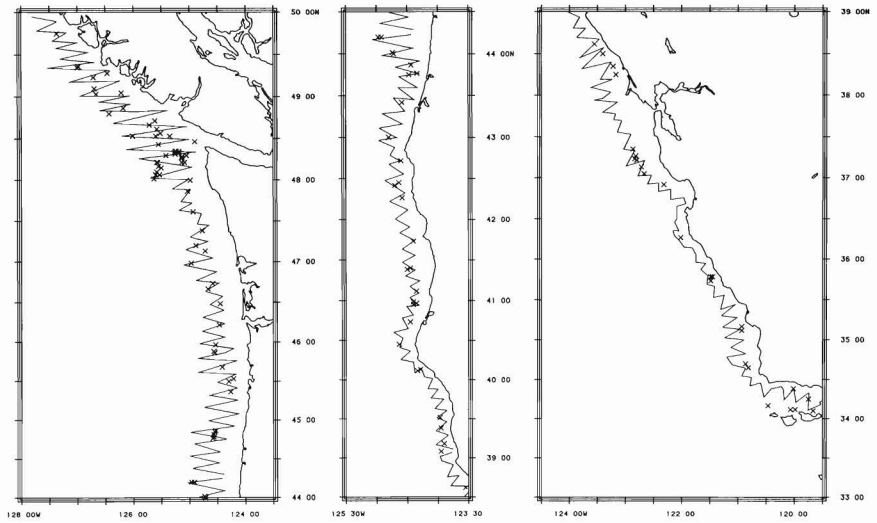

Figure 7.—Acoustic survey trackline and geographic distribution of midwater trawl hauls in 1977.

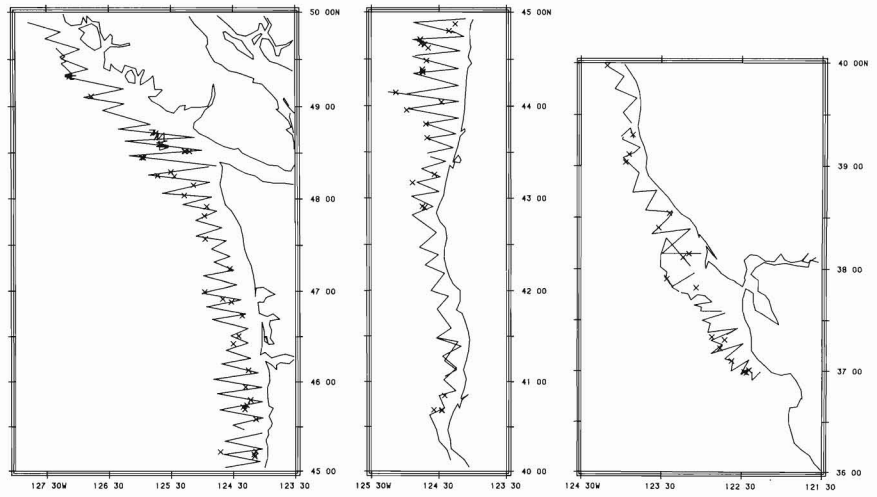

Figure 8.—Acoustic survey trackline and geographic distribution of midwater trawl hauls in 1980.

density. The number of successful midwater trawl hauls completed each year, by INPFC area, is shown in Table 3. The smaller amount of trawl sampling in the Vancouver area in 1980 was largely the result of vessel operation problems which reduced the time available to conduct the survey. This decrease in sampling effort was unfortunate because the number of species which occur in significant quantities in midwater is highest in the Vancouver area and identification and delineation of whiting schools is more difficult than in the other areas. In addition to whiting, the more abundant species in the area include walleye pollock, *Theragra chalcogramma*; Pacific herring, *Clupea harengus pallasi*; spiny dogfish, *Squalus acanthias*; yellowtail rockfish, *Sebastes flavidus*; and redstripe rockfish, *Sebastes proriger* (Table 4).

Estimates of the biomass of the off-bottom component of the whiting population are shown by year and INPFC area in Figure 9 and by year, INPFC area, and subarea in Table 5. In 1977 the biomass estimates for the Vancouver, Columbia, and Eureka INPFC areas were very similar and together they included 90 percent of the total estimate. Biomass estimates were not made for the Conception

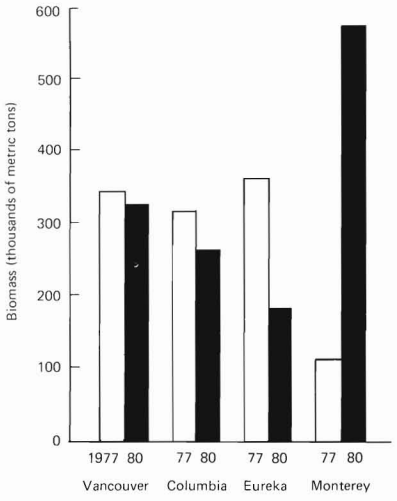

Figure 9.—Acoustic survey estimates of Pacific whiting biomass by INPFC area for 1977 and 1980.

Table 3.—Number of midwater trawl hauls for 1977 and 1980, by INPFC area and bottom depth (fathoms).

