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Distribution of Demersal Fishes in Hecate Strait, British Columbia, Based on Systematic Trawl Surveys Conducted From 1984-1987

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DISTRIBUTION OF DEMERSAL FISHES IN HECATE STRAIT, BRITISH COLUMBIA, BASED ON SYSTEMATIC TRAWL SURVEYS CONDUCTED FROM 1984-1987

by

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ABSTRACT

Fargo, J., A. V. Tyler and R. P. Foucher. 1990. Distribution of demersal fishes in Hecate Strait, British Columbia, based on systematic trawl surveys conducted from 1984-1987. Can. Fish. Aquat. Sci. Tech. Rep. 1745: 115 p.

Abundance and distribution of 14 major species in the Hecate Strait region were examined by season using survey catch rate data. Stable patterns of seasonal distribution were found for spiny dogfish, Pacific sanddab, arrowtooth flounder, and petrale sole. Big skate, rex sole, Pacific halibut, rock sole, Dover sole, and English sole showed some consistencies among surveys, but also enough variability in distribution that no definite conclusions can be drawn at this point. Ratfish, Pacific cod, Pacific ocean perch, and sablefish showed high variability in distribution among surveys. Estimates of standing crop calculated from survey data indicated that the most abundant species in summer were arrowtooth flounder and spiny dogfish, while big skate, ratfish, and English sole predominated in winter. Decreasing abundance between 1984 and 1987 was observed for spiny dogfish, English sole, ratfish, Pacific halibut, rock sole, Pacific sanddab, and petrale sole. Dover sole and rex sole appeared to be increasing in abundance between 1984 and 1987, while sablefish, big skate and arrowtooth flounder were at stable levels of abundance over the same time period.

RÉSUMÉ

Fargo, J., A. V. Tyler and R. P. Foucher. 1990. Distribution of demersal fishes in Hecate Strait, British Columbia, based on systematic trawl surveys conducted from 1984-1987. Can. Fish. Aquat. Sci. Tech. Rep. 1745: 115 p.

On a examiné l'abondance et la distribution de 14 espèces majeures de la région du détroit d'Hécate selon les saisons et à partir de taux de captures au cours de relevés. On a observé des variations stables de la distribution saisonnière dans le cas de l'aiguillat commun, de la limande sordide, de la plie à grande bouche et de la plie de Californie. On a observé une certaine régularité d'un relevé à l'autre, mais aussi assez de variabilité de la distribution pour qu'il soit impossible de parvenir pour l'instant à des conclusions certaines dans le cas de la raie tachetée, de la sole américaine, du flétan du Pacifique, de la sole de roche, de la sole du Pacifique et de la sole anglaise. Il y avait des variations considérables dans la distribution, d'un relevé à l'autre, dans le cas du rat de mer, de la morue du Pacifique, du sébaste du Pacifique et de la morue charbonnière. Selon les estimations de la biomasse calculées à partir des résultats obtenus grâce au relevés, il semble que les espèces les plus abondantes l'été étaient la plie à grande bouche et l'aiguillat commun alors que la raie tachetée, le rat de mer et la sole anglaise prédominaient l'hiver. On a observé une diminution de l'abondance entre 1984 et 1987 chez l'aiguillat commun, la sole anglaise, le rat de mer, la morue du Pacifique, la sole de roche, la limande sordide et la plie de Californie. La sole du Pacifique ainsi que la sole américaine semblent être devenues plus abondantes entre 1984 et 1987, alors que la morue charbonnière, la raie tachetée et la plie à grande bouche n'ont pas varié en abondance durant cette période.

INTRODUCTION

This report contains information concerning seasonal and annual trends in abundance and bathymetric distributions for 14 major species in the Hecate Strait region. During the last four decades, many demersal trawl surveys have been conducted in Hecate Strait (Ketchen 1956, Ketchen 1964, Thomson 1965, Westrheim et al. 1980, Stocker et al. 1981, Thompson et al. 1981, Fargo et al. 1982a, Fargo et al. 1982b, Fargo et al. 1983, McFarlane et al. 1984, Fargo et al. 1985). The purpose of these surveys was to assess the fishery resource of this region. Each survey was designed to provide information about a particular demersal fish species, though they were not comprehensive enough to include weights for all species caught. Through the analysis of these survey data, it became evident that there were homogeneous groups of fauna within the region that were distributed as distinct communities. Since regional productivity could well be a function of the interactions of species within these communities as well as the responses of these communities to external biotic and abiotic factors, we designed a repeatable on-bottom trawl survey to assess this resource from a multispecies perspective. Three surveys have been completed -- May 1984, February 1986, and May 1987.

A multispecies approach to stock assessment and yield estimation has been undertaken by other investigators in recent years (Tyler et al. 1982, Overholtz and Tyler 1985, and Dann 1987). Our longterm objectives are to use surplus production analysis to estimate sustainable yield for the multispecies fishery in Hecate Strait. Multispecies surplus production analysis has been attempted in other areas using commercial catch data (Ralston and Polovina 1982). However, most commercial fishery databases do not contain information comprehensive enough to produce accurate estimates of yield where multispecies production processes are concerned. For example, information on non-commercially valuable species or juvenile specimens of commercial species is not included in such databases. Our ultimate goal is to be able to fit a surplus production model to CPUE-based abundance indices for groups of species from biennial survey data and commercial fishery catch, effort and CPUE data from assemblage complexes. The first step in our approach is to examine the distribution patterns for important species in the Strait, using survey CPUE data to see if recurring patterns exist. The second step is to identify stable resident assemblages of demersal fishes in the Hecate Strait region. The third step is to determine the trophic relationships of these assemblages. The fourth step involves creating CPUE time series for all major species within trophically linked groups (referred to in Tyler et al. 1982 as assemblage production units). The fifth step would be to fit a multispecies surplus production model to these data to obtain improved estimates of potential yield(s) for the region. This report only contains information

on the first step above. Results of steps 2-5 will be the subjects for other reports.

METHODS

Three systematic trawl surveys of Hecate Strait have been conducted by the Pacific Biological Station between 1984 and 1987 (Fargo et al. 1984, Westrheim et al. 1984, Fargo and Davenport 1986, Foucher et al. 1988, and Fargo et al. 1988). The sampling sites for each year's survey are shown in Figures 1-3. The survey design has been summarized in the aforementioned reports. Briefly, haul locations were arrayed over a grid of 10 X 10 nautical mile (nm) blocks, with each 10-fathom depth stratum within each block considered for a potential sampling site. The exact position of the trawl-set depended on where trawlable bottom was first encountered on a systematic search of the stratum. In the later surveys, the search started on a track leading to the position of the set recorded on the previous survey. Because of currents in some areas, previous positions occasionally did not remain trawlable. Because sites were spaced among depth strata, one per stratum except where replicates were made, the sites were more or less evenly distributed with respect to depth, though on map coordinates the sites appeared geographically clumped since some 10 X 10 nm blocks have more trophic relief, and so more strata, than others. Detailed records of species compositions and biological data collected at these sites are contained in the data reports listed above. A summary of the number of usable hauls and the number of species sampled for each survey is as follows:

Vessel	Survey	No. usable hauls	No. species sampled
ARCTIC OCEAN	1984	82	44
G.B. REED	1984	64	38
DOUBLE DECKER	1986	58	33
G.B. REED	1986	68	58
EASTWARD HO	1987	90	49

The surveys were conducted with standardized gear (Yankee 36 trawl) and the entire catch was sorted and measured

for length by species. The first survey was conducted in May-June 1984, followed by two additional assemblage surveys, one in winter (February 1986) and one in summer (May-June 1987). The 1984 and 1986 surveys were joint vessel operations involving one chartered and one research vessel, while the 1987 survey was a single chartered vessel survey. The summer surveys were intended to provide synoptic data that could be used for mapping the distribution of fish assemblages available to bottom trawlers, and to develop a time series of relative abundance indices for these species. Data from the winter survey was intended to provide us with a check on seasonal variation in fish distribution.

The major species caught on the surveys were examined for distributional characteristics using a computer resident, two-dimensional interpolation function (Dudnik 1971) applied to relative CPUE (kg/hr) data for each species. Relative CPUEs for each major species on a particular survey were calculated for usable hauls (hauls completed in the required time period and without ripping the net) in the following manner :

$$P_{ij}=c_{ij}/C_i \quad \text{where:}$$

P = proportion
C = maximum CPUE in kilograms per hour
c = CPUE in kilograms per hour
i = species
j = haul

Five ranges of proportions (0.00, 0.01-0.25, 0.26-0.50, 0.51-0.75 and 0.76-1.00) were contoured and shaded to produce a density map for each species using a VAX/781 mainframe computer. The algorithm for calculating the density contours for each species was a distance-weighted least-squares approximation adapted from Shepard (1965).

Relative abundance indices for each major species in each assemblage were also computed by weight and size composition for each survey depth interval. The computation of mean CPUE in kilograms per hour involved the following procedure:

$$C_{ij}=(\sum_{k=1}^{n} c_{ij})/n \qquad \text{where:}$$

C = mean CPUE in kilograms per hour
c = CPUE in kilograms per hour
n = number of hauls
i = species
j = depth stratum
k = haul

The individual catch rate data within depth intervals were not normally distributed which precluded calculation of confidence limits. This is typical of survey data (Bannerot and Austin 1983, Fargo and Westrheim 1986). In the future we plan to do replicate hauls for specific sites on the survey to get an indication of variation in catch rate for the surveys.

Pooled catch rates, in numbers per hour, were computed for species size-groups in order to avoid the bias of extremely large catch rates that would occur in a calculation of the mean. The computation of pooled CPUE involved the following procedure:

$$C_{ij}=(\sum_{k=1}^{n} c_{ij}) / \sum_{k=1}^{n} e_{ij}) \quad \text{where:}$$

C = pooled CPUE in numbers per hour
c = catch in numbers
e = effort in hours
n = total number of hauls
i = species size-group
j = depth stratum
k = haul

Size composition data were categorized in the following way. For each major species, three size intervals were determined from a composite of all individual length frequencies for all cruises combined. The intervals were equivalent to the length ranges for juveniles (size group 1), adults (size group 2), and an older (roughly oldest 30%) of the population (size group 3). These length intervals varied among species because of differing growth characteristics. Pooled catch rates by haul in numbers per hour were then computed for each length-frequency group for each major species for each survey depth interval. For spiny dogfish, size composition data were collected for each sex and pooled catch rates were computed for each size group by sex.

Standing crop in tonnes was estimated for 12 of the 14 major species caught on the surveys. The schooling characteristics of Pacific cod and Pacific ocean perch made this calculation invalid and standing crop was not estimated for these 2 species. Standing crop for the other 12 species was calculated according to the following equation :

$$B_j = \sum_{i=1}^{n} A_i(b_{ij}/a_i) \quad \text{where:}$$

B = Standing crop in units of tonnes
A = Area in nm^2
b = Catch in tonnes
a = Area swept by the net in nm^2

n = Total number of depth strata (10)
i = Depth stratum
j = Species

The area swept by the net in one hour, 0.0142 nm^2, was computed assuming a wing spread under tow for a Yankee 36 trawl of 34.5 ft at an average towing speed of 2.5 nm/hr (Carrothers et al. 1969). A catching coefficient of 1 was assumed for the net, implying that the net caught all of the fish in its path on each trawl-set. Because of the limited area actually surveyed and the rather high degree of variability among catch rates, these estimates are not certain. They are, however, useful for examining annual and seasonal trends in abundance for 12 of these species because the estimates sum minimum biomass across all depth strata. This integration is difficult to grasp when one looks at mean catch rates only.

RESULTS

SEASONAL AND ANNUAL DISTRIBUTION

Density maps showing the relative abundance by area (Figure 4) for the 14 major species caught on the survey are presented in Figures 5-18. Species are referred to in the taxonomic order used by Hart (1973). The maps depict the relative abundance of each species within a single survey and overall differences in seasonal distribution. Density shading was proportionate to catch rate within a single survey, and while the relative patterns can be compared among panels, the catch rate grey-scales are not strictly comparable on a numerical basis.

Spiny dogfish, (Squalus acanthias), (Figure 5) exhibited seasonal changes in distribution, with higher concentrations of dogfish being observed in west Hecate Strait in the summer and in east Hecate Strait in winter. Areas of peak concentration in summer were variable, with high densities observed in the southwest, centralwest and northwest portions of the Strait in 1984 and in the northwest portion of the Strait in 1987.

Big skate (Raja binoculata) (Figure 6) densities were highest in the central and southern portions of Hecate Strait in summer and in the northwest portion of Hecate Strait in winter, although areas of peak density were quite variable. This may be indicative of seasonal migration patterns for the species.

Ratfish (Hydrolagus colliei) (Figure 7) densities were highest in the northwest portion of Hecate Strait in both summer and winter, but this species was widely distributed on all three surveys.

Pacific cod (Gadus macrocephalus) (Figure 8) were present in all areas of Hecate Strait. Areas of peak concentration varied widely among all 3 surveys. This distribution pattern is consistent with the schooling nature of this species.

Pacific ocean perch (Sebastes alutus) catch rates (Figure 9) were too few in frequency to produce adequate maps of area distribution for the 1984 and 1986 surveys. In 1987, a significant amount of effort was added in the southeast portion of Hecate Strait, the only area where this species was encountered in abundance.

Sablefish (Anoplopoma fimbria) (Figure 10) showed no seasonal or annual patterns in distribution with regard to area. However, densities were generally higher in the eastern portions of the Strait as opposed to the western portions.

Pacific sanddab (Citharichthys sordidus) (Figure 11) showed extremely stable seasonal and annual patterns of distribution and occurred in high densities only in the central portion of Hecate Strait on all 3 surveys.

Arrowtooth flounder (Atheresthes stomias) (Figure 12) densities were highest in the centraleast portion of the Strait in summer and in the northeast portion of the Strait in winter. The summer distribution of this species was exceptionally stable, with the areas of highest concentration matching well.

Petrale sole (Eopsetta jordani) (Figure 13) were present, in both the centraleast and southeast portions of the Strait in summer and winter, showing consistent patterns among all 3 surveys. This species is currently at low abundance levels (Fargo 1988), thus the distribution observed may reflect prime habitat.

Rex sole (Glyptocephalus zachirus) (Figure 14) were widely distributed in the northeast, centraleast and southeast portions of the Strait in summer. The position of highest concentration of this species was quite variable among all three surveys. Peak density of rex sole occurred in the southeast portion of the Strait in summer (1987), when this area was more intensively surveyed than in 1984. In winter, the highest concentrations occurred in the centraleast portion of the Strait.

Pacific halibut (Hippoglossus stenolepis) (Figure 15) was widely distributed and areas of highest concentration differed among all three surveys.

Rock sole (Lepidopsetta bilineata) (Figure 16) peak densities were observed in both the northern and southern portions of Hecate Strait in summer and winter. These concentrations probably correspond to discrete stocks described in Fargo (1988). Rock sole stocks were at low levels of abundance during the time of the surveys (Fargo 1988), and it is likely that the location of concentrations in Figure 16 indicate prime habitat for the species. Under conditions of high abundance we would expect the species to be more broadly distributed.

Dover sole (Microstomus pacificus) (Figure 17) occurred in highest concentrations in the northeast and centraleast portions of the Strait in summer and in the centraleast and southeast portions of the Strait in winter. In winter most of the Dover sole stock migrates out of the Strait for spawning (Fargo et al. 1985b). Yet the highest densities were observed in the centraleast portion of the Strait in summer (1984) and winter. The highest density in summer (1987) occurred in the northwest portion of the Strait.

English sole (Parophrys vetulus) (Figure 18) occurred in highest concentrations in the eastern portions of the Strait on all three surveys. They were more concentrated in centraleast Hecate Strait in winter than in summer.

SEASONAL ABUNDANCE WITH REGARD TO DEPTH

A summary of the mean catch rate (kg/h) by species by cruise for all species caught is contained in Table 1. The species are ranked in descending order, standardized to the 1984 Arctic Ocean survey. Mean catch rate (kg/hr) frequency distributions were examined, by depth interval, for the 14 major species (Table 2, Figures 19-23).

Spiny dogfish mean catch rates (Figure 19) were higher in summer than in winter, and occurred at depths less than 70 fathoms in summer and at depths greater than 70 fathoms in winter. In summer, the highest mean catch rate was 408 kg/hr in the 10-19 fathom depth interval. In winter, the highest mean catch rates were 188 kg/hr and 162 kg/hr in the 80-99 and 100-119 fathom depth intervals, respectively.

Big skate mean catch rates (Figure 19) were higher in winter than in summer. The highest mean catch rates in winter

occurred in the 30-59 fathom depth range. Catch rates were more evenly distributed in summer over a range of 10-59 fathoms. The highest mean catch rates in summer ranged from 11-31 kg/hr over a depth range of 10-49 fathoms. In winter, the highest mean catch rates were 290 kg/hr and 283 kg/hr in the 30-39 and 50-59 fathom depth intervals, respectively.

Ratfish mean catch rates (Figure 19) were higher in winter than in summer, and showed little seasonal difference in their frequency distributions with regard to depth. In summer, the highest mean catch rates were 164 kg/hr in the 40-49 fathom depth interval and 168 kg/hr in the 70-79 fathom interval. In winter, the highest mean catch rate was 294 kg/hr in the 60-69 fathom depth interval.

Pacific cod mean catch rates (Figure 20) increased steadily over the three years of survey, and were generally observed at deeper depths in winter than in summer. The schooling behaviour of this species tended to produce very high catch rates at specific sites which affected the calculation of the mean. In summer, the highest mean catch rates ranged from 185 to 259 kg/hr over a depth range of 20-59 fathoms. In winter, the highest mean catch rate was 534 kg/hr in the 70-79 fathom depth interval. This was the result of one extremely large haul (8000 kg/hr). Otherwise, catch rates varied from 36-114 kg/hr over the depth range of 20-79 fathoms.

Pacific ocean perch mean catch rates (Figure 20) were highest (2148 kg/hr) in the 80-99 fathom depth interval in the summer of 1987.

Sablefish mean catch rates (Figure 20) were quite variable in magnitude and showed different distributions for each survey with regard to depth. In summer, mean catch rates were highest, 128 kg/hr, at depths of 100-119 fathoms. In winter, mean catch rates were highest, 21 kg/hr, at depths of 120-139 fathoms.

