MARINE RESOURCE SURVEYS ON THE CONTINENTAL SHELF AND UPPER SLOPE OFF WASHINGTON, 1975-76

COMPLETION REPORT

July 1, 1975 to September 30, 1977

William H. Barss
Robert L. Demory
Neil Ten Eyck

Oregon Department of Fish and Wildlife

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ABSTRACT

Groundfish surveys off the Washington coast were conducted in September of 1975 and 1976 between Cape Flattery and the Columbia River. The primary purposes of the surveys were to obtain estimates of biomass and further our knowledge on population parameters of important groundfish species, especially flatfish, occupying the continental shelf and upper continental slope.

Survey design was based on a 5x6 N. mi grid with a random starting point. Samples were obtained for age, size and sex composition from important flatfish species. Weights were obtained from all species of fish.

Estimates of biomass, all species, were 143,447 and 147,303 metric tons in 1975 and 1976, respectively. Pacific hake and English sole were the most abundant species. Estimates of biomass and potential yield were determined for six species of flatfish. Data indicate that most flatfish species are not fully exploited, but several species may be nearing full utilization. Increased yield could be obtained without increased fishing effort if market demand would increase on certain under-utilized species.

Several population parameters were obtained. Age, length-weight constants, total annual and fishing mortality rates and exploitation rate were estimated for six species of flatfish. Distribution and abundance was depicted for major species by catch maps. Distribution of some species was closely correlated with depth and sediment type. Increase in mean weight was associated with increasing depth for many species. Strong year classes were indicated for several species. Data suggests that the Astoria Canyon may separate Dover sole and also arrowtooth flounder stocks.

INTRODUCTION

This report summarizes study activities from July 1, 1975 through September 30, 1977. The project was a comprehensive marine resource survey of the continental shelf and upper continental slope off Washington between Cape Flattery and the Columbia River. Objectives were: to obtain estimates of biomass for demersal fishes with particular emphasis on flatfish; to determine estimates for the population parameters of age composition, growth and mortality; to index year class strength of flatfishes important to the commercial trawl fishery prior to their recruitment to the fishery; and to estimate potential yield of selected species. Emphasis was placed on flatfish due to their historical importance to the Oregon trawl fishery.

The survey was a cooperative effort between the Oregon Department of Fish and Wildlife (ODFW), the Washington Department of Fisheries (WDF), and U.S. National Marine Fisheries Service (NMFS, 1975). WDF supplied one man-month of support per year plus commercial catch records and market sample data. Data collected on Pacific hake in 1975 were supplied to the NMFS as part of their 1975 synoptic hake survey.

ODFW initiated the survey off Washington because of the traditional importance of the area to the Astoria trawl fleet. The survey off Washington was a natural extension of surveys conducted off Oregon (1971-74) since some fish stocks transcend the political boundary. The Astoria Canyon and the Juan de Fuca Canyon appear to be natural barriers at least to some stocks as well as convenient geographical boundaries for this type of a study. Surveys based on a systematic sampling program were considered necessary to provide unbiased estimates of stock conditions. Commercial gear restrictions, market conditions and economic needs do not bias survey data.

Marine resource surveys have been used as a management and research tool off the Washington coast since 1951 (Alverson 1951). The two surveys (1975, 1976) under this study, however, were the first specifically planned to obtain reliable biomass estimates.

METHODS AND MATERIALS

Survey Design

The survey was conducted off the Washington coast (Figure 1) between Cape Flattery (lat. 48° 23'N) and the Columbia River (lat. 46° 16'N) in 10 to 300 fathoms (18-549 m). The survey period was late August to late September, usually a good weather interval and prior to most fish spawning migrations.

The study area was 2,733 N. mi^2 (9,374 km^2) in area (trawlable area). Trawling locations were systematically determined by use of a 5x6 N. mi (9.3x11.1 km) grid with a random starting point. Stations were located 5 miles apart along tracklines located at 6-mile intervals. There were 99 stations located in 1975, of which 74 were occupied. In 1976 there were 97 stations located of which 79 were occupied. Stations were located by loran A, depth and ship's radar. Tow length was one nautical mile except for 21, 30-minute duration calibration tows made in 1975 in cooperation with the NMFS. Catch rates of these tows were subsequently adjusted to one mile. All tows were made during daylight hours at speeds of 2 to 3 knots.

There were minor survey changes during the study concerning depth limits and number of tows. In 1976, depths surveyed were limited to 10 to 260 fathoms (18-476 m) due to vessel limitations. Also in the interest of time, we omitted the northern-most and southern-most tracklines in 1976 (one station each).

We attempted to make expendable bathythermograph (XBT) casts on both cruises, but the equipment failed to perform adequately at sea.

Vessel and Gear Characteristics

Two vessels were chartered. The 67-foot (20 m.) western seiner-type trawler R/V *Commando* was chartered in 1975, and the 75-ft (23 m.) schooner-type trawler M/V *Tordenskjold* was chartered in 1976.

R/V *Commando* was powered by a 358 hp engine. Doors (otter boards) were "V" type, steel, 5x7-ft (1.5x2.1 m.) and weighed 1,050 pounds (476 kg) each. M/V *Tordenskjold's* "V" type, steel otter boards were 5x7-ft and weighed about 1,350 pounds (612 kg) each. The vessel was powered by a 365 hp engine.

The trawl used was a 400-mesh eastern type constructed entirely of 3.5-in (89 mm) mesh, stretched measure. Footrope-headrope lengths were 77 and 60-ft (23.5; 18.3 m) respectively. The trawl had a rubber disc, chain footrope, made up of 4.5-in (114 mm) diameter rubber discs. Thirteen, 8-in (203 mm) plastic floats were equally spaced on the headrope. A 71-ft (21.6 m), 3/8-in (9.5 mm) tickler chain was attached to each end of the footrope.

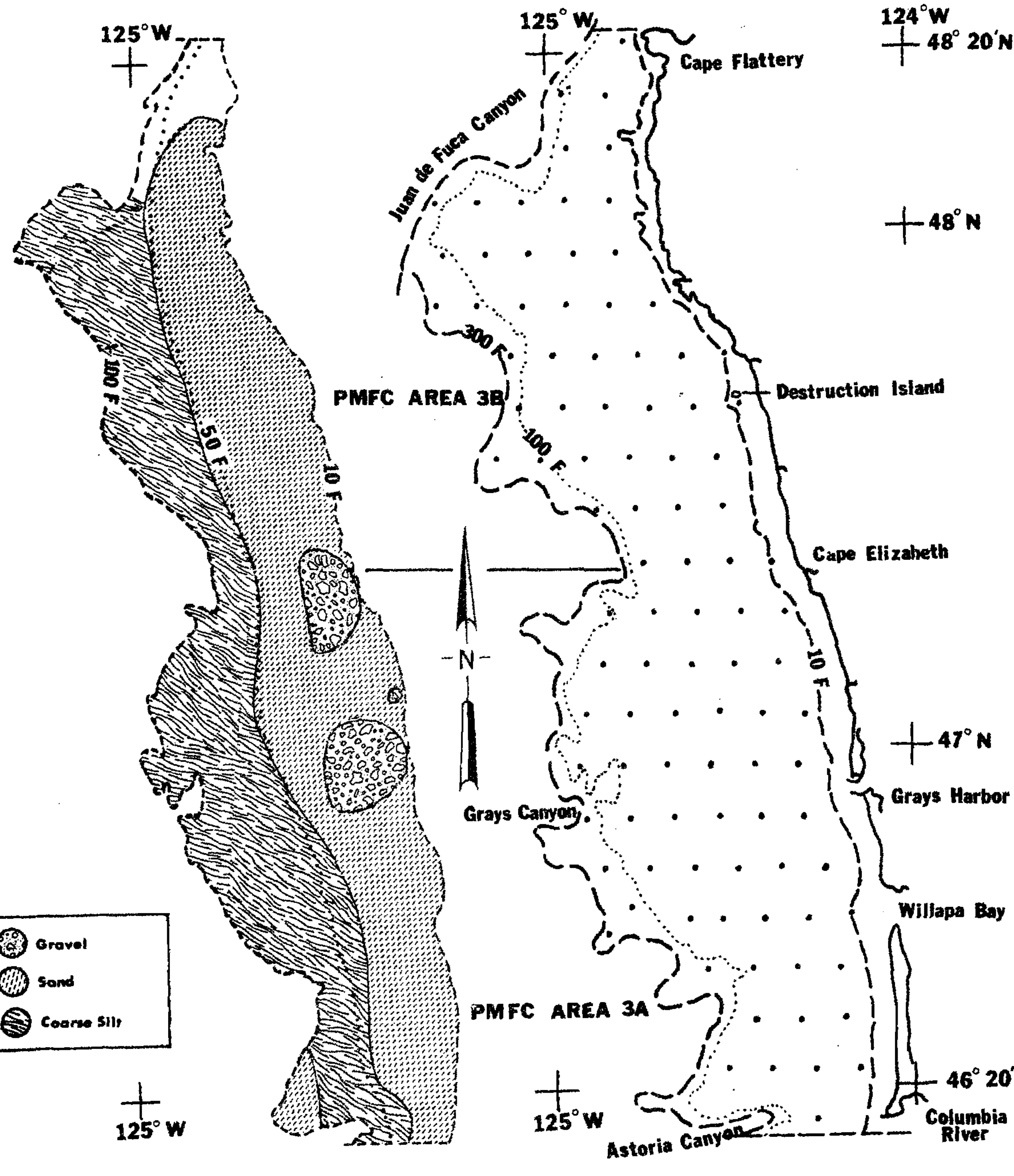

Figure 1. Location of trawl stations of groundfish surveys off Washington, 1975-76. Heavy broken line defines survey limits. Sediment types from Cross et al (1967), Roberts (1974) and Vendatarathnam (1973).

Short sweep lines [10-fm bridles (18.3 m), 5-fm dandy lines (9.1 m)] were used to reduce herding of fish into the trawl. ODFW and NMFS scientist-divers measured the horizontal and vertical openings and appraised the workability of the trawl in Puget Sound, Washington at towing speed in 8-12 fm (14.6-21.9 m) of water. Horizontal and vertical openings were about 30-ft and 5-ft (9.1; 1.5 m), respectively. Average swept area (length of tow x horizontal opening) was estimated to be 0.00494 N. mi^2 (1.694 ha).

Catch Processing

Catches were dumped into a 6-ft^2 by 1-ft deep sorting table. Catch was sorted by species, and weight determined for each species by using a 60-lb (27 kg) capacity spring scale. An average weight and estimated total weight was obtained for all fish species. Catch of Dungeness crab (*Cancer magister*) was recorded by number. Occurrence of other invertebrates was noted.

Ten flatfish species in 1975 and six in 1976 were sampled for age, length and sex composition. Length was measured from the snout to the center of the tail and recorded to the nearest cm. Sampling rate or the proportion of the catch sampled ranged from 5% to 100% but was most often 20% to 50%. Length by sex was recorded on plastic measuring strips and transcribed to a permanent record. Heads were removed to obtain otoliths or interopercles for aging. Dover sole (*Microstomus pacificus*) heads were not removed, but rather a fillet with skin attached was taken from the eyed side for scales. Heads and fillets by sex and tow were placed in plastic bags, labeled and frozen for processing ashore.

Once ashore, aging structures were prepared for aging and stored by sex and tow. Scales were mounted between glass slides; interopercles were stored dry in coin envelopes; and otoliths were stored in a 50% glycerine-water solution with a few thymol crystals added to retard mold formation. Age structures were examined and assigned an age in years using accepted techniques.

Estimates of Biomass, Usable Biomass and Potential Yield

The continental shelf area was stratified into 10-fm (18 m) strata between 10 and 99-fm (18-182 m). Slope strata were 100-199 fm (183-364 m) and 200-299 fm (365-547 m). The area of each stratum was calculated from measurements made with a compensating polar planimeter on CGS nautical charts 18480 and 18500.

Estimates of biomass and usable biomass were determined by the method described by Demory, et al, (1976). Estimates of usable biomass were determined for currently and potentially important flatfish species: that is, Dover sole (*Microstomus pacificus*), English sole (*Parophrys vetulus*), petrale sole (*Eopsetta jordani*), rex sole (*Glyptocephalus zachirus*), Pacific sanddab (*Citharichthys sordidus*) and arrowtooth flounder (*Atheresthes stomias*). Length-weight constants are given in Appendix 2.

Potential yield, under equilibrium conditions, was determined by multiplying usable biomass by estimates of the instantaneous fishing rate (F).

Year Class Strength

Relative year class strength, expressed in percent frequency, was determined for selected species, for each annual cruise. Age composition was compared by survey year, and outstanding brood years were noted.

Instantaneous Total Mortality Rate

Estimates of total instantaneous mortality rate (Z) were determined from catch curves using the method of Robson and Chapman (1961). To construct the catch curves, age samples were weighted to their respective catches by using the sampling rate.

Exploitation Rate and Fishing Rate

Exploitation rate (μ) was determined by dividing the commercial landings by usable biomass. The instantaneous fishing rate (F) was determined by the formula,

$$F = \frac{\mu Z}{\hat{a}}$$

where μ is the exploitation rate, Z is the instantaneous total mortality rate of females and $\hat{a}$ is the annual total mortality rate of females. Females were used because they dominate the fishery in terms of weight. Using females, which are normally longer lived than males, produces lower estimates of Z than estimates using males, hence the estimated fishing rate would be less conducive to over-exploitation.

RESULTS AND DISCUSSION

Estimates of Biomass

The total biomass estimate (all species) for the survey in 1976 was 147,303 m.t., an increase of 3% over the 1975 estimate of 143,447 m.t. (Table 1). Pacific hake was the most abundant species in 1976 comprising 24% of the biomass, a three fold increase over 1975 when hake ranked sixth in biomass.

The flatfish complex comprised about 50% of the estimated biomass. There were 70,617 m.t. of flatfish in 1976, down 17% from the 1975 estimate of 84,656 m.t. All major flatfish species showed a decrease in estimated biomass ranging from -12% for English sole to -51% for butter sole. Dover sole biomass was down by 23%.