INPFC area	No. of hauls, 1977				No. of hauls, 1980			
	50-75	76-100	>100	Total	30-75	76-100	>100	Total
Vancouver	17	19	6	[1]42	8	6	3	17
Columbia	11	11	6	28	6	21	8	35
Eureka	7	6	1	14	2	1	1	4
Monterey	5	2	15	[2]22	9	2	5	16
Conception	2	4	4	10				
Total	42	42	32	116	25	30	17	72

[1]Ten of the 42 hauls were concentrated in a relatively small area off the northern Washington coast during a 5-day cooperative acoustic survey with foreign research vessels.
[2]Four of the 22 hauls were made in that part of the Monterey area not surveyed in 1980.

Table 4.—Percent frequency of occurrence of selected species taken in midwater trawl hauls in 1977 and 1980, by catch size and INPFC statistical area.

Year and species	Catch range (lb)				Catch range (lb)			
	>0		50-499	>500	>0		50-499	>500
	%	(No.)	% (No.)	% (No.)	%	(No.)	% (No.)	% (No.)
	Vancouver (42 hauls)				Columbia (28 hauls)			
1977								
Pacific whiting, *Merluccius productus*	83.3	(35)	40.5 (17)	23.8 (10)	96.4	(27)	32.1 (9)	21.4 (6)
Walleye pollock, *Theragra chalcogramma*	61.9	(26)	21.4 (9)	2.4 (1)				
Yellowtail rockfish, *Sebastes flavidus*	71.4	(30)	19.0 (8)	2.4 (1)	42.9	(12)	14.3 (4)	3.6 (1)
Widow rockfish, *Sebastes entomelas*	21.4	(9)	7.1 (3)	4.8 (2)	39.3	(11)		17.9 (5)
Shortbelly rockfish, *Sebastes jordani*					10.7	(3)		
Redstripe rockfish, *Sebastes proriger*	11.9	(5)	4.8 (2)		21.4	(6)	10.7 (3)	
Canary rockfish, *Sebastes pinniger*	11.9	(5)			17.9	(5)		
Chilipepper, *Sebastes goodei*								
Bocaccio, *Sebastes paucispinis*	4.8	(2)			14.3	(4)		
Spiny dogfish, *Squalus acanthias*	50.0	(2)	4.8 (2)	9.5 (4)	14.3	(4)		
Pacific herring, *Clupea harengus pallasi*	42.9	(18)	4.8 (2)	4.8 (2)	14.3	(4)		
Northern anchovy, *Engraulis mordax*					10.7	(3)		
Eulachon, *Thaleichthys pacificus*	50.0	(21)	2.4 (1)		60.7	(12)		
Jack mackerel, *Trachurus symmetricus*	4.8	(2)						
Market squid, *Loligo opalescens*					3.6	(1)		
	Eureka (14 hauls)				Monterey (22 hauls)			
Pacific whiting	85.7	(12)	50.0 (7)	35.7 (5)	86.4	(19)	36.4 (8)	27.3 (6)
Walleye pollock								
Yellowtail rockfish	35.7	(5)			9.0	(2)	4.5 (1)	
Widow rockfish	28.6	(4)	14.3 (2)		9.0	(2)		
Shortbelly rockfish					36.4	(8)		3.6 (3)
Redstripe rockfish	14.3	(2)						
Canary rockfish	21.4	(3)			4.5	(1)	4.5 (1)	
Chilipepper					9.0	(2)	9.1 (2)	
Bocaccio					36.4	(8)	4.5 (1)	
Spiny dogfish	50.0	(7)	14.3 (2)		40.9	(9)	13.6 (3)	4.5 (1)
Pacific herring	7.1	(1)			9.0	(2)		
Northern anchovy								
Eulachon	35.7	(5)						
Jack mackerel	21.4	(3)						
Market squid	14.3	(2)			13.6	(2)	4.5 (1)	
	Conception (10 hauls)				Total (116 hauls)			
Pacific whiting	80.0	(8)	10.0 (1)		87.1	(101)	36.2 (42)	23.3 (27)
Walleye pollock					22.4	(26)	7.8 (9)	0.9 (1)
Yellowtail rockfish					42.2	(49)	11.2 (13)	1.7 (2)
Widow rockfish	10.0	(1)			23.3	(27)	4.3 (5)	6.0 (7)
Shortbelly rockfish	60.0	(6)	10.0 (1)		14.7	(17)	0.9 (1)	2.6 (3)
Redstripe rockfish					11.2	(13)	4.3 (5)	
Canary rockfish					12.1	(14)	0.9 (1)	
Chilipepper	50.0	(5)	10.0 (1)		6.0	(7)	2.6 (3)	
Bocaccio	50.0	(5)			16.4	(19)	0.9 (1)	
Spiny dogfish	50.0	(5)	10.0 (1)		39.6	(46)	6.9 (8)	4.3 (5)
Pacific herring					21.6	(25)	1.7 (2)	1.7 (2)
Northern anchovy			10.0 (1)		6.9	(8)	0.9 (1)	
Eulachon					37.1	(43)	0.9 (1)	
Jack mackerel					4.3	(5)		
Market squid	80.0	(8)	10.00 (1)	10.00 (1)	12.1	(14)	1.7 (2)	0.9 (1)

area because whiting aggregations were not observed, although trawl samples revealed age 0 fish dispersed in scattering layers. The Monterey area estimate was only about one-third as large as that in any of the three more northern INPFC areas. This probably was a reflection of the fact that the whiting population in 1977 was composed primarily of fish that were age 4 or older which are normally distributed north of the Monterey area. There were noticeable differences in abundance within INPFC areas, including a lack of fish in the southern part of the Monterey area (lat. 35°30′-37°00′N) and northern part of the Vancouver area (lat. 49°25′-50°00′N), as well as a distinct decrease in abundance between the southern (lat. 43°00′-45°00′N) and northern (lat. 45°00′-47°30′N) parts of the Columbia area (Table 5).

