MARINE RESOURCE SURVEYS ON THE CONTINENTAL SHELF OFF OREGON, 1971-74

COMPLETION REPORT

July 1, 1971 to June 30, 1975

Robert L. Demory
Michael J. Hosie
Neil Ten Eyck
Brent O. Forsberg

Oregon Department of Fish and Wildlife

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ABSTRACT

Groundfish surveys off Oregon were conducted over a four year period (1971-74) between the Columbia River and Cape Blanco. Primary purpose of the surveys was to obtain estimates of biomass of important groundfish occupying the continental shelf and upper continental slope.

Survey design was based on a 5 x 5 N mi grid with a random starting point. This resulted in trawling intensity of about 1 tow per 25 N mi^2 of trawlable bottom. Samples for age, size and sex composition were taken from important species of flatfish. Weights of all species caught were obtained.

Estimates of biomass (all species) were 283,750 metric tons in 1971-72 and 235,117 metric tons in 1973-74. Pacific hake was the most abundant species followed by Dover sole. Estimates of potential yield were determined for five species of flatfish. Data indicate that only petrale sole are being fully exploited. Increased yield could be obtained without increasing fishing effort if economic conditions were such that the species caught were more completely utilized.

Distribution of major species is depicted by catch maps. Distribution of some species is closely allied with depth and sediment type or both. No attempt was made to quantify species association.

INTRODUCTION

This report summarizes activities from July 1, 1970 through June 30, 1974. The program was a comprehensive marine resource survey of the continental shelf and upper continental slope off Oregon between the Columbia River (46°10'N Lat.) and Cape Blanco (42°45'N Lat.). Major objectives were: to obtain estimates of biomass for demersal fishes with particular emphasis on flatfish; to develop techniques of indexing year class strength of flatfishes important to the commercial trawl fishery prior to their recruitment to the fishery; and to obtain estimates of the population parameters of age, growth and mortality. These statistics coupled with estimates of exploitation and fishing rates provide a means of estimating optimal levels of yield.

Emphasis of the surveys was on flatfish because the Oregon trawl fishery was based on flatfish as it had been since the early 1940's. An additional reason for stressing work on flatfish was that in the initial planning, it was hoped that the National Marine Fisheries Service (N.M.F.S.) might do the offshore work, especially on rockfish. However, this did not occur, and the surveys therefore were extended seaward to include the upper continental slope in 1973-74.

Surveys, of the type described in this report, provide information which is difficult to obtain from commercial fishery statistics, e.g., estimates of recruitment, because of the larger mesh size used in commercial trawls and the discard of small unmarketable fish. Also surveys provide the survey party with absolute control over fishing activities; thus data obtained are not biased by market conditions, size limits or the economic need to fish primarily in areas of high abundance.

Survey work off Oregon started with shrimp (*Pandalus jordani*) in 1951 (Pruter and Harry 1952). Other surveys followed in 1952 (Alverson 1953), 1958 (Alverson et al., 1960), 1960 (Ronholt and Magill 1961), and 1961 (Hitz and Alverson 1963), all but the first conducted by the NMFS and devoted to both groundfish and shrimp. Surveys by the Oregon Department of Fish and Wildlife (formerly Fish Commission of Oregon) have been conducted since 1966, all funded under Public Law 88-309[1] and devoted to groundfish and shrimp. Groundfish surveys prior to 1971 were limited mainly to distribution studies of juvenile flatfish in waters adjacent to the Columbia River (Demory 1971). A deep water survey for Dover sole was conducted in 1970 from the Columbia River south to Yaquina Bay.

METHODS AND MATERIALS

Survey Design

The survey was conducted off the Oregon coast (Figure 1) between the Columbia River to just south of Cape Blanco (46°10' N Lat. to 42°45' N Lat.). These limits were chosen because they were, in part, biological barriers (Bakun, et al., 1974) as well as convenient geographical boundaries and included the bulk of the trawl fishery. Continuing the survey south of Cape Blanco would have required a survey to at least Point Saint George, California (41°50' N Lat.) or possibly further south to Cape Mendocino (40°25' N Lat.), more area than was possible to do with available funds and manpower. The survey period was from early September to early October each year, the best weather interval off Oregon. Also, stocks of fish are relatively stable at this time of year in that offshore spawning migrations for some species have not yet begun.

There were survey design changes during the study concerning depth limits, length of tow, trawl accessories and catch processing. In 1971-72, depths surveyed were limited to the continental shelf between 10 and 110 fm (18-200m). The offshore limit was extended to about 400 fm (730m) in 1973-74. The survey area was too large to adequately sample in a single year; thus two years were required to obtain a single view of the groundfish resources, i.e., 1971-72 and 1973-74. The northern halfhalf, to 44°50' N Lat., was surveyed in 1971 and 1973. The southern portion was surveyed in 1972 and 1974. An upper slope survey was attemped in 1973-74 but was only partially successful due to large expanses of untrawlable bottom. The upper slope area from about 43°55' N Lat. to 43°05' N Lat. was successfully completed in 1974. Except for upper slope tows in 1974, tow locations in 1973-74 were at or near tow locations of 1971-72.

Trawling locations were systematically determined by use of a 5 x 5 N mi grid with a random starting point. Stations were located by loran-A, depth and ship's radar. Tow length on shelf stations (<110 fm) was 0.75 N mi in 1971-72 and 1.0 N mi in 1973-74. Tow length was 1.5 N mi on slope stations in 1974. Nearly all tows were made to the south because prevailing winds were northerly and it was the choice of the charter vessel master to trawl with the wind. All tows were made during daylight between 0700 and 1930 hours, on bottom, at a speed of 2.0 to 2.5 knots.

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[1] Commercial Fisheries Research and Development Act, PL 88-309, 1964.

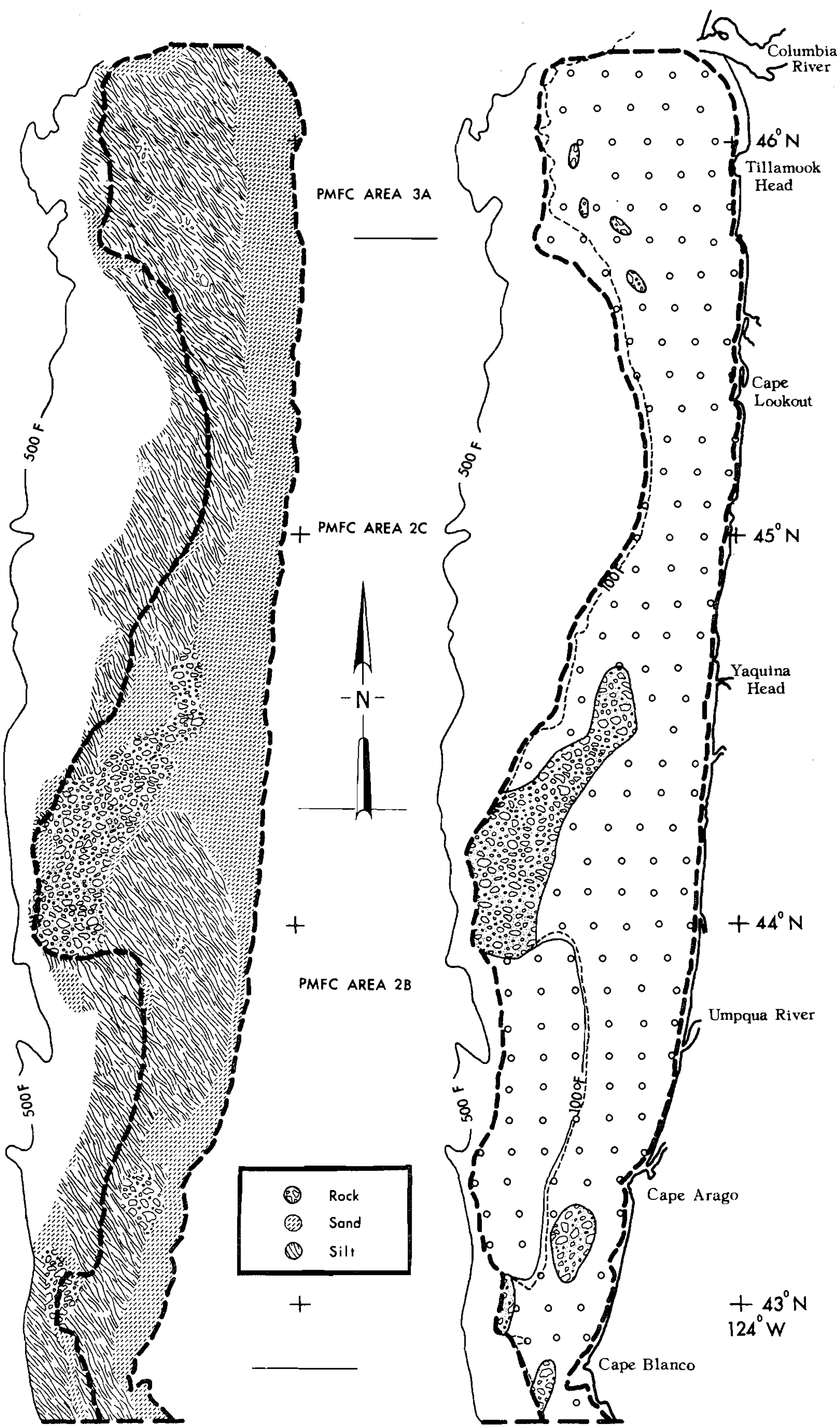

Figure 1. Location of trawl stations of groundfish surveys off Oregon, 1971-74. Heavy broken line defines survey limits (deep-water limit, lower portion, 1974 only). Sediment types after Byrne and Panshin (1972). PMFC statistical areas are indicated.

We attempted to make expendable bathythermograph (XBT) casts on all cruises. Technical problems precluded this; however, some XBT casts were made at trawl stations on alternate tracklines in 1972-73.

Vessel and Gear Characteristics

The 67-ft. western seiner-type trawler *R/V Commando*, powered by a 358 h.p. engine was used. Doors (otter boards), supplied by the vessel, were 5x7-ft and weighed 1,050 pounds each.

The trawl used was a 400-mesh eastern type constructed entirely of 3.5-in (89mm) mesh, stretched measure (Appendix 1). Sweep lines (10-fm bridles, 5-fm dandy lines) were used to reduce herding of fish into the trawl mouth. Our and N.M.F.S. 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 of water. Horizontal and vertical openings were 32-ft and 3.5-ft respectively in 1971-72. A change from the rope-wrapped footrope supplied with the trawl to a chain-disk footrope in 1973-74 reduced horizontal opening to 30-ft and increased vertical opening to nearly 6 ft. A further change in footropes was made in 1974. Tows on the upper slope were made with the trawl rigged with a roller-type footrope (Appendix 1). Estimated swept area (horizontal opening x tow length) was 0.00395 N mi^2 in 1971-72, 0.00494 N mi^2 in 1973-74 for shelf tows; and 0.00741 N mi^2 for upper slope tows in 1974.

Catch Processing

Trawl catches were dumped onto a stern-mounted sorting table 6-ft^2 by 1-ft deep. Catch was then sorted by species and weights were determined for each fish species by using a 60-lb capacity spring scale. An average weight was obtained for all species caught by weighing and counting whole catches or samples of catches. For Pacific hake (*Merluccius productus*), weight was determined by total number and sample average weight. Flatfish (up to 10 species) from each tow were retained for sampling.

A systematic sampling design was used to sample flatfish from each station for age and sex composition. The 1971-72 sample rate, or the proportion of the catch sampled, was variable, ranging from 5% to 100%, depending on the size of the catch. Usually the catch of a species was small and it was completely (100%) sampled. In 1973-74, sampling was modified in that sampling rates were usually fixed, depending on the species, at 25% to 50%. If a catch of any species was exceptionally large, (rarely) sampling rate was reduced to 5%. Also, beginning in 1972, length to the center of the tail was recorded to the nearest cm for flatfish in age samples. Length was not recorded in 1971.

To obtain aging structures (otoliths or interopercles), heads were removed at sea from nine species: English sole (*Parophrys vetulus*), petrale sole (*Eopsetta jordani*), rex sole (*Glyptocephalus zachirus*), Pacific sanddab (*Citharichthys sordidus*), arrowtooth flounder (*Atheresthes stomias*), sand sole (*Psettichthys melanostictus*), slender sole (*Lyopsetta exilis*), butter sole (*Isopsetta isolepis*), and flathead sole (*Hippoglossoides elassodon*). A fillet, with skin attached, was removed from the right side of Dover sole (*Microstomus pacificus*) for scales. Heads and fillets (by sex) were placed in plastic bags and frozen for later processing ashore.

Once ashore, scales from Dover sole, interopercles from English sole, and otoliths from the other species were removed and stored by sex and tow. Scales were mounted between two glass slides; interopercles were stored dry in coin envelopes; and otoliths were placed in a 50% glycerine-water solution. 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 (18m) strata between 10 and 110-fm (18-200m). Slope strata were 110-199 fm (200-374m), 200-299 fm (366-547m) and 300-399 fm (548-729m). This was done on C and GS charts 5902 and 5802. We used a planimeter to calculate area of each stratum on the charts.

Stratum areas were divided by the average swept area of a single tow, with the result that stratum areas were expressed in terms of total possible tows.

For each stratum, mean catch per tow and its variance was calculated. The stratified mean catch per standard tow was then calculated by weighting each stratum mean by the stratum area divided by the total area. Variance of the stratified mean was derived by weighting each stratum variance in proportion to the stratum area and inversely according to the number of tows made in the stratum (Cochran 1963). The formulae are:

$$\bar{y}_{st} = \frac{\Sigma\ N_h\ \bar{y}_h}{N}$$

$$s^2_{\bar{y}_{st}} = \frac{1}{N^2}\ \Sigma \left(\frac{N_h\ s_h^2}{n_h} \right)$$

where $\bar{y}_{st}$ and $s^2(\bar{y}_{st})$ are the stratified mean catch per tow and its variance respectively, and:

N_h = Standard tows possible in the h^{th} stratum;

$\bar{y}_h$ = mean catch per tow in the h^{th} stratum;

N = standard tows possible in the entire set of strata;

s_h^2 = variance of catches in the h^{th} stratum;

n_h = standard tows made in the h^{th} stratum.

Biomass equals $N\ \bar{y}_{st}$. Catchability of the trawl was assumed to be 1.0. The 95% confidence intervals were:

Population mean; $\bar{y}_{st} \pm ts\ (\bar{y}_{st})$

Population total (biomass); $N\bar{y}_{st} \pm tNs\ (\bar{y}_{st})$

There were 140 (1971-72) and 147 (1973-74) usable (trawlable) stations on the continental shelf and 22 usable stations deeper than 110 fm south of Heceta Bank (Demory 1971a, 1972, 1973; Hosie 1974). Original biomass estimates were converted to metric tons (1 metric ton = 2,206.4 pounds).

Estimates of usable biomass were determined for Dover, English, petrale and rex sole and Pacific sanddab, the current commercially important flatfish species. This was done by first apportioning the biomass to sex by weight ratio obtained from samples and converting weight to numbers using average weight. Usable biomass, B_u was determined as $B_u = \Sigma(P_i \bar{w}_i b_i)$ where:

P_i = number of fish at age i

$\bar{w}_i$ = mean weight of fish at age i

b_i = utilization rate at age i(TenEyck and Demory 1975).

Usable biomass is defined here as that portion of the exploitable biomass of a size that would be landed by commercial fishermen under present fishery conditions. Usable biomass is less than trawlable or exploitable biomass since the latter includes small fish that are normally discarded at sea.

Estimates of potential yield were determined by multiplying usable biomass by estimates of the instantaneous fishing rate (F).

Growth

Growth data was obtained from samples of whole fish frozen at sea and processed ashore. Length-weight and von Bertalanffy growth constants were determined by appropriate formulae (Ricker 1958) and are shown in Appendix 2.

Instantaneous Total Mortality Rate

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

Exploitation Rate and Fishing Rate

The exploitation rate (μ) was determined by dividing usable biomass by the commercial landings. Usable biomass was determined for PMFC Areas 2B, 2C and the southern portion of 3A south of the Columbia River (Figure 1). Because it required two years to complete one complete survey, average estimates of usable biomass were calculated for the appropriate years. The sequence was: Areas 3A and 2C, 1971 and 1973; Area 2B, 1972 and 1974. Average commercial landings were computed accordingly. To determine exploitation rate for the entire survey area, average landings were computed for 1971-72 and 1973-74 and divided by our 1971-72 and 1973-74 survey estimates of usable biomass.

The instantaneous fishing rate (F) was determined using the formula, $F = \frac{\mu Z}{A}$, where μ is the exploitation rate; Z is the total instantaneous mortality rate and A is the total annual mortality rate. Estimates of Z used were those computed from the combined catch curves for females. Rates for females were used because, in terms of weight, females dominate the fishery. Also females are generally longer lived, and estimates of Z will be less than Z for males; hence calculated fishing rate will be less conducive to over-exploitation.

Year Class Strength

Relative year class strength, expressed in percent frequency, was determined for ten flatfish species, for each annual cruise.