In 1976, the rockfish group (scorpaenidae) showed a 46% decrease to 6,442 m.t. compared to the 1975 estimate of 11,911 m.t. The commonly occurring species, yellowtail rockfish (*Sebastes flavidus*), canary rockfish (*Sebastes pinniger*) and split-nose rockfish (*Sebastes diploproa*) were down more than 50%. Biomass estimates of semi-pelagic species such as rockfish are under-estimated because the trawl was not efficient at catching off-bottom species; the survey trawl was designed for flatfish. Alverson and Pereyra (1969) discussed this subject.

Since the 95% confidence limits overlap, most changes in biomass estimates between survey years were of a magnitude that lie within expected variation. Therefore, while our biomass estimates indicate changes between surveys, we can not readily demonstrate that a statistically significant change actually occurred. Changes in biomass might be expected for species whose distribution extends into areas outside the survey limits. Food availability, currents or other environmental changes between years might influence fish availability; thus our estimates of biomass. By not occupying stations just north of the Columbia River, a high production area, we may have underestimated the biomass of species such as English sole, Dover sole and Pacific sanddab.

Table 1. Estimates of biomass (m.t.) of principle species between Cape Flattery and the Columbia River, 1975-76[1]. Confidence limits, 95%, are expressed as ±%.

Species[2]	Biomass m.t. 1975	±%	1976	±%	% change from 1975-76
Spiny dogfish	7,791	62	11,225	31	+44
Skates	12,991	44	13,343	26	+03
Ratfish	1,780	44	1,534	37	-14
American shad	709	55	534	76	-25
Pacific cod	1,977	81	1,491	93	-25
Pacific hake	11,400	79	35,662	52	+213
Walleye pollock	-	-	29	179	-
Rockfish					
Shortspine thorneyhead	504	112	329	67	-35
Pacific ocean perch	2,724	68	2,421	99	-11
Yellowtail rockfish	2,616	127	611	74	-77
Canary rockfish	1,976	91	825	62	-58
Splitnose rockfish	1,909	186	798	155	-58
Greenstripe rockfish	553	51	503	75	-9
Darkblotched rockfish	549	54	181	58	-67
Redbanded rockfish	374	87	79	76	-79
Yelloweye rockfish	279	104	169	109	-39
Rosethorn rockfish	107	43	108	110	+1
Boccacio	93	140	81	154	-13
Rougheye rockfish	66	75	36	168	-45
Black rockfish	50	142	75	200	+50
Sharpchin rockfish	48	114	183	168	+281
Stripetail rockfish	19	166	5	159	-74
Redstripe rockfish	16	200	19	195	+19
Silvergray rockfish	12	166	18	126	+50
Quillback rockfish	10	200	-	-	-
Aurora rockfish	4	200	-	-	-
Widow rockfish	2	200	1	200	-50
Sablefish	5,515	54	3,982	200	-28
Lingcod	4,717	37	2,498	33	-47
Flatfish					
English sole	18,443	60	16,141	55	-12
Arrowtooth flounder	15,070	42	10,558	37	-30
Dover sole	14,501	31	11,218	23	-23
Rex sole	13,511	31	13,938	24	+3
Pacific sanddab	8,442	69	8,276	26	-2
Butter sole	8,021	105	3,962	52	-51
Slender sole	2,345	47	2,091	31	-11
Petrale sole	1,650	33	1,043	25	-37
Starry flounder	1,011	144	1,359	55	+34
Flathead sole	1,018	108	1,067	43	+5
Sand sole	435	85	930	87	+114
Pacific halibut	84	147	-	-	-
Rock sole	78	78	8	114	-90
Curlfin sole	47	146	26	189	-45
Total	143,447		147,303		+3
Flatfish	84,656		70,617		-17
Rockfish	11,911		6,442		-46

1/ Survey limit: 48° 23' N Lat. - 46° 16' N Lat., 10-300 fm.
2/ Common and scientific names are shown in Appendix 1.

Estimates of Usable Biomass

Estimates of usable biomass for six common species of flatfish ranged from 14,452 m.t. in 1975 for arrowtooth flounder to 655 m.t. for petrale sole in 1976 (Table 2). Estimates were less in 1976 for Dover sole (25%), English sole (4%), petrale sole (49%) and arrowtooth flounder (30%) while estimates were greater for rex sole and Pacific sanddab (4 and 20% respectively).

Table 2. Estimated usable biomass, potential yield and commercial landings (m.t.) of principal species of flatfish for the Washington coast, 1975-76.

Species	Usable biomass, m.t. 1975	Usable biomass, m.t. 1976	F 1975	F 1976	Potential yield, m.t. 1975	Potential yield, m.t. 1976	Commercial landing, m.t. 1975	Commercial landing, m.t. 1976
Dover sole	8,630	6,495	.08	.16	690	1,039	579	865
English sole	6,940	6,645	.13	.27	902	1,794	695	1,353
Petrale sole	1,279	655	.75	1.15	959	753	854	569
Rex sole	5,918	6,178	.07	.08	414	494	316	384
Pacific sanddab1/	2,623	3,151	.01	.02	26	63	22	38
Arrowtooth flounder1/	14,452	10,126	.002	.01	29	101	32	83

1/ Species normally discarded at sea or avoided

Total Instantaneous Mortality Rate

Estimates of instantaneous total mortality rate (Z) varied widely between species and sex within species (Table 3). For example, Z for petrale sole was estimated at 0.24 in 1975 and 0.44 in 1976. Small catches of petrale sole precluded confidence in our estimates of Z for that species. Mortality rate estimates for arrowtooth flounder were complicated by the great difficulty in aging the samples.

Exploitation Rate and Fishing Rate

Exploitation rate (μ) ranged from 0 for arrowtooth flounder to 0.87 for petrale sole (Table 3). Exploitation rates for major commercial species of flatfish in 1976 were: Dover sole, 0.13; English sole, 0.20; petrale sole, 0.87; and rex sole, 0.06. The exploitation rates in 1976 were higher than those of 1975 and generally reflected the improved markets in 1976. Estimates of exploitation rate might be underestimated when market limits have the effect of surpressing exploitation. Discard of largely unsalable fish such as arrowtooth flounder also has the effect of surpressing the exploitation rate. We feel that an exploitation rate over .10 probably indicates target species with market demand.

The instantaneous fishing mortality rate F, ranged from near 0 for arrowtooth flounder to 1.15 for petrale sole (Table 2). In 1976, F was 0.16 for Dover sole, 0.27 for English sole, 1.15 for petrale sole and 0.08 for rex sole. The higher F in 1976 when compared to 1975 reflected improved markets. It appears that the fishing rate could be increased on most species with the possible exception of petrale sole. Since the calculated F for petrale sole exceeds Z, it is possible that petrale sole may require protection; however, if the biomass of petrale sole were underestimated then F is overestimated. Since catches of petrale sole were small during the two surveys, the estimates were most likely underestimated because of fish unavailability.

Table 3. Estimates of exploitation rate (μ), annual mortality rate ($\hat{a}$) and instantaneous mortality rate (Z) of principal species of flatfish for the Washington coast in 1975 and 1976.

			Mortality rates			
			Males		Females	
Species	Year	μ	$\hat{a}$	Z 1/	$\hat{a}$	Z 1/
Dover sole	1975	.067	.39	.50 (6-15)	.30	.35 (5-17)
	1976	.133	.44	.58 (6-17)	.31	.37 (6-23)
English sole	1975	.100	.35	.43 (3-12)	.39	.49 (3-13)
	1976	.204	.32	.38 (3-15)	.45	.60 (4-13)
Petrale sole	1975	.668	.48	.65 (6-11)	.24	.27 (5-17)
	1976	.869	.51	.71 (6-10)	.44	.58 (6-12)
Rex sole	1975	.053	.34	.41 (5-18)	.35	.43 (5-14)
	1976	.062	.44	.58 (6-14)	.42	.55 (6-14)
Pacific sanddab	1975	.008	.57	.84 (6-10)	.55	.79 (7-11)
	1976	.012	.56	.82 (7-10)	.53	.77 (7-11)
Arrowtooth flounder	1975	.002	.30	.35 (6-17)	.34	.42 (7-17)
	1976	.008	.34	.42 (9-17)	.15	.16 (4-23)

1/ Age range in parenthesis

Petrale sole are usually caught in a multi-species trawl fishery. The summer fishery is often on grounds occupied by more abundant species such as English sole, rex sole, lingcod and others. An overharvest of petrale sole may be unavoidable, in order to optimize yield from more abundant species (Pedersen, 1975). Fishing restrictions might be more justifiable during the spawning period when petrale are often concentrated in known areas and are mainly isolated from other species. Pedersen (1975) also concluded that a spawning ground fishery has a profound effect on the summer inshore fishery.

Fishing may be overemphasized as an adverse factor to petrale sole stock size. Ketchen and Forrester (1966) and Pedersen (1975) concluded that environmental effects on larval-juvenile survival were more important than fishing in reducing stock size.

Potential Yield

Estimates of potential annual yield ranged from 26 m.t. for Pacific sanddabs to 1,794 m.t. for English sole (Table 2). In 1976, potential yield was calculated at 1,039 m.t. for Dover sole; 1,794 m.t. for English sole; 753 m.t. for petrale sole and 494 m.t. for rex sole Our estimates of yield are limited by special conditions, Yield is only indicated for fish occupying the survey area, over trawlable bottom in September that were available to our survey trawl. Furthermore, potential yield for under-utilized species is probably underestimated, because we have not been able to qualify the effects of market limits, gear and discard mortality on μ and F.

Distribution

Catch maps (Figures 2-14) show distribution of most major species. Distribution by depth and abundance by area was often highly variable within survey periods and somewhat variable between survey years. The same areas of high abundance occurred for many species during both surveys. Most stations between Willapa Bay and the Columbia River were not occupied in 1975; therefore, while Figures 2-14 indicate low abundance in 1975 for that area, abundance was not actually determined.

Flatfish were most abundant in an area west to southwest of Destruction Island in 20-50 fm (37-91 m). Here the largest catches for a 1 N mi tow were 1,454 lb (660 kg) of English sole, 1,230 lb (558 kg) of Pacific sanddab, 1,000 lb (454 kg) of butter sole, 465 lb (211 kg) of rex sole and 314 lb (142 kg) of Dover sole. A second area that produced large catches was the flat just south of Grays Canyon in 100-300 fm. Here, highest catches were 694 (315 kg) of rockfish, 314 lb (142 kg) of sablefish and 195 lb (88 kg) of Dover sole. Tows were generally good just north of the Astoria Canyon, and they produced up to 377 lb (171 kg) of rex sole and 244 lb (111 kg) of Dover sole. The largest single catch of Dover sole, 526 lb (239 kg), was made in deep water off Cape Flattery.

While catches were generally best in the above areas, several species were associated with certain depths or bottom types (Figure 15). Figure 1 grossly shows sediment type distribution1/. Butter sole were caught primarily shallower than 30 fm (55 m) over sand. English sole and Pacific sanddab were generally taken inside of 60 fm (110 m) over sand. Arrowtooth flounder and sablefish were usually found outside of 50 fm (91 m) over silt bottom. Dover sole, rex sole and lingcod were caught throughout most survey depths, but Dover sole tended to show a preference for silt bottom. Flathead sole were caught primarily over silt. Bottom type preference was not apparent for rex sole and petrale sole, although petrale sole were not caught in shallow water over sand. Sediment was almost entirely sand inside of 50 fm, although gravel areas were found off Cape Elizabeth and Grays Harbor. Sediments outside of 50 fm were mostly coarse silt.

Many species showed an increase in mean weight with increasing depth. This was especially apparent for English sole, petrale sole and sablefish and to a lesser degree, for Dover sole, rex sole, butter sole and starry flounder. Slender sole were rather uniform in mean weight regardless of depth strata (Table 4).

A bimodal depth distribution was observed for Dover sole (Figure 15). Females dominated the catch inside of 70 fm (128 m) while males were more plentiful in deeper water. The mean weight was generally greater for deep water Dover sole. The 1976 data showed that mean length for Dover sole females generally increased with depth out to 70 fm where it then leveled off (Table 5). With minor exceptions, mean length

1/ This figure was prepared by summarizing several marine sediment studies (Roberts 1974, Vandatarathnam and McManus 1973 and Gross et al, 1967).