Pacific sanddab mean catch rates (Figure 21) were similar in summer and winter, and there were no seasonal differences in their frequency distributions with regard to depth. In summer, the highest mean catch rates were 33 kg/hr in the 40-49 fathom depth interval. In winter, the highest mean catch rate was 35 kg/hr in the 40-49 fathom depth interval.

Arrowtooth flounder mean catch rates (Figure 21) were distinctly higher in summer than winter. There was little seasonal difference in their frequency distributions with regard to depth. In summer, the highest mean catch rates ranged from 520-596 kg/hr over a depth range of 50-79 fathoms. In winter, mean catch rates ranged from 5-95 kg/hr over a depth range of 50-139 fathoms.

Petrale sole mean catch rates (Figure 21) were extremely low on all three surveys, reflecting the abundance level of this stock (Fargo 1988). There was little seasonal difference in their frequency distributions with regard to depth. In summer, the highest mean catch rate was 17 kg/hr at the 70-79 fathom depth interval. In winter, the highest mean catch rate was 6 kg/hr over a depth range of 60-79 fathoms.

Rex sole mean catch rates (Figure 22) were similar in summer and winter, but peaked at deeper depth strata in the summer of 1987 compared to summer, 1984. This difference is due to there being no sites at depths greater than 80 fathoms in the 1984 survey. In the summer of 1987, the highest mean catch rate, 232 kg/hr, occurred in the 80-99 fathom depth interval. In winter, mean catch rates peaked at 122 kg/hr in the 70-79 fathom depth interval.

Pacific halibut mean catch rates (Figure 22) were highest in summer. Catches in the deepest depth stratum (120-139 fathoms) occurred only in winter. Highest mean catch rates in summer ranged from 76-84 kg/hr, over a depth range of 20-59 fathoms. The highest mean catch rate in winter, 35 kg/hr, occurred in the 120-139 fathom depth interval.

Rock sole mean catch rates (Figure 22) showed little seasonal difference in frequency distributions with regard to depth. Highest mean catch rates occurred at depths less than 40 fathoms in summer and winter. In summer, the highest mean catch rate, 65 kg/hr, occurred in the 10-19 fathom depth interval. In winter, the highest mean catch rate was 63 kg/hr in the 30-39 fathom depth interval.

Dover sole mean catch rates (Figure 23) were significantly greater in summer than in winter and the range of depth intervals where Dover sole were caught was greater in summer as well. In summer, mean catch rate peaked at 238 kg/hr in the 70-79 fathom depth interval. In winter, the highest mean catch rate was 6 kg/hr in the 120-139 fathom depth interval. Dover sole were only present in abundance at depths greater than 40 fathoms.

English sole mean catch rates (Figure 23) were similar in summer and winter, with the exception of the extremely high mean catch rate for the 40 fathom depth stratum on the 1984 survey. This was the result of the influence of extremely high catch rates (2652 kg/hr and 3678 kg/hr) for two trawl-hauls out of 23 made in this depth stratum. Mean catch rates showed little seasonal difference in their frequency distributions with regard to depth. Highest mean catch rates occurred in the 30-79 fathom range. In summer, the highest mean catch rate was 349 kg/hr in the 40-49 fathom depth interval. However, this catch rate was calculated on the basis of only 2 trawl-hauls. In winter, the

highest mean catch rate was 166 kg/hr in the 50-59 fathom depth interval.

SEASONAL ABUNDANCE OF SIZE GROUPS WITH REGARD TO DEPTH

The total length frequency distributions for each species for the summer 1987 cruise are shown in Figures 24-28. A summary of pooled catch rates (n/hr) for 3 size groups by species by cruise by depth stratum is contained in Table 3 and Figures 29-43. Species are referred to in the taxonomic order used by Hart (1973). Overall, there are only a few differences in depth distributions among fish size groups within species.

Spiny dogfish showed similar seasonal pooled catch rate by depth distributions for both sexes (Figures 29,30). Likewise, all size groups of each sex showed similar seasonal pooled catch rate by depth distributions. Catch rates for males were highest in summer, and were highest for size group 2. Catch rates for females were generally higher in winter and were highest for size group 1.

Big skate showed similar seasonal pooled catch rate by depth distributions for all three size groups (Figure 31). Catch rates were higher in winter than in summer and were highest for size group 2 in both summer and winter.

Ratfish showed similar seasonal pooled catch rate by depth distributions for all three size groups (Figure 32). Pooled catch rates were generally greater in winter than in summer and were highest for size group 1 and 2.

Pacific cod showed similar seasonal pooled catch rate by depth distributions for all three size groups (Figure 33). Catch rates for size group 1 were highest on the winter (1986) survey and the second summer survey (1987). This was consistent with a significant increase in recruitment observed for the species in 1987 (Tyler and Foucher 1989).

Pacific ocean perch pooled catch rates (Figure 34) were highest for size group 2 and were highest on the 1987 survey at depths greater than 80 fathoms. This was because the habitat for this species was more adequately covered on the 1987 survey. The paucity of data for this species on the 1986 survey precludes evaluation of seasonal trends of pooled catch rates by depth by size group (Figure 34).

Sablefish showed a depth stratification by size group with larger fish caught at deeper depths (Figure 35). Pooled catch rates for size group 1 were highest over the depth range of

10-39 fathoms while catch rates for size group 2 were highest over a depth range of 40-49 fathoms and catch rates for size group 3 were highest at 100-119 fathoms. Catch rates were generally higher in summer than in winter for all three size groups.

Pacific sanddab showed similar seasonal pooled catch rate by depth distributions for all three size groups (Figure 36). The magnitude of catch rates for all size groups was similar in summer and winter, and catch rates for size group 2 were highest for all three surveys.

Arrowtooth flounder showed similar seasonal pooled catch rate by depth distributions for all three size groups (Figure 37). Catch rates were higher in summer than in winter, and catch rates on the summer surveys were highest for size group 2 while catch rates on the winter survey were highest for size group 1.

Petrale sole showed similar seasonal pooled catch rate by depth distributions for all three size groups (Figure 38). There was little seasonal difference in catch rates by size group, and they were highest for size group 2 in both summer and winter.

Rex sole showed similar seasonal pooled catch rate by depth distributions for all three size groups (Figure 39). Catch rates were highest for size group 2 in both summer and winter, and were distinctly higher on the 1987 survey. This was due to the high catch rates for rex sole in southeast Hecate Strait where more effort was allocated after 1984.

Pacific halibut showed similar seasonal pooled catch rate by depth distributions for all three size groups (Figure 40). However, catch rates were observed from the deepest depth intervals only in winter. Overall, catch rates for halibut were relatively low, but were highest for size group 2 in both summer and winter.

Rock sole showed similar seasonal pooled catch rate by depth distributions for all three size groups (Figure 41). Catch rates were highest for size group 1 on all three surveys, and did not differ appreciably between summer and winter.

Dover sole showed similar seasonal pooled catch rate by depth distributions for all three size groups (Figure 42). Catch rates were significantly higher for all three size groups in summer than in winter. This is consistent with the seasonal migration pattern for this stock (Fargo et al. 1985b).

English sole showed similar seasonal trends in pooled catch rate by depth distributions for all three size groups

(Figure 43). Peak catch rates were slightly higher in summer than winter and were more variable as well. Catch rates were highest for size group 2 on the 1984 survey, and for size group 1 on the 1986 and 1987 surveys.

STANDING CROP FOR MAJOR SPECIES IN HECATE STRAIT

Estimates of standing crop for major species in the Hecate Strait region are contained in Table 4. The estimates are ranked in descending order, standardized to the 1984 survey. On both summer surveys (1984,1987) arrowtooth flounder and spiny dogfish ranked 1 and 2, respectively. They accounted for 52% and 55% of the biomass of the 12 selected major species on the 1984, 1987 surveys, respectively. The dominant species on the winter (1986) survey were big skate, ratfish, and English sole, which accounted for 64% of the biomass of the 12 selected major species on that survey. Arrowtooth flounder, spiny dogfish, and Dover sole appeared to be more abundant or available during summer than winter. English sole, ratfish, and big skate appeared to be less abundant or available during summer than winter. Rex sole and rock sole showed similar abundance and availability levels in summer and winter. Arrowtooth flounder, big skate and sablefish showed no significant change in biomass between 1984 and 1987. Increases in biomass between 1984 and 1987 were noted for Dover sole, and rex sole. Decreases in biomass between 1984 and 1987 were noted for spiny dogfish, English sole, ratfish, Pacific halibut, rock sole, Pacific sanddab, and petrale sole.

Previous estimates of biomass for arrowtooth flounder and spiny dogfish were available through past reports. These estimates were 52,750 t for arrowtooth flounder (40-100 fathoms) (Fargo et al. 1981), and 113,873 tonnes (10-100 fathoms) for spiny dogfish (Saunders et al. 1984). The estimates for these two species from our surveys, although not close, did fall within the 95% confidence limits of the estimates from the two prior surveys.

SUMMARY AND DISCUSSION

We compared our species distribution results with results available for some previous studies of demersal species in Hecate Strait conducted between the early 1950s through the mid-1980s. Our purpose was to examine the stability of fish distributions over a longer time period and, where appropriate,

make comparisons of the relative species composition in the region past and present. Results of previous studies are compared in chronological order.

Some of the first results concerning research on the groundfish resource in Hecate Strait were published by Ketchen (1956) in a paper concerning English sole. Although the area coverage of the Strait for his work was very limited, and the fishing techniques primitive, he made the following observations concerning English sole. He noted a stratification by depth by size for the species, with larger fish occurring in deeper depths. He also noted, citing early tagging experiments, that it appeared that the English sole population exhibited changes in distribution with regard to season. They were more prominent in the northern part of the Strait in spring-summer and in the southern-central part of the Strait in the fall-winter. We observed high densities of this species in northern Hecate Strait in both summer and winter. High densities also occurred in central Hecate Strait, but only in winter. We observed no depth stratification by size for the species, which supported Fargo and Westrheim (1986b).

Forrester and Thomson (1969) examined results of research surveys conducted in the region from the late 1950s to the mid-1960s and listed rock sole and butter sole as the dominant species in northern Hecate Strait at depths of 10-40 fathoms in all areas except the northern section where Pacific cod and English sole predominated. Ketchen (1961) reported seasonal bathymetric distributions for Pacific cod, with distribution being confined to shallower depths in spring-summer and deeper depths in fall-winter. Westrheim and Taggart (1984) concurred with this. Butter sole was not an abundant species on our surveys and landings for the species have not been significant for the last 20 years. Rock sole occurred in highest densities at depths less than 40 fathoms on our surveys, while English sole occurred in highest densities at depths of 40-59 fathoms, especially in the northwest portion of the Strait on our summer surveys. Pacific cod occurred in high densities only in the central portion of the Strait during our surveys, and Pacific cod catch rates were higher in the deeper depths in winter as compared to summer for our surveys as well. Comparisons of survey results with regard to this species should be made with caution, due to its schooling characteristic.

The first intensive Canadian trawl surveys of Hecate Strait occurred during the summers of 1965-66 under the Industrial Development Service of the Department. Although the primary purpose of these surveys was to 'discover new fishing grounds', some effort was devoted to determining species composition and collecting biological samples for trawl hauls made (Thomson 1965, Thomson 1966). The total area surveyed here was smaller than in our surveys, and the primary effort was

directed to southern Hecate Strait, from the tip of Banks Island to Moresby Gully. In 1965, most of the attention of the survey was devoted to the western side of the Strait while in 1966, most of the attention was devoted to the eastern side of the Strait. The total species composition is listed in the reports as follows. In 1965, Pacific cod, Pacific ocean perch, and rock sole accounted for 77% of the total catch on the survey. Arrowtooth flounder, accounted for only 6% of the catch. In 1966, Pacific cod, Pacific ocean perch, and rock sole accounted for 53% of the total catch, while arrowtooth flounder dominated, accounting for 30% of the catch. It is difficult to compare these results to our work because the exact locations of catches were not completely accurate due to navigational limitations during that time. Also, it appears that only catches of commercially valuable species were reported. On our most extensive summer survey (1987), Pacific cod and English sole dominated in southcentral Hecate Strait, accounting for 65% of the total species catch by weight in this area. Spiny dogfish, rock sole, big skate, and Pacific halibut accounted for 89% of the total species catch by weight in southwest Hecate Strait. In southeast Hecate Strait, Pacific ocean perch and arrowtooth flounder accounted for 67% of the total species catch by weight.

The results of trawl surveys for juvenile rock sole and English sole in Hecate Strait were published by Fargo and Westrheim (1986). They suggested that, on the basis of their work, CPUE data for several different species might be amenable to establishing abundance time series. The species they mentioned included rock sole, English sole, Pacific halibut, big skate, and spiny dogfish. Their observations concerning the distribution of these species were very similar to those contained in this report. Rock sole catch rates on these surveys were highest at depths of less than 40 fathoms, while English sole catch rates were highest at depths between 40 and 59 fathoms. Pacific halibut and spiny dogfish were species commonly caught with rock sole while Pacific cod, and Pacific sanddab were components commonly caught with English sole.

A survey for arrowtooth flounder in Hecate Strait was conducted in June 1980 (Fargo et al. 1981). This survey covered a depth range of 40-100 fathoms in the Strait. Highest concentrations of the species were encountered in the central portion of the Strait. There was also more variability in catch rates for the species in southern Hecate Strait as opposed to northern Hecate Strait. Our surveys showed highest densities of the species in the northern and central portions of the Strait. Catch rates for this species were more variable in southern Hecate Strait as opposed to northern Hecate Strait in our work as well. Our survey consisted of a small-meshed trawl as compared to commercial gear used in the 1980 survey. Thus, one would expect that our survey would result in higher catch rates for juveniles. This was the case, with maximum catch rates of 496

fish per hour recorded for the 1987 survey for size group 1. This compares with a maximum catch rate of 55 fish per hour for size group 1 fish on the 1980 survey.

A survey of spiny dogfish was conducted in Hecate Strait by Saunders et al. (1984) in 1982. This survey took place in September, and showed a greater range of depths occupied by the species than our survey did. This is consistent with a transition period for the species in fall, corresponding to the time they would start migrating to deeper depths. Saunders observed higher densities in southern Hecate Strait as opposed to northern Hecate Strait, while we observed high densities in both the northern and southern portions of the Strait. The differences here may be related to the different seasonal timing of the surveys.

The consistency in distribution that we have observed for some of these species suggests that abundance monitoring may be possible. Spiny dogfish, Pacific sanddab, petrale sole, and arrowtooth flounder all showed consistency in distributions. Areas of peak densities for these species were fairly constant over the study period. Pacific sanddab and arrowtooth flounder were almost constant with regard to distribution over the study period. Spiny dogfish showed different distributions with regard to season consistent with prior surveys. The data show a bathymetric migration to deeper water in winter. The relatively stable seasonal distribution of this species in the Strait adds to the feasibility of abundance monitoring.

Big skate, rex sole, Pacific halibut, rock sole, Dover sole, and English sole showed some consistencies among surveys, but also enough variability in pattern that it is difficult to draw conclusions at this point on whether differences in catch rates truly reflect abundance differences. The fact that all of these species are non-schooling and are not up in the water column makes them possible candidates for abundance indexing. Pacific halibut and English sole showed decreasing CPUE trends over the survey period consistent with declining abundance for these species in this area (Bruce Leaman of this Station, pers. comm. and Fargo (1988)). However, these two species, along with big skate and rex sole showed highly variable distributions among all 3 surveys. Rock sole also showed peak densities in northern and southern portions that were consistent with stock delineation for this species, although variability in overall distributions among all 3 surveys was high. Dover sole occurred in fairly low densities on the survey. The area of peak concentration, centraleast Hecate Strait, was consistent between summer (1984) and winter. Bathymetric migration out of the Strait makes summer the only time when an abundance indexing for this species could be accomplished. Also, the species is most abundant in the Dundas area, north of the area surveyed, at that time of the year.

Ratfish, Pacific cod, and sablefish showed such high variability among surveys that it is unlikely that catch rates relate well to abundance. They are schooling species and are sometimes up in the water column, making them unlikely candidates for abundance indexing. Ratfish distribution was quite variable except for a high concentration observed in the northern portions of the Strait on all 3 surveys. However, if the proportion of the stock in this area is constant among years, abundance indexing may be possible. Pacific cod showed enough variability in catch rates to make abundance monitoring questionable. It is possible that a relative index can be developed for this species, but confirmation will require a longer time series of data. Sablefish showed little consistency in catch rate frequency distributions with regard to area or depth and the extreme fluctuations of availability of this species in the Strait probably precludes the use of catch rate data to index its abundance.

Pacific ocean perch showed consistent distributions among all 3 surveys, but catch rate data collected for the species was extremely limited. Habitat for this species was only partially covered by these surveys. It was not our objective to obtain abundance estimates for this species. It was included in the survey to provide a source of contrast for species catch data. This allows us to better determine connectivity patterns for other species on the surveys (Tyler 1989).

The assemblage survey is probably capable of providing us with recruitment/abundance indices and potential yield estimates for a number of commercially and non-commercially valuable species within Hecate Strait. For the non-commercially valuable species this would be the only source of stock assessment data available. Although they are not landed from commercial trawl fishing trips they are, nevertheless, components of the catches of commercial trawlers (Stanley 1985). Thus, they are subject to commercial exploitation and associated fishing mortality. The current cost of the survey at about 100 thousand dollars every two years or 50 thousand dollars per year is a small fraction of the average annual ex-vessel value (8-10 million dollars) of the fishery in this region for the last four years.

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Table 1. Mean catch rates (kg/hr) for fish species caught on the Hecate Strait Surveys 1984-1987[a].