Evaluation of Sampling Techniques

A systematic sampling scheme was used to sample fish for age composition. The ratio of number of fish sampled to number of fish caught varied inversely to catch size. In 1972 tests were conducted to determine difference in size composition and sex ratio. Size composition of samples was tested against size composition of the catch by a χ^2 test of homogeneity (P=0.05). There were 38 tests made: Dover sole, 20; English sole, 4; rex sole, 9; and sanddab, 5. Sex ratio was tested by χ^2 (P=0.05). There were only 16 tests made since not all catches were sexed.

Evaluation of a Small Mesh Trawl

In 1972 a trawl constructed of 2.5-in mesh was tested to determine its ability to capture smaller fish, especially Dover sole, than were caught by our standard 3.5-in mesh survey trawl. The smaller-mesh trawl was rigged the same and was the same overall size as, the survey trawl. Testing was done at two different depths to account for differences in depth distribution of some species. Where species overlapped by depth, data were combined, thus depth was not a variable. A 2.5-in mesh codend attached to the body of the 3.5-in mesh survey trawl was also tested.

Length of Tow Experiments

In 1972 an attempt was made to test the effect of tow length on mean length of capture for selected flatfish species. The null hypothesis was that length of tow would not influence mean length. Tow lengths were 0.75 N mi and 1.5 N mi.

RESULTS AND DISCUSSION

Estimates of Biomass

The total biomass estimate (all species) for the shelf survey in 1973-74 was 235,117 metric tons, a reduction of 17% from the estimate of 1971-72 (Table 1). Pacific hake was the most abundant species (by weight) at 68,177 m.t., about one-half the 1971-72 estimate of 132,626 m.t.

Table 1. Estimates of biomass (m.t.) of principle species on the Continental shelf and upper slope between the Columbia River and Cape Blanco, Oregon, 1971-74. Confidence limits, 95%, are expressed as ±%.

	Biomass (m.t.) Continental Shelf				Continental Slope		% change from 1971-72
Species[1/]	1971-72	±%	1973-74	±%	1974[2/]	±%	shelf only
Spiny dogfish	3,655	55	12,687	36	3	200	+247
Skates	16,925	20	17,019	12	169	96	+1
Ratfish	12,883	27	12,396	27	84	77	-4
Pacific cod	747	99	807	65	-	-	+8
Pacific hake	132,626	34	68,177	30	2,316	65	-49
Rockfish							
Bocaccio	1,172	82	897	97	-	-	-23
Widow rockfish	167	147	113	122	14	105	-32
Black rockfish	290	107	471	77	-	-	+62
Yellowtail rockfish	2,152	95	2,055	78	-	-	-5
Canary rockfish	2,727	57	16,969	177	-	-	+522
Blackmouth rockfish	592	66	895	58	306	106	+51
Redstripe rockfish	-	-	151	141	-	-	-
Pacific oceanperch	397	126	738	36	267	63	+86
Stripetail rockfish	462	98	729	98	-	-	+58
Splitnose rockfish	114	161	154	117	534	86	+35
Flag rockfish	845	139	170	68	33	78	-80
Sharpchin rockfish	332	98	70	114	3	200	-80
Greenstriped rockfish	5,284	46	3,610	53	3	200	-32
Rosethron rockfish	32	113	383	157	3	200	+1,097
Yellowmouth rockfish	152	107	14	170	-	-	-91
Longjaw rockfish	497	128	74	200	-	-	-85
Rougheye rockfish	3	200	2	127	66	85	-33
Aurora rockfish	35	200	25	116	41	67	-29
Turkey-red rockfish	-	-	119	97	-	-	-
Shortspine thornyhead	1,298	46	2,509	35	941	26	+93
Sablefish	11,351	63	9,763	33	9,103	42	-14
Lingcod	4,400	26	4,097	40	12	200	-7
Flatfish							
Pacific sanddab	10,894	56	11,988	36	-	-	+10
Arrowtooth flounder	7,759	24	7,187	19	374	28	-7
Slender sole	481	34	555	26	8	79	+15
Petrale sole	5,804	40	3,980	27	52	69	-31
Flathead sole	389	59	262	48	-	-	-33
Sand sole	1,235	100	536	50	-	-	-57
Butter sole	457	39	776	53	-	-	+70
English sole	17,936	25	19,713	41	60	200	+10
Rock sole	330	96	326	75	-	-	-1
Dover sole	26,128	20	22,835	17	4,391	33	-13
Rex sole	12,130	20	10,843	22	819	31	-11
Starry flounder	471	90	408	77	-	-	-13
Curltin sole	111	111	109	73	-	-	-2
Pacific halibut	487	71	505	81	-	-	+4
Total	283,750	-	235,117	-	19,602	-	-17
Rockfish	16,551	-	30,148	-	2,211	-	+82
Flatfish	84,612	-	80,023	-	5,704	-	-5

1/ Common and scientific names are shown in Appendix 3.
2/ Survey limit: 43° 57.5' N Lat. - 43° 2.5' N Lat.

Biomass of the flatfish group amounted to about 80,000 m.t. in 1973-74, down 5% from 1971-72. Dover sole biomass declined 13% from 26,128 m.t. in 1971-72 to 22,835 m.t. in 1973-74. Other important flatfish showing a decrease from 1971-72 were petrale sole which declined by 31% to 3,980 m.t. and rex sole which dropped 11% to 10,843 m.t. Two important flatfish increased by 10% in biomass in 1973-74: English sole to 19,713 m.t. and Pacific sanddab to 11,988 m.t.

The rockfish group (Scorpaenidae) in 1973-74 showed an 82% increase (to 30,148 m.t.) over 1971-72. The increase was primarily attributed to one catch of canary rockfish (*Sebastes pinniger*) in 1973-74 that accounted for about 90% of the total catch for this species and about 46% of the total catch of all rockfish species on the continental shelf. Biomass of semipelagic species were under-estimated because our type of gear was not efficient for catching semipelagic species (Alverson and Pereyra 1969).

The 1974 survey also included the upper continental slope south of Heceta Bank (Figure 1)1/. This area supports a major fishery, primarily for Dover sole. Of the three most important species, Dover sole biomass was estimated at 4,391 m.t. while petrale and rex sole amounted to 52 m.t. and 819 m.t. respectively (Table 1). The upper slope estimates are not directly comparable with shelf estimates because roller gear used on the slope apparently allowed substantial escapement from the trawl. Based on six comparative tows the mean catch rate of Dover sole was nearly four times greater with the chain-disk footrope. However, no adjustments to data were made to compensate for the apparent differences in catch rate.

Estimates of Usable Biomass

Estimates of usable biomass for the five major species of flatfish ranged from 23,266 m.t. of Dover sole (1973-74) to 2,885 m.t. of petrale sole (1973-74). Estimates were less in 1973-74 for English, petrale and rex sole than in 1971-72 (Table 2). The estimate for Dover sole was greater in 1973-74, but this included fish from the upper slope, which was not surveyed in 1971-72.

Table 2. Estimates of usable biomass, potential yield and landings from the survey area, 1971-74. All values in metric tons.

Species	Usable Biomass		F	Potential Yield		Average Landings	
	1971-72 1/	1973-74 2/		1971-72 1/	1973-74 2/	1971-72 1/	1973-74 3/
Dover sole	22,219	23,266	0.15	3,333	3,490	1,950	1,769
English sole	7,448	6,551	0.21	1,564	1,376	635	474
Petrale sole	3,743	2,885	0.28	1,048	808	544	862
Rex sole	7,304	6,195	0.21	1,534	1,301	272	395
Pacific sanddab	3,303	4,266	0.30	991	1,280	272	91

1/ Continental shelf only.
2/ Includes slope estimate south of Heceta Bank.
3/ Includes slope landings south of Heceta Bank.

1/ The large untrawlable area near the center of the survey area.

Total Instantaneous Mortality Rate

Estimates of total instantaneous mortality rates varied widely between species and in some cases among species. There were also considerable differences between sexes of the same species (Table 3). A complicating factor was that estimates were based on catch curves containing several year classes rather than on separate year classes. For example, estimates of Z for English sole females based on survey data ranged from 0.35 to 0.48. The combined estimate was 0.43. An estimate for females based on samples from commercial landings in the Columbia River area was 0.56. This estimate was computed by the method of Jackson (1939) on the combined 1960-62 year classes. For Dover sole, the combined survey-based estimate was 0.45 and 0.31 for males and females, respectively. Estimates of 0.35 and 0.25 for males and females, respectively were determined based on samples of commercial landings. There is some evidence that estimates of Z for Dover sole males, based on age data, might lead to erroneous conclusions regarding mortality rates in that males may be underaged (Demory 1972a). Another complicating factor regarding Dover sole is that mature males tend to congregate in deep water off the continental shelf (Westrheim and Morgan 1963). Therefore, estimates of Z for males obtained only from shelf waters might well overestimate Z for the male stock as a whole.

Exploitation Rate and Fishing Rate

Exploitation rate, μ, ranged from 0 for sanddabs in PMFC Area 2C to 0.37 for petrale sole in PMFC Area 2B. In nearly all cases, exploitation rates were higher in Area 2B than in other areas (Table 4). The exception was in Area 3A where rex sole was exploited at a higher rate than in other areas. When the survey area, all species, as a whole was considered, exploitation rates ranged from about 0.01 (sanddab) to 0.24 (petrale sole).

There are possible sources of error associated with the estimates of μ: market limits (catch limits) would suppress exploitation; the survey estimate may not be accurate; changes in distribution might affect availability to the trawl; and there are limitations on accuracy and completeness of data to fisherman logbooks from which area of commercial catch is obtained.

Instantaneous fishing mortality F, ranged from 0 for sanddabs in Area 2C to 0.43 for petrale sole in Area 2B (Table 5). Fishing rates were highest in Area 2B. It appears that an increase is possible in fishing rate for all species except petrale sole. However, an increase in F for some species may be detrimental to other species. Although the data indicate that sanddab, rex sole and English sole could sustain increases in F in most areas the data are misleading because of market conditions; fish are caught, thus subject to fishing mortality, but are not always utilized.

Petrale sole appear to be in need of protection in Area 2B since F exceeded Z. Several factors may be operating here, however. If biomass was underestimated, then F will necessarily be overestimated; the estimate of Z may not be correct; and stock definition is not well known. On the surface this appears to be a problem, but Ketchen and Forrester (1966) and Pedersen (1975) concluded that year class strength was more important than fishing in reducing stock size. Pedersen (op. cit) also pointed out that species like petrale sole (low abundance, high value) may well be kept at low levels of abundance in the interest of optimizing yield from a multispecies trawl fishery where other less valuable but more abundant species dominate the catch.

Table 3. Estimates of total instantaneous mortality rate Z for flatfish taken on groundfish surveys, 1971-74.

Species	Instantaneous Mortality Rate				
	Year	Males	Age range	Females	Age range
Dover sole	1971	0.43	8-17	0.33	10-22
	1972	0.47	8-18	0.46	10-21
	1973	0.36	7-17	0.32	8-20
	1974	0.42	7-17	0.31	8-25
	Combined	0.45	8-18	0.31	8-25
English sole	1971	0.36	5-16	0.48	5-14
	1972	0.43	4-15	0.47	4-15
	1973	0.43	5-17	0.35	3-16
	1974	0.33	2-14	0.46	4-13
	Combined	0.42	5-17	0.43	4-16
Petrale sole	1971	0.62	5-12	0.45	5-13
	1972	0.66	6-13	0.34	6-16
	1973	0.55	5-12	0.44	6-15
	1974	0.38	4-14	0.26	3-18
	Combined	0.53	5-14	0.38	5-18
Rex sole	1971	0.45	7-16	0.40	7-18
	1972	0.49	6-16	0.38	6-18
	1973	0.66	7-14	0.58	7-16
	1974	0.54	6-13	0.80	8-14
	Combined	0.56	7-16	0.50	7-18
Pacific sanddab	1971	0.66	5-10	0.79	6-13
	1972	0.65	6-10	0.59	6-12
	1973	0.77	6-12	0.86	7-12
	1974	0.76	7-12	0.72	7-13
	Combined	0.62	6-12	0.80	7-13
Arrowtooth flounder	1971	0.36	4-12	0.32	4-15
	1972	0.46	4-11	0.37	4-16
	1973	0.57	6-20	0.47	6-19
	1974	0.75	7-10	0.51	7-22
	Combined	0.37	4-20	0.34	4-22
Sand sole	Combined	0.56	3-10	0.51	3-10
Slender sole	Combined	0.68	6-10	0.65	10-17
Butter sole	Combined	0.87	6-12	0.61	5-11
Flathead sole	Combined	0.53	7-12	0.35	5-15

Table 4. Exploitation rate μ for selected species of flatfish by PMFC area and the survey area. Weight units are metric tons.

	PMFC Area			Survey Area	
Species	3A	2C	2B	1971-72	1973-74
Dover sole:					
Usable biomass	5511.2	5112.0	11973.6	22199.5	23248.5
Landings	192.4	52.2	1556.5	1953.2	1580.5
μ	0.035	0.010	0.130	0.088	0.068
English sole:					
Usable biomass	889.4	3597.8	1842.7	7441.2	6545.5
Landings	138.8	200.3	315.7	628.0	598.2
μ	0.156	0.056	0.171	0.084	0.091
Petrale sole:					
Usable biomass	861.8	1592.4	781.9	3739.9	2882.0
Landings	197.8	151.7	286.0	547.6	676.5
μ	0.230	0.095	0.366	0.146	0.235
Rex sole:					
Usable biomass	1955.9	1695.0	2736.5	7300.0	6189.4
Landings	173.5	3.9	85.1	273.3	266.7
μ	0.089	0.002	0.031	0.037	0.043
Pacific sanddab					
Usable biomass	630.5	951.8	2346.6	3300.5	4262.1
Landings	3.2	0	57.4	24.9	77.2
μ	0.005	0	0.024	0.008	0.018

Table 5. Instantaneous fishing rate F for selected species of flatfish by PMFC Area, 1971-74.

Species	$Z^{1/}$	a	μ			Fishing Rate				
									Survey Area	
			3A	2C	2B	3A	2C	2B	1971-72	1973-74
Dover sole	0.31	0.27	0.035	0.010	0.130	0.04	0.01	0.15	0.10	0.08
English sole	0.43	0.35	0.156	0.056	0.171	0.19	0.07	0.21	0.10	0.11
Petrale sole	0.38	0.32	0.230	0.095	0.366	0.27	0.11	0.43	0.17	0.28
Rex sole	0.50	0.39	0.089	0.002	0.031	0.11	0.003	0.04	0.05	0.06
Pacific sanddab	0.80	0.55	0.005	0	0.024	0.007	0	0.03	0.01	0.03

1/ Combined estimates for females only, from Table 3.

Potential Yield

Estimates of potential yield were obtained by multiplying F by usable biomass. Values of F (from Table 5, in part) were:

Species	F (Area)
Dover sole	0.15 (PMFC Area 2B)
English sole	0.21 (PMFC Area 2B)
Petrale sole	0.28 (1973-74 survey estimate)
Rex sole	0.21 (arbitrary)
Sanddab	0.30 (arbitrary)

Estimates of annual potential yield ranged from nearly 3,500 m.t. for Dover sole to about 800 m.t. for petrale sole (Table 2). Estimates for Dover, petrale and rex sole for 1973-74 are underestimated since estimates include catches made using the trawl rigged with the roller type footrope. When estimates of potential yield are compared to the survey area landings there is substantial room for increasing the catch with the possible exception of petrale sole. The species offering the greatest potential are English sole, rex sole and sanddab. Increases in yield could be obtained by effecting changes in market conditions which would encourage utilization of species (or sizes) that are presently discarded rather than by increasing F. Effectively this would mean increasing exploitation rate.

Distribution

Distribution of major species was highly variable, not only between survey periods but also within survey periods. Examination of the catch maps (Figures 2-13) readily shows distribution of most species. Two prominent features are apparent: the area near the Columbia River and the area adjacent to Heceta Bank south to about 43°30' N Lat. were high-catch regions. This pattern prevailed in both survey periods. Conversely, the area north of Heceta Bank was usually sparsely populated.