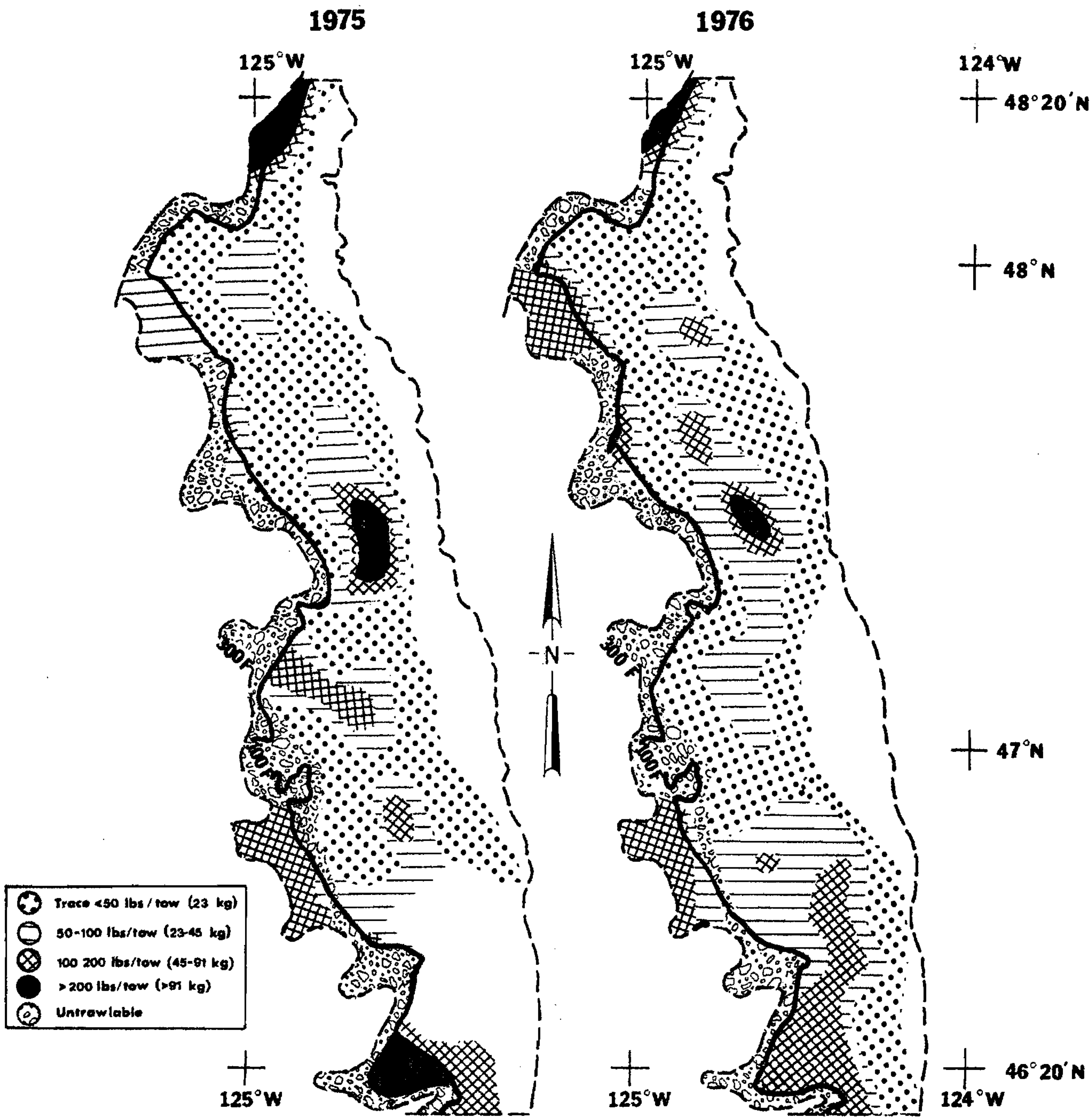

Figure 2. Distribution and relative abundance (weight) of Dover sole in September 1975 and 1976 off Washington as determined by groundfish surveys. The heavy broken line defines survey limits.

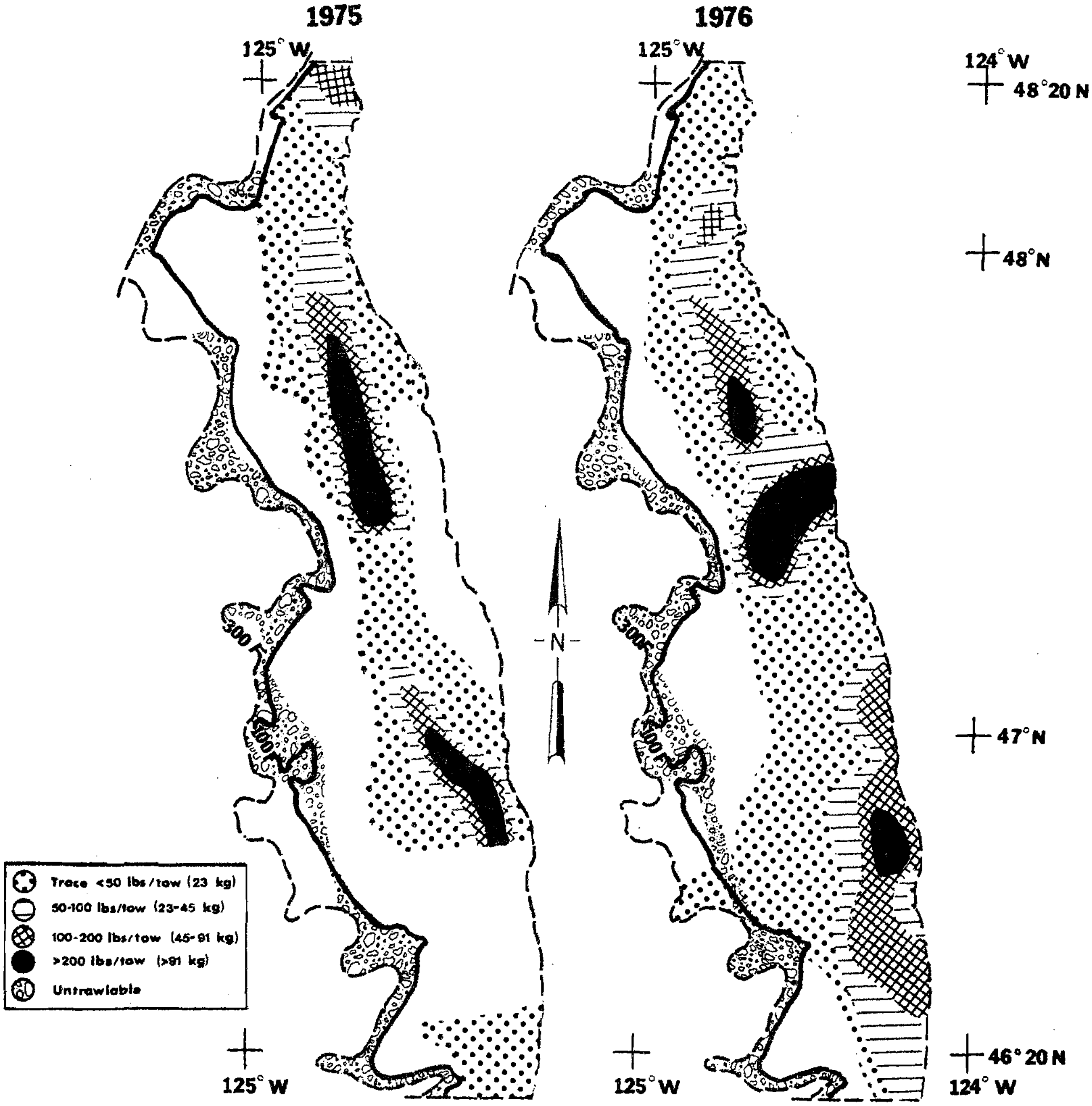

Figure 3. Distribution and relative abundance (weight) of English sole in September 1975 and 1976 off Washington as determined by groundfish surveys. The heavy broken line defines survey limits.

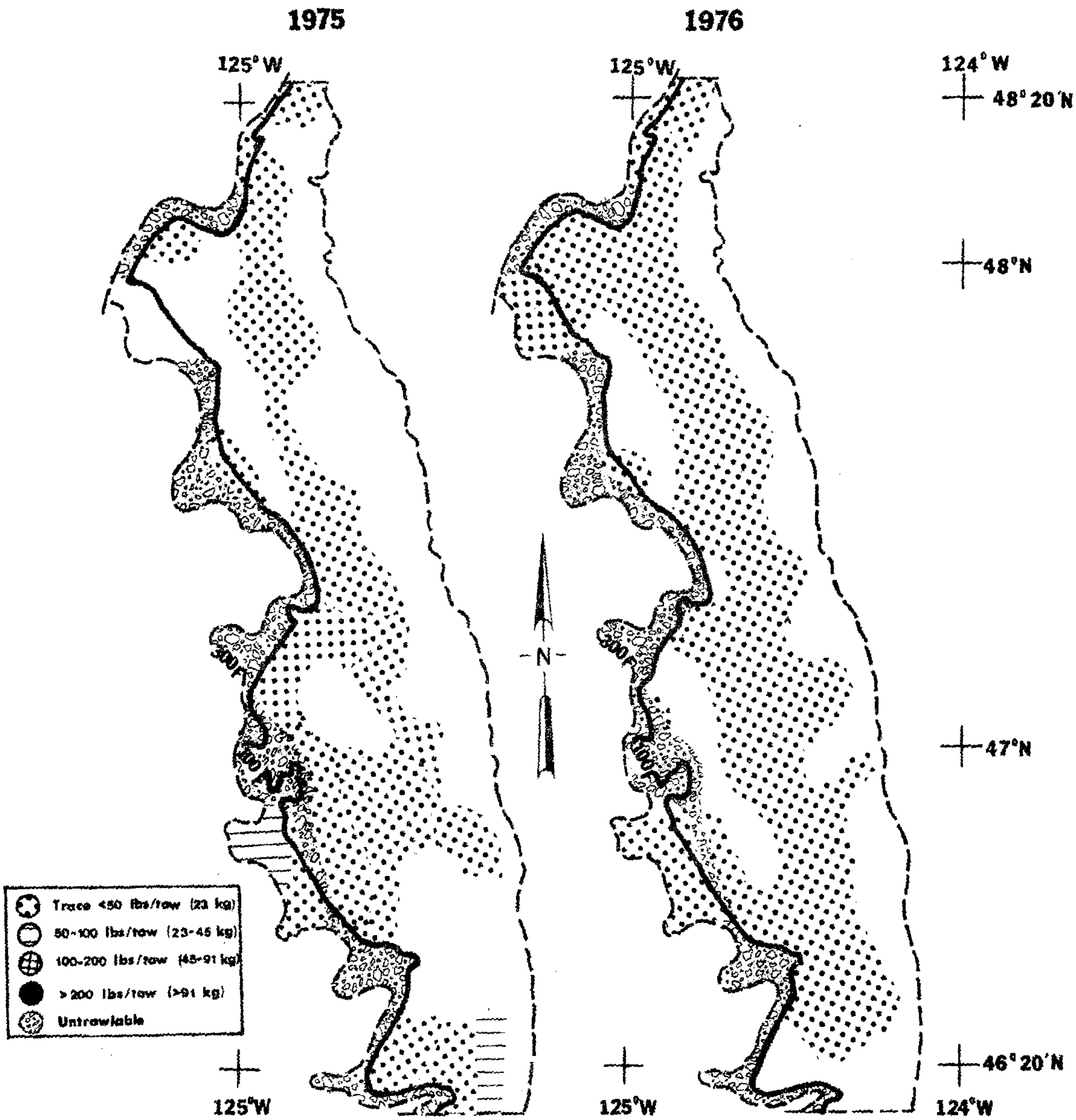

Figure 4. Distribution and relative abundance (weight) of petrale sole in September 1975 and 1976 off Washington as determined by groundfish surveys. The heavy broken line defines survey limits.

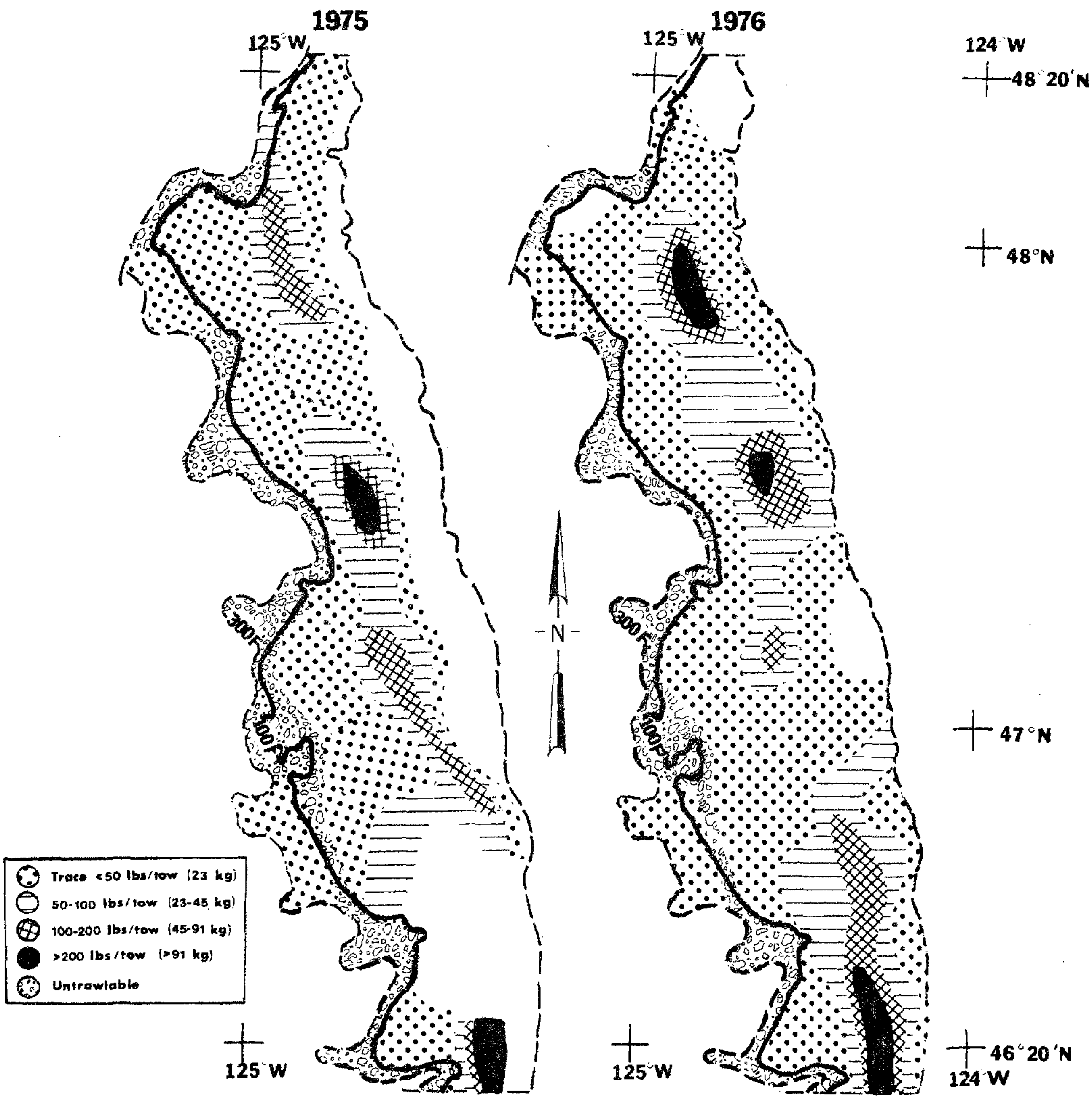

Figure 5. Distribution and relative abundance (weight) of rex sole in September 1975 and 1976 off Washington as determined by groundfish surveys. The heavy broken line defines survey limits.