Species	Mean CPUE (kg/hr) ARCTIC OCEAN 1984	G.B.REED 1984	DOUBLE DECKER 1986	G.B.REED 1986	EASTWARD HO 1987
Spiny dogfish	91.2	187.1	2.1	26.4	135.4
English sole	72.5	153.1	57.1	74.6	73.0
Arrowtooth flounder	53.8	336.0	15.9	39.8	235.8
Pacific halibut	52.1	62.7	9.0	14.5	25.2
Pacific cod	35.5	25.7	195.8	48.4	108.2
Ratfish	26.2	140.3	67.3	135.0	40.9
Big skate	23.4	1.3	233.2	25.6	16.0
Rock sole	21.9	17.8	37.6	15.6	20.9
Sablefish	19.4	27.1	0.2	0.8	6.6
Rex sole	18.2	64.6	15.2	28.3	28.8
Lingcod	13.0	16.8	9.4	31.9	13.4
Walleye pollock	12.8	17.4	0.5	1.6	18.1
Bocaccio	9.0	38.5	0.0	1.7	.9
Pacific sanddab	8.1	17.4	8.7	14.3	8.9
Butter sole	5.5	0.3	19.9	1.7	1.2
Dover sole	5.2	101.5	0.1	0.3	48.6
Silvergray rockfish	3.8	21.2	0.0	5.5	23.7
Flathead sole	2.1	5.0	0.4	4.2	4.0
Petrale sole	2.1	8.5	0.3	3.0	1.3
Yellowtail rockfish	1.4	2.6	0.0	3.3	11.6
Sand sole	1.2	0.0	2.1	0.4	1.0
Longnose skate	1.0	18.7	2.0	0.0	0.3
Quillback rockfish	1.0	0.2	0.1	0.2	3.6
Canary rockfish	0.9	15.4	0.0	3.5	0.7
Pacific ocean perch	0.7	5.2	0.0	4.0	76.4
Curlfin sole	0.7	0.2	1.3	0.1	0.1
Starry flounder	0.6	0.0	1.0	0.1	0.2
Pacific tomcod	0.4	0.1	0.0	0.2	0.0
Pygmy rockfish	0.3	0.0	0.0	0.0	0.0
Pacific herring	0.2	0.0	0.2	0.0	0.0
Black skate	0.1	0.6	0.2	0.0	0.2
Redbanded rockfish	0.1	0.1	0.0	3.4	10.2
Eulachon	0.0	0.3	0.0	0.4	5.7
Pacific hake	0.0	0.0	0.0	0.1	0.0
Poachers	0.0	0.0	0.0	0.2	0.0
Salmon	0.0	0.0	0.0	0.2	0.0
Shiner perch	0.0	0.0	4.7	1.7	0.0
Sculpins	0.0	0.0	0.7	0.0	0.0
Shortspine thornyhead	0.0	0.0	0.0	0.1	0.7
Copper rockfish	0.0	0.0	0.0	0.0	0.6

Table 1 (cont'd.)

Species	Mean CPUE (kg/hr) ARCTIC OCEAN 1984	G.B.REED 1984	DOUBLE DECKER 1986	G.B.REED 1986	EASTWARD HO 1987
Yelloweye rockfish	0.0	0.0	0.0	0.5	0.2
Redstripe rockfish	0.0	0.0	0.0	0.1	0.2
Rougheye rockfish	0.0	0.0	0.0	0.1	0.1
Widow rockfish	0.0	0.0	0.0	0.4	0.1
Slender sole	0.0	0.2	0.0	0.6	0.3

[a]The species are ranked in descending order of catch rate according to the 1984 ARCTIC OCEAN survey.

Table 2. Mean catch rates (kg/hr), by year by depth interval for the 14 major species caught on the Hecate Strait surveys.

Species/ Year	CPUE (kg/hr) Depth interval (fathoms)[a] 1	2	3	4	5	6	7	8	9	10
Spiny dogfish										
1984	197	140	98	86	152	103	200	0	0	0
1986	0	0	1	4	9	16	28	188	162	57
1987	408	87	74	121	78	47	89	44	29	36
Bigskate										
1984	31	20	23	17	2	1	3	0	0	0
1986	14	49	290	184	283	31	21	3	8	5
1987	28	27	11	34	11	0	0	0	11	0
Ratfish										
1984	2	6	15	164	60	103	168	0	0	0
1986	5	36	155	128	176	294	22	1	11	3
1987	0	18	7	31	71	150	57	8	15	16
Pacific cod										
1984	8	47	15	21	41	56	25	0	0	0
1986	2	57	114	48	93	36	534	69	2	0
1987	10	185	259	12	216	13	51	0	2	0
Pacific ocean perch										
1984	0	0	0	0	1	1	22	0	0	0
1986	0	0	0	0	0	0	0	0	87	50
1987	0	0	0	0	0	0	169	2148	300	110
Sablefish										
1984	9	20	17	75	10	4	7	0	0	0
1986	0	0	0	0	0	0	0	1	0	21
1987	0	2	1	1	4	2	11	6	128	74
Pacific sanddab										
1984	0	1	19	33	18	3	0	0	0	0
1986	0	1	24	35	15	8	0	0	0	0
1987	0	10	11	19	21	1	0	0	0	0
Arrowtooth flounder										
1984	0	3	40	57	457	141	677	0	0	0
1986	0	0	13	20	61	57	52	15	59	95
1987	0	2	23	81	520	521	596	284	150	104
Petrale sole										
1984	0	0	1	3	5	10	17	0	0	0
1986	0	0	0	0	2	6	6	0	0	0
1987	0	0	2	1	2	3	3	0	0	0
Rex sole										
1984	0	0	17	87	71	32	41	0	0	0
1986	0	0	2	6	26	16	122	4	3	9
1987	0	1	4	23	68	9	45	232	54	60

Table 2 (cont'd)

Species/ Year	CPUE (kg/hr) Depth interval (fathoms)[a] 1	2	3	4	5	6	7	8	9	10
Pacific halibut										
1984	50	84	79	76	54	31	6	0	0	0
1986	2	9	20	13	18	15	8	2	0	35
1987	46	51	23	34	18	0	3	0	0	0
Rock sole										
1984	47	34	36	19	2	2	1	0	0	0
1986	31	43	63	34	11	3	0	0	0	0
1987	65	31	33	11	1	0	0	0	0	0
Dover sole										
1984	0	0	2	43	42	54	238	0	0	0
1986	0	0	0	0	0	0	1	0	0	6
1987	0	0	0	69	71	85	98	211	98	104
English sole										
1984	11	17	86	349	96	54	41	0	0	0
1986	1	2	37	92	166	104	93	24	0	0
1987	8	11	138	104	186	39	23	0	0	0

[a]1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Table 3. Pooled catch rates (n/hr), by size group, by year, by depth interval for the 14 major species caught on the Hecate Strait surveys.

Year	Species/ size group	CPUE (n/hr) Depth interval (fathoms)[a] 1	2	3	4	5	6	7	8	9	10
Spiny dogfish (males)											
1984	size group 1	4	0	0	2	1	0	2			
	size group 2	27	19	11	5	14	3	18			
	size group 3	0	0	0	0	1	0	0			
1986	size group 1	0	0	0	0	0	0	1	3	2	0
	size group 2	0	0	0	1	1	1	2	4	8	8
	size group 3	0	0	0	0	0	0	0	0	0	0
1987	size group 1	12	0	0	1	1	0	2	2	2	0
	size group 2	123	10	2	9	3	4	7	1	0	4
	size group 3	0	0	0	0	0	0	0	0	0	0
Spiny dogfish (females)											
1984	size group 1	34	37	16	16	13	10	17			
	size group 2	18	7	11	8	10	12	13			
	size group 3	0	1	0	0	1	1	1			
1986	size group 1	0	0	0	0	1	5	4	4	64	8
	size group 2	0	0	0	1	1	3	3	38	14	8
	size group 3	0	0	0	0	0	0	0	1	0	0
1987	size group 1	80	11	4	20	12	13	26	5	6	0
	size group 2	19	12	12	16	11	5	7	6	5	4
	size group 3	1	1	1	1	1	0	0	1	0	0
Big skate											
1984	size group 1	2	0	0	0	0	0	0			
	size group 2	2	1	1	0	0	0	0			
	size group 3	1	0	1	0	0	0	0			
1986	size group 1	0	0	4	5	2	0	0	0	0	2
	size group 2	1	3	11	14	9	2	2	0	2	0
	size group 3	0	2	3	3	1	0	0	0	0	0
1987	size group 1	0	0	0	0	0	0	0	0	0	0
	size group 2	1	1	0	1	0	0	0	0	2	0
	size group 3	0	1	0	1	0	0	0	0	0	0

Table 3 (cont'd)

Year	Species/ size group	CPUE (n/hr) Depth interval (fathoms)[a] 1	2	3	4	5	6	7	8	9	10
	Ratfish										
1984	size group 1	0	0	0	39	9	16	22			
	size group 2	4	11	11	325	81	130	168			
	size group 3	1	2	8	66	25	35	64			
1986	size group 1	0	9	161	229	39	113	50	14	17	5
	size group 2	5	48	214	162	152	417	33	0	6	5
	size group 3	2	6	17	9	8	0	0	0	0	0
1987	size group 1	0	8	11	72	164	25	71	39	9	0
	size group 2	0	24	8	31	55	180	64	2	26	20
	size group 3	0	0	0	0	0	0	0	0	2	0
	Pacific cod										
1984	size group 1	1	184	13	4	1	0	0			
	size group 2	7	6	9	9	19	19	9			
	size group 3	1	1	1	3	7	13	4			
1986	size group 1	7	408	243	141	298	39	69	21	2	0
	size group 2	0	1	4	2	4	4	3	7	2	0
	size group 3	0	1	11	8	12	8	14	16	0	0
1987	size group 1	3	78	54	22	13	2	0	0	0	0
	size group 2	11	175	155	10	182	11	48	0	2	0
	size group 3	0	7	27	0	6	1	5	0	0	0
	Pacific ocean perch										
1984	size group 1	0	0	0	3	2	8	9			
	size group 2	0	0	0	0	6	11	114			
	size group 3	0	0	0	0	0	0	5			
1986	size group 1	0	0	0	0	0	0	3	6	20	2
	size group 2	0	0	0	0	0	0	0	1	114	248
	size group 3	0	0	0	0	0	0	0	0	3	6
1987	size group 1	0	0	0	0	0	0	2	0	9	0
	size group 2	0	0	0	0	2	1	172	5791	918	70
	size group 3	0	0	0	0	0	0	10	635	173	128
	Sablefish										
1984	size group 1	24	0	1	0	0	0	0			
	size group 2	98	64	53	215	18	9	9			
	size group 3	0	0	0	2	2	1	4			
1986	size group 1	0	0	0	0	0	0	0	0	0	0
	size group 2	0	0	1	4	7	1	1	1	0	3
	size group 3	0	0	0	0	0	0	0	2	0	27
1987	size group 1	0	0	0	0	0	0	0	0	0	0
	size group 2	1	7	3	2	6	0	2	7	2	0
	size group 2	0	0	0	0	2	2	9	0	112	44

Table 3 (cont'd)

Year	Species/ size group	CPUE (n/hr) Depth interval (fathoms)[a] 1	2	3	4	5	6	7	8	9	10
	Pacific sanddab										
1984	size group 1	3	10	115	63	9	2	0			
	size group 2	2	1	79	187	109	20	0			
	size group 3	0	0	5	3	2	0	0			
1986	size group 1	0	5	102	178	33	13	0	1	0	0
	size group 2	0	2	111	209	80	45	5	0	0	0
	size group 3	0	0	7	3	4	1	0	0	0	0
1987	size group 1	0	3	16	23	7	1	0	0	0	0
	size group 2	0	31	56	118	121	9	0	0	0	0
	size group 3	0	6	3	1	1	0	0	0	0	0
	Arrowtooth flounder										
1984	size group 1	0	1	6	8	41	25	67			
	size group 2	0	3	21	47	530	145	677			
	size group 3	0	1	10	8	32	14	69			
1986	size group 1	0	1	23	70	180	83	173	23	97	82
	size group 2	0	0	4	11	49	55	51	19	80	80
	size group 3	0	0	3	3	12	9	3	0	6	11
1987	size group 1	0	2	4	4	54	57	45	336	70	32
	size group 2	0	1	13	56	318	339	496	234	300	78
	size group 3	0	0	4	11	51	50	45	27	50	18
	Petrale sole										
1984	size group 1	0	0	1	4	2	1	0			
	size group 2	0	0	0	2	4	7	12			
	size group 3	0	0	0	1	1	2	3			
1986	size group 1	0	0	0	1	2	3	3	1	0	0
	size group 2	0	0	0	0	5	8	8	2	0	0
	size group 3	0	0	0	0	0	0	0	0	0	0
1987	size group 1	0	0	1	2	2	1	0	0	0	0
	size group 2	0	0	0	1	2	6	4	0	0	0
	size group 3	0	0	1	0	0	0	0	0	0	0
	Rex sole										
1984	size group 1	0	0	27	37	31	15	4			
	size group 2	0	1	79	528	372	197	175			
	size group 3	0	0	4	24	37	11	27			
1986	size group 1	0	0	9	12	17	3	8	0	2	5
	size group 2	0	0	4	24	169	85	574	62	24	47
	size group 3	0	0	0	4	4	5	14	1	2	14
1987	size group 1	0	0	0	1	2	0	1	0	5	0
	size group 2	0	8	17	98	313	26	184	1781	67	236
	size group 3	0	0	1	7	30	10	22	289	18	34

Table 3 (cont'd)

Year	Species/ size group	CPUE (n/hr) Depth interval (fathoms)[a] 1	2	3	4	5	6	7	8	9	10
	Pacific halibut										
1984	size group 1	1	3	4	1	1	2	0			
	size group 2	6	15	14	12	12	4	1			
	size group 3	1	2	2	1	1	1	0			
1986	size group 1	0	1	1	2	1	0	0	0	0	2
	size group 2	0	0	3	3	2	3	2	1	0	11
	size group 3	0	1	0	0	1	0	0	0	0	0
1987	size group 1	7	1	2	0	0	0	0	0	0	0
	size group 2	6	7	2	5	4	0	1	0	0	0
	size group 3	1	1	1	1	0	0	0	0	0	0
	Rock sole										
1984	size group 1	28	33	62	13	2	1	0			
	size group 2	52	33	43	19	2	3	0			
	size group 3	3	4	2	2	0	0	0			
1986	size group 1	4	21	132	135	39	1	0	0	0	0
	size group 2	22	37	37	17	7	4	0	0	0	0
	size group 3	3	3	4	1	0	0	0	0	0	0
1987	size group 1	62	44	34	13	0	0	0	0	0	0
	size group 2	53	33	30	8	1	0	0	0	0	0
	size group 3	9	2	4	2	1	0	0	0	0	0
	Dover sole										
1984	size group 1	0	1	11	49	30	0	0			
	size group 2	0	0	1	74	64	65	265			
	size group 3	0	0	0	0	3	11	44			
1986	size group 1	0	0	0	1	1	2	2	0	0	0
	size group 2	0	0	0	0	0	1	1	0	2	12
	size group 3	0	0	0	0	0	0	0	0	0	0
1987	size group 1	0	1	2	131	5	2	18	18	2	0
	size group 2	0	0	0	51	126	91	151	335	158	142
	size group 3	0	0	0	0	3	18	6	4	17	6
	English sole										
1984	size group 1	94	42	289	544	117	44	9			
	size group 2	28	33	222	994	232	162	109			
	size group 3	3	5	14	39	22	9	4			
1986	size group 1	22	25	189	382	529	99	55	4	0	0
	size group 2	1	4	49	171	292	165	228	78	0	0
	size group 3	0	1	13	25	19	15	3	0	0	0
1987	size group 1	45	30	668	157	326	22	0	0	0	0
	size group 2	12	22	277	280	316	103	63	0	0	0
	size group 3	1	1	8	16	57	6	3	0	0	0

[a]1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Table 4. Standing crop (tonnes) for 12[a] major species caught based on the Hecate Strait surveys 1984-87.

Species	Standing crop (tonnes) 1984	1986	1987
Arrowtooth flounder	94229	21424	95444
Spiny dogfish	86003	27199	59441
English sole	37765	49261	15369
Ratfish	28644	54292	14157
Pacific halibut	25830	8073	8204
Dover sole	23497	361	34951
Rex sole	15600	17699	25900
Rock sole	12347	13458	8213
Sablefish	8134	1139	10852
Big skate	5731	63058	5567
Pacific sanddab	3947	4375	1817
Petrale sole	2285	970	384

[a]Pacific cod and Pacific ocean perch excluded.