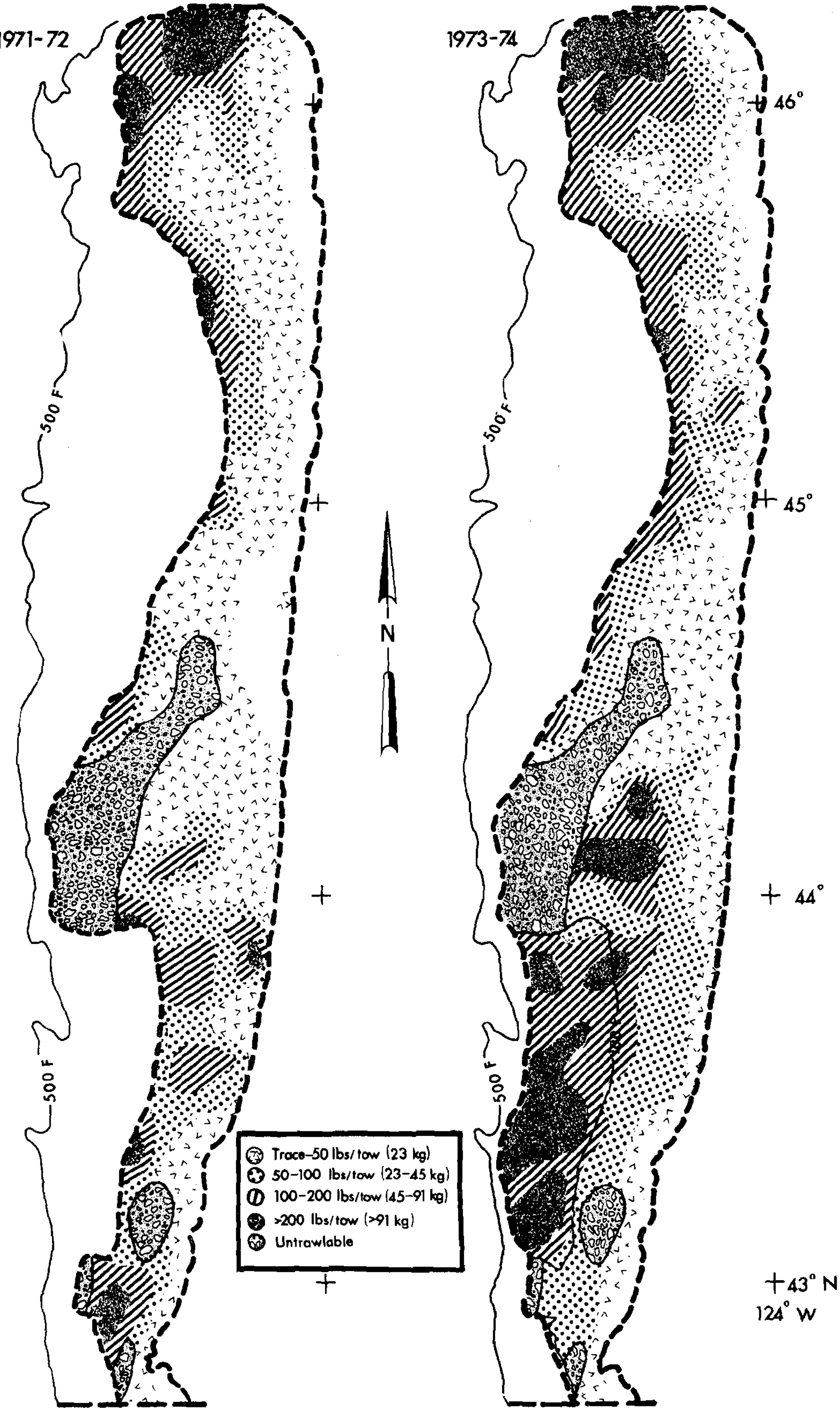

Figure 2. Distribution and relative abundance (weight) of Dover sole in September 1971-72 and 1973-74 off Oregon as determined by groundfish surveys. Heavy broken line is limit of survey.

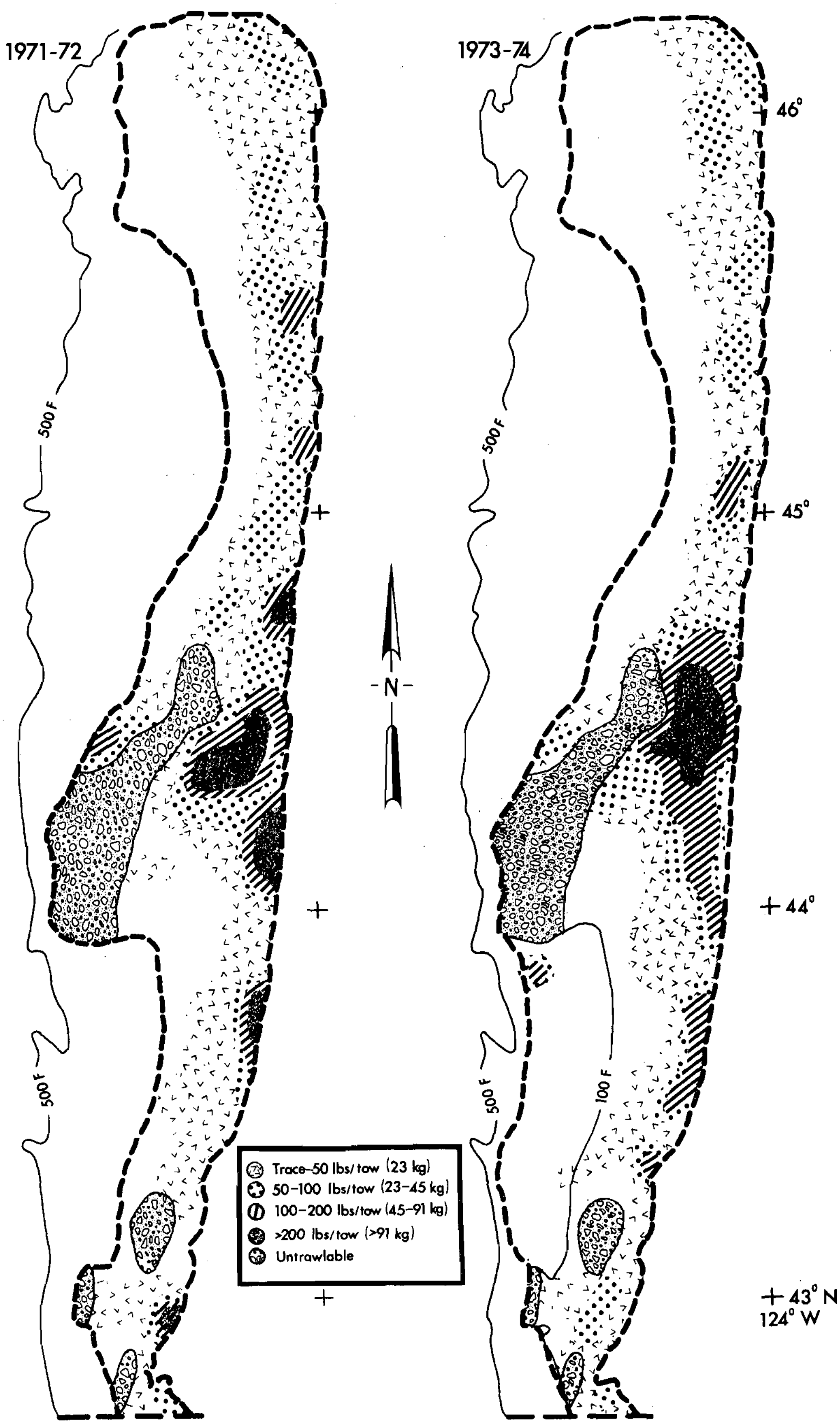

Figure 3. Distribution and relative abundance (weight) of English sole in September 1971-72 and 1973-74 off Oregon as determined by groundfish surveys. Heavy broken line is limit of survey.

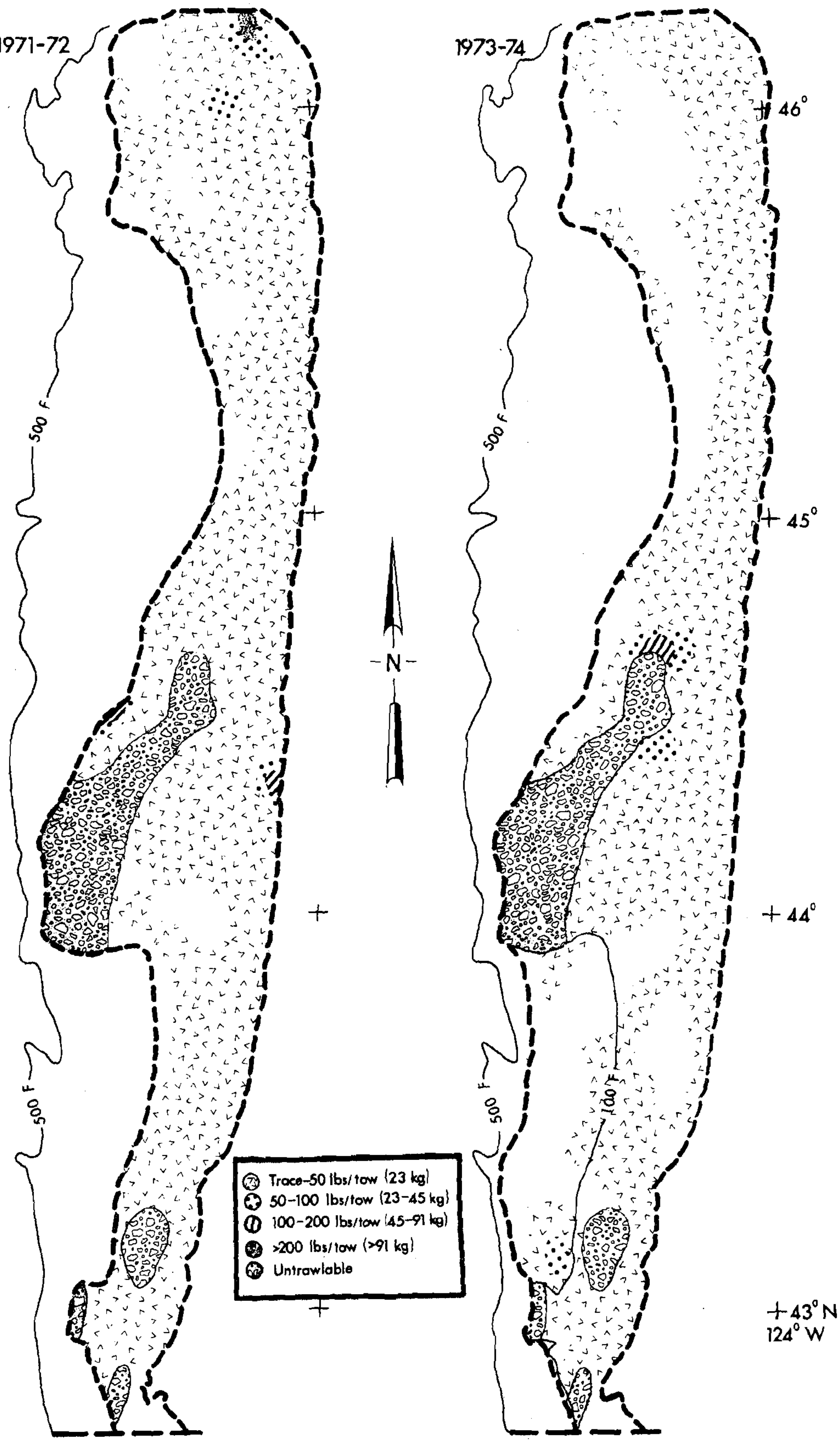

Figure 4. Distribution and relative abundance (weight) of petrale sole in September 1971-72 and 1973-74 off Oregon as determined by groundfish surveys. Heavy broken line is limit of survey.

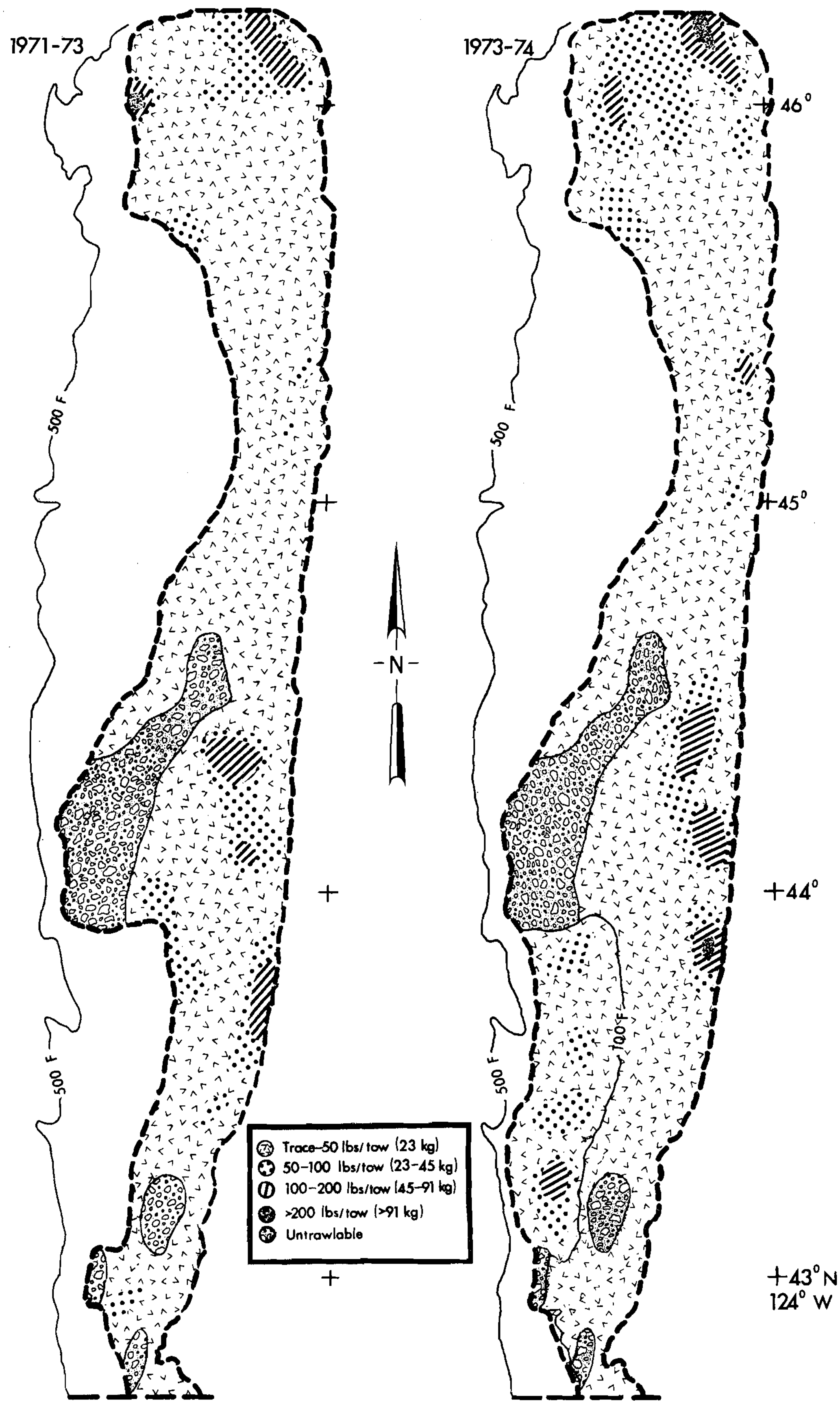

Figure 5. Distribution and relative abundance (weight) of Rex sole in September 1971-72 and 1973-74 off Oregon as determined by groundfish surveys. Heavy broken line is limit of survey.

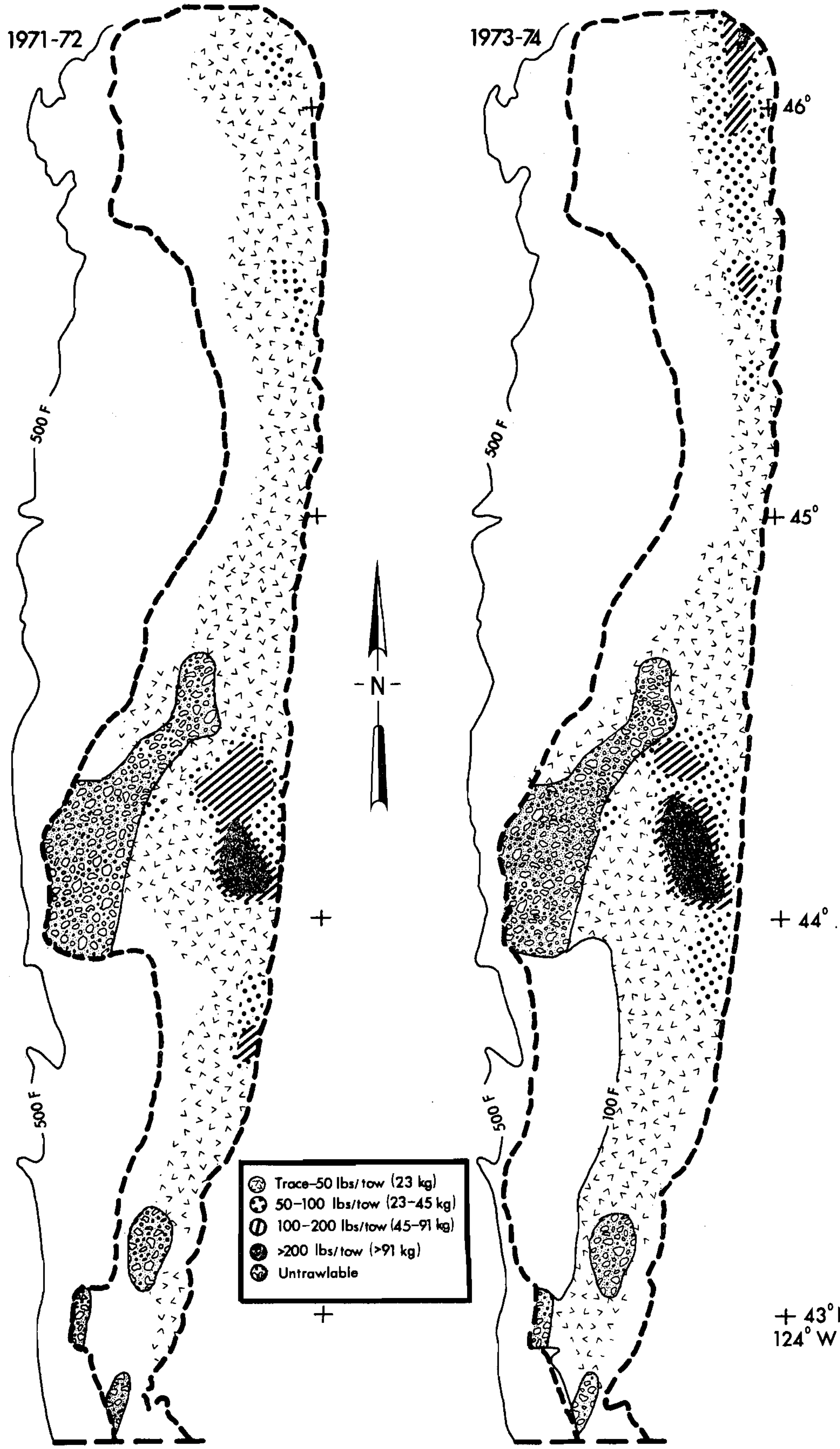

Figure 6. Distribution and relative abundance (weight) of Pacific sanddab in September 1971-72 and 1973-74 off Oregon as determined by groundfish surveys. Heavy broken line is limit of survey.