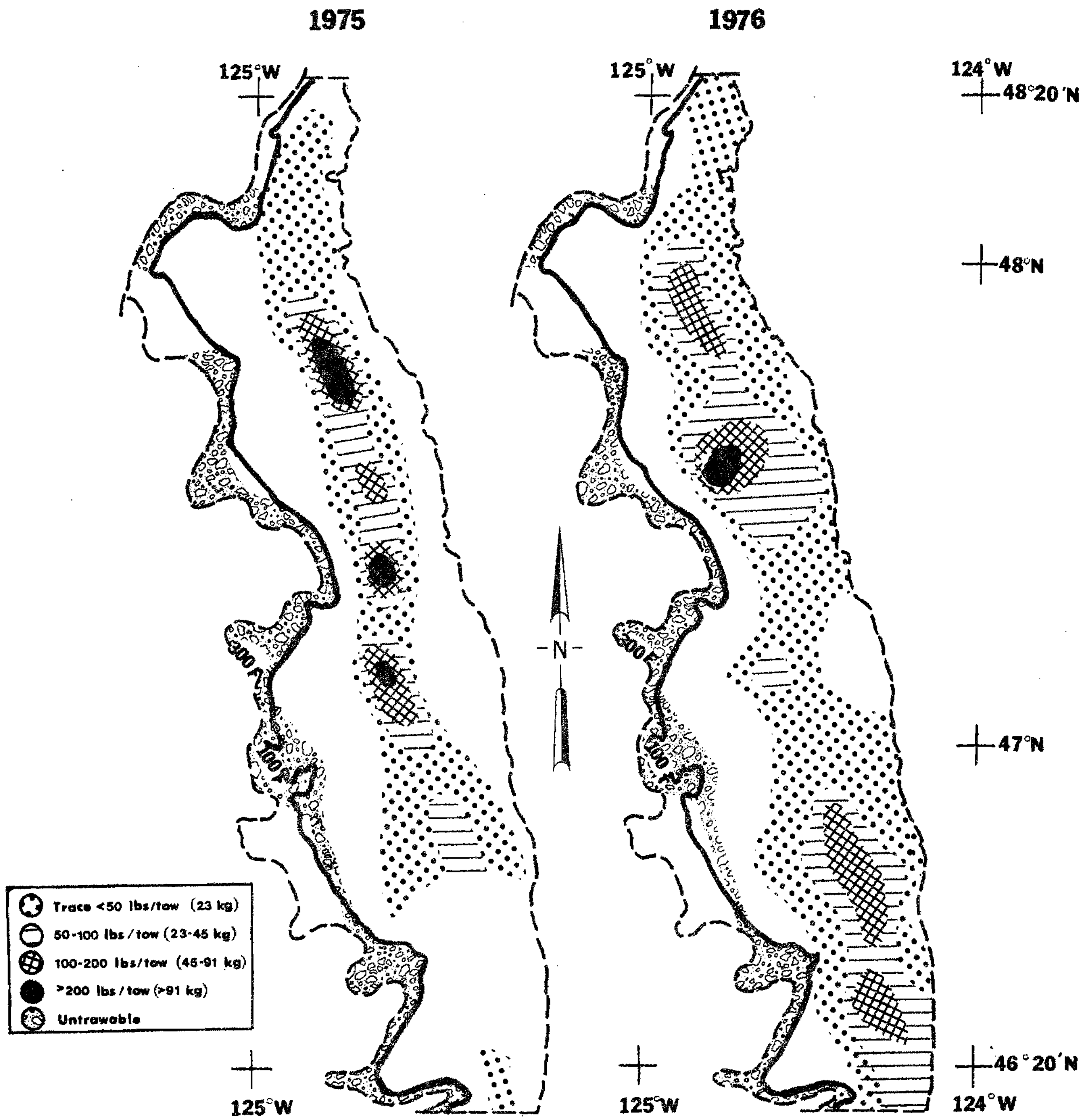

Figure 6. Distribution and relative abundance (weight) of Pacific sanddabs in September 1975 and 1976 off Washington as determined by groundfish surveys. The heavy broken line defines survey limits.

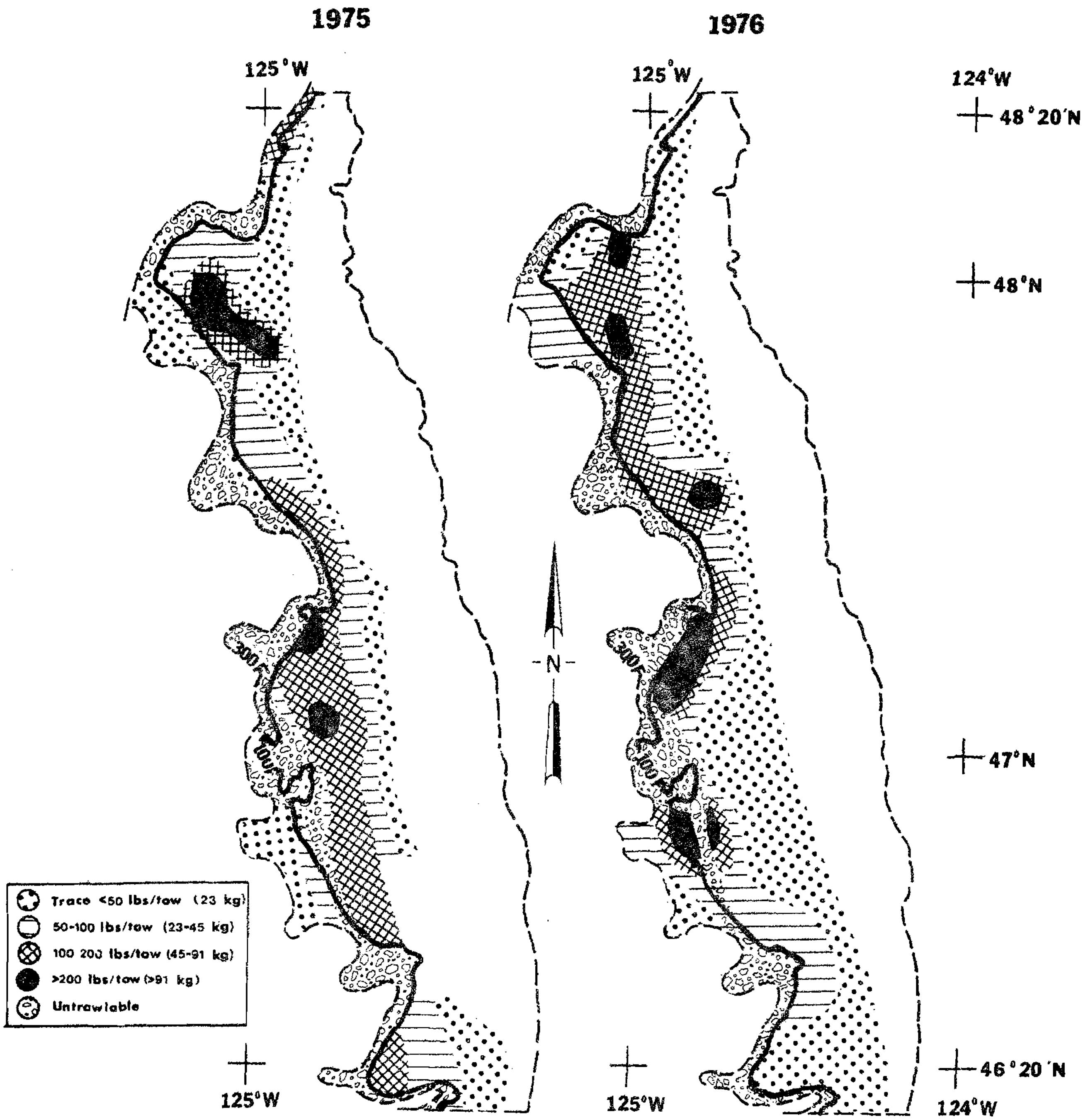

Figure 7. Distribution and relative abundance (weight) of arrowtooth flounder in September 1975 and 1976 off Washington as determined by groundfish surveys. The heavy broken line defines survey limits.

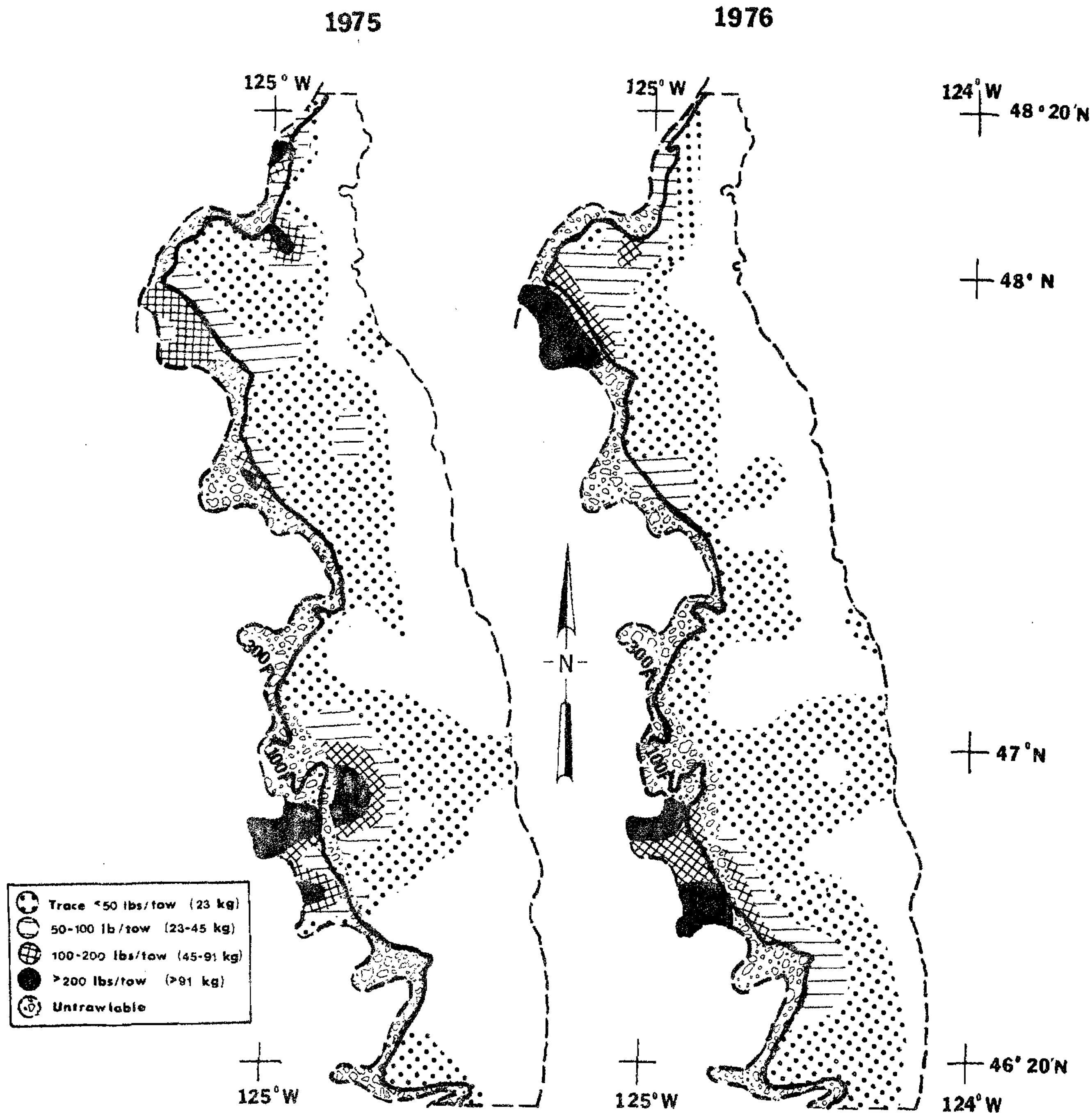

Figure 8. Distribution and relative abundance (weight) of rockfish in September 1975 and 1976 off Washington as determined by groundfish surveys. The heavy broken line defines survey limits.