The amount of change between 1977 and 1980 in the total biomass estimates for the off-bottom component of the population was small compared to that for fish available to bottom trawls (Tables 2 and 5). However, due to the large size of the 1977 year class, there was a similar but somewhat less pronounced geographic shift in abundance between years. The biomass estimate for the Monterey area in 1980 accounted for 43 percent of the total, while only about 10 percent of the total was found there in 1977. Also, it was estimated that over 75 percent of the biomass in the area was composed of 3-year-old fish. North of the Monterey area, the most significant change in abundance occurred in the Eureka area where the biomass estimate decreased by almost 50 percent between 1977 and 1980.

In all INPFC areas during both years, a majority of the biomass of the off-bottom component of the whiting population was found over the continental shelf, i.e., inside the 100-fathom isobath (Fig. 10). The percentage of the total biomass located over the shelf increased from 59 percent in 1977 to 75 percent in 1980. This increase occurred partly because the 1980 survey included depths of 30-50 fathoms, whereas in 1977 that depth zone was sampled

Table 4.—Continued.

Year and species	Catch range (lb) >0 % (No.)	50-499 % (No.)	>500 % (No.)	Catch range (lb) >0 % (No.)	50-499 % (No.)	>500 % (No.)
1980	Vancouver (17 hauls)			Columbia (35 hauls)		
Pacific whiting	70.6 (12)	11.8 (2)	41.2 (7)	85.7 (30)	28.6 (10)	34.3 (2)
Walleye pollock	23.5 (4)	17.6 (3)				
Yellowtail rockfish	70.6 (12)	11.8 (2)	5.9 (1)	28.6 (10)	14.3 (5)	
Widow rockfish	11.8 (2)		5.9 (1)	22.9 (8)	5.7 (2)	5.7 (2)
Shortbelly rockfish				8.6 (3)	2.9 (1)	2.9 (1)
Redstripe rockfish	41.2 (7)		11.8 (2)	5.7 (2)	2.9 (1)	
Canary rockfish	5.9 (1)			11.4 (4)		
Chilipepper						
Bocaccio						
Spiny dogfish	70.6 (12)	35.3 (6)	5.9 (1)	20.0 (7)		
Pacific herring	47.1 (8)	5.9 (1)	5.9 (1)	11.4 (4)		
Northern anchovy				2.9 (1)		
Eulachon	41.2 (7)			28.6 (10)	5.7 (2)	
Jack mackerel				20.0 (7)		2.9 (1)
Market squid				11.4 (4)		
	Eureka (4 hauls)			Monterey (16 hauls)		
Pacific whiting	100.0 (4)	25.0 (1)	75.0 (3)	93.8 (15)	18.8 (3)	50.0 (8)
Walleye pollock						
Yellowtail rockfish	25.0 (1)	25.0 (1)		6.3 (1)		
Widow rockfish	25.0 (1)			6.3 (1)		
Shortbelly rockfish	25.0 (1)			37.5 (6)		18.8 (3)
Redstripe rockfish						
Canary rockfish	25.0 (1)					
Chilipepper	25.0 (1)			31.3 (5)		
Bocaccio				12.5 (2)		
Spiny dogfish	50.0 (2)			37.5 (6)	12.5 (2)	6.3 (1)
Pacific herring				12.5 (2)		
Northern anchovy						
Eulachon						
Jack mackerel				31.3 (5)	6.3 (1)	6.3 (1)
Market squid				50.0 (8)	6.3 (1)	
				Total (72 hauls)		
Pacific whiting				84.7 (61)	22.2 (16)	41.7 (30)
Walleye pollock				5.6 (4)	4.2 (3)	
Yellowtail rockfish				33.3 (24)	11.1 (8)	1.4 (1)
Widow rockfish				16.7 (12)	2.8 (2)	4.2 (3)
Shortbelly rockfish				13.9 (10)	1.4 (1)	5.6 (4)
Redstripe rockfish				12.5 (9)	1.4 (1)	2.8 (2)
Canary rockfish				8.3 (6)		
Chilipepper				8.3 (6)		
Bocaccio				2.8 (2)		
Spiny dogfish				37.5 (27)	11.1 (8)	2.8 (2)
Pacific herring				19.4 (14)	1.4 (1)	1.4 (1)
Northern anchovy				1.4 (1)		
Eulachon				23.6 (17)	2.8 (2)	
Jack mackerel				16.7 (12)	1.4 (1)	2.8 (2)
Market squid				16.7 (12)	1.4 (1)	

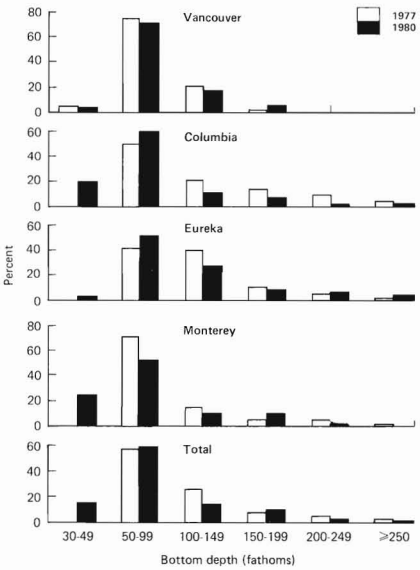

Figure 10.—Distribution by depth, for each INPFC area, of acoustic survey estimates of Pacific whiting biomass for 1977 and 1980.