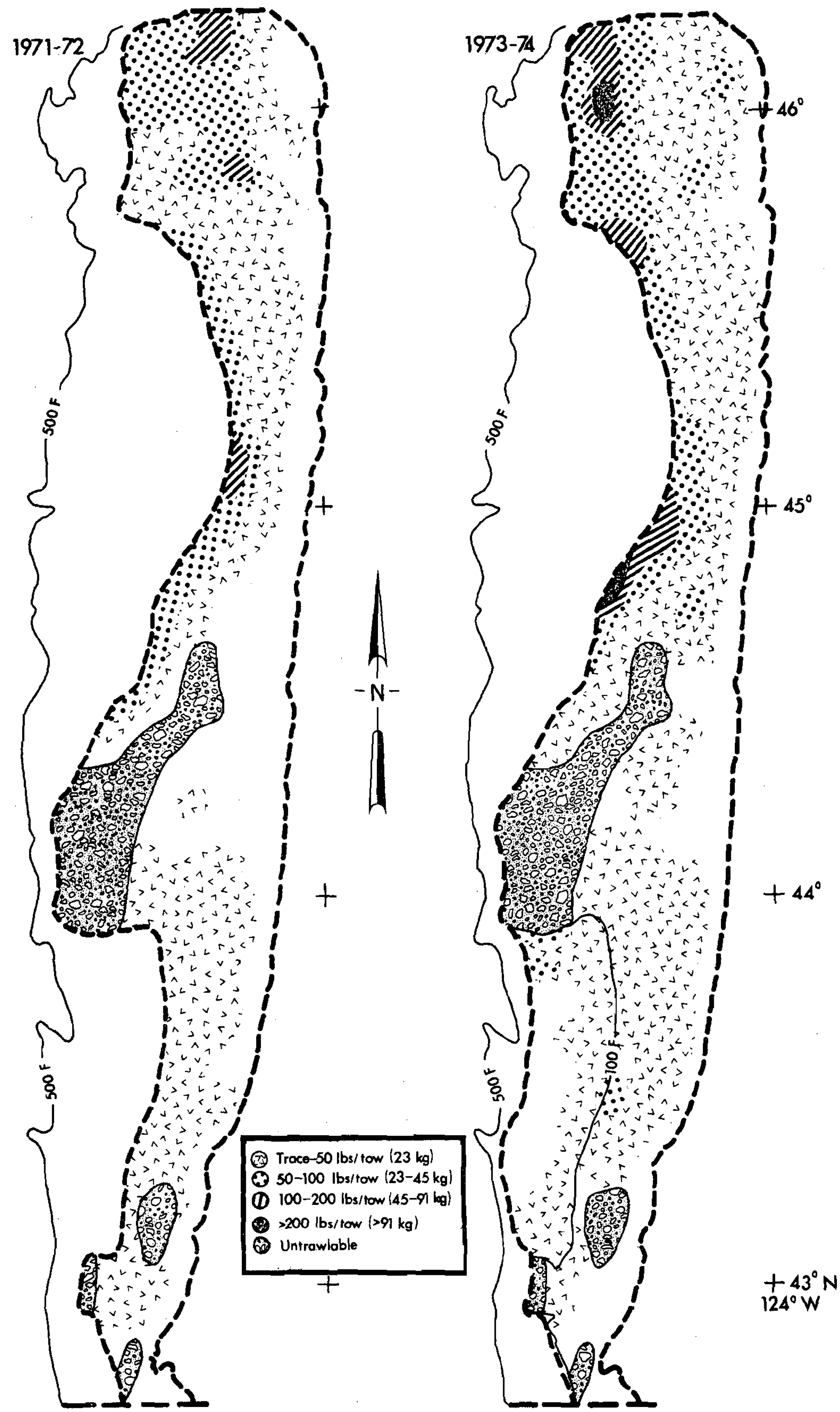

Figure 7. Distribution and relative abundance (weight) of arrowtooth flounder in September 1971-72 and 1973-74 off Oregon as determined by groundfish surveys. Heavy broken line is limit of survey.

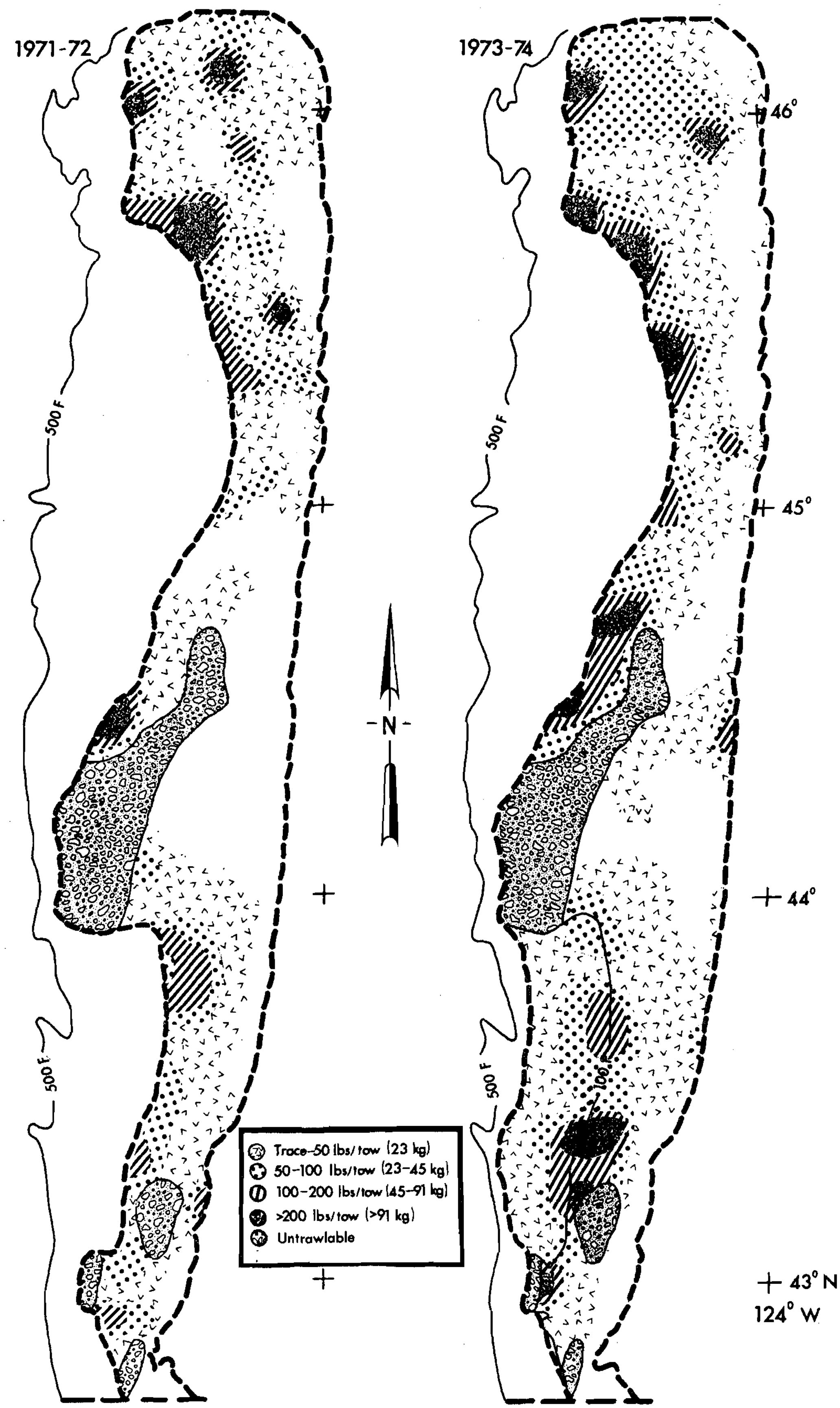

Figure 8. Distribution and relative abundance (weight) of rockfish in September 1971-72 and 1973-74 off Oregon as determined by groundfish surveys. Heavy broken line is limit of survey.

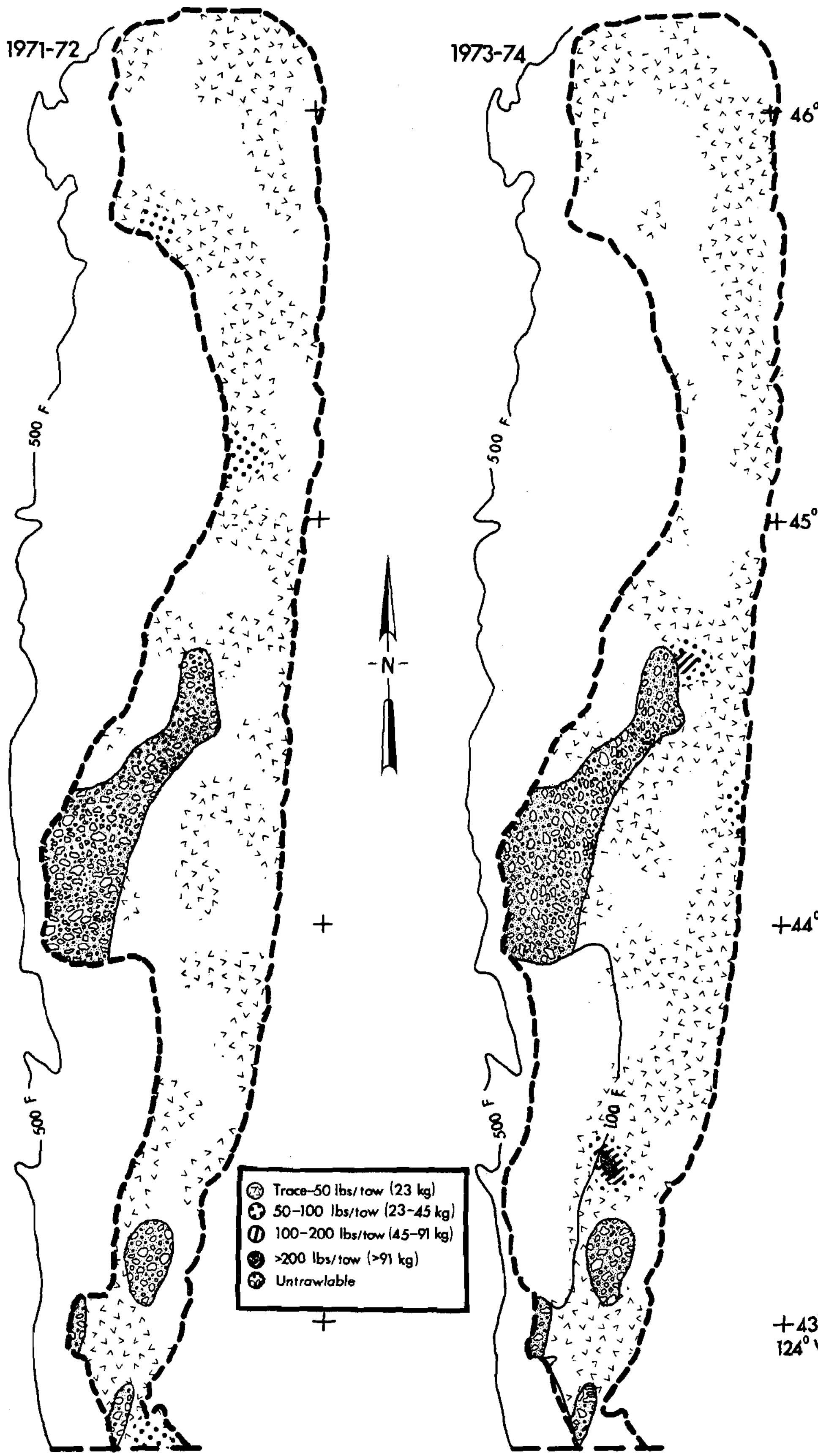

Figure 9. Distribution and relative abundance (weight) of lingcod in September 1971-72 and 1973-74 off Oregon as determined by groundfish surveys. Heavy broken line is limit of survey.

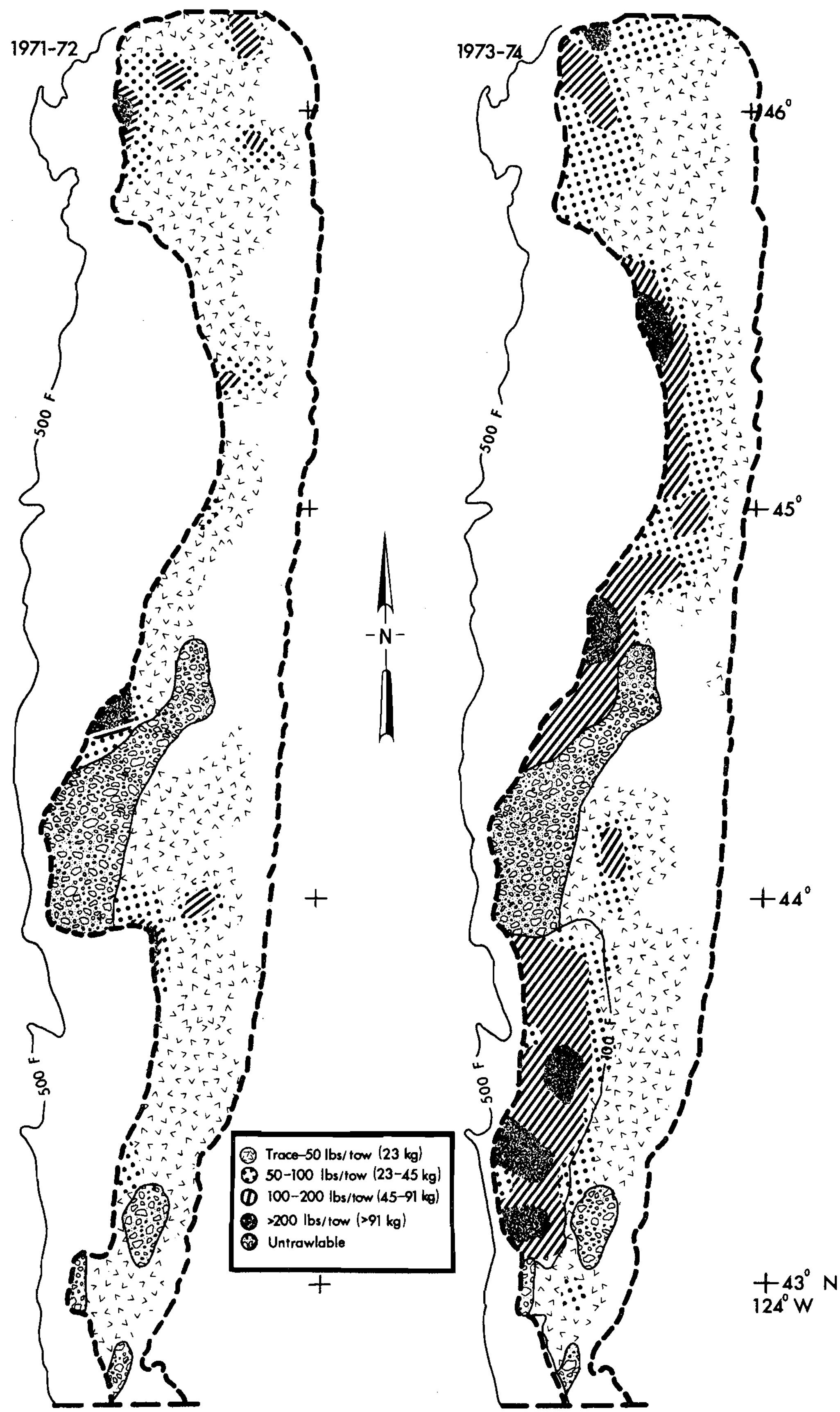

Figure 10. Distribution and relative abundance (weight) of sablefish in September 1971-72 and 1973-74 off Oregon as determined by groundfish surveys. Heavy broken line is limit of survey.