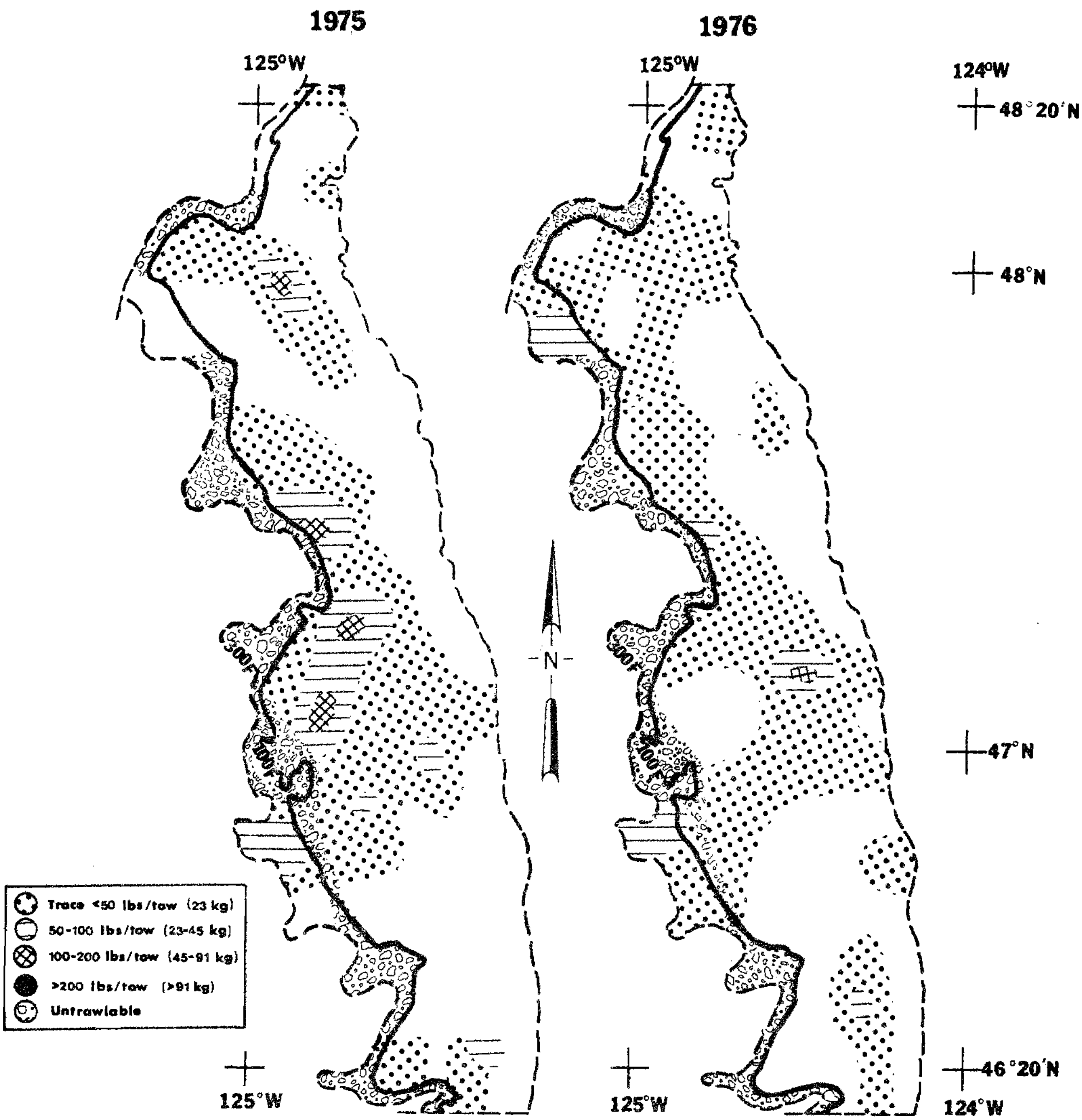

Figure 9. Distribution and relative abundance (weight) of lingcod in September 1975 and 1976 off Washington as determined by groundfish surveys. The heavy broken line defines survey limits.

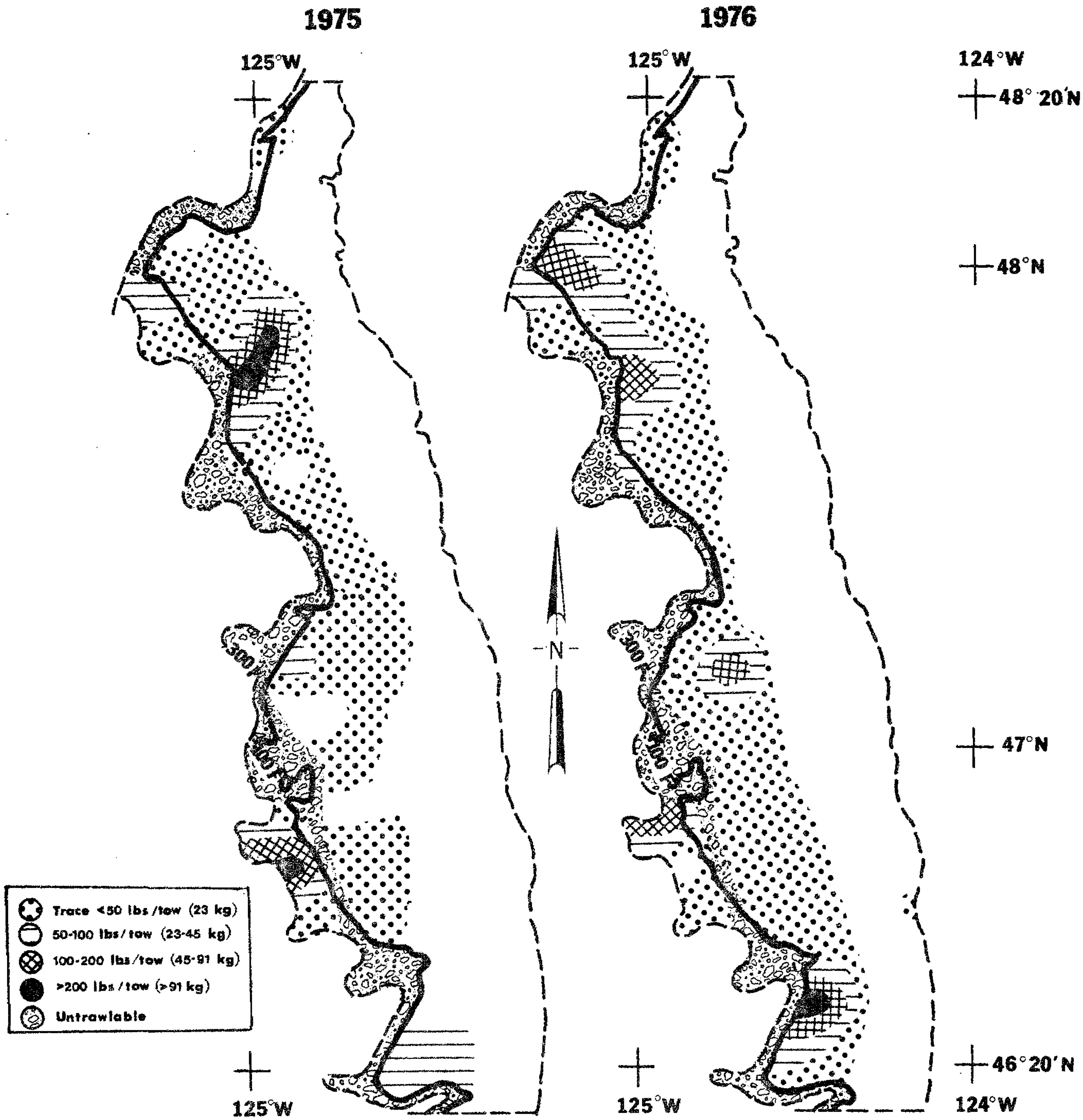

Figure 10. Distribution and relative abundance (weight) of sablefish in September 1975 and 1976 off Washington as determined by groundfish surveys. The heavy broken line defines survey limits.

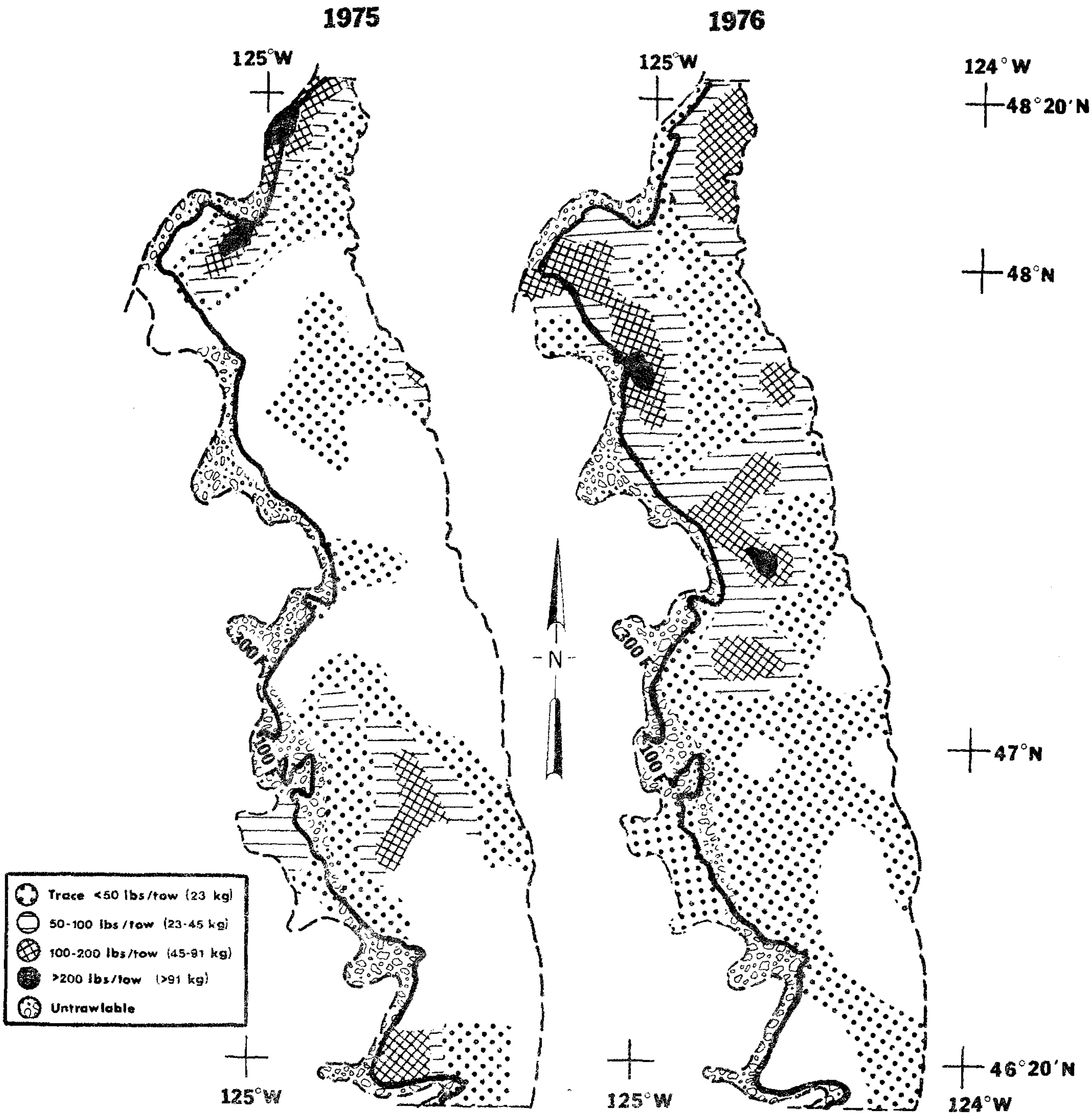

Figure 11. Distribution and relative abundance (weight) of spiny dogfish in September 1975 and 1976 off Washington as determined by groundfish surveys. The heavy broken line defines survey limits.

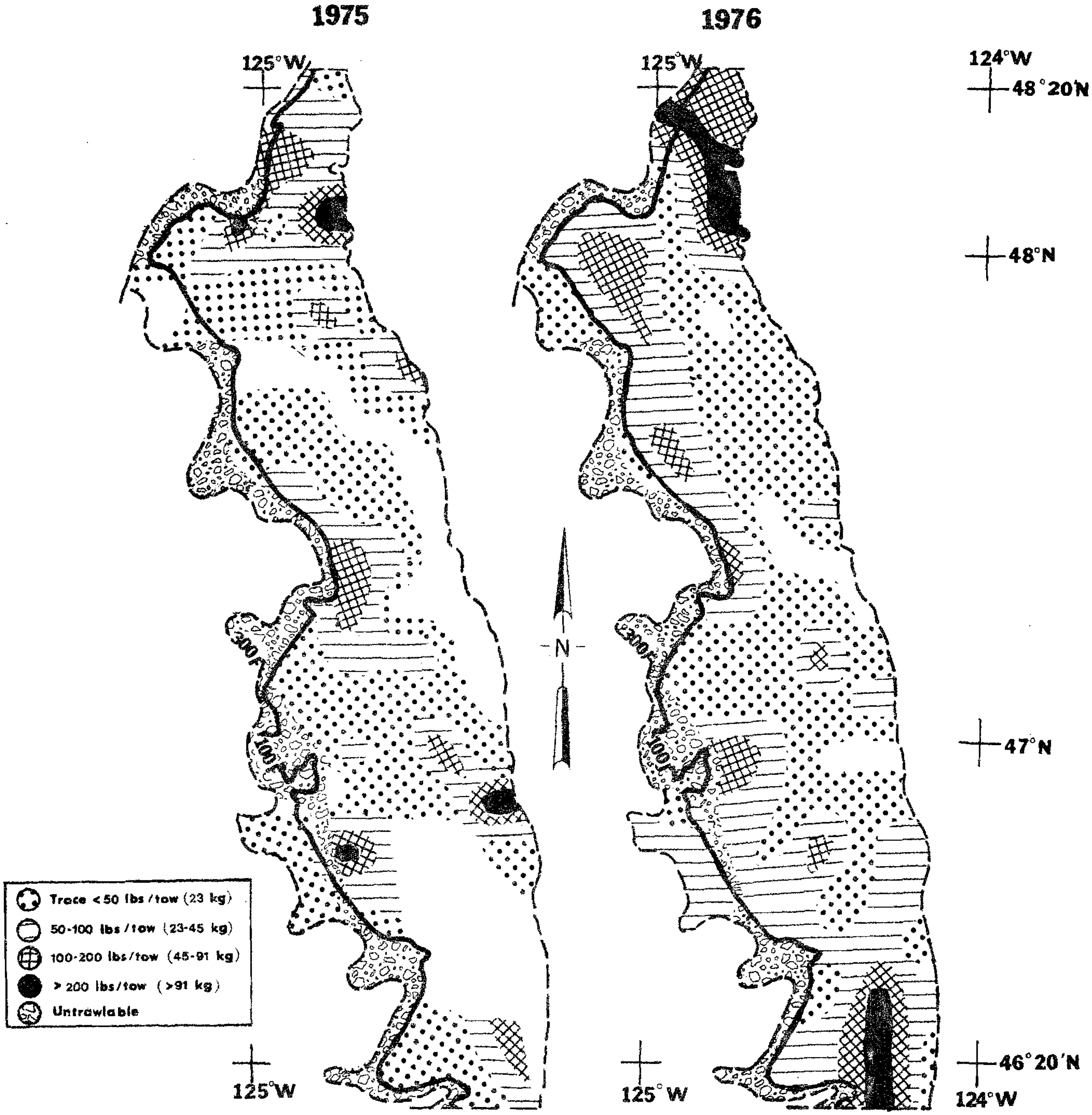

Figure 12. Distribution and relative abundance (weight) of skates (all species) in September 1975 and 1976 off Washington as determined by groundfish surveys. The heavy broken line defines survey limits.