Table 5.—Acoustic survey estimates of Pacific whiting biomass (t) and associated 95% confidence intervals for 1977 and 1980, by INPFC area and latitudinal subarea.

	1977				1980			
INPFC area	Latitudinal subarea	Biomass (t)	Percent of total	95% confidence interval	Latitudinal subarea	Biomass (t)	Percent of total	95% confidence interval
Vancouver (47°-30'-50°30'N)[1]	48°-26'-49°26'	142,422	12.6	± 30,808 (± 22%)	48°-11'-49°26'	247,742	18.4	± 76,892 (± 31%)
	47°-30'-48°26'	201,399	17.8	± 77,459 (± 39%)	48°-03'-48°10'	17,935	1.3	± 28,487 (± 16%)
	Area total	343,821	30.4	± 83,325 (± 24%)	47°-27'-48°00'[3]	56,658	4.7	± 26,068 (± 46%)
					Area total	322,335	23.9	± 86,044 (± 27%)
Columbia (43°-00'-47°30'N)	46°-44'-47°30'	15,526	1.4	± 10,358 (± 67%)	46°-40'-47°23'	76,813	5.7	± 13,625 (± 18%)
	45°-50'-46°44'	26,776	2.4	± 3,415 (± 13%)	46°-21'-46°36'	19,802	1.5	± 10,172 (± 53%)
	45°-00'-45°50'	18,604	1.6	± 3,834 (± 21%)	45°-41'-46°12'	81,749	6.1	± 35,504 (± 13%)
	44°-08'-45°00'	55,966	5.0	± 14,441 (± 26%)	45°-10'-45°20'	9,158	0.7	± 2,354 (± 26%)
	43°-00'-44°08'	199,568	17.7	± 65,879 (± 33%)	44°-45'-44°51'	5,516	0.4	± 3,038 (± 55%)
	Area total	316,440	28.0	± 68,276 (± 22%)	44°-37'-44°43'	4,614	0.3	± 3,460 (± 75%)
					43°-57'-43°59'	555	0.1	± 482 (± 87%)
					43°-51'-43°58'	3,513	0.3	± 3,427 (± 98%)
					42°-59'-43°35'[3]	58,757	4.4	± 20,842 (± 35%)
					Area total	260,477	19.4	± 44,979 (± 17%)
Eureka (40°-30'-43°00'N)	41°-47'-43°00'	169,493	15.0	± 47,710 (± 28%)	40°-36'-42°00'	182,783	13.6	± 45,762 (± 25%)
	40°-25'-41°47'[3]	191,451	17.0	± 60,156 (± 31%)				
	Area total	360,944	32.0	± 76,647 (± 21%)				
Monterey (35°-30'-40°30'N)[2]	38°-49'-40°16'	58,860	5.2	± 20,758 (± 35%)	40°-07'-40°15'	3,547	0.3	± 2,131 (± 60%)
	37°-07'-38°49'	49,227	4.4	± 25,705 (± 52%)	38°-54'-40°01'	158,534	11.8	± 64,184 (± 40%)
	Area total	108,087	9.6	± 32,949 (± 30%)	37°-49'-38°47'	407,225	30.3	± 105,354 (± 26%)
					37°-45'-37°47'	9,535	0.7	± 10,530 (± 110%)
					Area total	578,841	43.1	± 123,883 (± 21%)
	Total	1,129,292	100.0	± 136,375 (± 12%)	Total	1,344,436	100.0	± 163,875 (± 12%)

[1]Area between lat 50°00' and 50°30' not surveyed.
[2]Area south of lat. 36°55' not surveyed in 1980.
[3]Includes small part of adjacent INPFC area to south.

only in the northern part of the Vancouver area. Only 7 percent and 3 percent of the total acoustic estimates of biomass for 1977 and 1980 were in depths greater than 200 fathoms.

Because of the survey method's high sampling rate, the estimated precision of the acoustic estimates of biomass was relatively high compared with the precision of bottom trawl based estimates (Table 5). The 95 percent confidence intervals for INPFC subarea biomass estimates in 1977 ranged from ± 13 percent to ± 67 percent with a mean of ± 33 percent of the point estimate. For 1980, the corresponding range and mean were ± 16 percent to ± 110 percent and ± 51 percent of the point estimate. In 1980 estimates were made for several relatively small concentrations of whiting, and the larger confidence intervals reflect the small sample sizes. In both years, none of the confidence intervals for individual INPFC areas exceeded ± 30 percent. It should be recognized that the confidence intervals provide a measure of the precision of the biomass estimates, but they do not incorporate the effect of variability in the target strength parameter.

Age and Length Composition

Bottom Trawl Surveys

Whiting population-age compositions by INPFC area as determined from the 1977 and 1980 bottom trawl samples are shown in Figure 11. During both years the population in most areas was dominated by one or two year classes and the commonly observed increase in average age with latitude was apparent.