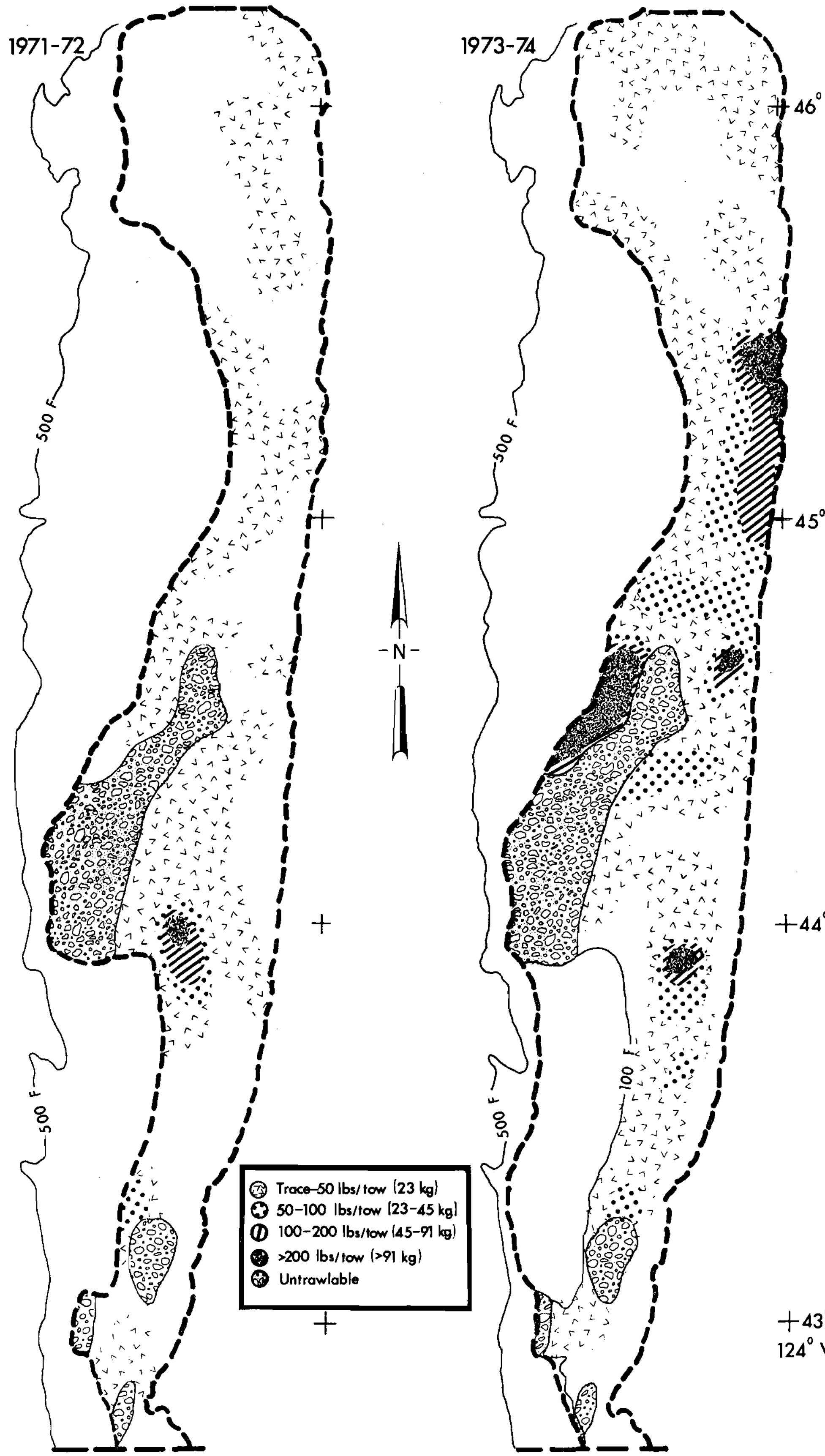

Figure 11. Distribution and relative abundance (weight) of spiny dogfish in September 1971-72 and 1973-74 off Oregon as determined by groundfish surveys. Heavy broken line is limit of survey.

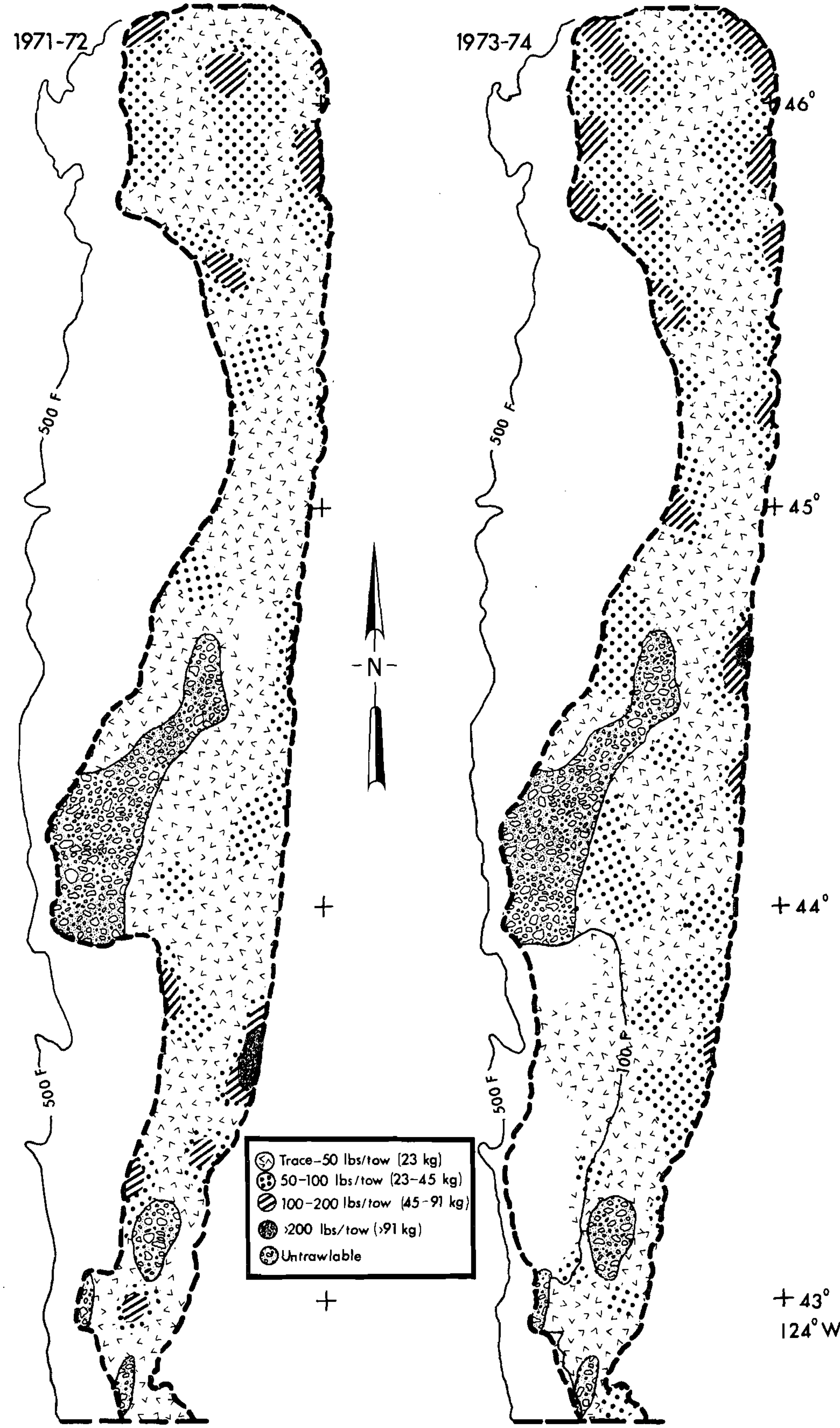

Figure 12. Distribution and relative abundance (weight) of skates in September 1971-72 and 1973-74 off Oregon as determined by groundfish surveys. Heavy broken line is limit of survey.

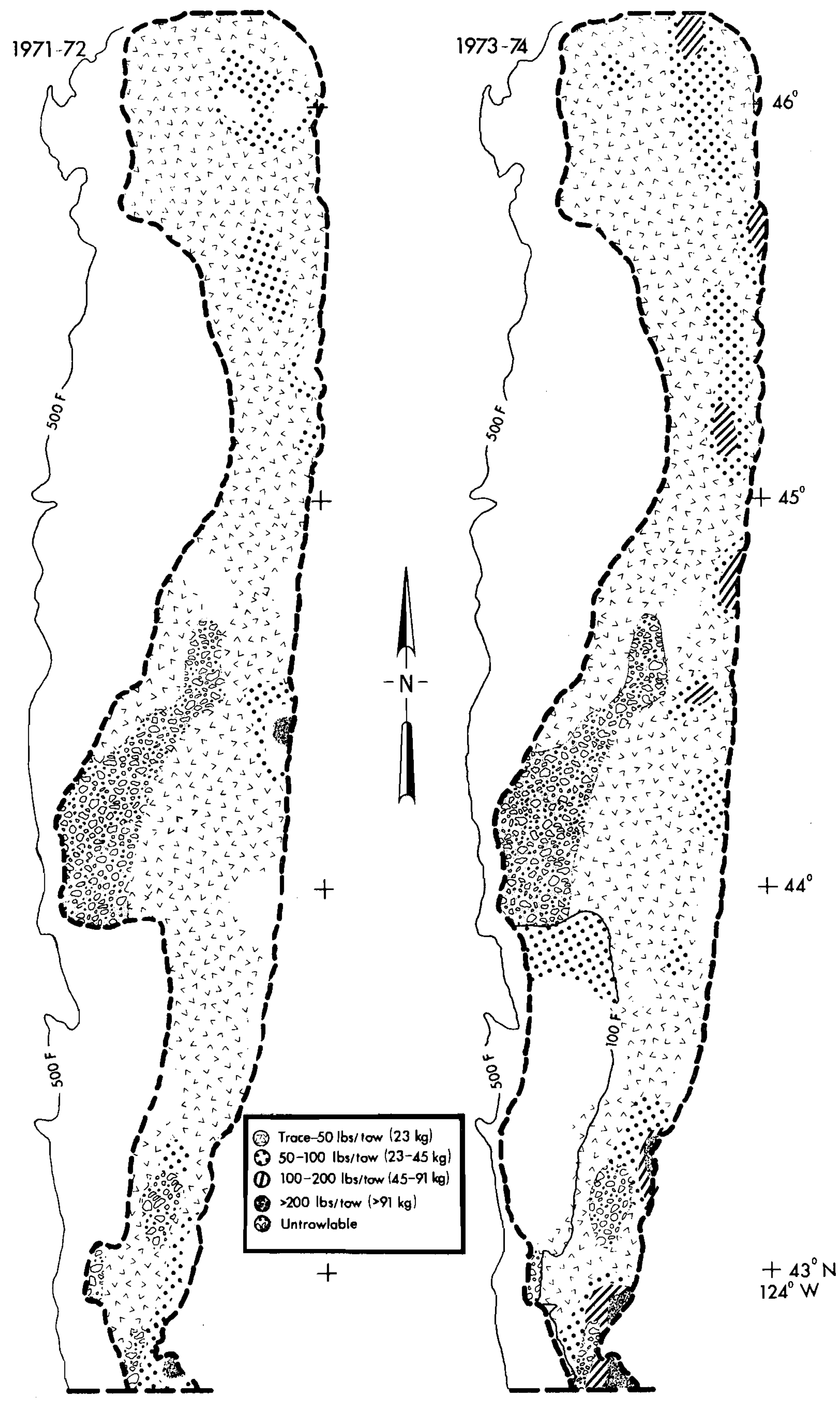

Figure 13. Distribution and relative abundance (weight) of ratfish in September 1971-72 and 1973-74 off Oregon as determined by groundfish surveys. Heavy broken line is limit of survey.

If catch maps are compared with distribution of sediment types (Figure 1) it is apparent that English sole and sanddab occurred mostly inshore over sand sediments, whereas Dover sole, arrowtooth flounder and sablefish were most abundant over mud sediments in deeper water.

Another view of distribution was obtained by plotting biomass against sediment type and depth. Benthic structure for the Oregon continental shelf have been delineated by major sediment types (Byrne and Panshin 1972). For the purpose of this report only mud and sand were used. For the area south of Heceta Bank at depths greater than 200 fm sediment type was assumed to be mud although sand patches do occur. There is a marked decline in the amount of sand with increasing depth and, conversely, a marked increase of mud with increasing depth (Figure 14, top left). When biomass of major species was categorized by depth and sediment type, definite preferences were shown by some species while other species were less affected by sediment type or depth.

Dover sole, arrowtooth flounder and sablefish were most abundant over mud sediment and depths greater than 60 fathoms. English sole, petrale sole and sanddab were more abundant at lesser depths where sand sediment was dominant. Other species of flatfish, not shown in Figure 14, but limited to shallow depths and sand sediments were butter sole, sand sole and starry flounder (*Platichthys stellatus*). Flathead sole and slender sole (not shown) were most often encountered over mud sediment in deeper strata. The other species shown in Figure 14 were more cosmopolitan, with depth, but ratfish (*Hydrolagus colliei*) were more abundant over sand sediment.

Although Figure 14 shows distribution by depth as well as abundance with depth and sediment type we still do not know which of the two factors control distribution. Since the amount of mud increases with depth, inversely to sand, it was not possible to separate the influence of depth from bottom sediment type on species distribution. For example, do English sole respond to shallow depth or to sand sediment? We suspect that other variables such as temperature, or more importantly, food availability or preference have greater influence in determining distribution. The latter factors may not be independent of depth or sediment either. Unfortunately the bottom temperatures taken did not allow correlation with distribution and we have inadequate data on food habits and prey distribution that would show us why species occur as they do.

Year Class Strength

A relative indicator of year class (brood year) strength was indicated by following year classes for the ten flatfish species over the four year survey period. A strong 1966 year class was common for five of the ten species. The 1968 year class showed well for English, petrale, rex, and butter sole. For petrale, and butter sole the 1970 year class also appeared to be strong (Figure 15). The 1961 year class, even though on 10-13 year old fish, was still noticeable in Dover, English, petrale, rex, and flathead sole. This year class was the strongest for Dover sole off Oregon since the 1942 year class. For arrowtooth flounder, the 1967 and 1969 year classes appeared to be prominent. The 1969 year class was also abundant in sand sole. No prominent year class was apparent for slender sole.

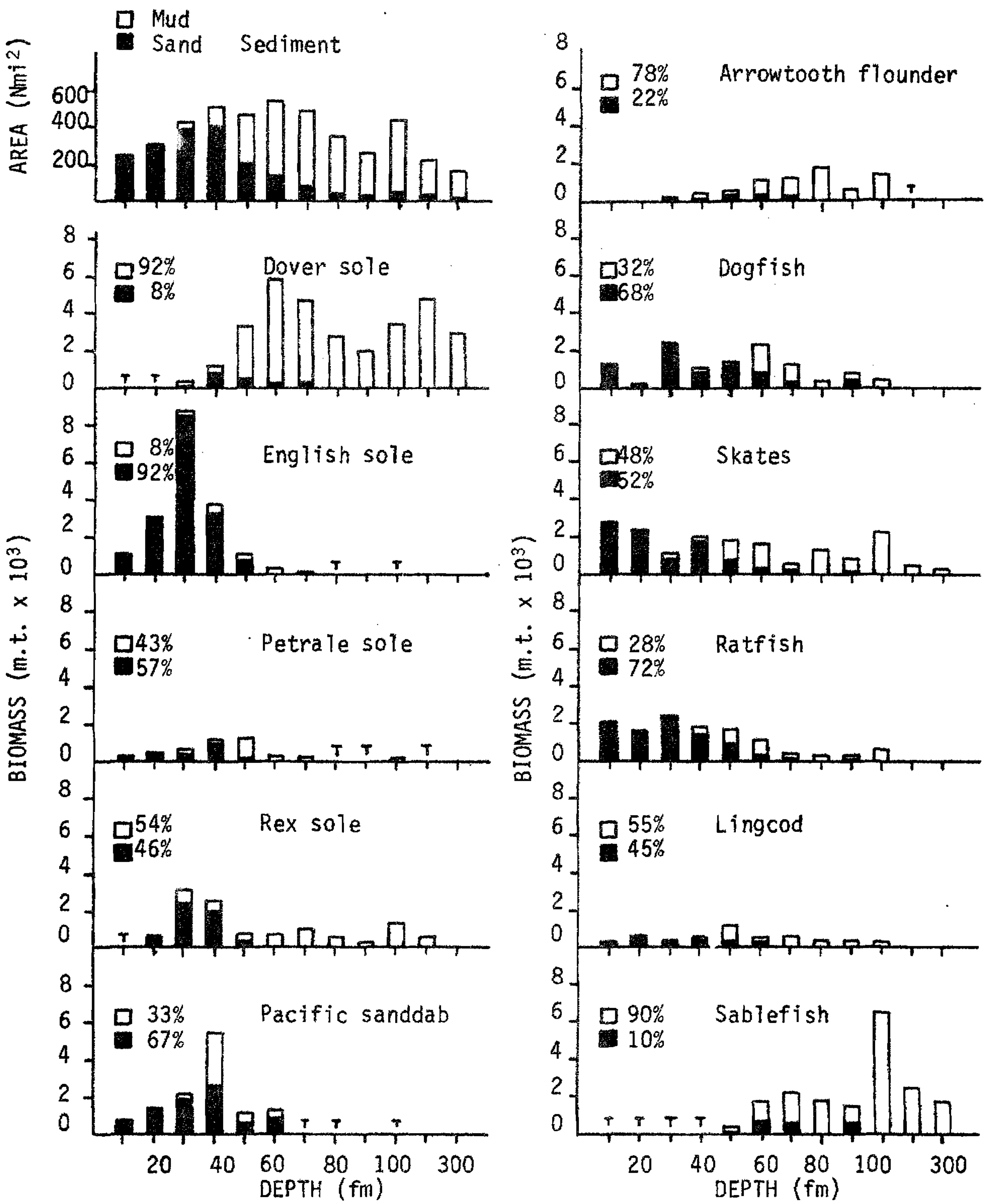

Figure 14. Correlation of abundance of selected species with depth and sediment type within depth 1973-74. Percent shows abundance related to sediment type. Note change in strata at 100 fm. T = <100 m.t.