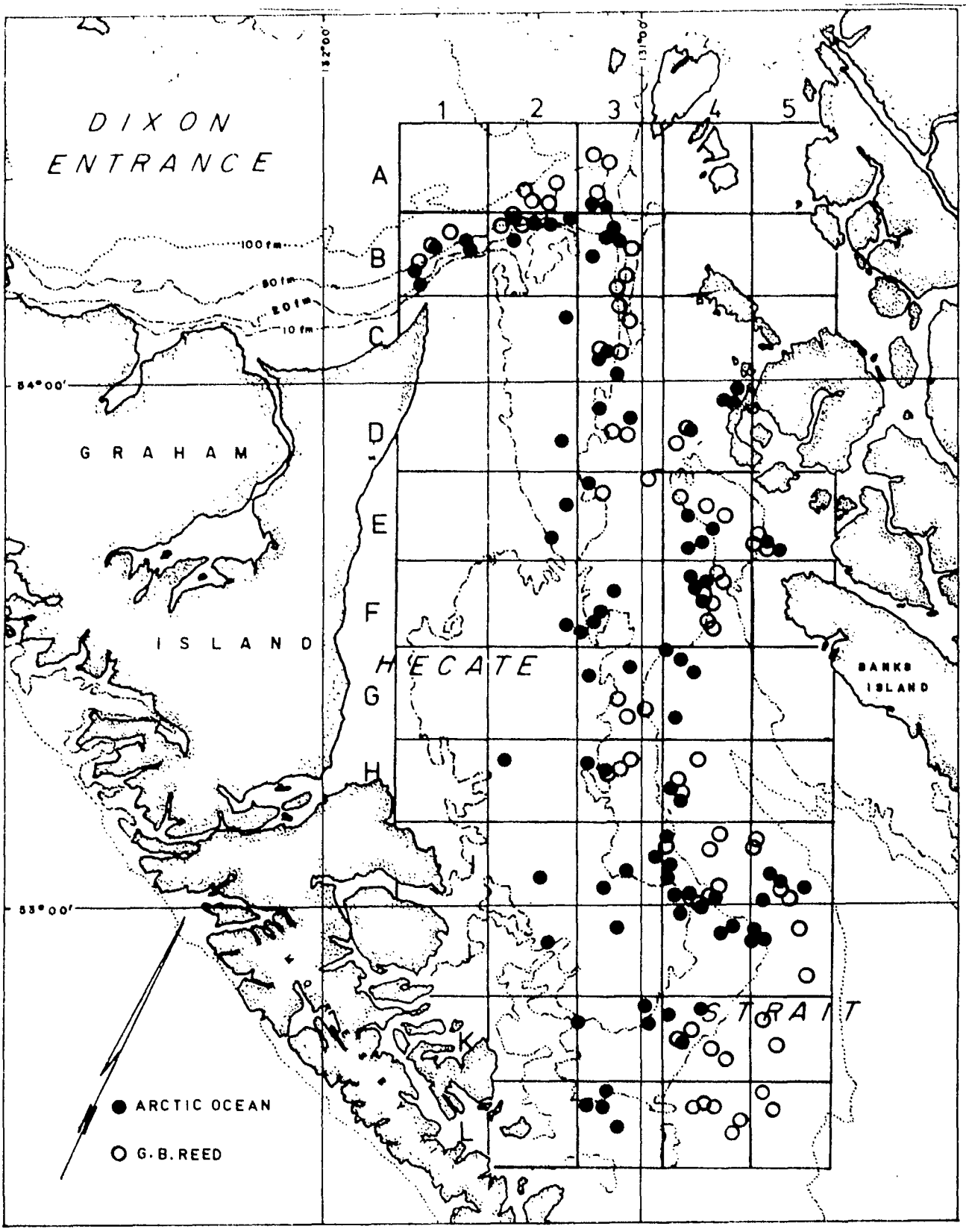


Fig. 1. Trawl sampling sites for the research cruises of the ARCTIC OCEAN and G.B. REED for the period May 24 to June 17, 1984.

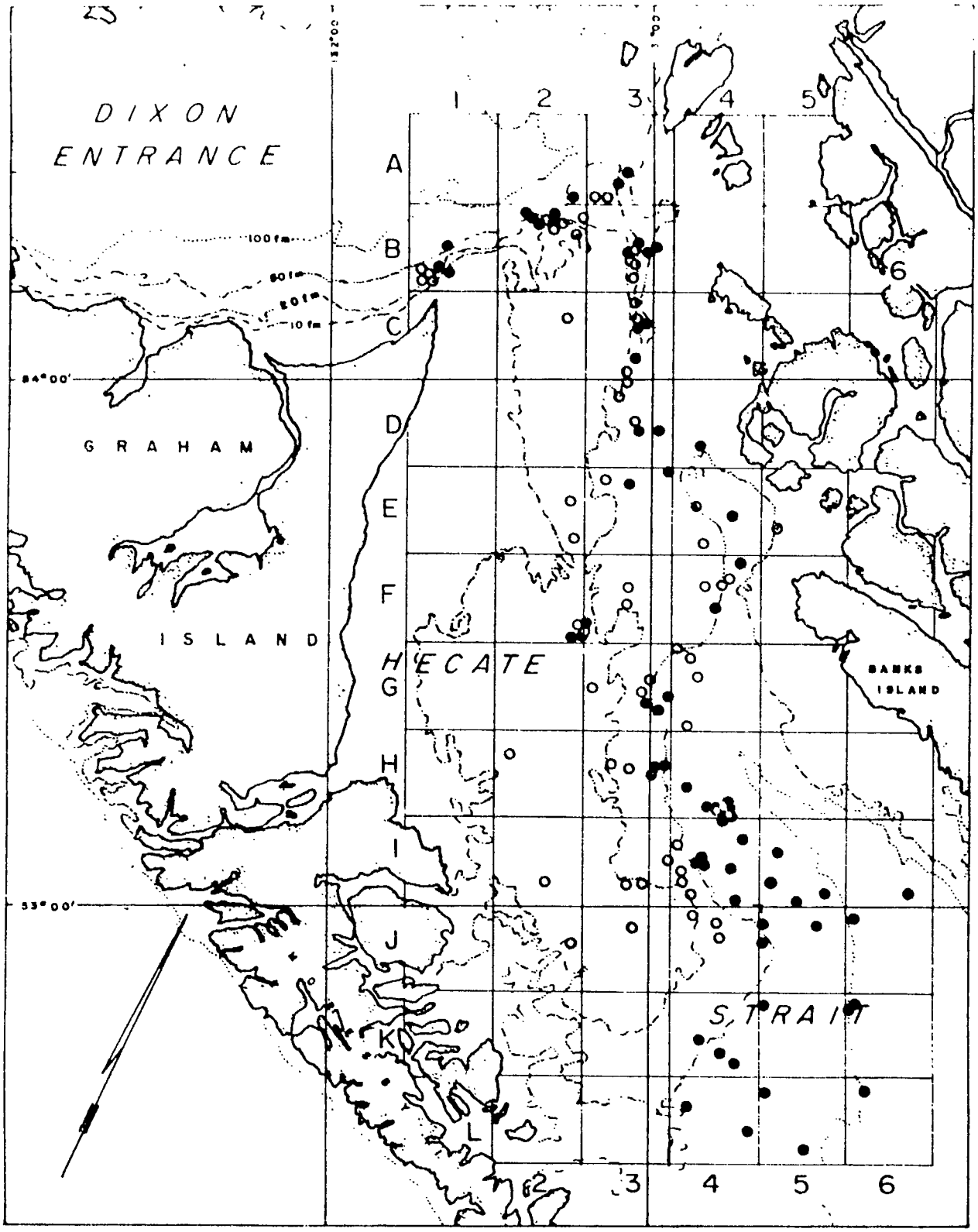


Fig. 2. Trawl sampling sites for the research cruise of the DOUBLE DECKER and the G.B. REED for the period Jan. 27 - Feb. 29, 1986.

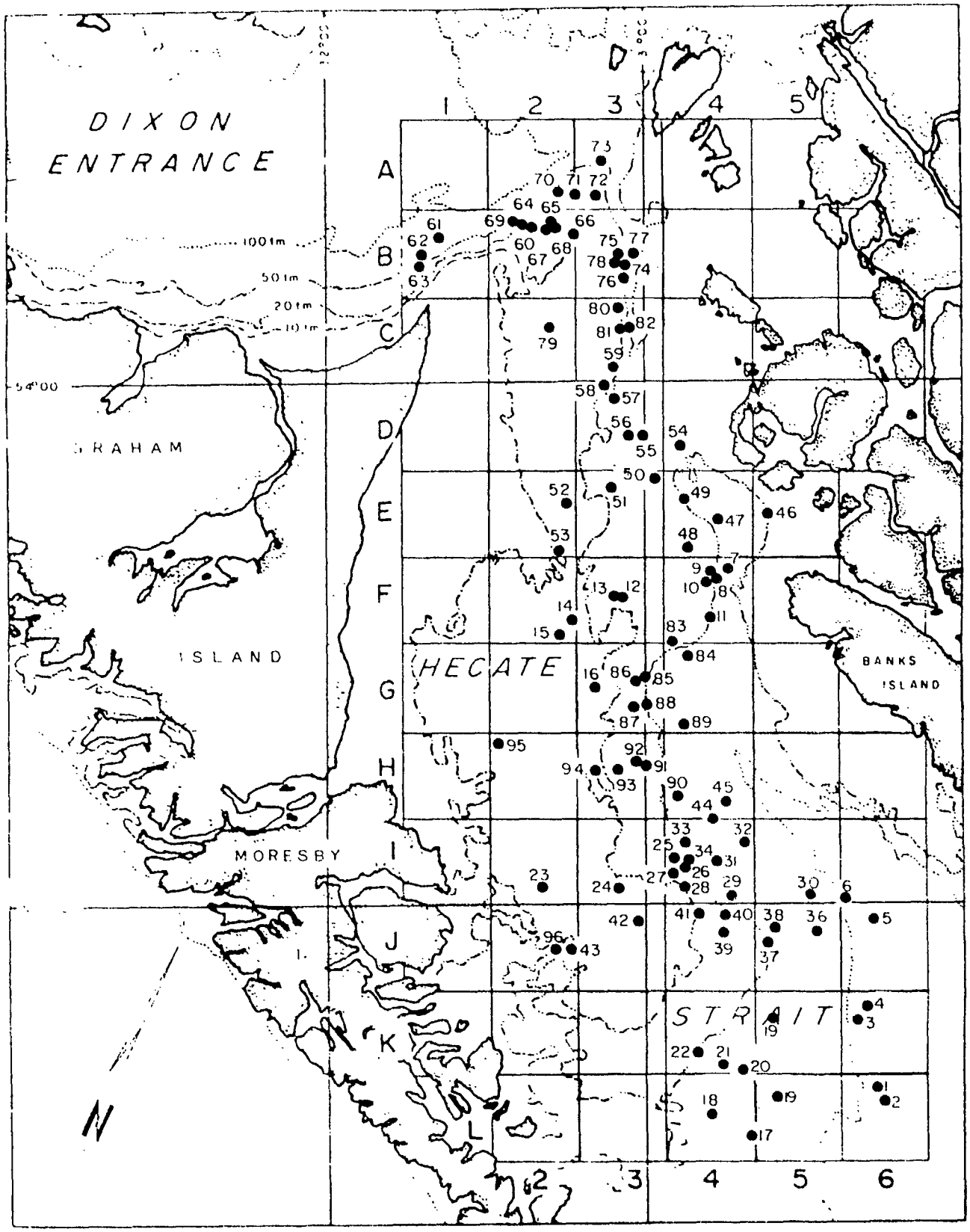


Fig. 3. Trawl sampling sites for the research cruise of the EASTWARD HO for the period May 27 - June 17, 1987.

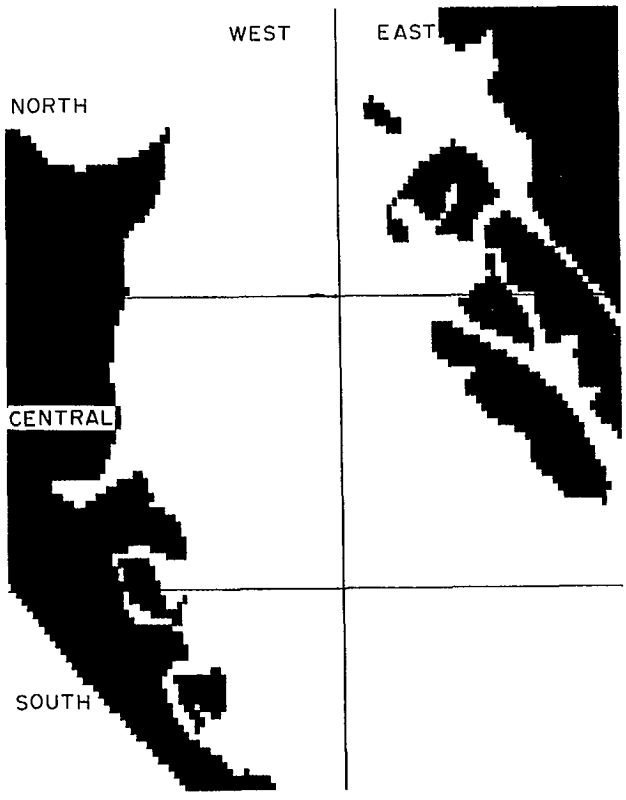


Fig. 4. Areas referred to in Hecate Strait for results of species distribution studies.

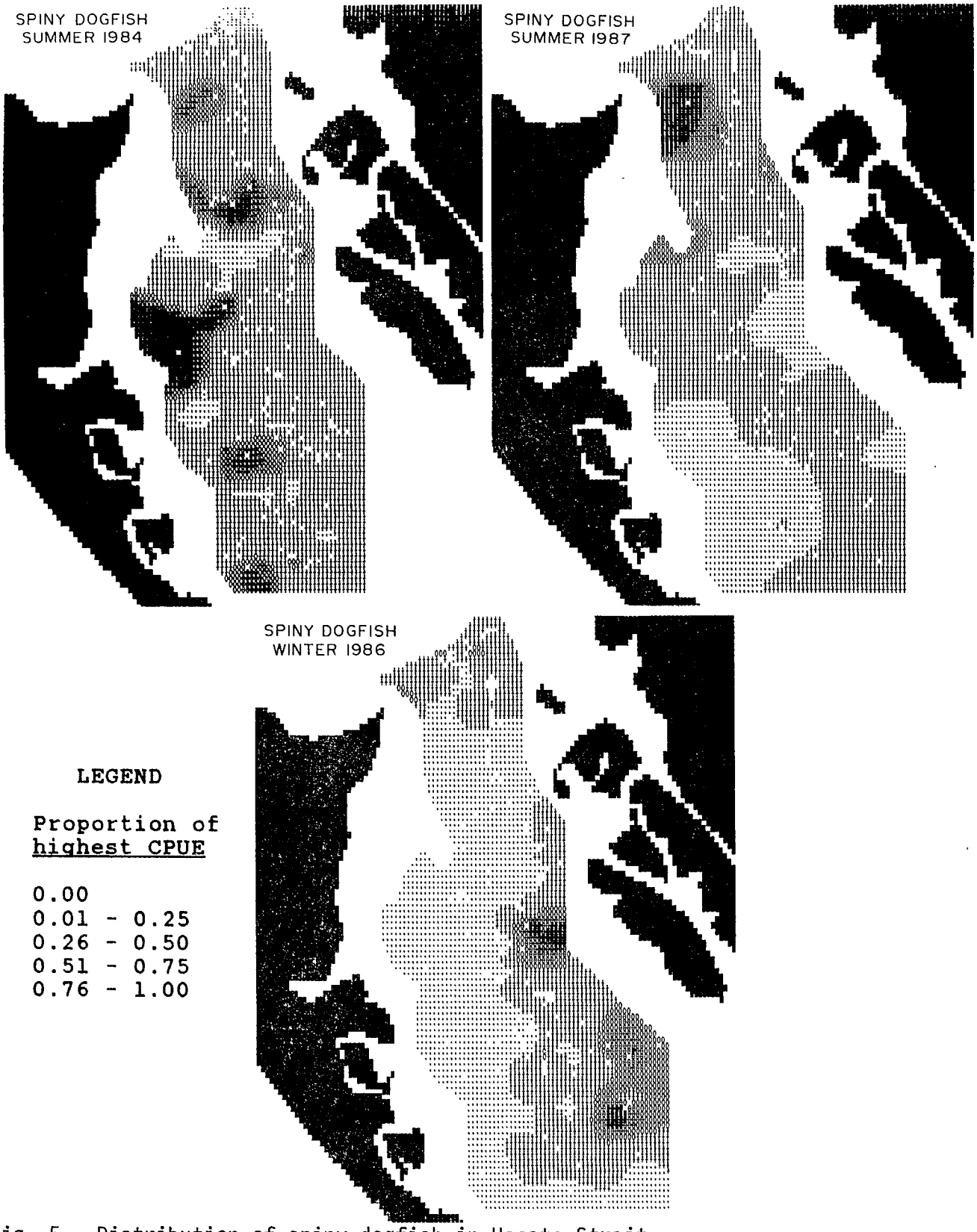


Fig. 5. Distribution of spiny dogfish in Hecate Strait.

Fig. 6. Distribution of big skate in Hecate Strait. See Figure 5 for density scale.

Fig. 7. Distribution of ratfish in Hecate Strait. See Figure 5 for density scale.

Fig. 8. Distribution of Pacific cod in Hecate Strait. See Figure 5 for density scale.

Fig. 9. Distribution of Pacific ocean perch in Hecate Strait. See Figure 5 for density scale.

Fig. 10. Distribution of sablefish in Hecate Strait. See Figure 5 for density scale.

Fig. 11. Distribution of Pacific sanddab in Hecate Strait. See Figure 5 for density scale.

Fig. 12. Distribution of arrowtooth flounder in Hecate Strait. See Figure 5 for density scale.

Fig. 13. Distribution of petrale sole in Hecate Strait. See Figure 5 for density scale.

Fig. 14. Distribution of rex sole in Hecate Strait. See Figure 5 for density scale.

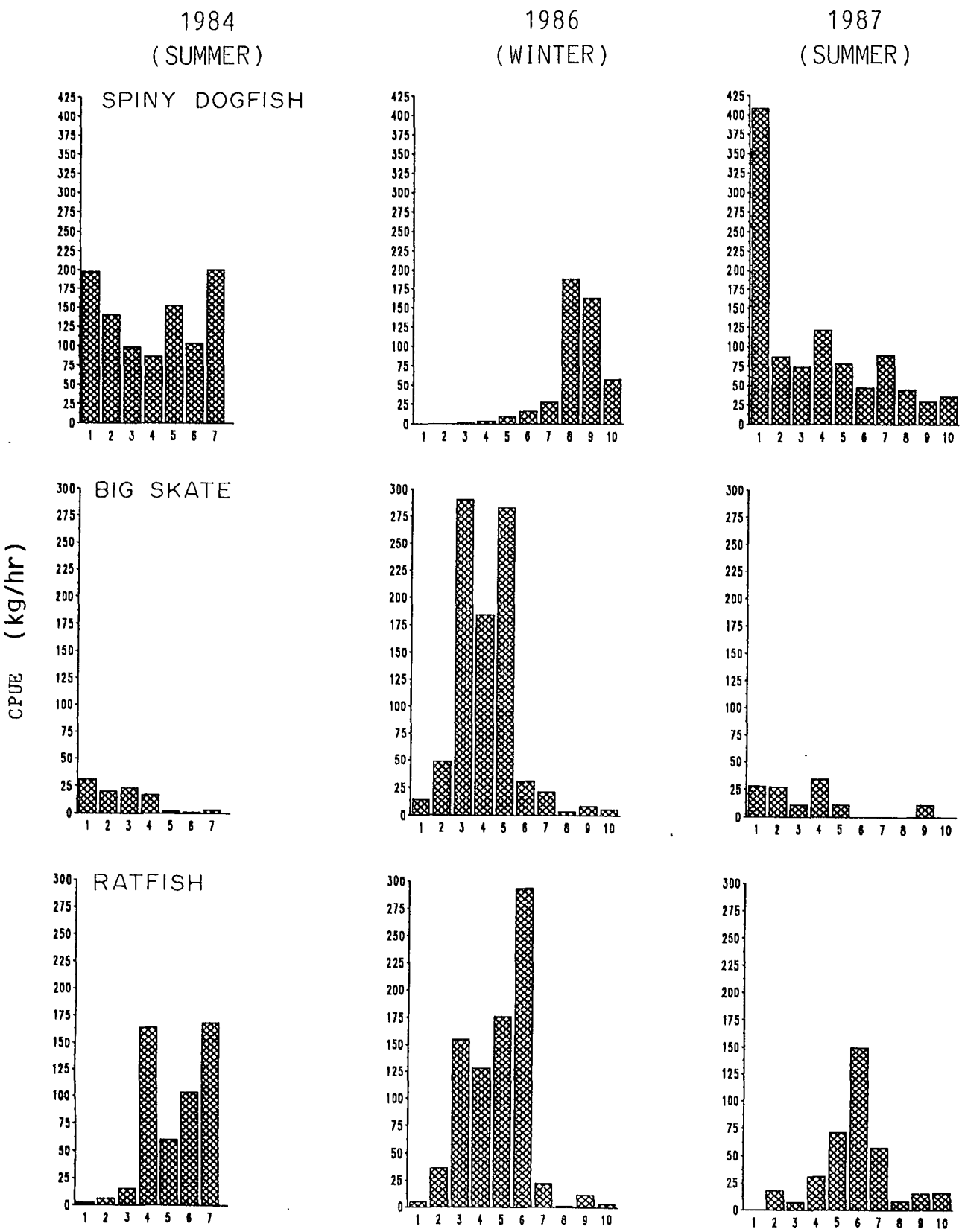
Fig. 15. Distribution of Pacific halibut in Hecate Strait. See Figure 5 for density scale.