In 1977 4- or 7-year-old whiting, or both, representing the 1973 and 1970 year classes, predominated in four of five INPFC areas. The abundance of these age groups relative to one another is mainly a function of latitude. The very strong 1970 year class (age 7) was the most abundant age group in the Vancouver, Columbia, and Eureka areas. Four-year-old whiting (1973 year class) were the second most abundant age group in the Eureka area and were the dominant group in the Monterey area. The large size of the 1973 year class was further evident in its unusually high abundance in the Vancouver and Columbia areas. The 1977 year class (age 0) was the dominant age group (82 percent) in the Conception area in 1977, but also was about 7 percent of the population in the Monterey area which is indicative of its large size.

In 1980 the whiting population sampled by bottom trawls in the Eureka area and, especially the Monterey area, was completely dominated by 3-year-old fish of the 1977 year class. Even though it was almost absent in the Vancouver and Columbia areas, that year class accounted for about 53 percent of the total biomass estimated by the bottom trawl survey. In the Vancouver and Columbia areas there was no dominant age group. The 3-year-old whiting did not occur in significant numbers that far north, and the strong 1970 and 1973 year classes had

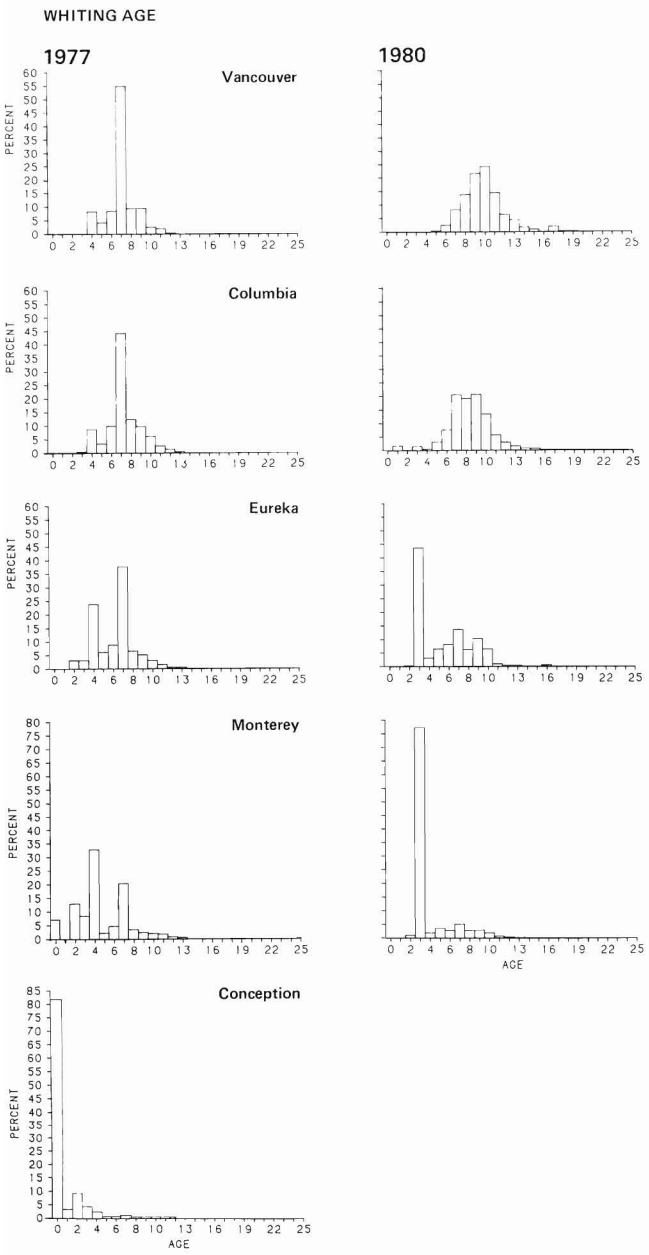

Figure 11.—Age compositions of Pacific whiting by INPFC area for 1977 and 1980, as determined from bottom trawl samples.