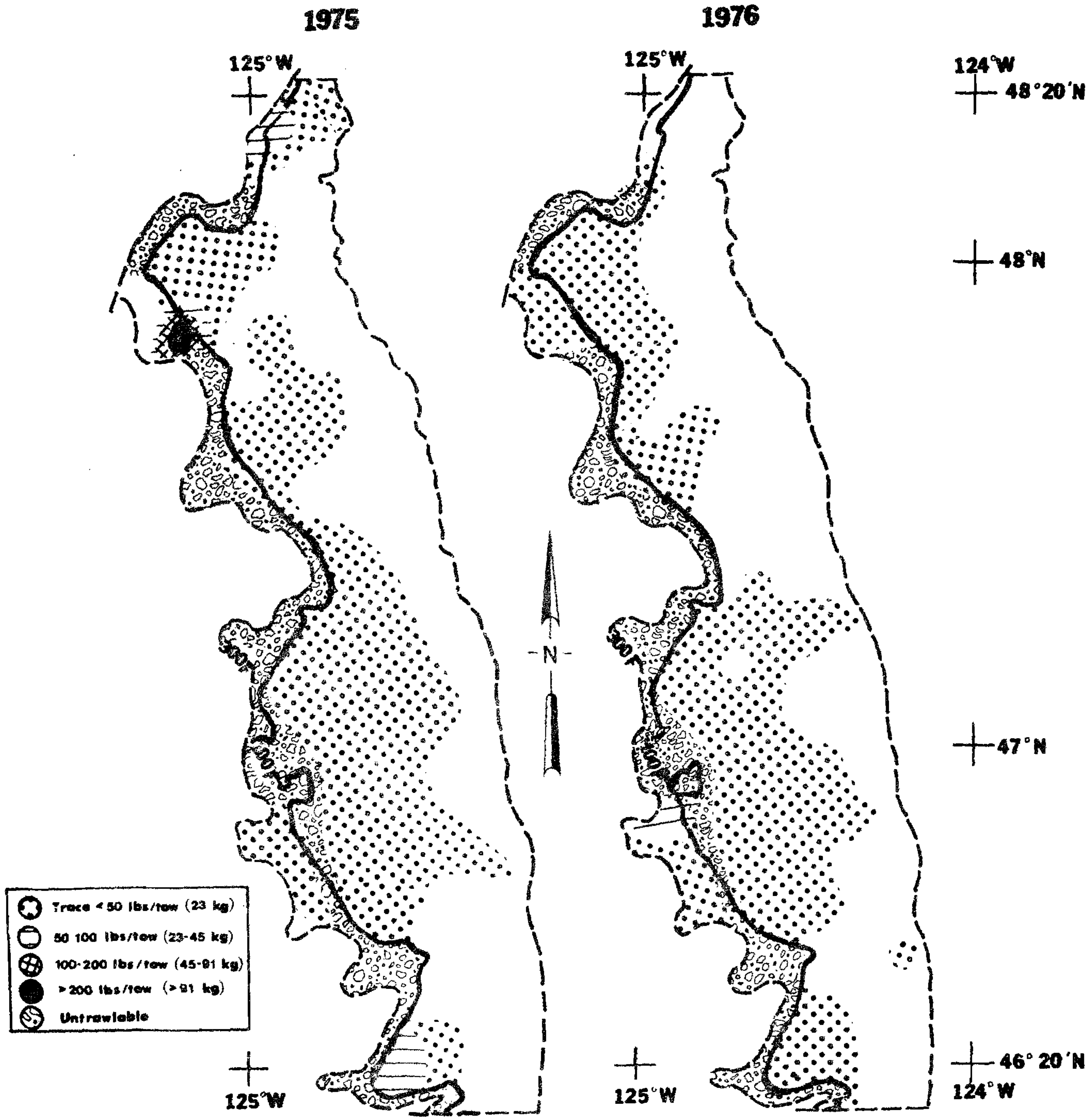

Figure 13. Distribution and relative abundance (weight) of ratfish in September 1975 and 1976 off Washington as determined by groundfish surveys. The heavy broken line defines survey limits.

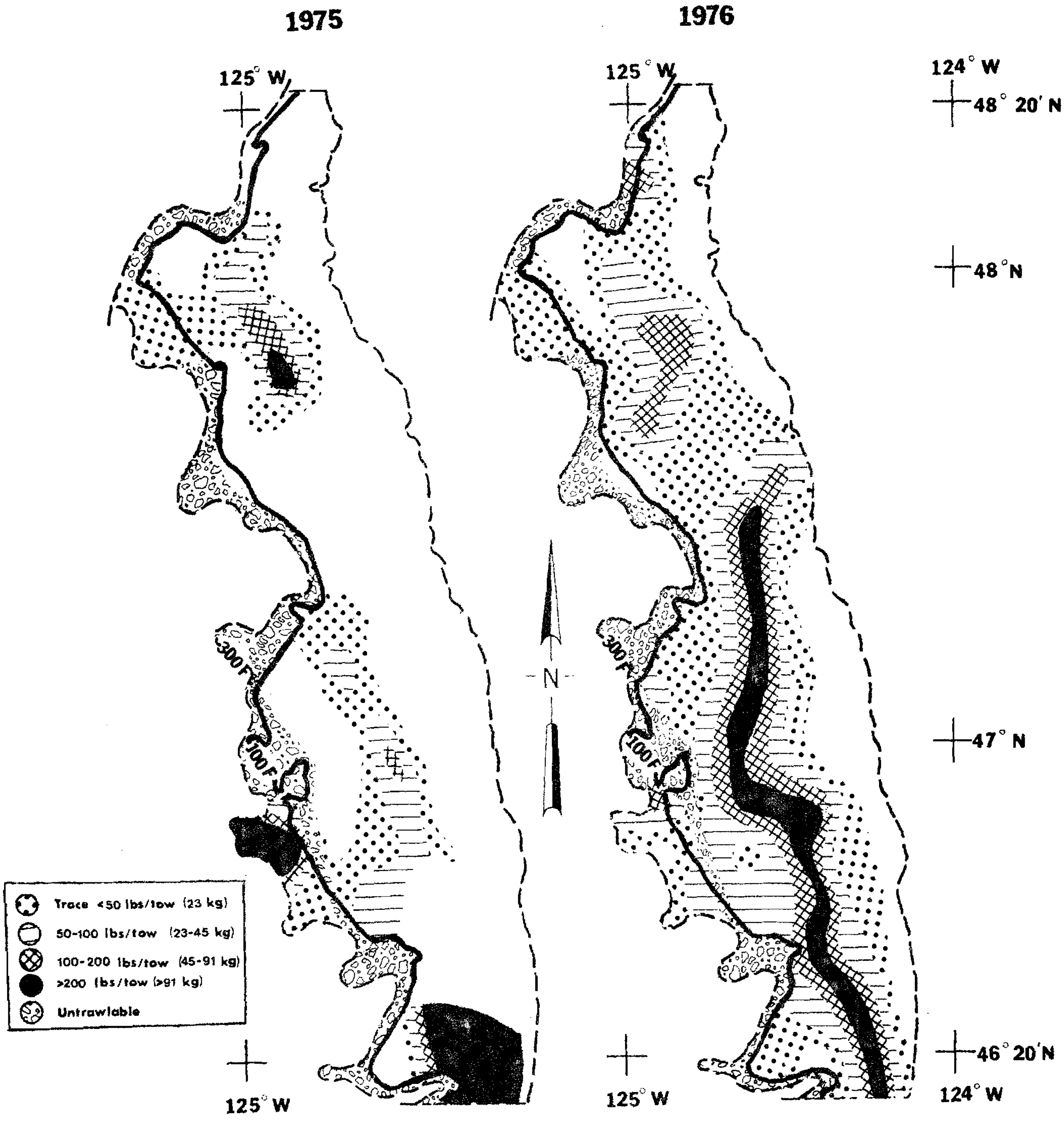

Figure 14. Distribution and relative abundance (weight) of Pacific hake in September 1975 and 1976 off Washington as determined by groundfish surveys. The heavy broken line defines survey limits.

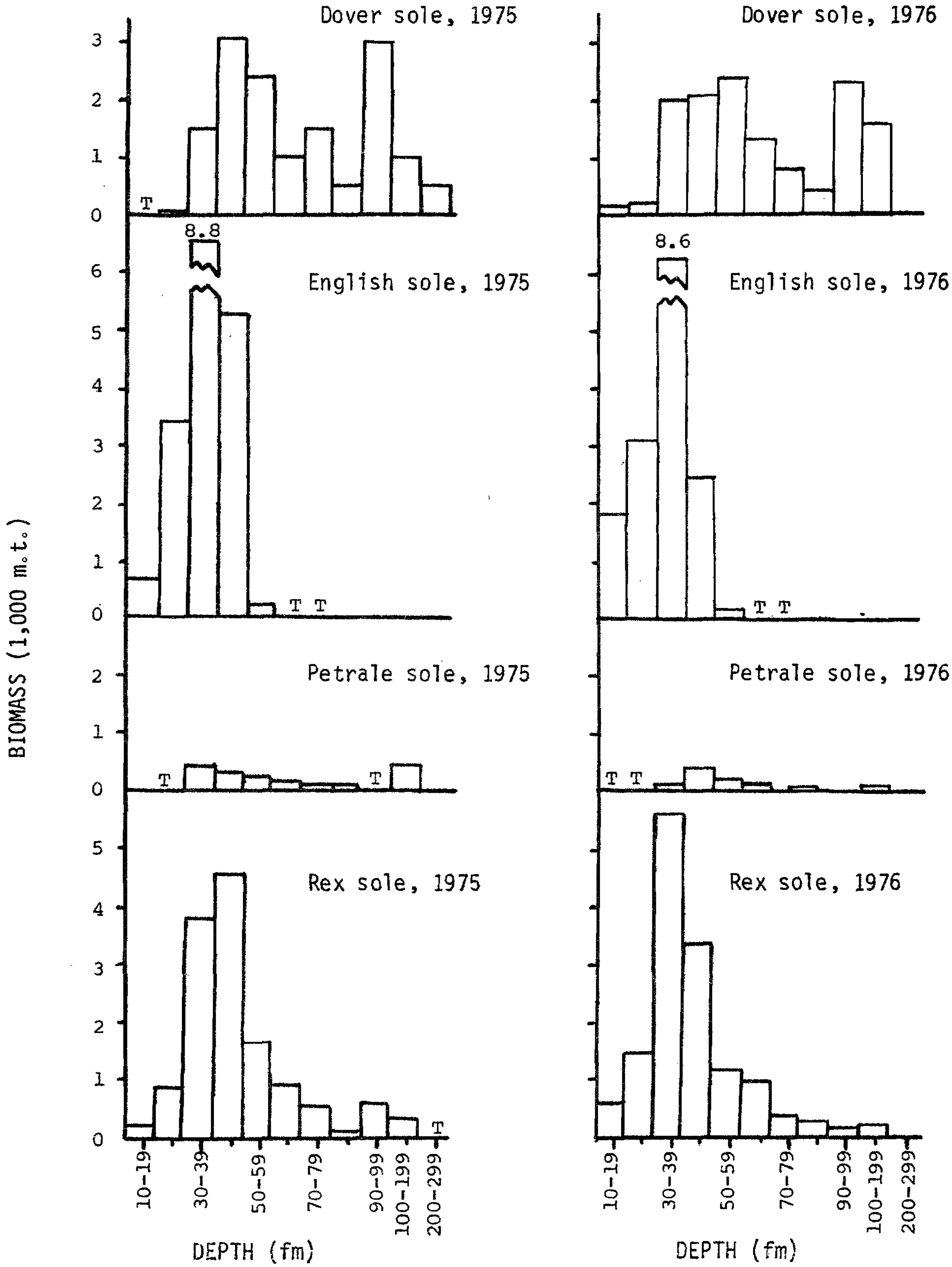

Figure 15. Distribution of selected species by depth as determined from groundfish surveys off Washington, 1975-76. T = <50 m.t.

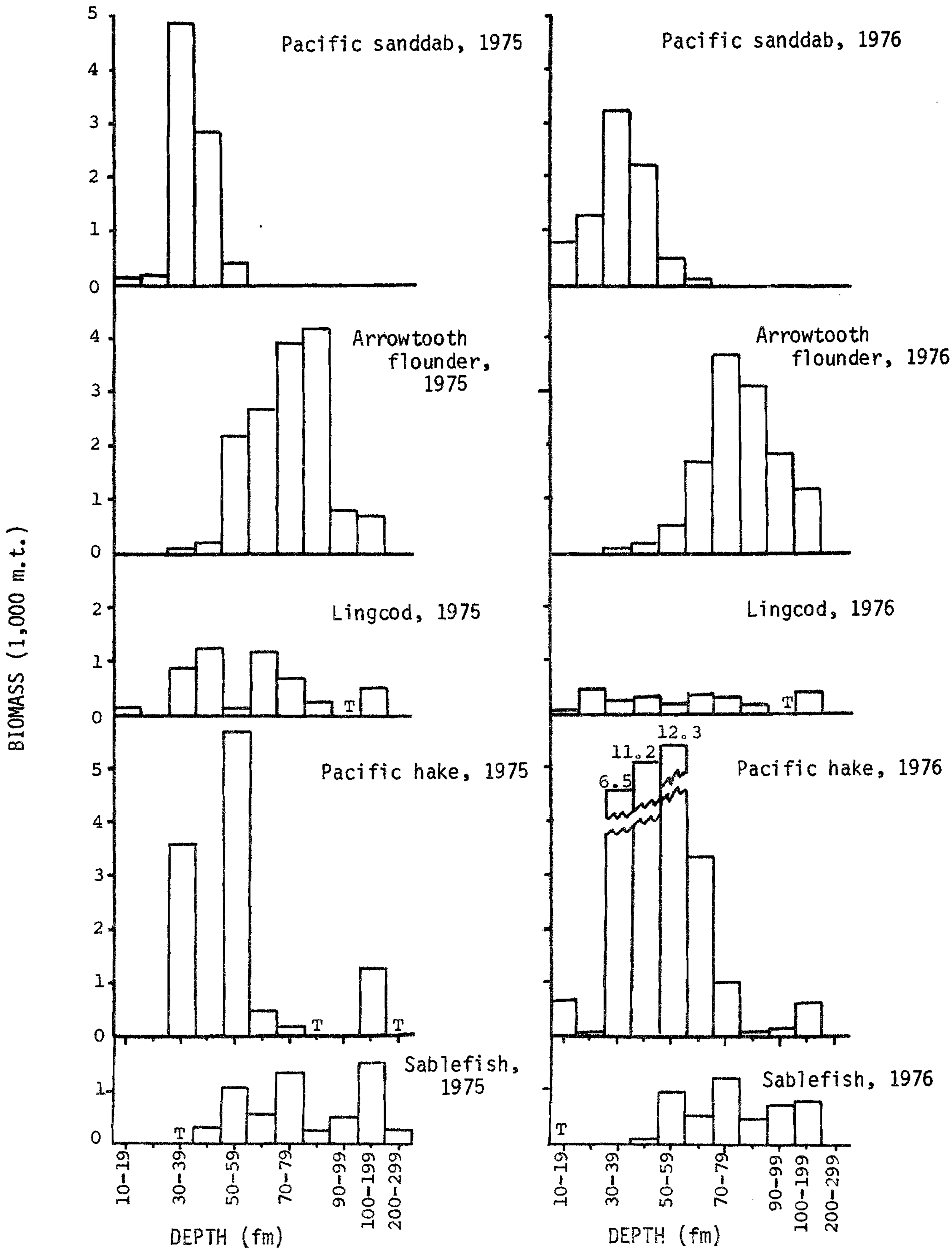

Figure 15. Continued.

for males increased with depth. Mean age generally increased with depth for Dover sole but dropped slightly for females outside of 90 fm (165 m) and dropped sharply for males caught outside of 100 fm (183 m) (Table 5).