Fig. 16. Distribution of rock sole in Hecate Strait. See Figure 5 for density scale.

Fig. 17. Distribution of Dover sole in Hecate Strait. See Figure 5 for density scale.

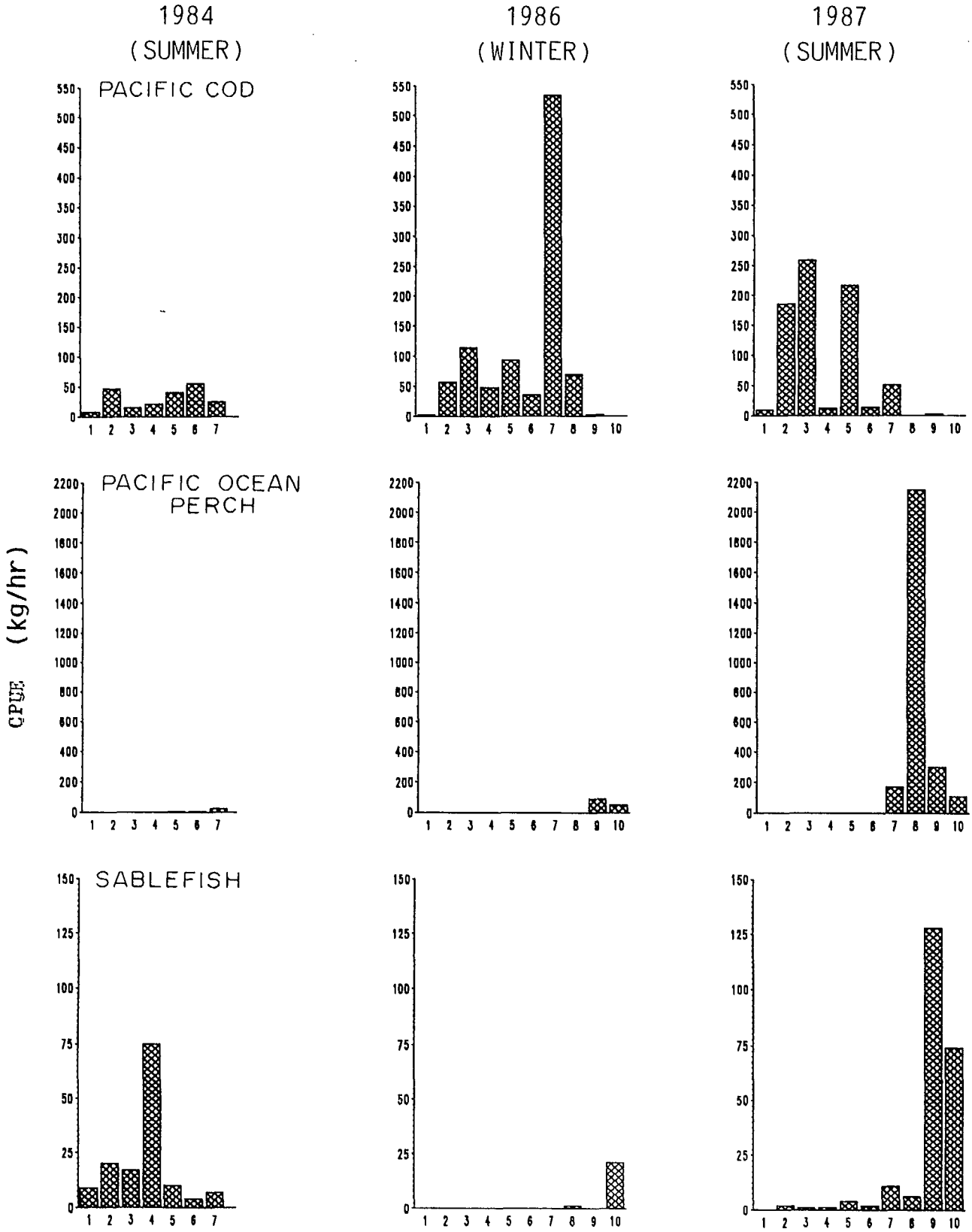
Fig. 18. Distribution of English sole in Hecate Strait. See Figure 5 for density scale.

Fig. 19. Abundance of spiny dogfish, big skate and ratfish by depth interval in Hecate Strait, based on CPUE (kg/hr) from bottom trawl surveys conducted from 1984-1987.



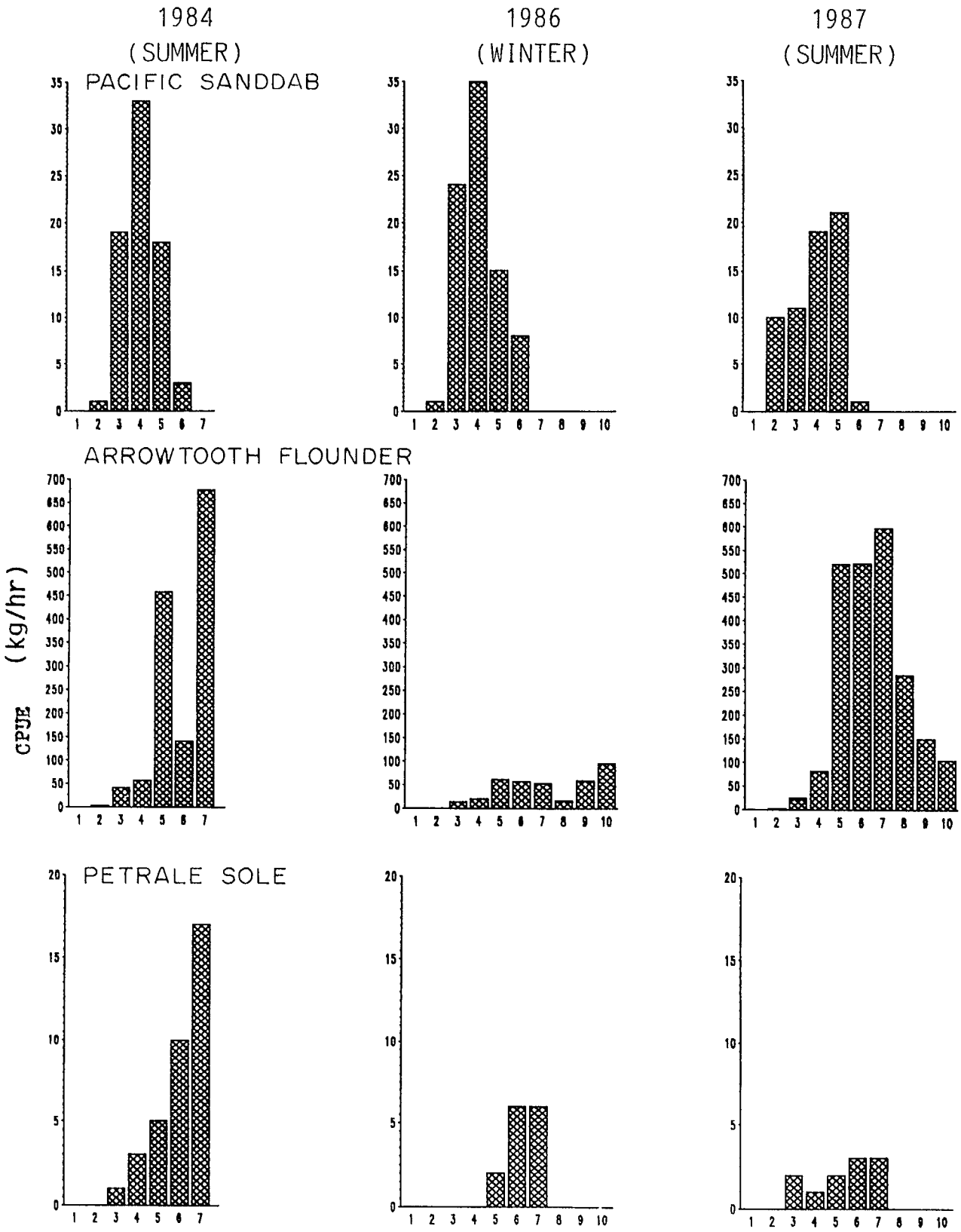
(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 20. Abundance of Pacific cod, Pacific ocean perch, and sablefish by depth interval in Hecate Strait, based on CPUE (kg/hr) from bottom trawl surveys conducted from 1984-1987.



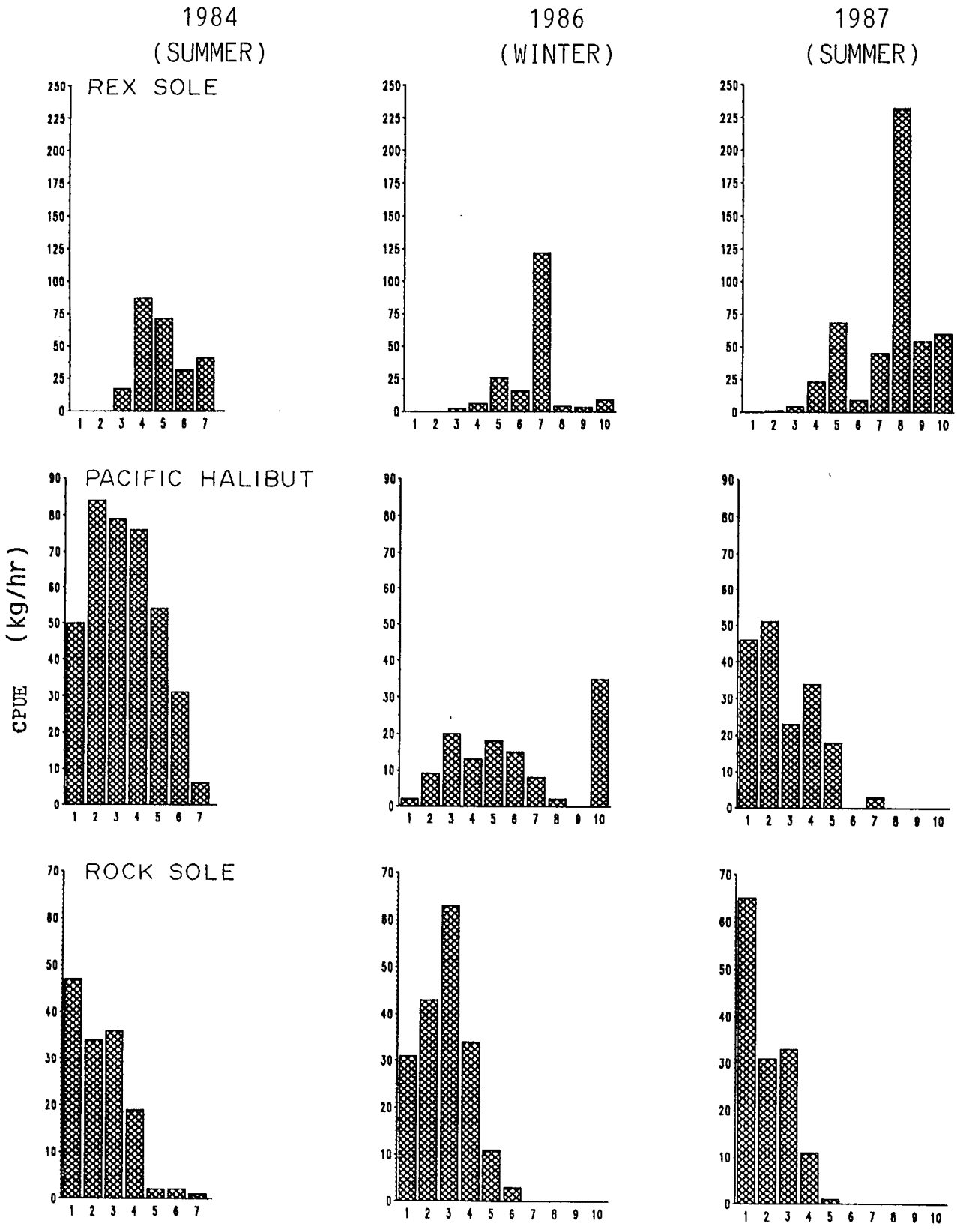
(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 21. Abundance of Pacific sanddab, arrowtooth flounder, and petrale sole by depth interval in Hecate Strait, based on CPUE (kg/hr) from bottom trawl surveys conducted from 1984-1987.



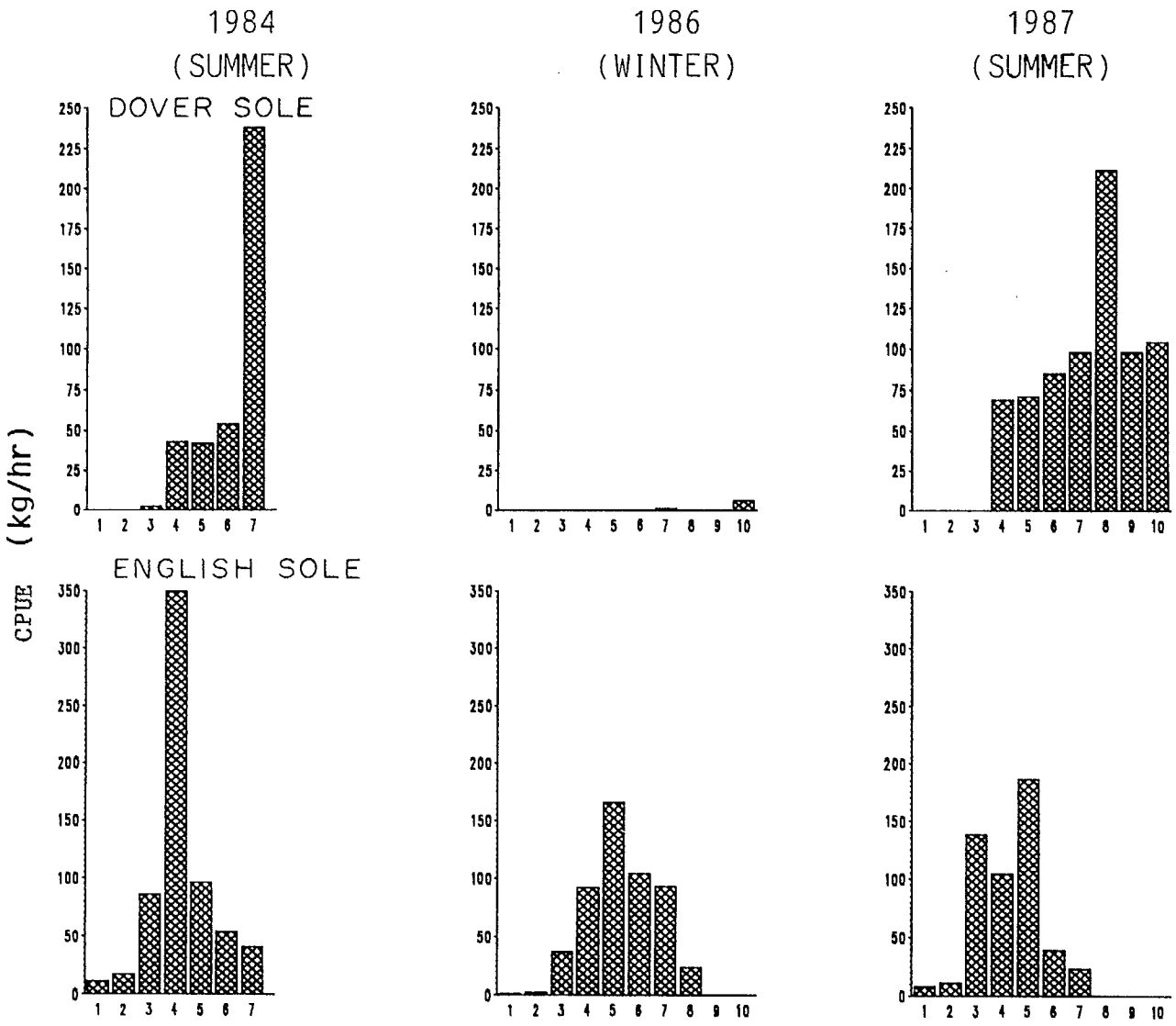
(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 22. Abundance of rex sole, Pacific halibut, and rock sole by depth interval in Hecate Strait, based on CPUE (kg/hr) from bottom trawl surveys conducted from 1984-87.