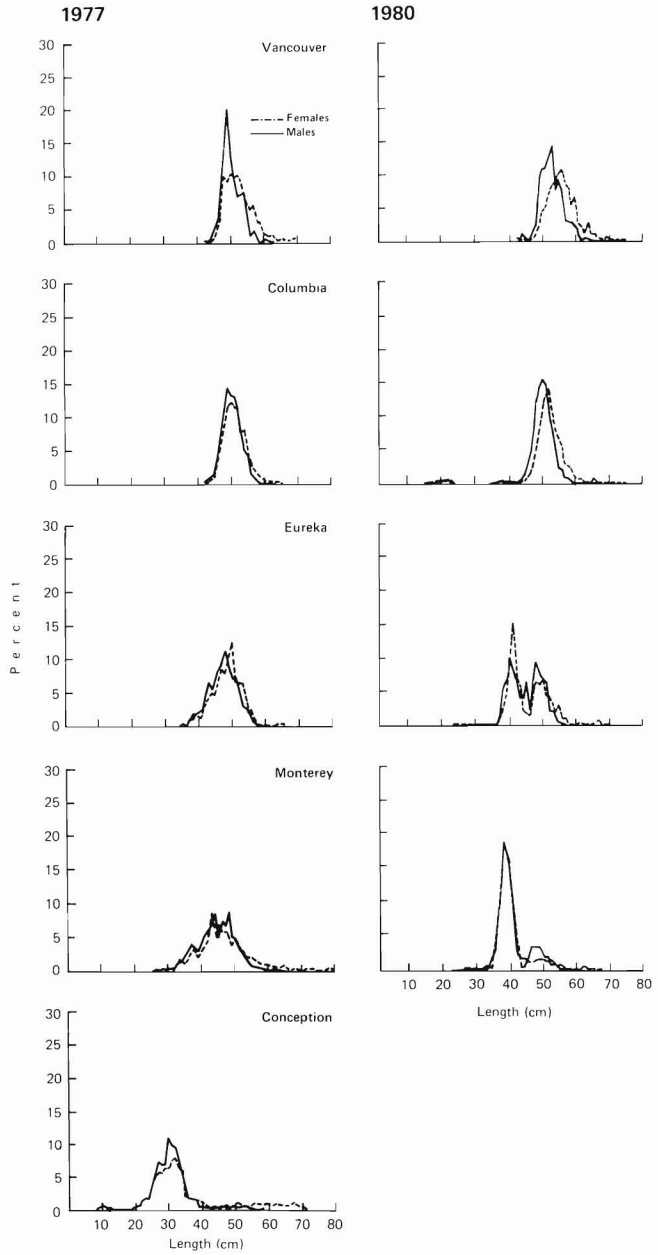

Figure 12.—Length distributions of Pacific whiting for 1977 and 1980, by sex and INPFC area, as determined from bottom trawl samples.

been significantly reduced in size by the effects of fishing and natural mortality.

The length distributions of whiting from bottom trawl samples in 1977 and 1980 (Fig. 12) reflect the more prominent features of the age compositions. In both years, an increase in mean length with latitude is apparent for both sexes, and differences in length range among INPFC areas correspond with changes in the number of age groups represented in the samples. The larger mean length of females in most areas each year is in agreement with growth studies (Dark, 1975) which indicate that after age 3, the average length-at-age of females is greater than that of males. Also, it is apparent that among the larger and older fish, females are

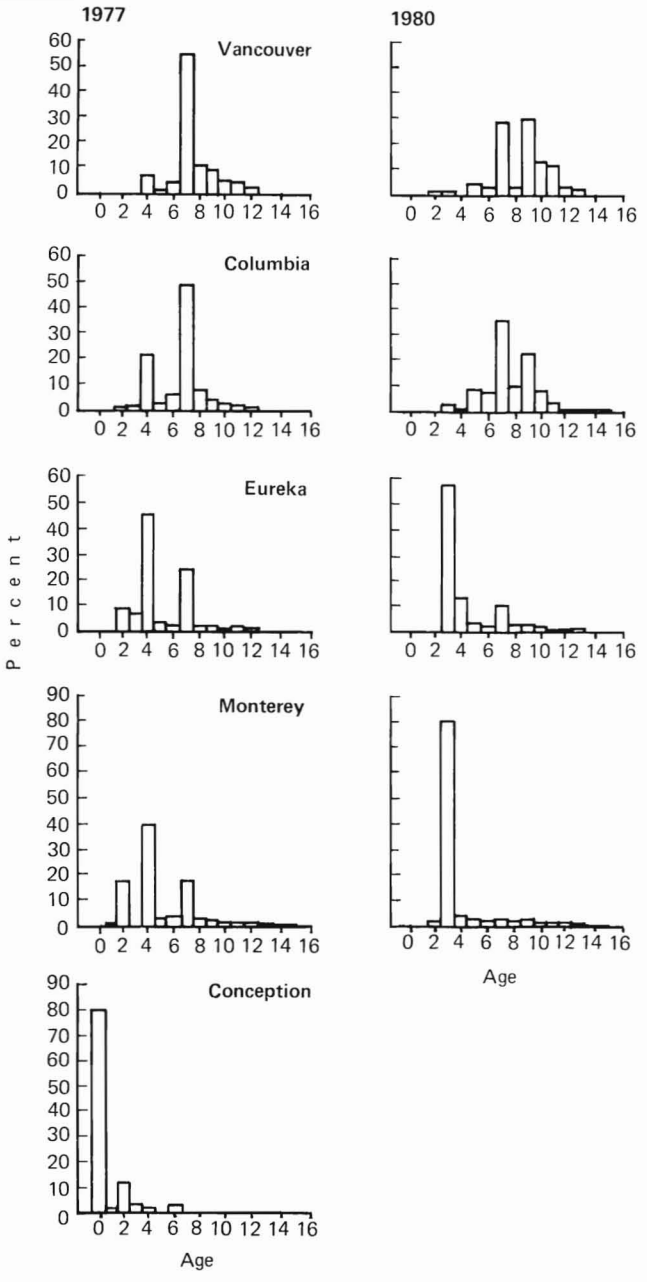

Figure 13.—Age composition of Pacific whiting by INPFC area for 1977 and 1980, as determined from midwater trawl samples.

more abundant. In 1977 there were sharp modes at 50-52 cm in the Vancouver and Columbia areas that were related to the dominance of 7-year-old fish in those areas. In the more southern areas where younger age groups were important, the length modes were less pronounced (except in the Conception area where unsexed age 0 fish (not shown in Fig. 12) were dominant). The 1980 length distributions in the Vancouver and Columbia areas were unimodal, but due to the absence of a dominant age group, the modes were less pronounced than in 1977. Length distributions in the Eureka and Monterey areas were bimodal in 1980 and mean sizes were 2.5.-5.0 cm smaller than in 1977, reflecting the presence of the abundant 3-year-old age group together with smaller numbers of 4- to 10-year-olds.