Table 4. Mean weight (kg) of selected species by depth strata as determined from groundfish survey off Washington, 1975-76.

Species	Depth Strata 10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-199	200-299
Dover sole	.28	.34	.29	.30	.44	.69	.54	.63	.62	.50	.59
English sole	.18	.16	.25	.30	.43	.61	.56	-	-	.45	-
Petrale sole	.64	.51	.56	.77	.81	1.33	.97	1.47	1.70	1.52	-
Rex sole	.25	.17	.17	.17	.18	.19	.20	.19	.20	.21	.24
Pacific sanddab	.23	.20	.21	.20	.22	.17	-	-	-	-	-
Arrowtooth flounder	.12	-	1.25	.95	.71	.83	.85	.86	.87	1.19	2.36
Slender sole	-	.14	.12	.15	.16	.16	.16	.15	.15	.14	.09
Butter sole	.17	.17	.19	.18	-	-	-	-	-	-	-
Flathead sole	-	.22	.34	.23	.16	.20	.24	.33	.24	.37	-
Sablefish	.14	-	.49	.57	.96	1.25	1.34	1.65	1.40	1.47	2.62
Lingcod	4.74	5.52	3.98	3.86	4.08	4.69	4.79	4.51	1.77	6.51	-
Pacific hake	1.08	1.08	1.19	1.06	1.13	1.86	1.12	1.08	1.36	1.48	.96
Starry flounder	1.35	2.51	-	-	-	-	-	-	-	-	-

Table 5. Mean length (cm) and mean age (yr) by depth strata (fm) for Dover sole from groundfish survey off Washington, 1976[1/].

Depth strata	Mean length Male	Mean length Female	Mean age Male	Mean age Female
10-19	30.9	31.0	5.0	5.0
20-29	30.8	41.8	5.4	5.0
30-39	29.0	31.1	5.5	5.6
40-49	30.8	34.1	6.2	7.2
50-59	32.1	36.7	6.6	7.6
60-69	33.6	40.2	7.0	9.0
70-79	35.3	40.9	7.6	9.2
80-89	36.4	40.6	8.2	9.2
90-99	38.4	40.3	8.3	7.8
100-199	35.4	39.8	6.6	8.8

1/ Weighted to sampling rate

Year Class Strength

Age composition was analyzed for six flatfish species by comparing age frequencies and by following brood years (Figure 16).

The 1970 year class was strong for Dover sole, rex sole, petrale sole, English sole and Pacific sanddabs off Washington. The 1972 English sole brood year dominated the survey catch in 1975 and remained relatively strong in 1976. The 1972 year class

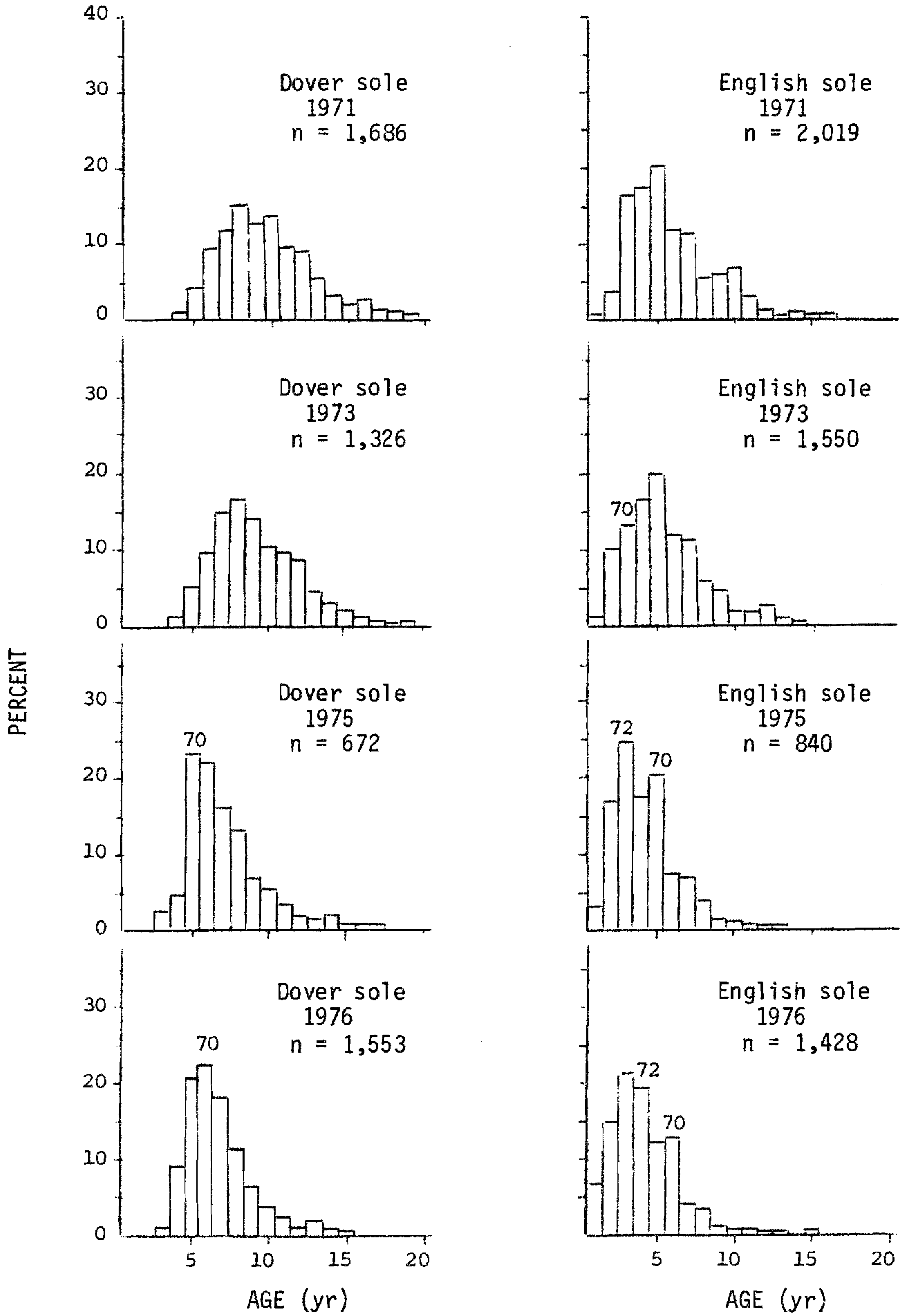

Figure 16. Relative year class strength, as indicated by percent frequency from groundfish surveys off northern Oregon (1971, 1973) and Washington (1975-76).

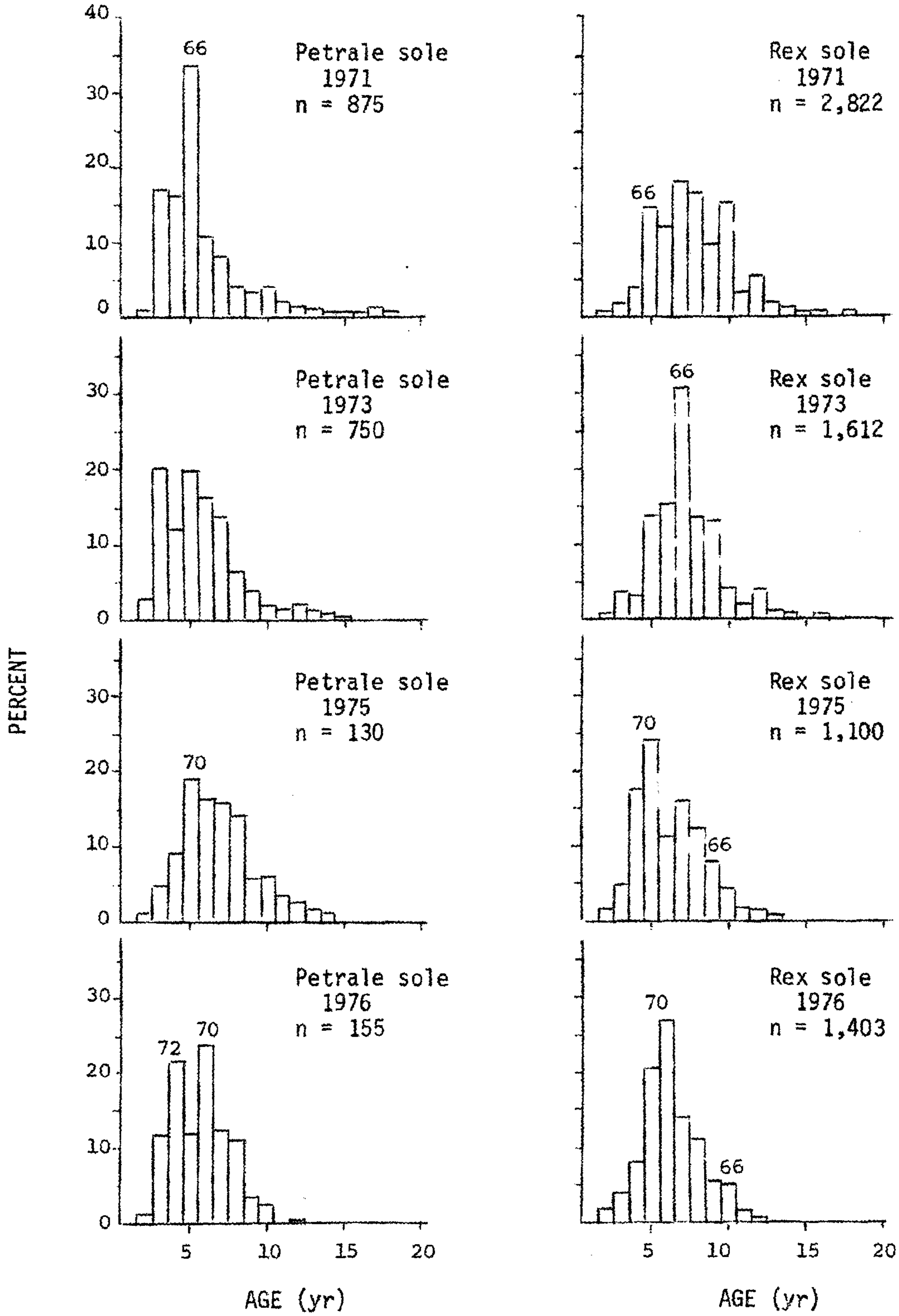

Figure 16. Continued.

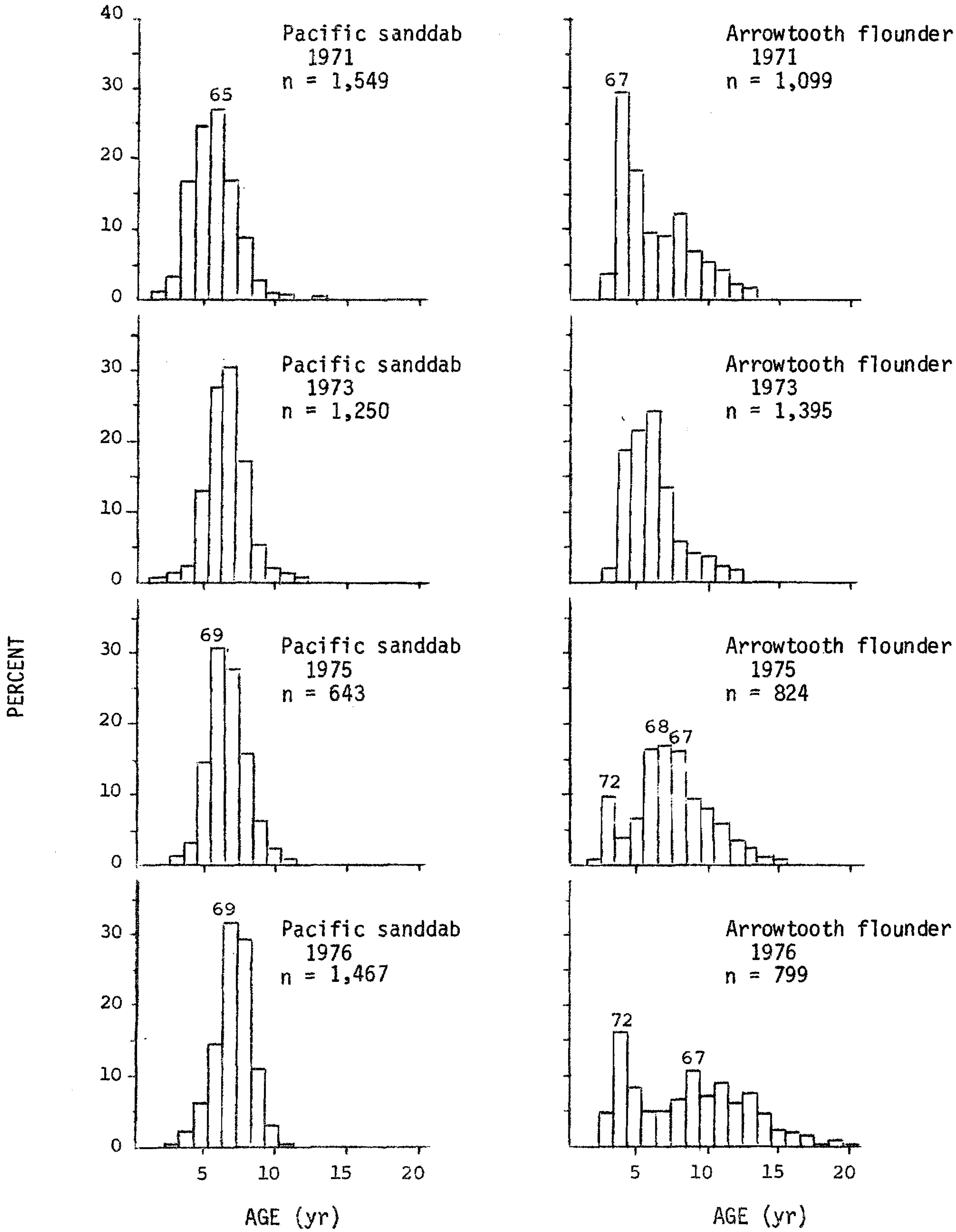

Figure 16. Continued.

showed promise for petrale sole, arrowtooth flounder and English sole.