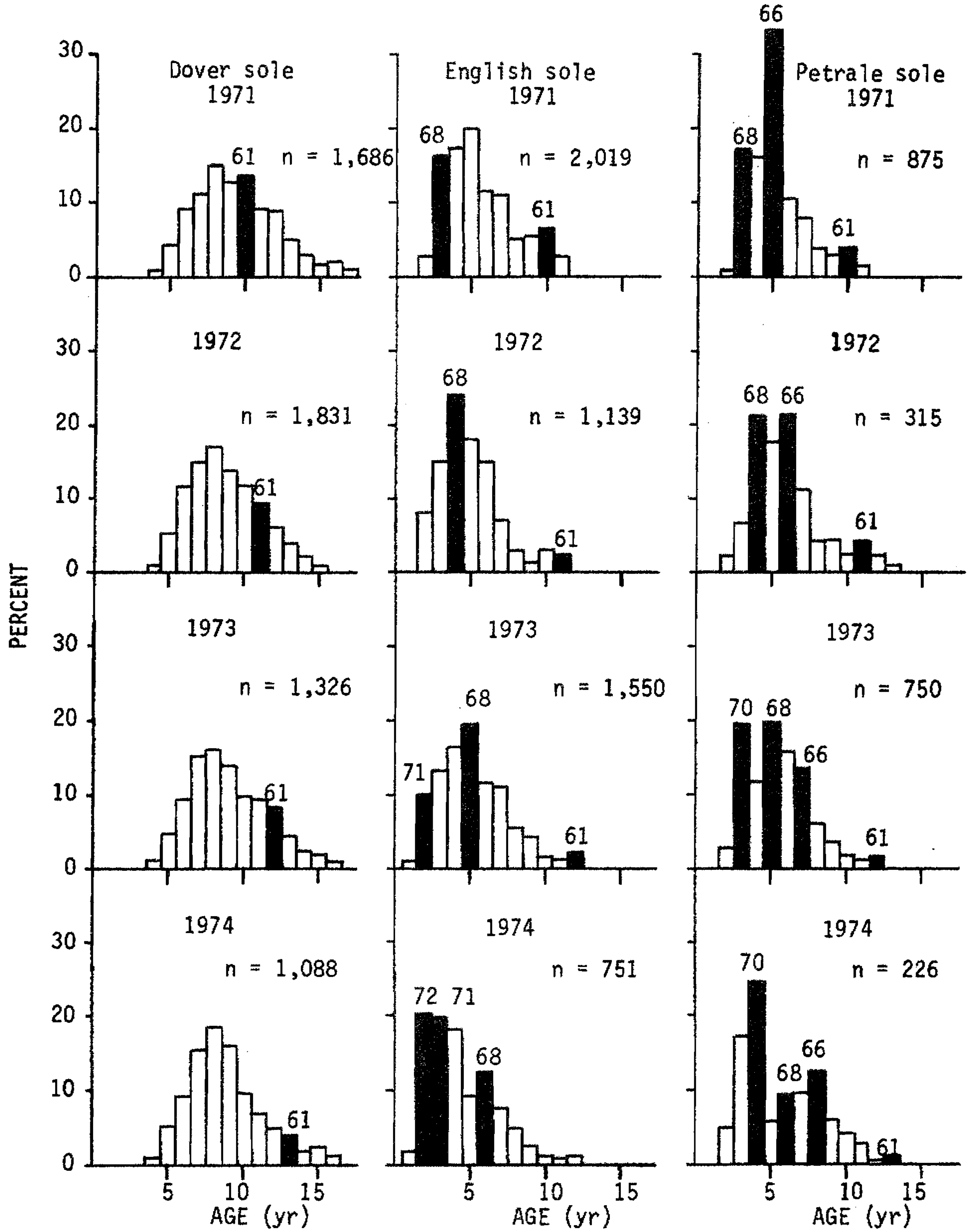

Figure 15. Year class strength (of ten flatfish species), as indicated by relative frequency 1971-1974. Age frequencies of <1 percent are not shown. Data applies only to continental shelf stations.

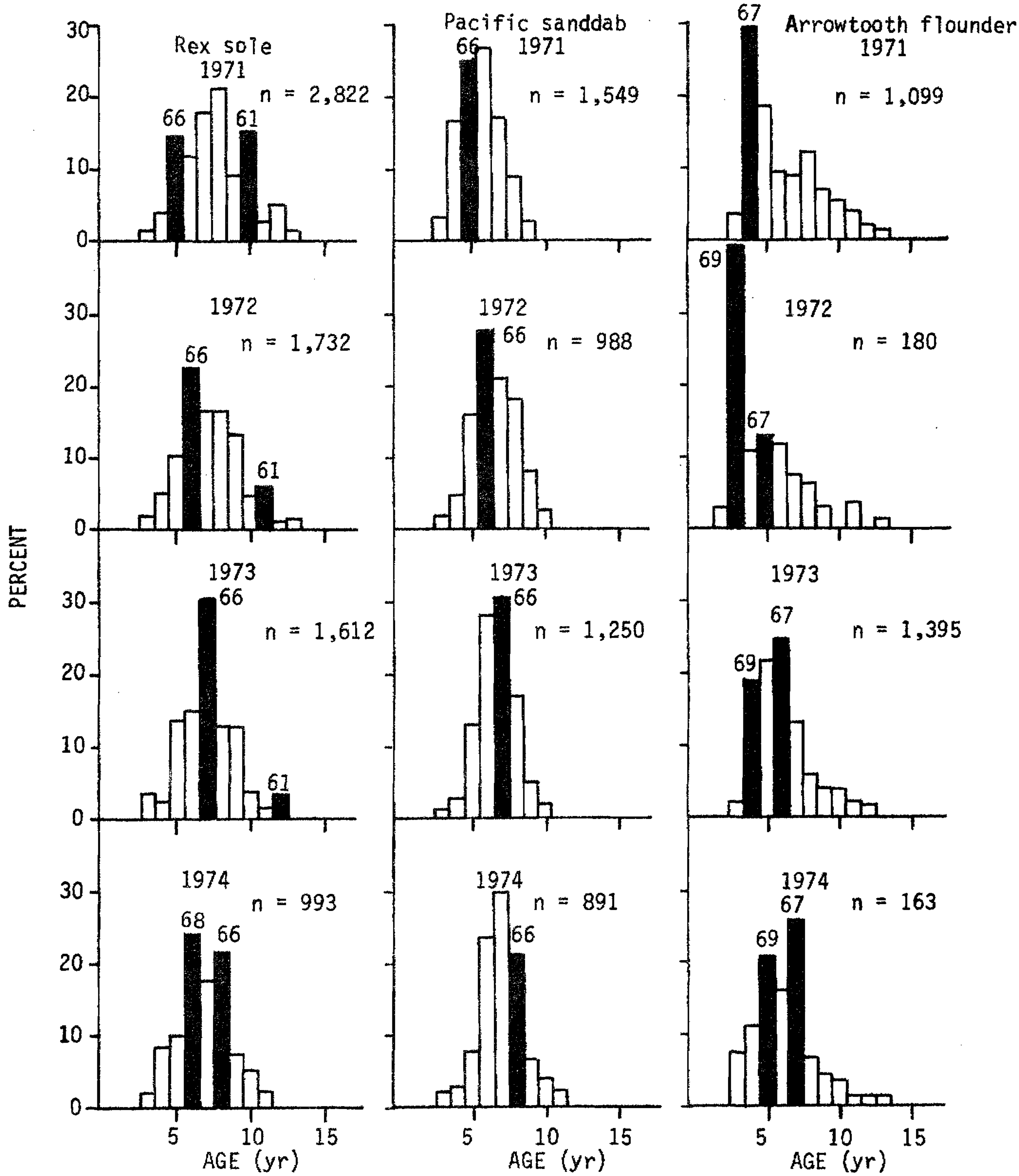

Figure 15. Continued.

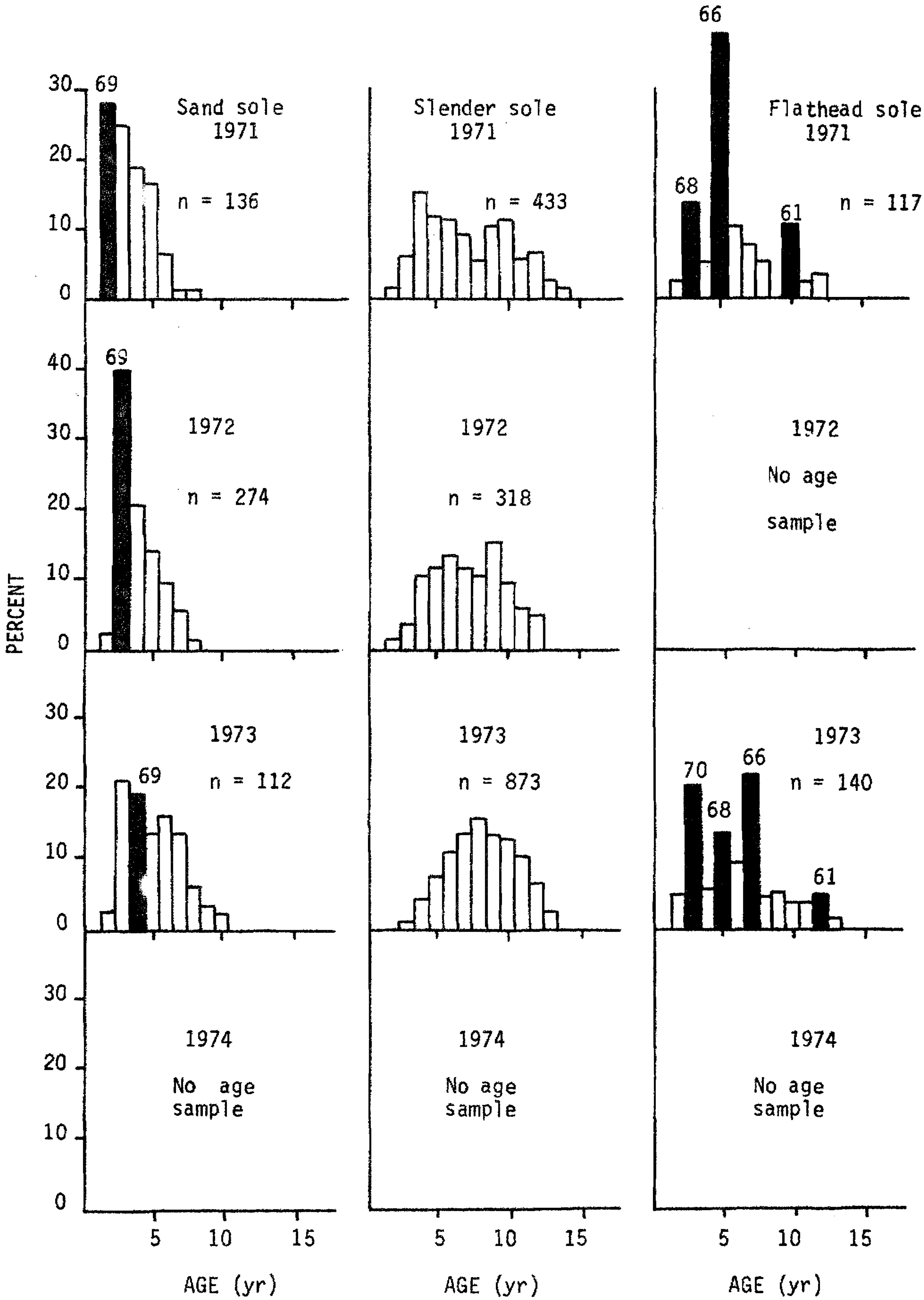

Figure 15. Continued.

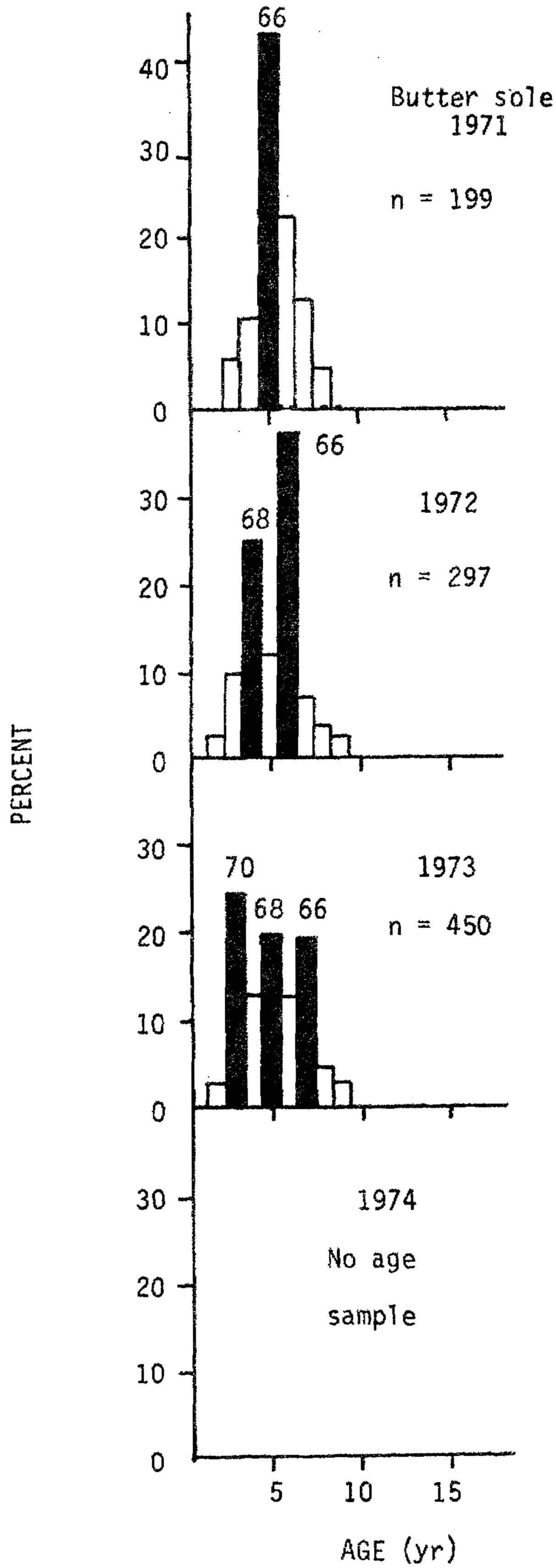

Figure 15. Continued.

Evaluation of Survey Design

As stated previously, the survey design was a systematic 5x5 N mi grid (a stratified random design was considered). A problem inherent in the systematic design is that hidden periodicities may align with sampling locations. Also, an unbiased estimate of population variance cannot be obtained. However, for samples of the same size, systematic sampling provides a more precise estimate of the population mean than does random sampling if there are consistent trends (gradients) or clustering of the values of y; that is, if values of y are not randomly distributed throughout the population (Sampford 1961). In our opinion, trawling intensity was such that statistical requirements were adequate for estimating biomass. Density of stations ranged from 1 tow per 14 N mi^2 to 34 N mi^2 in 1971-72 and from 1 tow per 11 N mi^2 to 50 N mi^2 in 1973-74 (Table 6). Overall, sampling density was about 1 tow per 27 N mi^2 and 25 N mi^2, respectively, in 1971-72 and 1973-74.

The biomass estimates may be precise, but since confidence intervals are overestimated by the systematic sample (assuming use of random sampling formulae) our ability to detect actual population changes was reduced (Cochran sp. cit.).

Evaluation of Sampling Methods

During the 1972 cruise, a series of tows was made where the entire catch of selected flatfish species was sexed and measured. The purpose of the experiment was to test the ability of the systematic sample to estimate sex ratio and length composition.

There were no significant differences in size composition between samples and the catch from which they were drawn (38 tests). Although age composition of the sample vs. age composition of the catch was not tested, it was assumed that if size composition was estimated, then age composition was also estimated. There were no significant differences in sex ratio.

The ability of the systematic sample to estimate number caught was not statistically tested. Because number caught was equal to the number in the sample multiplied by the sample rate, a limit of ±5 fish was set as acceptable for estimating total catch. Numbers caught were estimated within limits of ±5 fish in 33 of 38 cases tested. In fact, in 30 of the 38 cases, numbers caught were estimated within limits of ±2 fish. There were five cases where numbers estimated were in error, all attributable to human error. The error ranged from overestimating the catch by 69 fish to underestimating the catch by 83 fish. The mean difference was -5 fish. Weight caught was not tested, but it was assumed that if numbers caught were accurately estimated then weight caught would be accurately estimated. Of the five cases of sampling error just cited the error in weight ranged from -7.9 pounds to +45.6 pounds. The mean difference was +13.3 pounds.