Acoustic-Midwater Trawl Surveys

Age compositions for 1977 and 1980 from midwater trawl samples are shown in Figure 13. In 1977 the trend in age composition by INPFC area was generally similar to that observed in the bottom trawl samples. In each INPFC area except Conception, 4- or 7-year-olds, or both, predominated. The midwater trawl and bottom trawl age compositions were most similar in the Conception area where the population was dominated by the age 0 group. The most noticeable differences between the age composition determined from the two types of sampling occurred in the Columbia area where 1- and 2-year-old whiting were represented in midwater trawl samples, but absent in bottom trawl samples; in the Eureka area where 4-year-olds dominated in midwater trawl samples instead of 7-year-olds as in the bottom trawl samples; and in the Monterey area where age 0 specimens occurred in bottom trawl samples but not in midwater trawl samples.

The 1980 midwater trawl age compositions for the Eureka and Monterey areas were also similar to those determined from bottom trawl samples, with both types of samples clearly showing the dominance of the 1977 year class in both areas. The importance of this year class is particularly evident in estimates of biomass by age (Fig. 14). In the Vancouver and Columbia areas in 1980, where there was no dominant age group, there was noticeably more variation between the midwater and bottom trawl age compositions. In particular, 8-year-olds were noticeably less abundant in the midwater trawl samples. It is suspected that this difference is due to sampling variability or a bias in age determina-

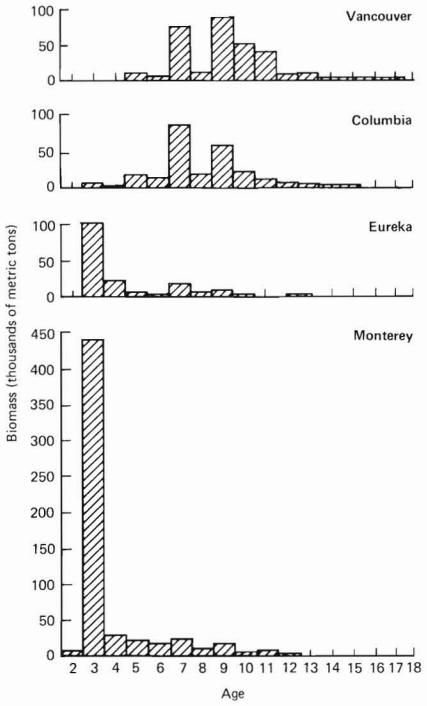

Figure 14.—Acoustic survey estimates of Pacific whiting biomass for 1980, by age and INPFC area.

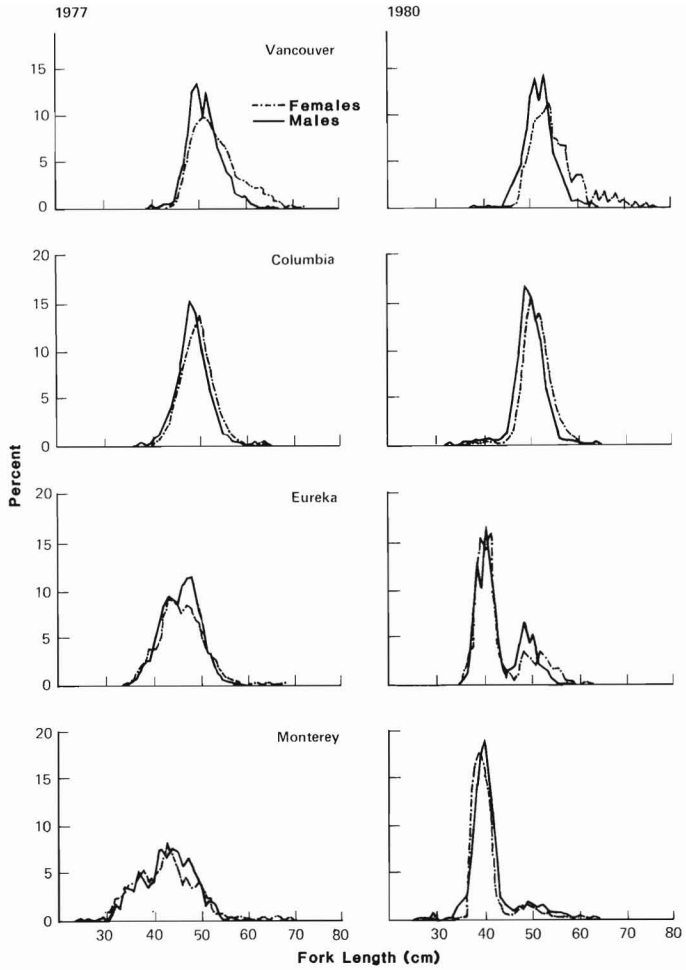

Figure 15.—Length distributions of Pacific whiting for 1977 and 1980, by sex and INPFC area, as determined from unweighted midwater trawl samples.

tions. As in the case of the bottom trawl sample age composition, the strength of the 1973 and 1970 year classes was still apparent in the relative abundance of 7- and 10-year-old fish in the Vancouver-Columbia region. In most instances, the length distributions of midwater trawl samples (Fig. 15) were similar to those of bottom trawl samples, with noticeable differences between the two types corresponding with the more obvious differences in age composition mentioned previously. Although the differences were relatively small, there was a consistent tendency for the mean length of whiting taken in midwater trawl hauls to be less than that in bottom trawl hauls. With the exception of the Vancouver area in 1977 and the Columbia area in 1980 (males only), this difference by gear type occurred for each sex, in each INPFC area, during both years (Table 6).