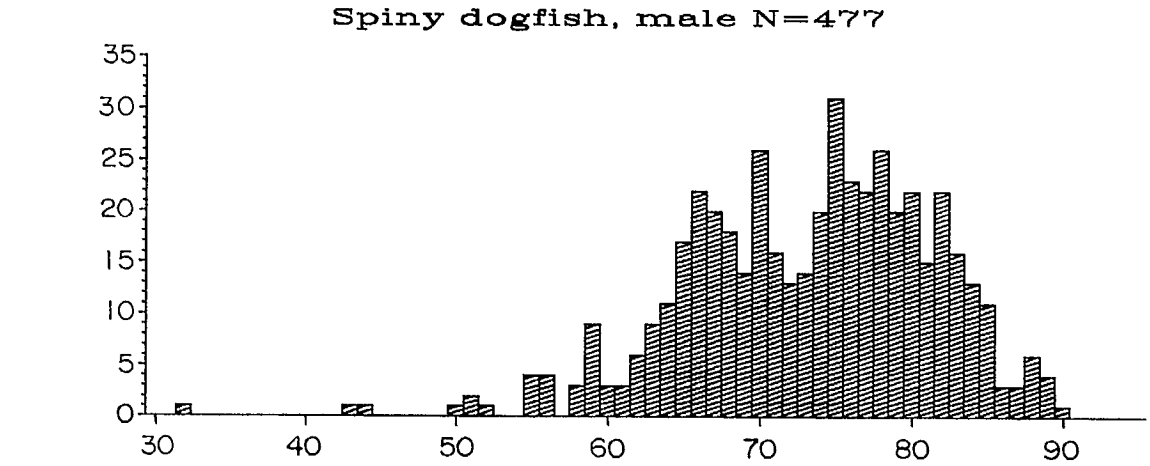
(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

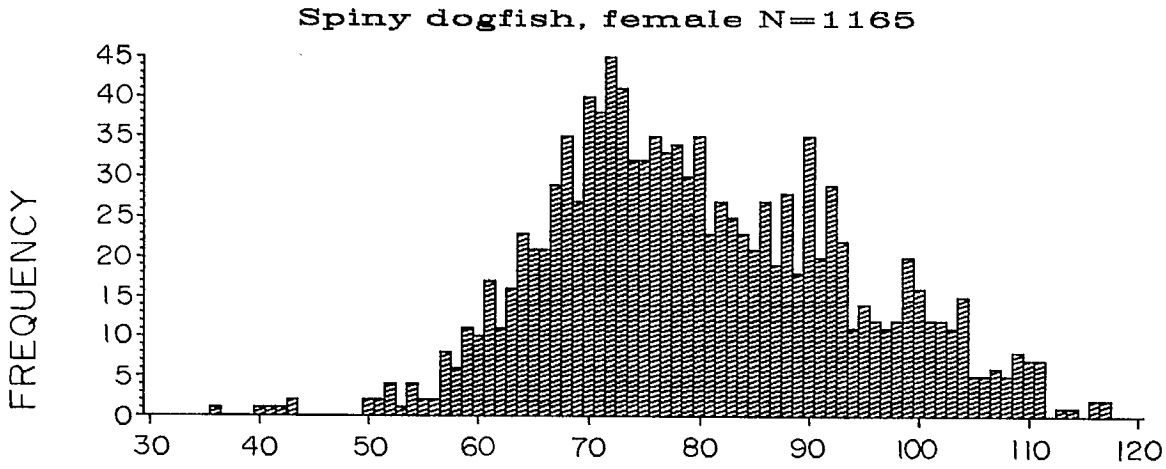
Fig. 23. Abundance of Dover sole, and English sole by depth interval in Hecate Strait, based on CPUE (kg/hr) from bottom trawl surveys conducted from 1984-1987.



(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 24. Total size frequency compositions for spiny dogfish (males and females) and big skate for the summer, 1987 survey of Hecate Strait.


Spiny dogfish, male N=477
35
30
25
20
15
10
5
0
30
40
50
60
70
80
90


Spiny dogfish, female N=1165
FREQUENCY
45
40
35
30
25
20
15
10
5
0
30
40
50
60
70
80
90
100
110
120

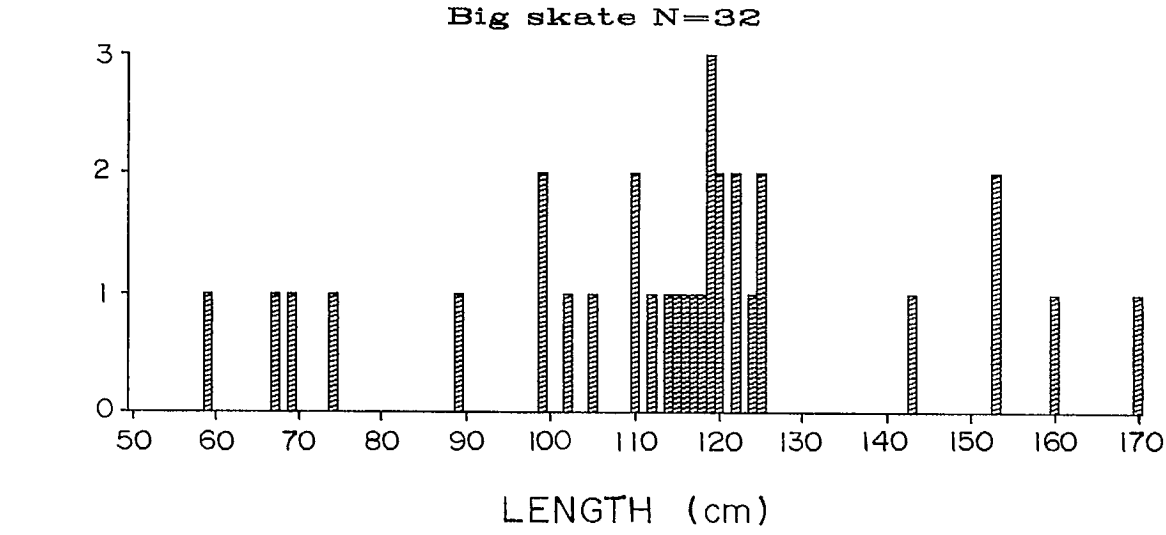

Big skate N=32
3
2
1
0
50
60
70
80
90
100
110
120
130
140
150
160
170
LENGTH (cm)

Fig. 25. Total size frequency compositions for ratfish, Pacific cod, and Pacific ocean perch for the summer, 1987, survey of Hecate Strait.

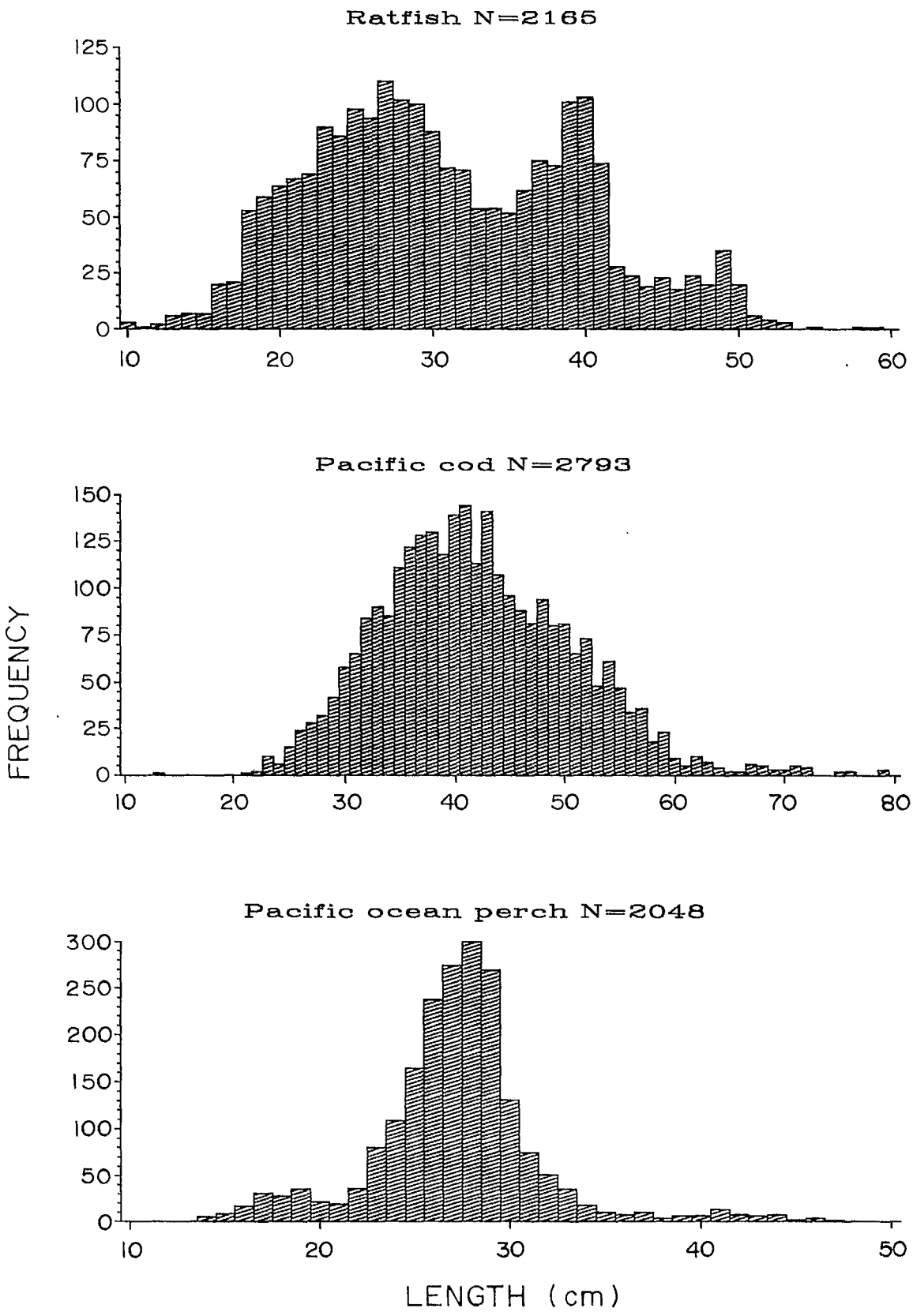

Ratfish N=2165
125
100
75
50
25
0
10
20
30
40
50
60
Pacific cod N=2793
150
125
100
75
50
25
0
FREQUENCY
10
20
30
40
50
60
70
80
Pacific ocean perch N=2048
300
250
200
150
100
50
0
10
20
30
40
50
LENGTH (cm)

Fig. 26. Total size frequency compositions for sablefish, Pacific sanddab, and arrowtooth flounder for the summer, 1987, survey of Hecate Strait.

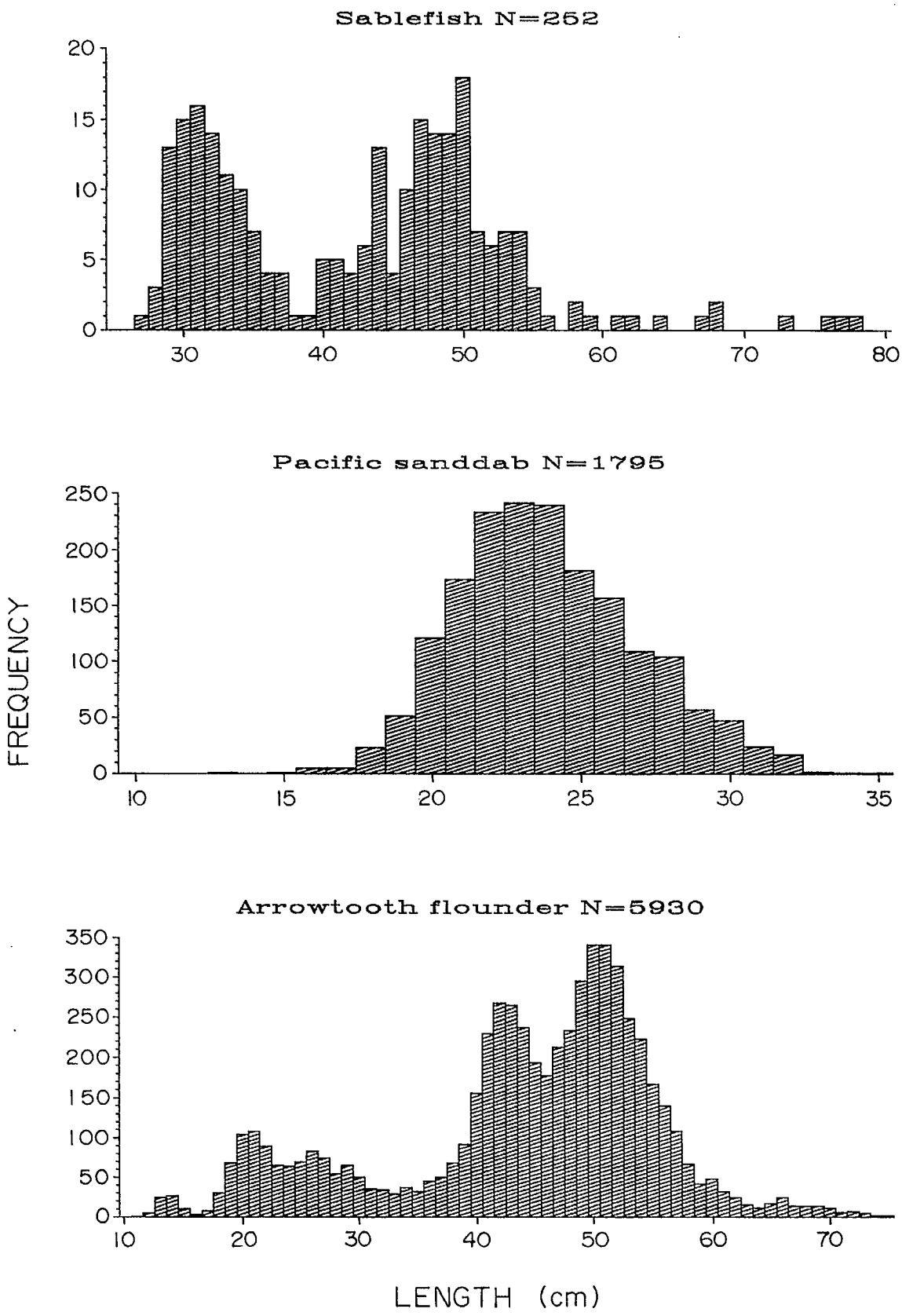

Sablefish N=252
20
15
10
5
0
30
40
50
60
70
80
Pacific sanddab N=1795
FREQUENCY
250
200
150
100
50
0
10
15
20
25
30
35
Arrowtooth flounder N=5930
350
300
250
200
150
100
50
0
10
20
30
40
50
60
70
LENGTH (cm)

Fig. 27. Total size frequency compositions for petrale sole, rex sole, and Pacific halibut for the summer, 1987, survey of Hecate Strait.

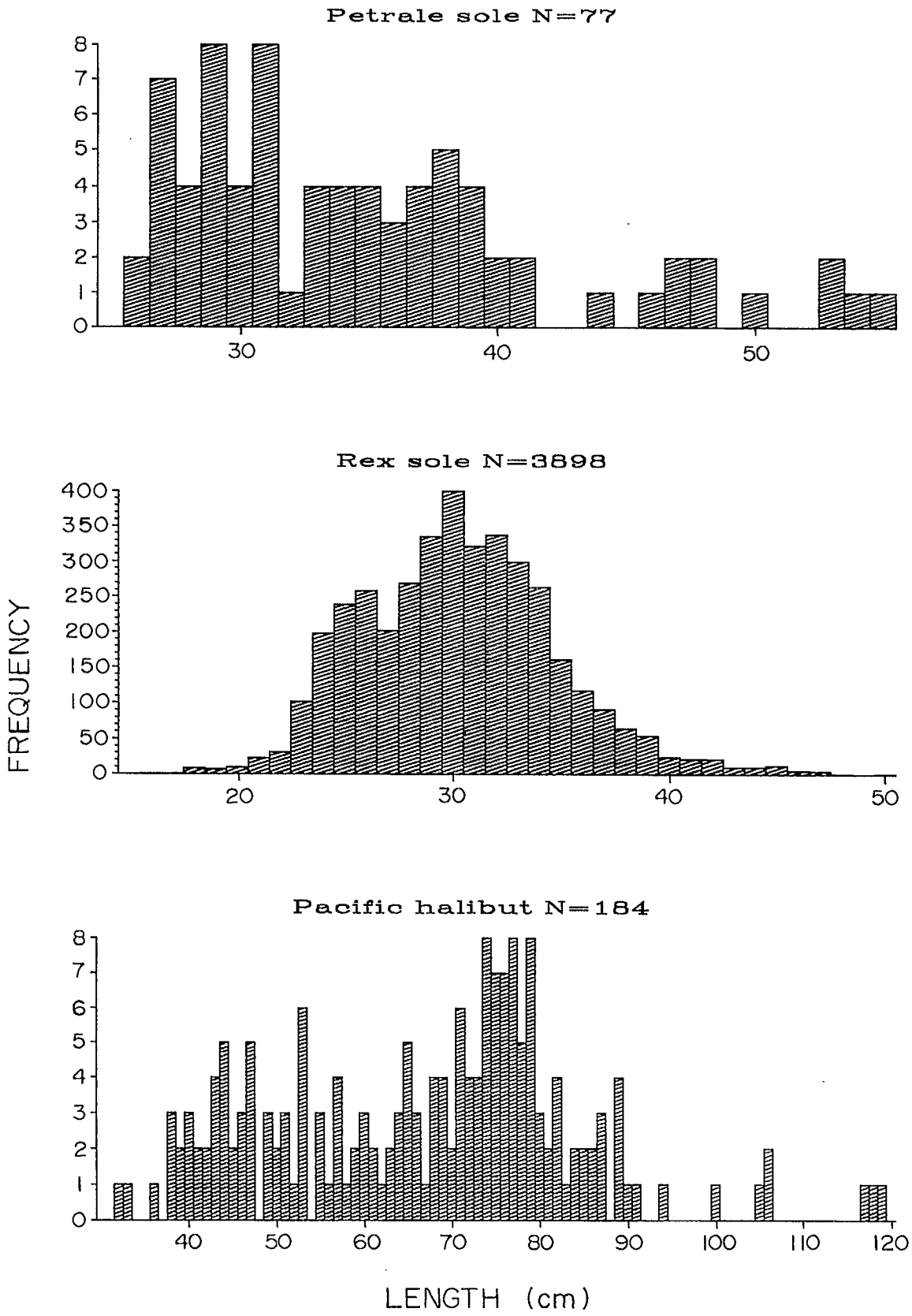

Petrale sole N=77
0
1
2
3
4
5
6
7
8
30
40
50
Rex sole N=3898
FREQUENCY
0
50
100
150
200
250
300
350
400
20
30
40
50
Pacific halibut N=184
0
1
2
3
4
5
6
7
8
40
50
60
70
80
90
100
110
120
LENGTH (cm)

Fig. 28. Total size frequency compositions for rock sole, Dover sole and English sole for the summer, 1987 survey of Hecate Strait.