Mistakes in recording proportion sampled and mistakes in counting the number to be sampled have the potential of serious error. For example, during the 1971-72 surveys 32 English sole catches were sampled in their entirety; these catches represented 30% of the English sole sampled, but only 8% of the English sole caught. At the other extreme, catches of English sole sampled at an intensity of 1:10 occurred nine times; the number of fish sampled was 18% of the total English sole

Table 6. Trawlable area (N mi^2) by depth strata, percent mud by strata, and area allocated per tow from Columbia River to Cape Blanco, 1971-74.

Depth Strata1/	Trawlable area2/	% Mud	N mi^2/tow			
			No. of tows	1971-72	No. of tows	1973-74
10-19	238.2	0	7	34.2	9	26.5
20-29	294.4	0	13	22.6	15	19.6
30-39	400.5	7	14	28.6	12	33.4
40-49	492.0	20	18	27.3	18	27.3
50-59	455.8	58	20	22.8	16	28.5
60-69	523.2	77	17	30.8	22	23.8
70-79	477.8	88	14	34.1	17	28.1
80-89	342.1	95	16	21.4	17	20.1
90-99	251.1	93	8	31.4	5	50.2
100-109	180.9	95	13	13.9	16	11.3
110-199	249.2	89	-	-	7	35.6
200-299	209.5	93	-	-	9	23.3
300-399	177.0	94	-	-	6	29.5
Total	4291.7	-	140	-	169	-
mean				26.7		25.4

1/ Continental slope limits (>110 fm.), 43° 57.5' N Lat. to 43° 2.5' N Lat.

2/ There were 606.4 N mi^2 of untrawlable area on the continental shelf.

sampled, but in terms of catch those nine samples represented nearly 50% of the total English sole caught (Table 7).

During cruises in 1973-74, sample rate was less variable. Proportions most frequently used were 1:4 and 1:5 (Table 8). For the surveys as a whole mean sample size ranged from 42 for Dover sole in 1971-72 (Table 7) to 12 for petrale sole in 1973-74 (Table 8).

In reviewing the literature, it was apparent that sampling methods have to be tailored to fit objectives of the program, bearing in mind that catch size, station pattern, manpower, etc., all have to be considered. We believe our method was adequate to fit our needs. The few really large catches that occurred were readily handled by the systematic scheme. As the tests showed, the systematic sample was able to depict certain attributes of the catch from which it was drawn, but sample size was fairly large, ranging from 26 to 79 fish. Smaller samples may not have given similar results.

Evaluation of Small Mesh Trawl

In initial planning it was decided to omit a fine mesh liner from the codend of the survey trawl. The rationale was that 3.5-in mesh would suffice. It was not certain what minimum size of fish would be caught but mesh size selection studies (Best 1961, Jurkovich 1954) indicated that the 3.5-in mesh would be a reasonable compromise. In 1972 a small mesh trawl (2.5-in mesh throughout) and a 2.5-in mesh codend attached to the body of the 3.5-in mesh survey trawl was tested against the 3.5-in mesh trawl. The purpose of the 2.5-in mesh codend was to simulate a liner.

The smaller mesh trawls usually caught smaller fish than did the 3.5-in mesh trawl. The exception was for slender sole, where the smaller fish were caught by the larger mesh. Within species, length frequency distributions of fish retained by the two smaller mesh trawls were similar. Length frequency distributions of arrowtooth flounder showed the least difference between mesh sizes. Another facet considered was how much additional work was required to process larger catches of smaller fish. For Dover sole, mean catch (per 0.75 N mi tow) was 51, 100 and 228 fish for the 3.5-in, 3.5x2.5-in, and 2.5-in trawls respectively, an increase of 2 to 4 times that of the survey trawl (Figure 16). The catch of English sole increased by nearly three times when the smaller mesh was used while the catch of sanddab increased by 8 and 10 times for the 3.5x2.5-in and 2.5-in mesh trawls respectively. Catches of rex sole and arrowtooth flounder increased by about twice when the smaller mesh was used. It was decided that the additional work load imposed by the use of a smaller mesh trawl was not worth the additional effort because the alternative was to sacrifice tows or develop a method to subsample the catch (unsuccessfully attempted in 1970).

A final view regarding mesh size, is what might happen to estimates of biomass and yield if a smaller mesh was used. Let us assume that the 3.5x2.5-in mesh trawl would approximate a trawl with a codend liner and let us further assume that the English sole catch for the 3.5x2.5-in mesh trawl (Figure 16) was from a square nautical mile. Results are as follows:

Mesh Size	Biomass	Usable Biomass	F	Yield
3.5-in	80 lbs.	29 lbs.	0.21	6 lbs.
3.5x2.5-in	158 lbs.	32 lbs.	0.21	6.8 lbs.

Table 7. Percent of total number sampled, percent of total catch, mean sample size and frequency of use of sampling ratios employed on groundfish survey, 1971-72.

Ratio of sample: catch	Species: Dover sole				English sole				Petrale sole			
	Freq.	% of sample	% of catch	mean n	Freq.	% of sample	% of catch	mean n	Freq.	% of sample	% of catch	Mean n
All	40	43.2	19.3	38	32	29.9	7.8	30	83	85.3	59.7	12
1/2	19	24.1	21.5	45	14	19.1	10.0	43	2	5.7	8.0	34
1/3	16	21.5	28.9	47	12	15.9	12.4	42	2	4.8	10.1	29
1/4	2	3.1	5.6	55	8	10.0	10.4	40	-	-	-	-
1/5	5	6.0	13.6	42	2	3.5	4.6	56	1	4.2	14.7	50
1/6	-	-	-	-	1	1.4	2.2	45	-	-	-	-
1/7	-	-	-	-	1	1.1	2.1	35	-	-	-	-
1/8	-	-	-	-	1	0.9	2.0	29	-	-	-	-
1/10	3	2.1	9.4	25	9	18.2	47.4	64	-	-	-	-
1/15	-	-	-	-	-	-	-	-	-	-	-	-
1/20	-	-	-	-	-	-	-	-	-	-	-	-
Total	85	3,530	7,886	42	80	3,187	12,205	40	88	1,190	1,700	14
% of total catch sampled		45				26				70		

Table 7. Continued.

Ratio of sample: catch	Species											
	Rex sole				Pacific sanddab				Arrowtooth flounder			
	Freq.	% of sample	% of catch	mean n	Freq.	% of sample	% of catch	mean n	Freq.	% of sample	% of catch	mean n
All	67	47.7	18.3	34	41	48.9	15.8	34	36	62.2	40.2	22
1/2	19	18.3	14.0	46	13	20.9	13.5	46	13	30.1	38.9	30
1/3	16	13.3	15.3	39	3	3.9	3.8	37	4	6.9	13.4	22
1/4	5	3.6	5.6	34	3	4.8	6.1	45	-	-	-	-
1/5	11	10.0	19.2	43	5	8.8	14.2	50	1	0.8	2.7	10
1/6	1	0.8	1.9	38	-	-	-	-	-	-	-	-
1/7	-	-	-	-	-	-	-	-	-	-	-	-
1/8	1	1.1	3.2	52	3	4.0	10.3	38	-	-	-	-
1/10	6	4.7	18.0	37	3	5.0	16.2	47	-	-	-	-
1/15	-	-	-	-	3	3.5	17.1	33	-	-	-	-
1/20	1	0.5	3.7	24	1	0.2	1.6	6	-	-	-	-
Total	127	4,740	12,352	37	75	2,842	8.787	38	54	1,300	2,012	24
% of total catch sampled		38				32				65		

Table 8. Percent of total number sampled, percent of total catch, mean sample size and frequency of use of sampling ratios employed on groundfish surveys, 1973-74.

	Species											
Ratio of Sample: catch	Dover sole				English sole				Petrale sole			
	Freq.	% of sample	% of catch	Mean n	Freq.	% of sample	% of catch	Mean n	Freq.	% of sample	% of catch	Mean n
1:1	-	-	-	-	-	-	-	-	28	47.7	30.5	17
1:2	-	-	-	-	-	-	-	-	55	52.3	67.0	9
1:3	-	-	-	-	-	-	-	-	-	-	-	-
1:4	134	83.0	65.7	20	19	19.3	10.8	24	-	-	-	-
1:5	11	14.7	25.0	44	47	52.0	36.4	26	-	-	-	-
1:10	2	2.3	7.8	38	6	18.9	26.5	73	-	-	-	-
1:15	-	-	-	-	1	1.8	3.8	42	-	-	-	-
1:20	-	-	-	-	2	7.9	22.2	92	-	-	-	-
Total	147	3,385	9,626	22	75	2,321	16,592	31	83	986	1,540	12
% of total catch sampled		34.1				14.0				64.0		

	Species											
Ratio of sample: catch	Rex sole				Pacific sanddab				Arrowtooth flounder			
	Freq.	% of sample	% of catch	Mean n	Freq.	% of sample	% of catch	Mean n	Freq.	% of sample	% of catch	Mean n
1:1	-	-	-	-	-	-	-	-	-	-	-	-
1:2	-	-	-	-	-	-	-	-	102	99.9	99.7	16
1:3	-	-	-	-	-	-	-	-	-	-	-	-
1:4	-	-	-	-	19	40.9	26.3	52	1	0.01	0.03	2
1:5	137	87.6	71.9	19	52	40.9	32.8	19	-	-	-	-
1:10	5	8.2	13.4	48	5	11.0	17.7	53	-	-	-	-
1:15	-	-	-	-	-	-	-	-	-	-	-	-
1:20	3	4.3	14.0	42	2	7.2	23.0	87	-	-	-	-
Total	164	2,927	17,843	18	78	2,403	14,970	31	103	1,608	3,296	16
% of total catch sampled		16.4				16.1				48.8		

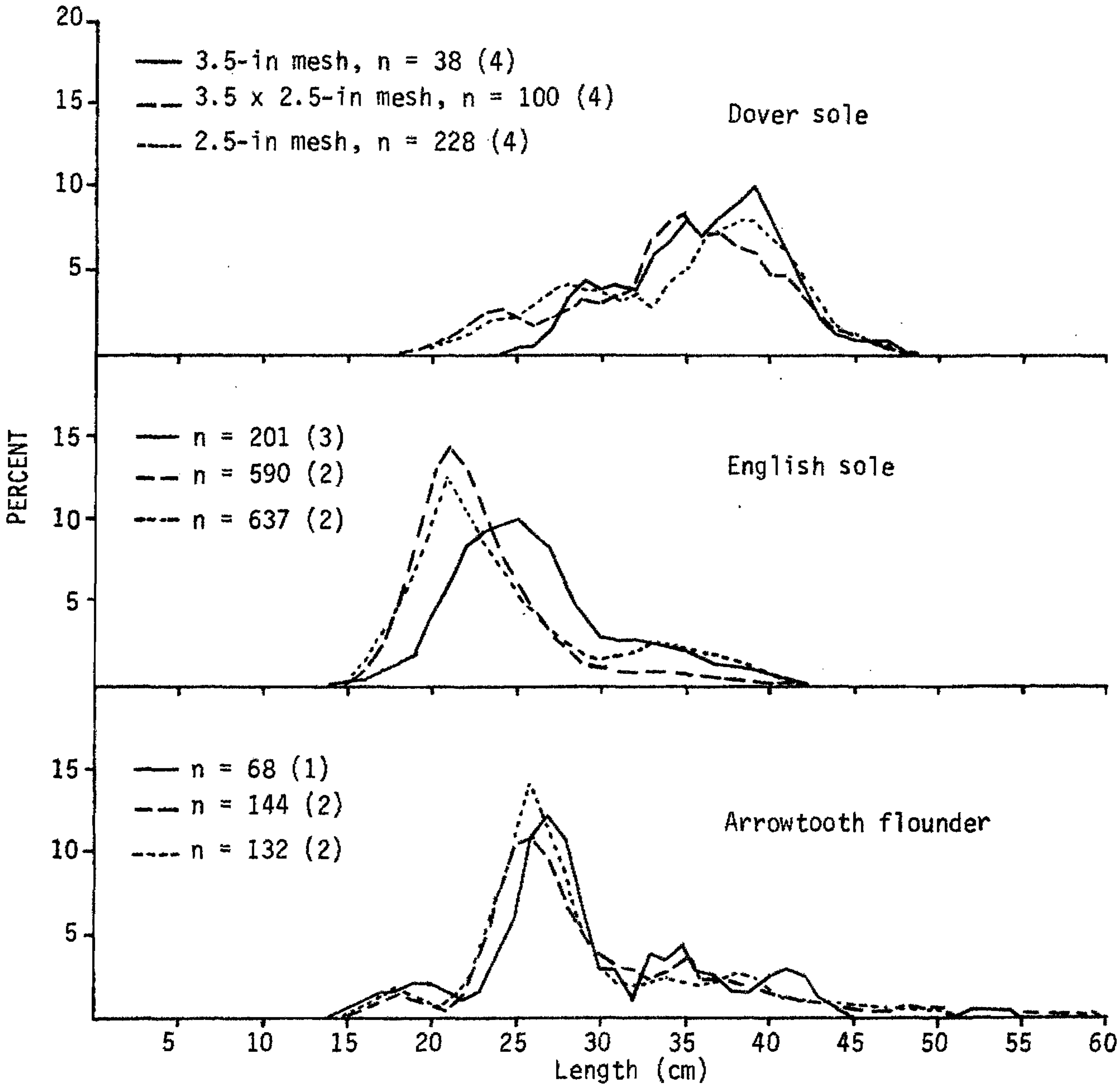

Figure 16. Length-frequency distributions of selected species of flatfish caught by three different mesh sizes, September 1972. n = mean number caught/0.75 N mi tow. Number of tows in parentheses.

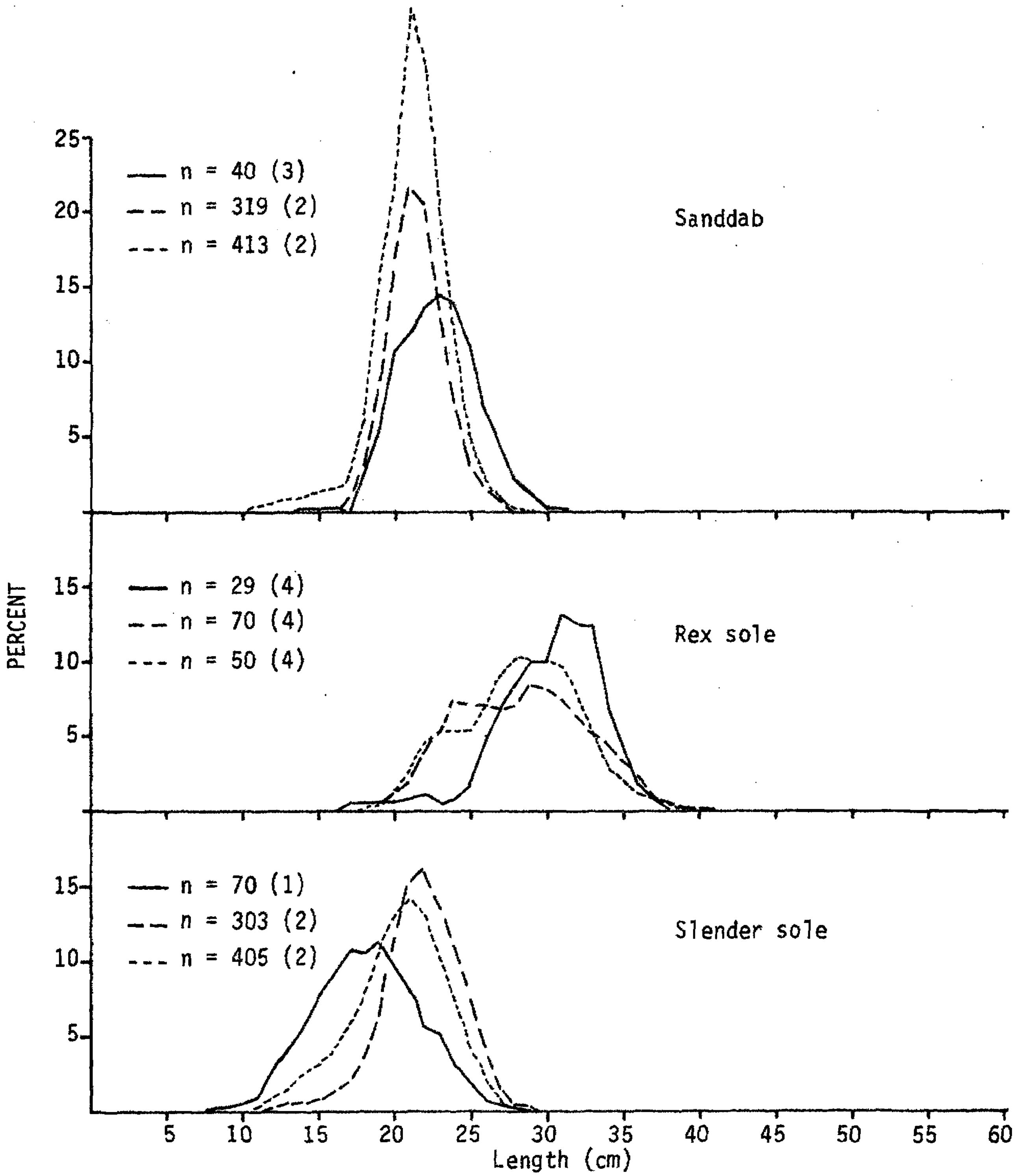

Figure 16. Continued.