Apparent stock differences were found by comparing age frequencies from Oregon to those off Washington. The Dover sole population appeared to be much younger off Washington than the population south of the Astoria Canyon. This conclusion is supported by a Dover sole tagging study (Westrheim and Morgan 1963) and suggests that the Astoria Canyon is a natural barrier to Dover sole. The same might apply to arrowtooth flounder in that the stocks north of the Astoria Canyon are older than stocks to the south.

Figure 17 shows how age frequencies of our survey samples relate to the age frequencies expected in the usable biomass. It is apparent that survey data helped to show the contribution of young fish to the population. Such data should help show what may be available to the commercial catch at a later date.

Survey Evaluation

The Washington surveys enabled us to meet our proposed objectives. We obtained, under partially controlled conditions, reasonably unbiased indications of the status of important flatfish species. We were able to obtain a new insight on fish distribution and relative abundance. We feel that our 3.5-inch mesh trawl net captured sufficient numbers of younger fish to enable us to monitor year class strength prior to commercial exploitation.

The surveys did not enable us to determine exact biomass nor could we detect small annual changes in biomass. Biomass over untrawlable grounds was not estimated. Also a picture of seasonal distribution was not obtained.

We should note that reference to total biomass off the Washington coast includes biomass beyond the depth limitations of our survey. Several species such as Dover sole and starry flounder have distributions which commonly extend into depths outside of our study area. Such species therefore have biomass off Washington not detected by our survey. Movement of such species into or out of our survey area might affect biomass calculated for the survey area.

The resource survey complements traditional studies of the commercial fishery, i.e., fishery catch and CPUE. The survey is presently one of our best tools for research and management. Biomass estimates from surveys are valuable as indicators of population trends and estimates of stock size within relatively wide confidence limits.

Costs

Costs of the program by fiscal year (FY) are shown below:

Budget Category	FY 1976	FY 1977 1/
Personal Services	$ 58,919	$108,261
Contractual Services	27,641	54,610
Equipment & Supplies	6,689	9,266
Overhead	14,045	24,000
Miscellaneous	4,905	7,973
Total	$112,119	$204,110

1/ 15 month contract

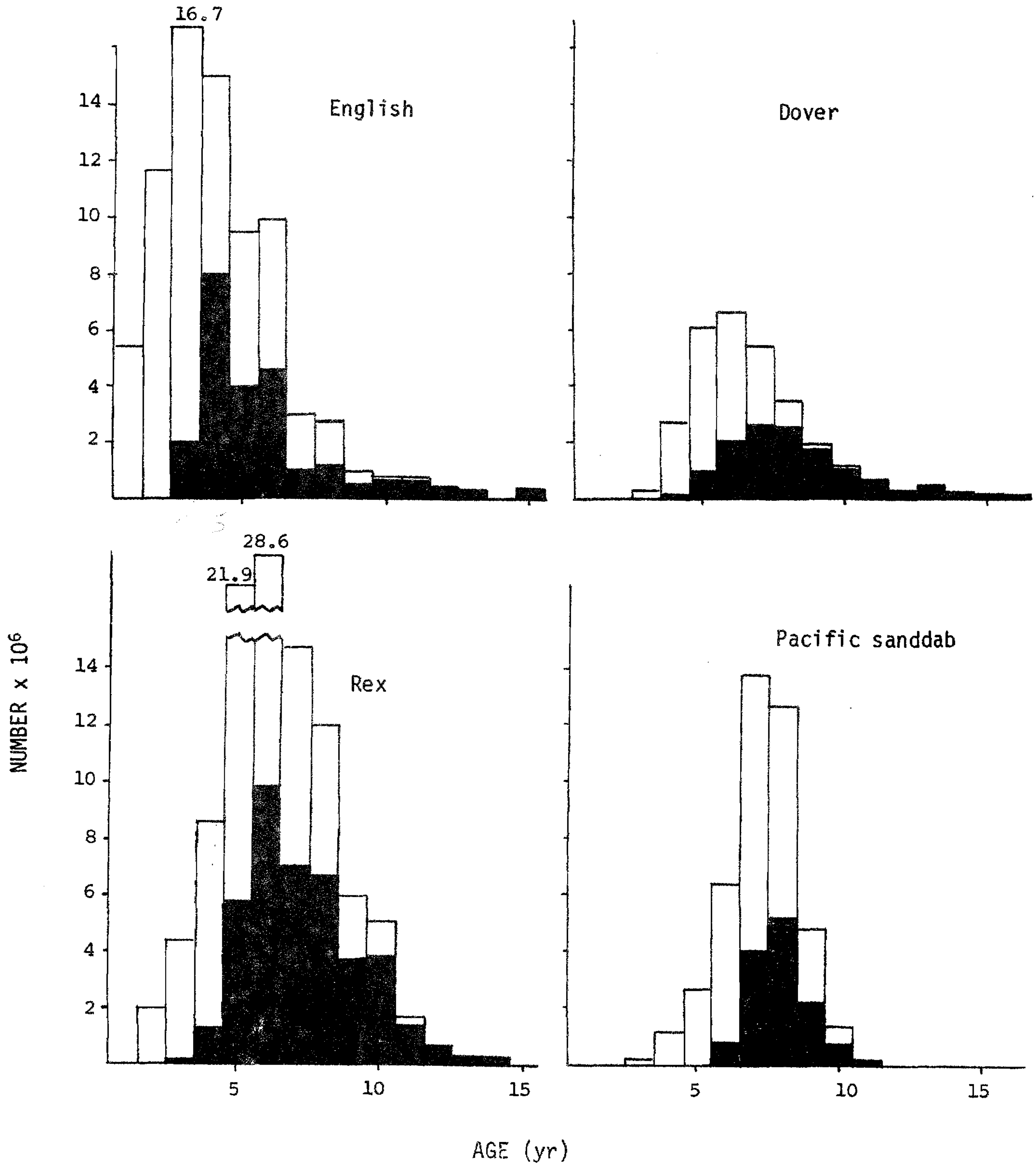

Figure 17. Total number by age of selected species compared to the commercially utilizable portion (dark part of the bar graphs) off Washington (1976).

SUMMARY

A comprehensive marine resource survey was conducted on the continental shelf and upper continental slope off Washington in 1975 and 1976. Objectives were: to estimate biomass of demersal fishes by an on bottom trawl, with emphasis on flatfish; to estimate population parameters of age composition, growth and mortality; and to index year class strength of commercially important flatfish.

The survey was a systematic design based on a 5x6 N mi grid with a random starting point. Catches of flatfish were sampled systematically.

Estimates of usable biomass were determined by applying age-specific utilization rate: and age-specific mean weights to estimated biomass. Estimates of yield were determined by multiplying usable biomass by the estimated instantaneous fishing mortality rate, F.

Total biomass (all species) was estimated at 143,447 m.t. in 1975 and 147,303 m.t. in 1976. Flatfish comprised about 50% of the total biomass. English sole was the major species in 1975 while Pacific hake was the most plentiful species in 1976. Usable biomass for principal species of flatfish ranged from 14,452 m.t. for arrowtooth flounder to 655 m.t. for petrale sole.

Estimates of potential yield ranged from 1,794 m.t. for English sole to 26 m.t. for Pacific sanddab. Species offering the greatest potential for increased harvest were arrowtooth flounder and Pacific sanddab. Improved market demand is required for increased utilization of these species.

Species distribution indicated preferences for depth and/or sediment type. English sole, Pacific sanddab and butter sole occurred mostly in shallow water over sand sediments. Arrowtooth flounder and sablefish were usually found in deeper water over silt bottom. Dover sole and flathead sole were most abundant over silt bottom.

Many species showed an increase in mean weight with increasing depth.

A bimodal depth distribution occurred for Dover sole. A greater proportion of females were found in shallow water, while more males were found in deep water.

Strong year classes were indicated for many species. The year classes of 1970 and 1972 were strong for several species.

Our data suggests that the Dover sole and arrowtooth flounder stocks found north of the Astoria Canyon are separate stocks from like species found south of the canyon.

For six species of flatfish age, length-weight constants, total annual and fishing mortality rates (Z, $\hat{a}$, F), and exploitation rate (μ) were estimated.

Recommendations

1. Survey refinement is desirable to include assessment by season, untrawlable bottom, mid-water and depths presently not surveyed. This would give a more complete picture of the distribution, abundance, composition and health of the marine fish community.

2. We recommend that a survey of the type described in this report be repeated biennially with a reduced sampling intensity.

ACKNOWLEDGMENTS

We give special thanks to the captains and crews of the R/V *Commando* and M/V *Tordenskjold* for providing outstanding support. We gratefully acknowledge the assistance of personnel from Oregon Department of Fish and Wildlife, Washington Department of Fisheries, and Oregon State University, for their participation at sea. Valuable assistance was provided by Louis Fredd with statistics and by our Clackamas clerical staff in preparing the distribution and abundance maps. Funding was granted through P.L. 88-309, the Commercial Fisheries Research and Development Act of 1964, under annual contracts: 1975, N 04-6-208-41003 and 1976, N 04-6-208-40037.

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Appendix 1. Common and scientific names of species on groundfish surveys off Washington, 1975 and 1976.

Common Name	Scientific Name
Spiny dogfish	*Squalus acanthias*
Skates	*Rajidae*
Ratfish	*Hydralagus colliei*
American shad	*Alosa sapidissima*
Pacific cod	*Gadus macrocephalus*
Pacific hake	*Merluccius productus*
Walleye pollock	*Therogra chalcogramma*
Shortspine thornyhead	*Sebastolobus alascanus*
Rougheye rockfish	*Sebastes aleutianus*
Pacific ocean perch	*Sebastes alutus*
Aurora rockfish	*Sebastes aurora*
Redbanded rockfish	*Sebastes babcocki*
Silvergray rockfish	*Sebastes brevispinis*
Darkblotched rockfish	*Sebastes crameri*
Splitnose rockfish	*Sebastes diploproa*
Greenstriped rockfish	*Sebastes elongatus*
Widow rockfish	*Sebastes entomelas*
Yellowtail rockfish	*Sebastes flavidus*
Rosethorn rockfish	*Sebastes helvomaculatus*
Quillback rockfish	*Sebastes maliger*
Black rockfish	*Sebastes melanops*
Bocaccio	*Sebastes paucipinis*
Canary rockfish	*Sebastes pinniger*
Redstripe rockfish	*Sebastes proriger*
Yelloweye rockfish	*Sebastes ruberrimus*
Stripetail rockfish	*Sebastes saxicola*
Sharpchin rockfish	*Sebastes zacentrus*
Sablefish	*Anoploroma fimbria*
Lingcod	*Ophiodon elongatus*
Pacific sanddab	*Citharichthys sordidus*
Arrowtooth flounder	*Atheresthes stomias*
Petrale sole	*Eopsetta jordani*
Rex sole	*Glyptocephalus zachirus*
Flathead sole	*Hippoglossoides elassodon*
Pacific halibut	*Hippoglossus stenolepis*
Butter sole	*Isopsetta isolepis*
Rock sole	*Lepidopsetta bilineata*
Slender sole	*Lyopsetta exilis*
Dover sole	*Microstomus pacificus*
English sole	*Parophrys vetulus*
Starry flounder	*Platichthys stellatus*
Curlfin sole	*Pleuronichthys decurrens*
Sand sole	*Psettichthys melanosticus*

Appendix 2. Length-weight constants obtained through linear regression of mean weight by length[1]/.

Species	Males a	Males b	Females a	Females b
Dover sole	-1.96514	2.95833	-2.12630	3.06697
English sole	-1.81046	2.83217	-2.09881	3.04795
Petrale sole[2]/	-2.11289	3.135	-2.4437	3.348
Rex sole	-3.00881	3.51367	-3.09201	3.57285
Pacific sanddab	-2.26826	3.17960	-2.38859	3.29136
Arrowtooth flounder	-2.49291	3.26895	-2.46547	3.26485
Slender sole	-2.50958	3.20714	-3.00625	3.59390
Flathead sole	-2.43440	3.28206	-2.53236	3.35309
Butter sole	-2.22167	3.12243	-2.10104	3.05275

1/ 1975 survey data.

2/ Constants from Pedersen, 1975 for female petrale sole.