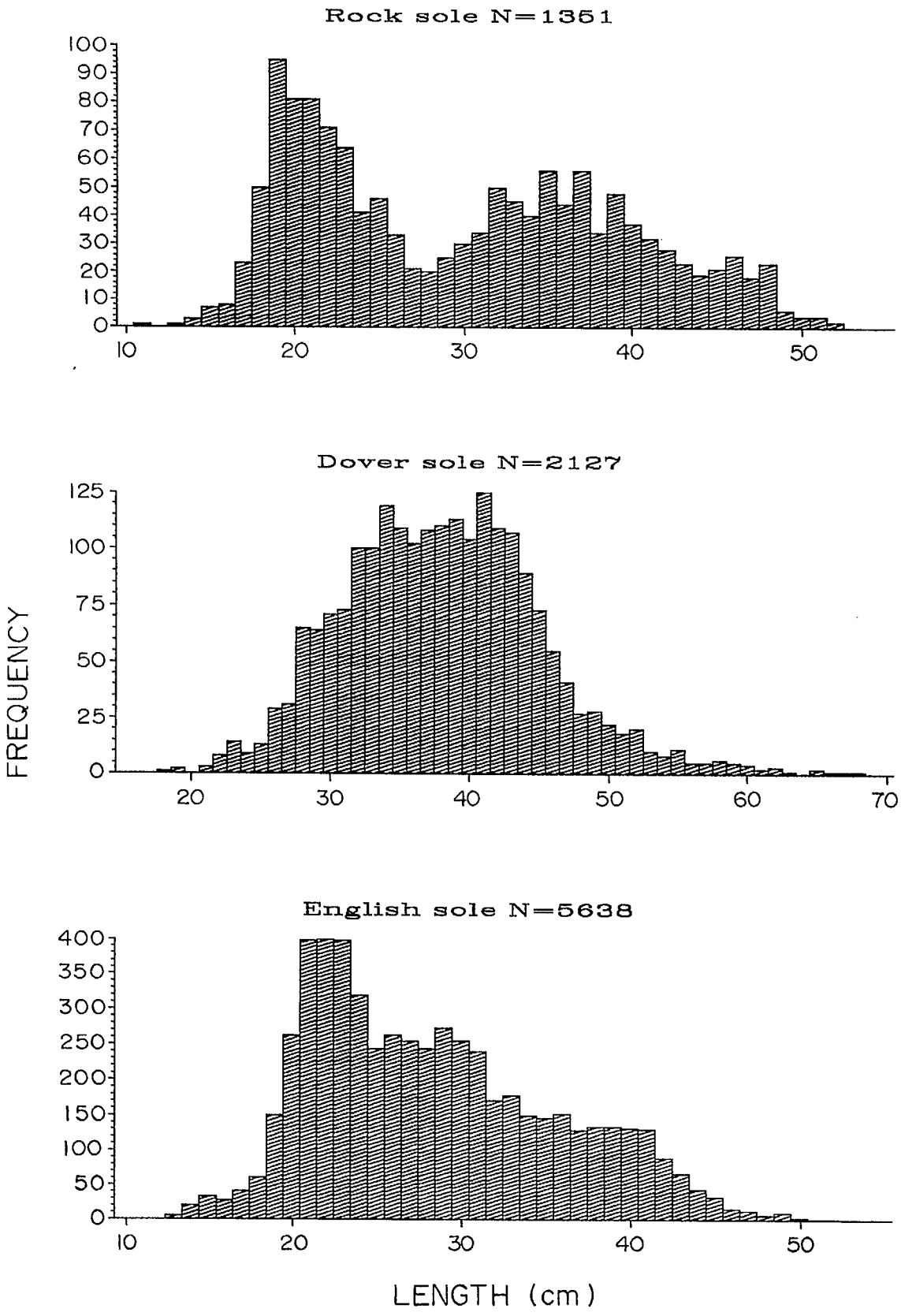
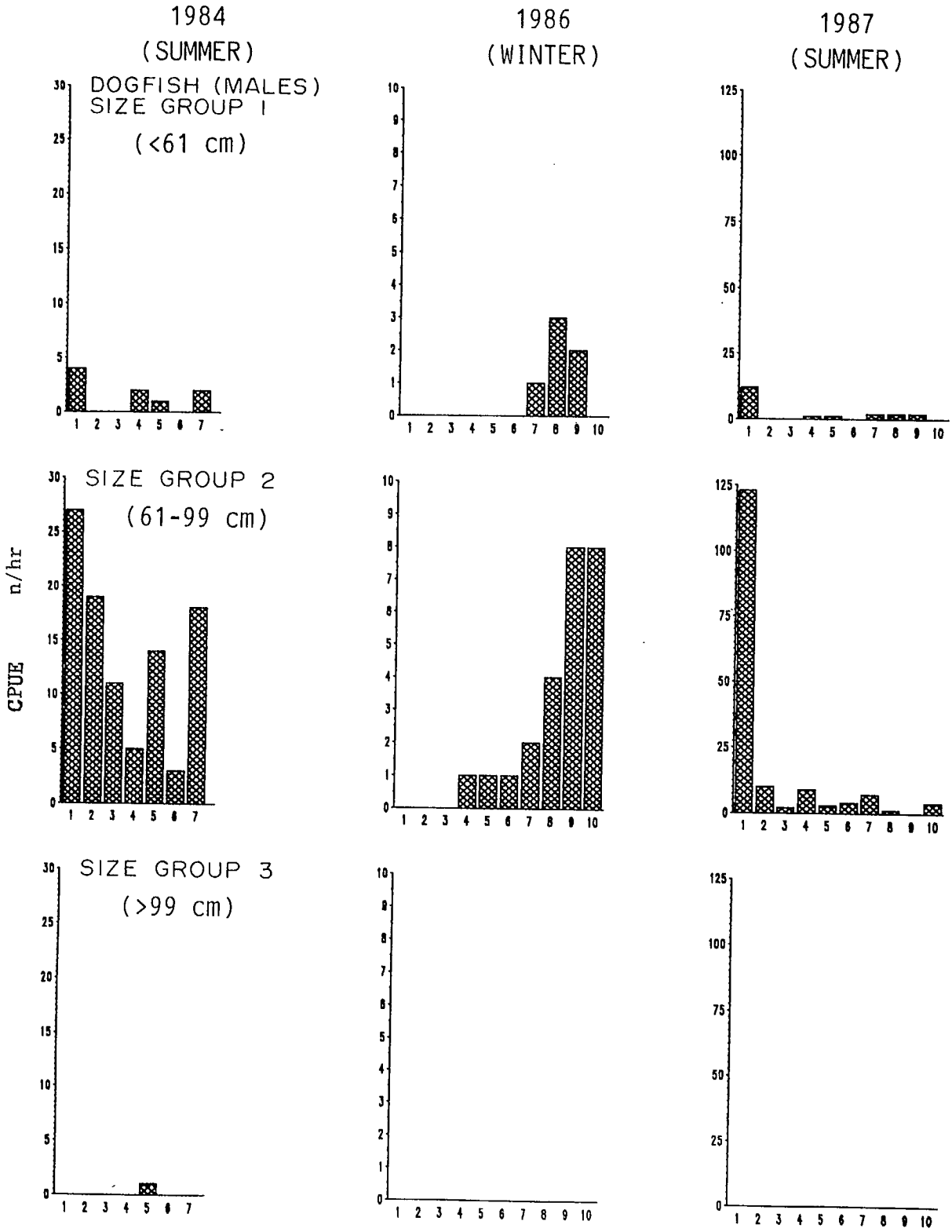
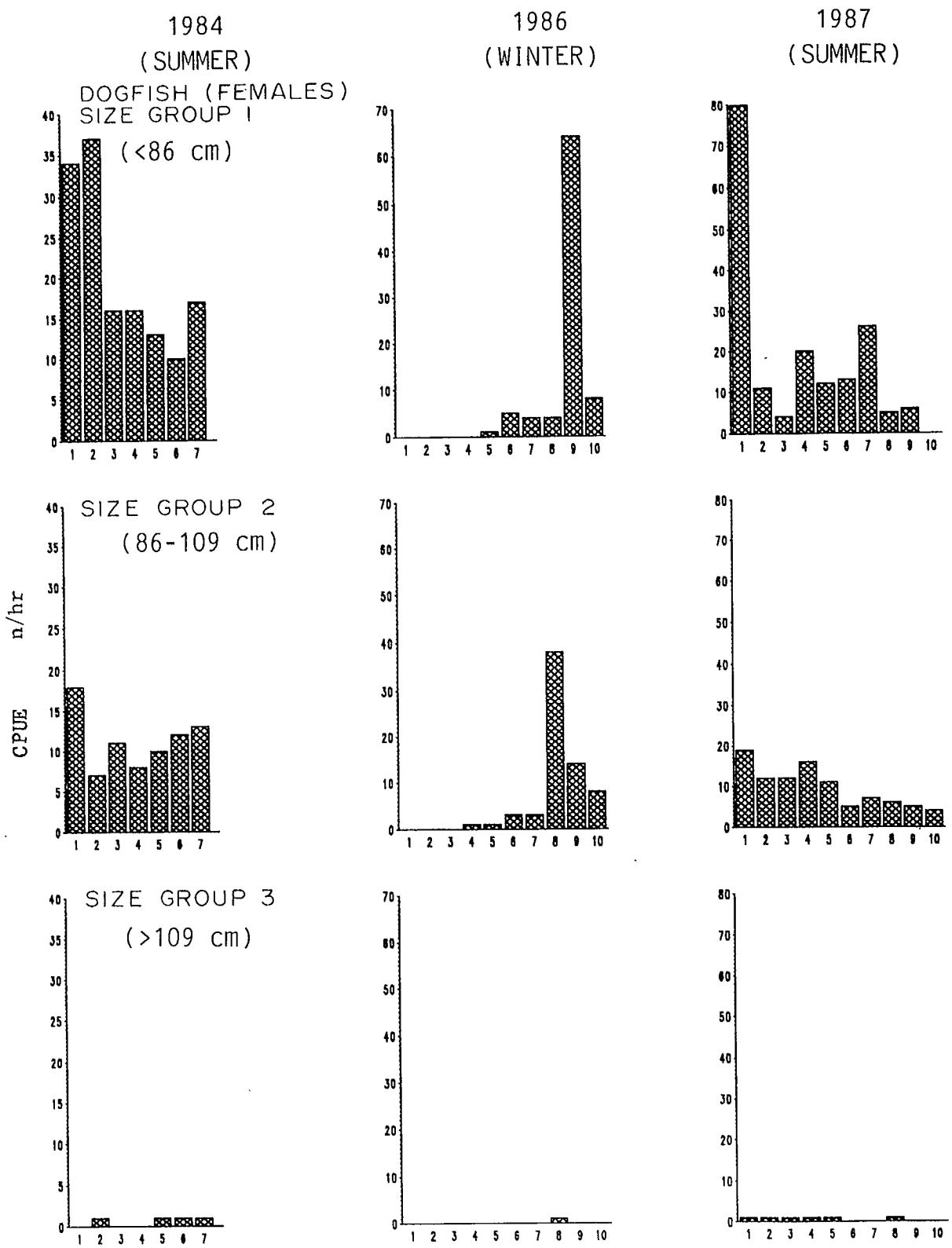

Rock sole N=1351
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
Dover sole N=2127
125
100
75
50
25
0
FREQUENCY
20
30
40
50
60
70
English sole N=5638
400
350
300
250
200
150
100
50
0
10
20
30
40
50
LENGTH (cm)

Fig. 29. Abundance of size groups of spiny dogfish males by depth interval in Hecate Strait, based on CPUE (n/hr) from bottom trawl surveys conducted from 1984-87.



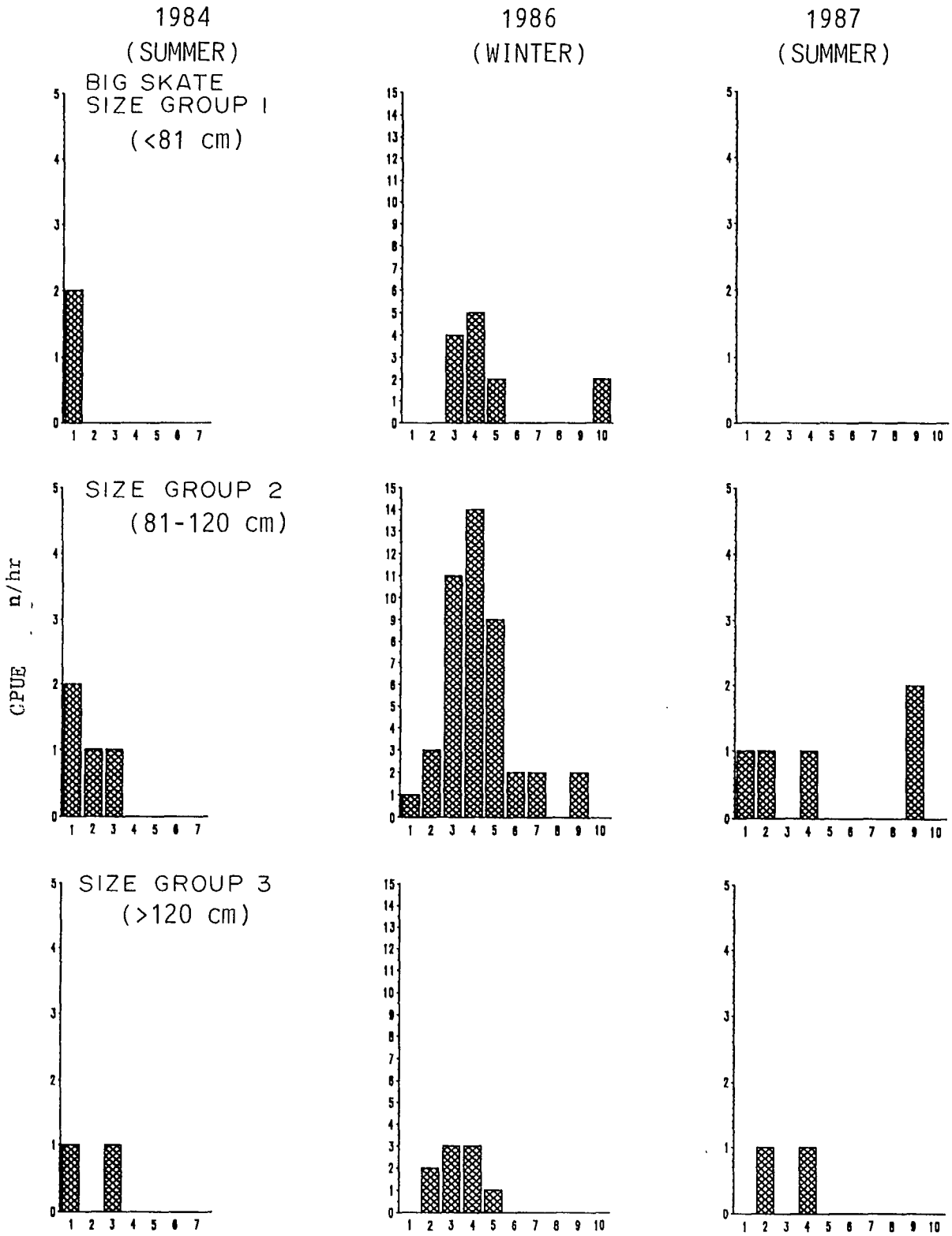
(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 30. Abundance of size groups of spiny dogfish females by depth interval in Hecate Strait based on CPUE (n/hr) from bottom trawl surveys conducted from 1984-87.