Table 6.—Mean lengths (cm) of Pacific whiting (male, female, and combined) in bottom trawl and midwater trawl catches by INPFC area for 1977 and 1980.

INPFC area	1977						1980					
	Bottom trawl			Midwater trawl			Bottom trawl			Midwater trawl		
	Male	Female	Comb.	Male	Female	Comb.	Male	Female	Comb.	Male	Female	Comb.
Vancouver	50.4	52.5	51.8	51.4	53.8	53.0	52.8	55.9	55.2	52.0	54.9	53.8
Columbia	50.1	51.6	50.9	48.6	49.8	49.2	49.7	52.0	51.1	49.7	51.2	[1]50.0
Eureka	47.1	48.6	48.0	45.2	45.7	45.4	44.8	45.8	45.3	42.4	43.0	42.7
Monterey	44.2	47.0	[1]43.1	42.7	43.1	42.9	40.6	40.4	40.5	39.8	40.3	[1]39.6

[1]Includes unsexed specimens which were nearly all ≤20 cm.

Total Biomass Estimates

Total whiting biomass estimates were 1,198,932 t and 1,537,183 t in 1977 and 1980, respectively (Table 7). In both years, a very large percentage of the total estimate and the estimates for each INPFC area[1] were derived

[1]Excluding the Conception area in 1977 which had no acoustic estimate.

Table 7.—Combined bottom trawl survey and acoustic survey estimates of Pacific whiting biomass (t) for 1977 and 1980, by INPFC area.

	1977						1980					
	Bottom trawl		Acoustic		Total		Bottom trawl		Acoustic		Total	
INPFC area	t (%)[1]	(%)[2]	t (%)[1]	(%)[2]	t (%)[1]	(%)[2]	t (%)[1]	(%)[2]	t (%)[1]	(%)[2]	(%)[1]	(%)[2]
Vancouver	6,560 (1.9)	9.4	343,821 (98.1)	30.4	350,821 (100.0)	29.3	17,286 (5.1)	9.0	322,335 (94.9)	23.9	339,621 (100.0)	22.1
Columbia	32,917 (9.4)	47.3	316,440 (90.6)	28.0	349,357 (100.0)	29.1	20,156 (7.2)	10.5	260,477 (92.8)	19.4	280,633 (100.0)	18.3
Eureka	9,501 (2.6)	13.6	360,944 (97.4)	37.0	370,445 (100.0)	30.9	11,481 (5.9)	5.9	182,783 (94.1)	13.6	194,264 (100.0)	12.6
Monterey	18,266 (14.5)	26.2	108,087 (85.5)	9.6	126,353 (100.0)	10.5	143,824 (19.9)	74.6	578,841 (80.1)	43.1	722,665 (100.0)	47.0
Conception	2,396 (100.0)	3.4			2,396 (100.0)	0.2						
Total	69,640 (5.8)	100.0	1,129,292 (94.2)	100.0	1,198,932 (100.0)	100.0	192,747 (12.5)	100.0	1,344,436 (87.5)	100.0	1,537,183 (100.0)	100.0

[1]Percentage by type of survey.
[2]Percentage of total for all INPFC areas combined.

from the acoustic survey. Except for the Monterey area, the bottom trawl estimates were all less than 10 percent of the combined estimates. The difference between the two types of estimates was noticeably less in the Monterey area, particularly in 1980, and suggests that 2- and 3-year-old whiting may be relatively less available to acoustic sampling than older age groups. The exceptionally large difference between the two types of estimates in the Vancouver area in 1977 was partially due to the absence of bottom trawl sampling in most of that area. The distribution of the biomass among INPFC areas was essentially the same as that described previously for the acoustic estimates.

Summary

The results of acoustic and bottom trawl surveys conducted in 1977 and 1980 have provided additional information on the biology and behavior of Pacific whiting. The highly variable year-class strength reported by others (Alverson and Larkins, 1969; Dark, 1975; Bailey et al.,[2]) was observed in both years. The 1973 year class was dominant in 1977, and 3 years later the 1977 year class was extremely abundant. The estimated biomass increased about 28 percent between 1977 and 1980 from 1,129,000 t to 1,537,000 t, primarily due to the recruitment of the 1977 year class. Such variable recruitment not only influences the size of the whiting resource but also affects its coastwide distribution. The center of abundance can occur almost anywhere over about 12 degrees of latitude depending, at least partly, on the age structure of the population. Ten percent of the biomass was in the Monterey area in 1977, but 47 percent was estimated to be there in 1980 when the population was dominated by 3-year-olds.

The coastwide distribution of the bottom component of the population was more uniform in 1977 than in 1980 and in both years most of the resource was located over the continental shelf in waters less than 100 fathoms deep. On the average, 90 percent of the biomass was found to be aggregated in pelagic schools unavailable to the bottom trawls used. The mean size of whiting taken by midwater trawl tended to be slightly smaller than the mean size in bottom trawl samples. This may be a reflection of feeding behavior, with small fish seeking euphasiids and planktonic organisms throughout the water column and large fish focusing their feeding efforts on a greater array of prey species including fish and shrimp found adjacent to the bottom.

Further information about methods and a discussion of the accuracy of biomass estimates and the role of surveys in assessments of Pacific whiting can be found in Nelson and Dark (In press).

[2]Bailey, K. M., R. C. Francis, and P. R. Stevens. 1982. The life history and fishery of Pacific hake *Merluccius productus*. Processed Rep. 82-03, 81 p. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

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