The initial biomass was nearly doubled by use of the smaller mesh but usable biomass and yield (F from Table 5) were similar. This simple example is not meant to justify our not using a liner. The objectives of the program must dictate, in part, whether or not a liner is used. We chose not to use a codend liner even though we compromised our ability to collect better data on recruitment and better index incoming year classes. On the credit side we were able to maintain a higher level of effort (number of tows) which we felt was the over-riding criterion.

Length of Tow Experiments

The purpose of the length of tow experiments was to test whether length of tow would influence length of fish caught. There was some indication that this was possible (Clark 1963). This view was also expressed by some commercial fishermen.

Results were inconclusive. Regarding the 3.5-in mesh trawl, mean length of fish from a 1.50 N mi tow was greater for 5 of 6 species (Table 9). Three species showed a significant increase in mean length. Regarding the 3.5x2.5-in mesh trawl there were only two cases where mean length was greater with the longer tow, but four cases (all significant) where the mean length was less. Mean length of fish caught on the longer tow by the 2.5-in mesh trawl was greater in three cases (two were significant) and in three cases mean length was less (one was significant).

Between trawl types, only Dover sole showed a greater mean length associated with the longer tow. Mean length of the other species showed both a greater and lesser mean length associated with the longer tow.

Table 9 also shows number of fish caught by the two different-length tows for the three trawl types. In all cases the longer tow caught more fish. In five cases, the catch was doubled or more so. Overall, the catch from the longer tow increased by a factor of 1.2 to 1.6.

Costs

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

Budget Category	FY 1972	FY 1973	FY 1974	FY 1975
Personal Services	$43,552	$44,255	$43,634	$43,691
Contractual Services	25,205	23,994	22,136	21,282
Equipment & Supplies	5,762	2,324	8,499	3,399
Overhead	8,000	7,630	10,161	10,140
Miscellaneous	4,019	4,688	1,164	3,302
Total	$86,538	$82,891	$85,594	$81,814

Table 9. Summary of length of tow experiments: mean length (cm) at two tow lengths for three different mesh sizes and number of tows and fish, September 1972.

Species	3.5-in mesh Length of Tow 0.75 N mi	3.5-in mesh 1.50 N mi	Dev.1/	3.5x2.5-in mesh Length of Tow 0.75 N mi	3.5x2.5-in mesh 1.50 N mi	Dev.	2.5-in mesh Length of Tow 0.75 N mi	2.5-in mesh 1.50 N mi	Dev.
	Mean Length			Mean Length			Mean Length		
Dover sole	36.0	37.0	+1.0	34.5	34.8	+0.3	34.9	36.0	+1.1*
English sole	26.2	26.5	+0.3	23.0	23.8	+0.8*	24.6	24.1	-0.5*
Rex sole	30.1	30.9	+0.8*	28.5	27.1	-1.4*	28.2	27.6	-0.6
Pacific sanddab	22.8	22.4	-0.4	21.6	21.4	-0.2	21.2	21.3	+0.1
Arrowtooth flounder	42.9	34.2	+4.6*	30.0	28.4	-1.6*	29.5	28.8	-0.7
Slender sole	18.2	19.4	+1.2*	21.8	20.1	-1.7*	20.2	20.7	+0.5*
	No. tows/No. fish			No. tows/No. fish			No. tows/No. fish		
Dover sole	4/153	4/260	(1.70)2/	4/398	4/504	(1.28)2/	4/913	411,972	(2.16)2/
English sole	3/602	3/912	(1.51)	2/1,179	2/1,244	(1.06)	2/1,274	2/2,217	(1.74)
Rex sole	4/116	4/138	(1.19)	4/281	4/415	(1.48)	4/201	4/409	(2.03)
Pacific sanddab	3/119	3/237	(1.99)	2/637	2/855	(1.34)	2/825	2/1,740	(2.11)
Arrowtooth flounder	1/68	1/101	(1.49)	2/287	2/426	(1.48)	2/263	2/399	(1.52)
Slender sole	1/70	1/164	(2.34)	2/605	1/729	(1.20)	2/810	2/1,289	(1.59)
Total fish	1,128	1,812	(1.61)	3,387	4,173	(1.23)	4,286	7,026	(1.64)

* Significant at 95%

1/ Deviation: 1.50 mi tow - 0.75 mi tow

2/ Numbers in parentheses is magnitude of increase in catch size of 1.50 mi tow over 0.75 mi tow.

SUMMARY

A comprehensive marine resource survey was conducted on the continental shelf and upper continental slope off Oregon from 1971-74. Objectives were to estimate biomass of species susceptible to capture by an on-bottom trawl, with particular emphasis on flatfish; to index year class strength of important flatfish; and to obtain estimates of age composition, growth and mortality.

The survey was a systematic design based on a 5x5 N mi grid with a random starting point. Catches of flatfish were sampled systematically.

Estimates of biomass were determined by first stratifying the survey area into depth strata, then calculating the stratified mean catch per standard tow by weighting each stratum mean by the stratum area divided by the total area.

Estimates of usable or marketable biomass were determined by applying an age-specific utilization rate and age-specific mean weight to estimated biomass. Estimates of yield were determined by multiplying usable biomass by estimated instantaneous fishing mortality rate, F.

Total biomass (all species) was estimated at 283,750 m.t. in 1971-72, and 235,117 m.t. in 1973-74. Flatfish comprised 30 and 34% of the total biomass in 1971-72 and 1973-74 respectively. Dover sole was the major species. Usable biomass for principal species of flatfish ranged from 23,266 m.t. for Dover sole to 2,885 m.t. for petrale sole.

Estimates of potential annual yield ranged from 3,500 m.t. for Dover sole to 800 m.t. for petrale sole. Species offering the greatest potential increase were English sole, rex sole and Pacific sanddab. We concluded that increases in yield could be obtained without increasing fishing rate if species caught were more intensively utilized.

Distribution of some species indicated definite preferences for depth and sediment type, or both, while other species did not. English sole and Pacific sanddab occurred mostly over sand sediments in shallower water while Dover sole and arrowtooth flounder occurred mostly over mud sediments in deeper water.

Strong year classes were evident for most species. The year classes of 1961, 1966, and 1968 were most prominent.

The systematic design of the survey coupled with the intensity of sampling was adequate to reliably estimate abundance. Confidence limits, though usually less than ±50% for major species, were probably over-estimated by the systematic design; thus our ability to detect population changes was reduced.

Catch sampling methods were tested. Size composition, sex ratio and numbers caught were adequately estimated.

Tests conducted with small mesh trawls indicated initial estimates of biomass might double, but usable biomass and yield would be similar when compared to estimates based on the survey trawl. We concluded that the additional work required to process larger catches made by the small mesh trawls would effect an unacceptable

sacrifice in the number of tows made. The survey trawl caught adequate numbers of juvenile fish to enable indexing of incoming year classes.

Length of tow experiments were, in part, inconclusive, however, results indicated that increasing length of tow in some cases, increased the mean length of fish captured. We concluded that additional work is required to develop standardized survey techniques.

Sex-specific estimates of age structure for ten species of flatfish (Dover, English, rex, petrale, slender, butter, flathead and sand sole; Pacific sanddab and arrowtooth flounder) were obtained. For all but flathead and butter sole, von Bertalanffy growth constants (L_∞, K, t_o); length-weight relationships; total and fishing mortality rates (Z,F); and exploitation rates (u) were estimated. By subtraction (Z-F), estimates of instantaneous natural mortality rate (M) can be obtained.

Recommendations

1. We recommend that the surveys of the type described in this report be repeated biennially with a reduced sampling intensity. Surveys of this type can more reliably measure stock status than the traditional use and analysis of commercial fishery statistics.

2. Additional work should be done on standardizing and testing survey methods, especially length of tow and type of footrope.

3. The systematic sampling design is more convenient than random sampling; it is adequate for the purpose of documenting demersal fish stock status, and should be utilized in future such surveys; it is especially useful in species assemblage (Personal Comm., A.V. Tyler, Oregon State University).

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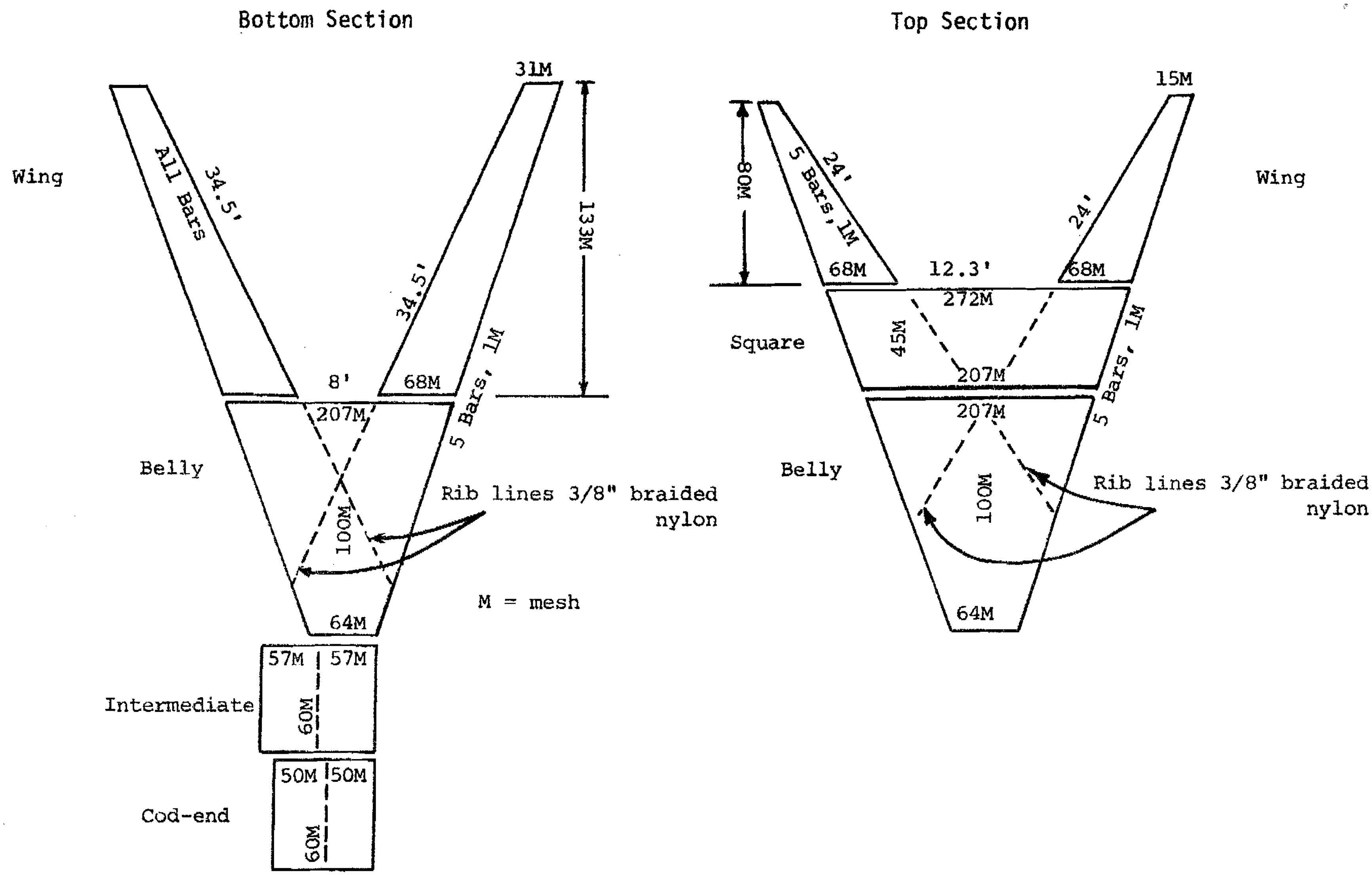

Appendix 1. Schematic diagram of trawl used on Oregon ground fish surveys, 1971-74. (Adapted after Greenwood 1958).

Appendix 1. Continued. Specifications of trawl used on Oregon groundfish surveys, 1971-74.

Type:	400 mesh eastern
Wings, square, belly:	3.5-in mesh (stretched measure), 42 thread nylon.
Intermediate:	3.5-in mesh, 60 thread nylon.
Codend:	3.5-in mesh, 96 thread nylon.
Sweep lines:	bridles, 10 fm x 3/8-in wire; dandy lines, 5 fm x 3/8-in wire.
Headrope:	60-ft 4-in plus eyes, 3/8-in galvanized wire rope wrapped with 1/4-in polypropylene.
Floats:	8-in, spherical, evenly spaced on headrope. Eleven used in 1971-72, 12 in 1973, 13 in 1974. In 1974 on tows >110 fm 20 8-in and 2 10-in floats were used.
Footrope:	77-ft plus eyes, 1/2-in galvanized wire rope wrapped with 3/8-in polypropylene. In 1971-72 50 pounds of chain attached. In 1973-74 a second footrope of 3/8-in chain threaded through 4.5-in rubber discs was used. Roller gear used in 1974 was made up of 2, 18-in rubber wheels, 10, 14-in wing bobbins and 1, 18-in bobbin attached to each wing tip (Gunderson, 1969).
Tickler chain:	70-ft x 5/16-in attached to each wing tip.

Appendix 2. Preliminary estimates of Length-Weight and Von Bertalanffy Age-Length Growth Constants of Flatfish Taken on Groundfish Surveys; 1971-74.

Species	Length-Weight Constants a	b	Von Bertalanffy Age-Length Constants L_∞	K	t_0
Dover sole					
Males	-1.8730	2.8911	44.08	0.2186	-0.02
Females	-1.9927	2.9655	60.70	0.1110	-0.18
English sole					
Males	-2.1067	3.0132	36.30	0.2560	-1.08
Females	-2.6579	3.4003	46.70	0.1430	-4.67
Petrale sole					
Males	-2.3947	3.2812	45.40	0.2018	-1.82
Females	-2.5264	3.3760	54.40	0.2119	+0.08
Rex sole					
Males	-3.0659	3.5428	31.10	0.2274	-0.36
Females	-3.0460	3.5269	38.50	0.1454	-1.19
Arrowtooth flounder					
Males	-2.0566	2.9822	43.10	0.3481	-1.37
Females	-2.5727	3.3160	68.80	0.1562	-0.46
Pacific sanddab					
Males	-2.3662	3.2323	24.60	0.3801	+0.16
Females	-2.6672	3.4708	29.50	0.3073	+0.13
Sand sole					
Males	-1.7681	2.8484	41.70	0.4328	+0.34
Females	-2.1839	3.1285	46.10	0.4565	+0.31
Slender sole					
Males	-2.5770	3.2440	27.40	0.1634	-2.17
Females	-2.6083	3.2632	29.50	0.1833	-1.44
Butter sole					
Males	Insufficient data		Insufficient data		
Females	-1.9896	2.9424	Insufficient data		
Flathead sole	Insufficient data				

Appendix 3. List of Common and Scientific Names.

Common Name	Scientific Name
Spiny dogfish	*Squalus acanthias*
Big skate	*Raja binoculata*
Black skate	*R. kincaidi*
Longnose skate	*R. rhina*
Ratfish	*Hydrolagus colliei*
Pacific hake	*Merluccius productus*
Pacific cod	*Gadus macrocephalus*
Rougheye rockfish	*Sebastes aleutianus*
Pacific ocean perch	*S. alutus*
Aurora rockfish	*S. aurora*
Redbanded rockfish	*S. babcocki*
Silvergrey rockfish	*S. brevispinis*
Darkblotched rockfish	*S. crameri*
Splitnose rockfish	*S. diploproa*
Greenstriped rockfish	*S. elongatus*
Widow rockfish	*S. entomelas*
Yellowtail rockfish	*S. flavidus*
Rosethorn rockfish	*S. helvomaculatus*
Black rockfish	*S. melanops*
Bocaccio	*S. paucispinis*
Canary	*S. pinniger*
Redstripe rockfish	*S. proriger*
Yellowmouth rockfish	*S. reedi*
Turkey-red rockfish	*S. ruberrimus*
Stripetail rockfish	*S. saxicola*
Sharpchin rockfish	*S. zacentrus*
Shortspine thornyhead	*Sebastolobus alascanus*
Sablefish	*Anoplopoma fimbria*
Lingcod	*Ophiodon elongatus*
Pacific sanddab	*Citharichthys sordidus*
Arrowtooth flounder	*Atheresthes stomias*
Petrale sole	*Eopsetta jordani*
Rex sole	*Glyptocephalus zachirus*
Flathead sole	*Hippoglossoides elassodon*
Butter sole	*Isopsetta isolepis*
Rock sole	*Lepidopsetta bilineata*
Slender sole	*Lyopsetta exilis*
Dover sole	*Microstomus pacificus*
English sole	*Parophrys retulus*
Starry flounder	*Platichthys stellatus*
Curlfin sole	*Pleyronichthys decurrens*
Sand sole	*Psettichthys melanosticus*
Halibut	*Hippoglossus stenolepis*