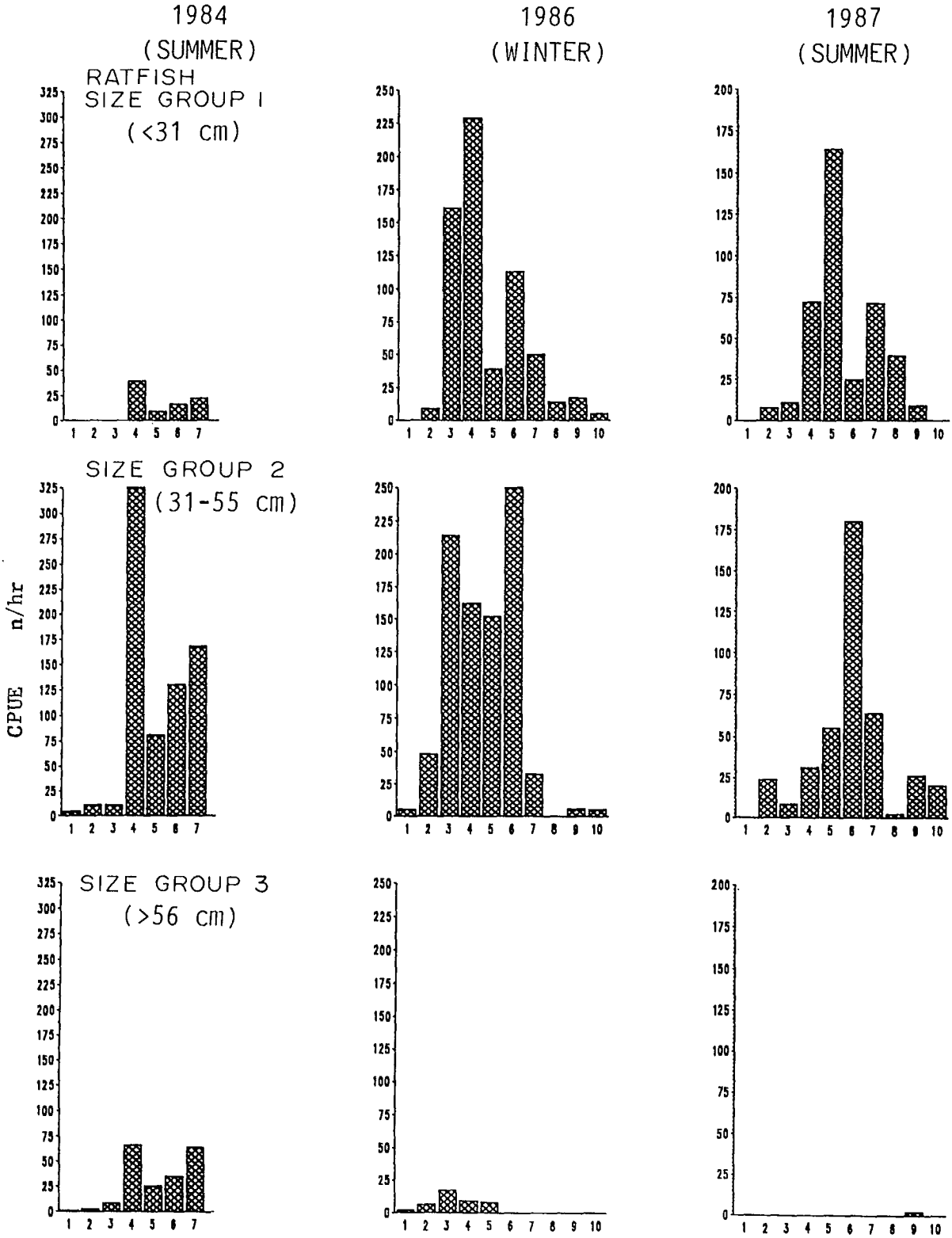
(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 31. Abundance of size groups of big skate by depth interval in Hecate Strait based on CPUE (n/hr) from bottom trawl surveys conducted from 1984-87.



(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 32. Abundance size groups of ratfish by depth interval in Hecate Strait, based on CPUE (n/hr) from bottom trawl surveys conducted from 1984-87.



(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 33. Abundance of size groups of Pacific cod by depth interval in Hecate Strait, based on CPUE (n/hr) from bottom trawl surveys conducted from 1984-87.

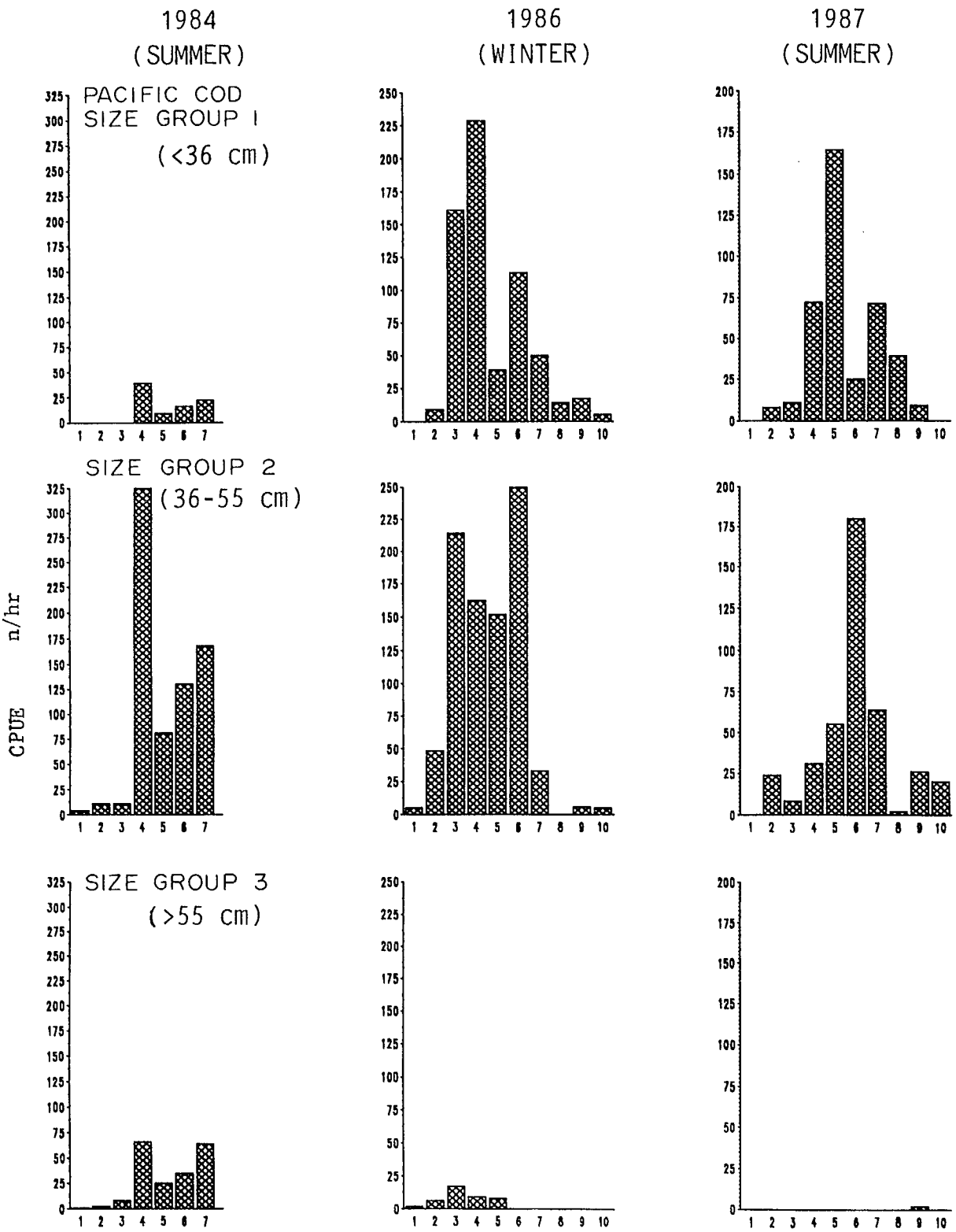
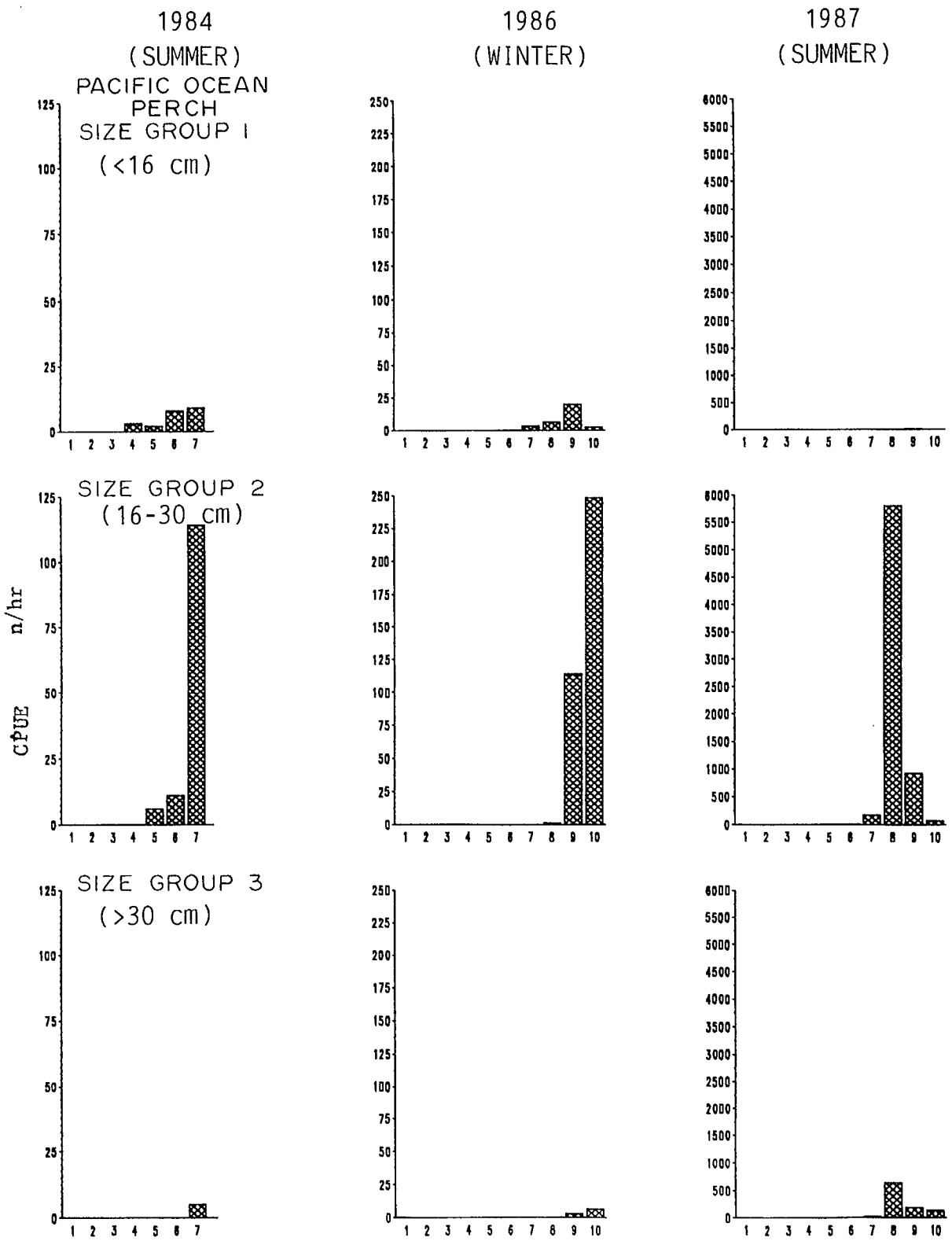
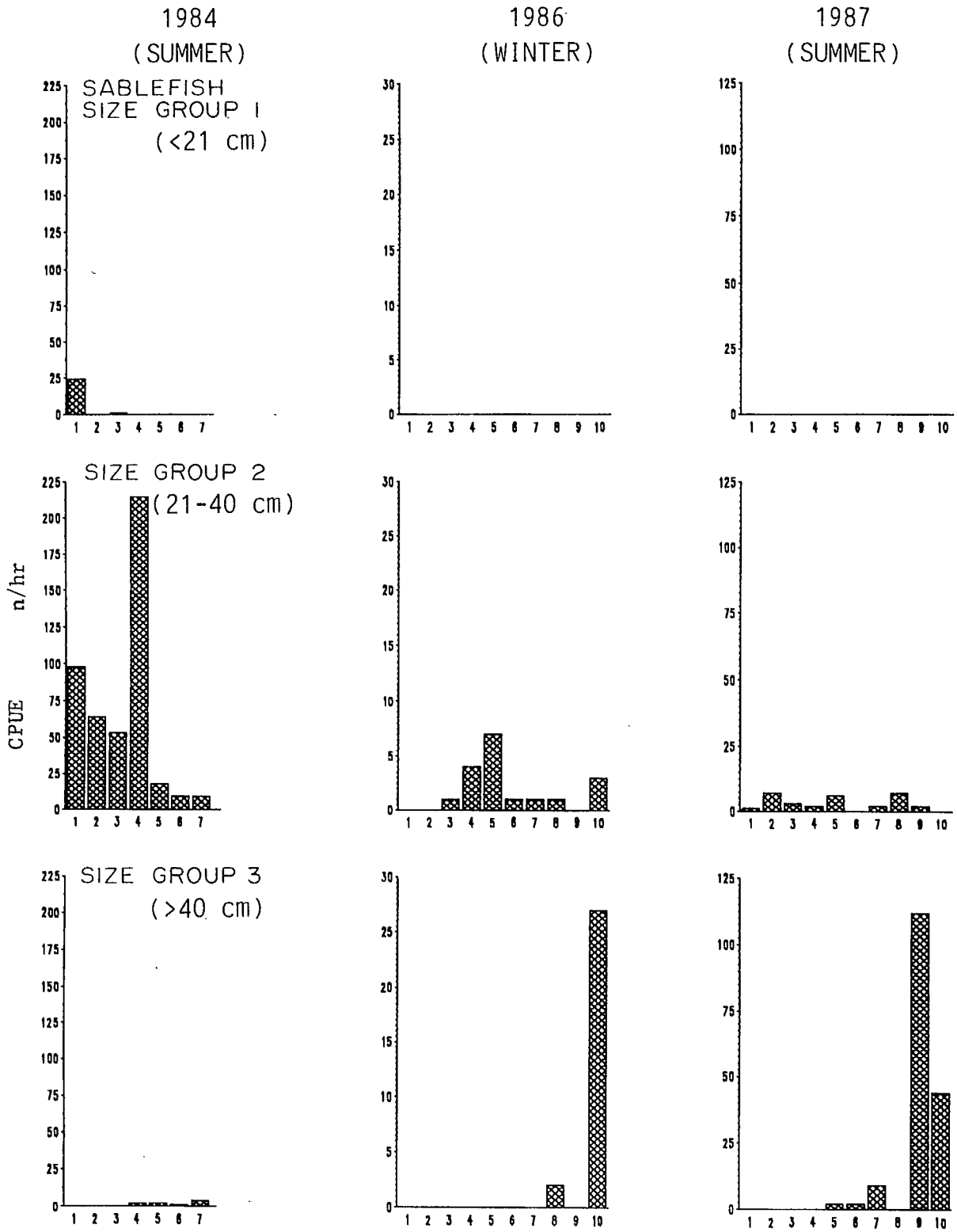

1984
(SUMMER)
1986
(WINTER)
1987
(SUMMER)
PACIFIC COD
SIZE GROUP 1
(<36 cm)
SIZE GROUP 2
(36-55 cm)
SIZE GROUP 3
(>55 cm)
CPUE n/hr
DEPTH INTERVAL (fathoms)[1]
(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59,
6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 34. Abundance of size groups of Pacific ocean perch by depth interval in Hecate Strait, based on CPUE (n/hr) from bottom trawl surveys conducted from 1984-87.



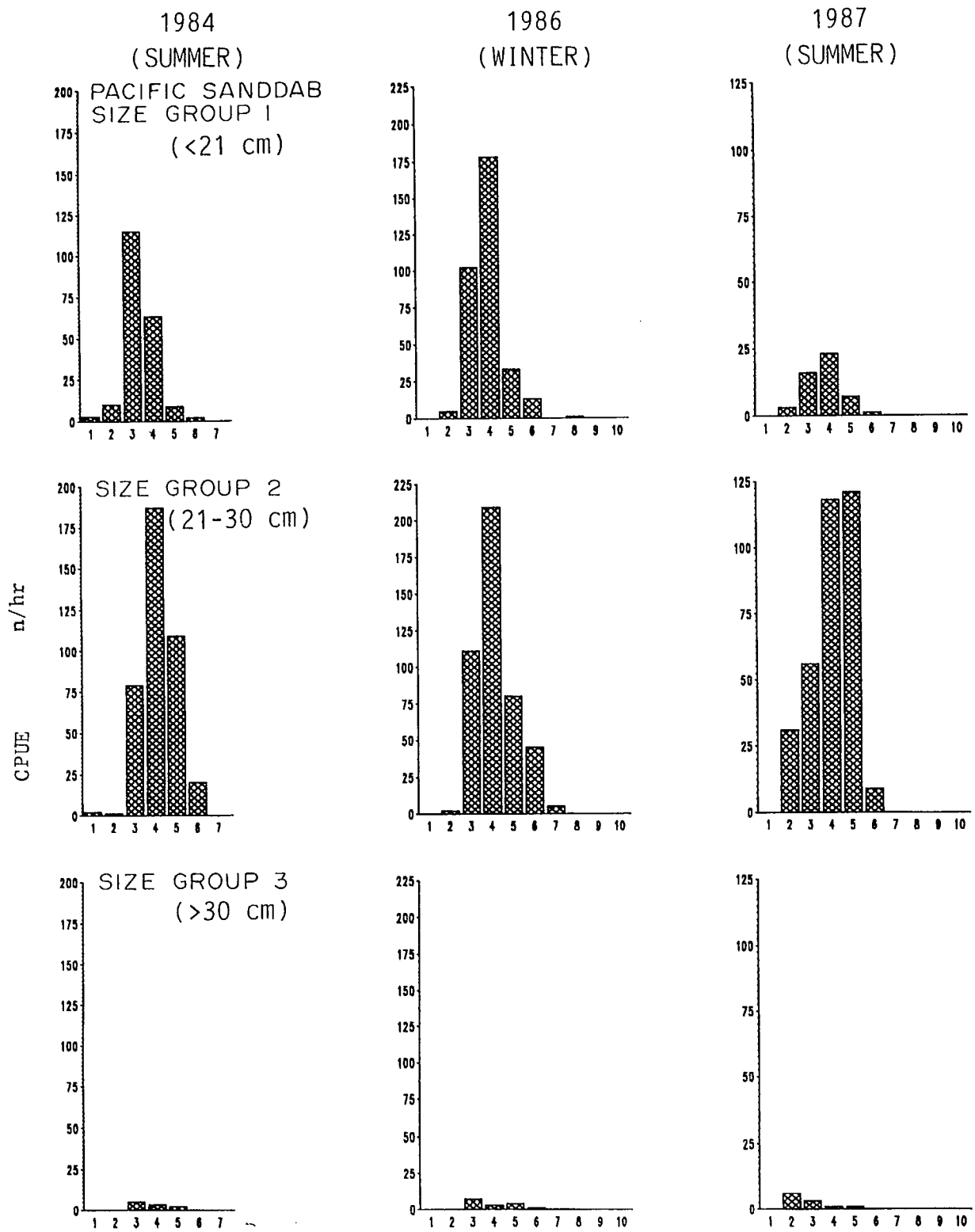
(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 35. Abundance of size groups of sablefish by depth interval in Hecate Strait, based on CPUE (n/hr) bottom trawl surveys conducted from 1984-87.



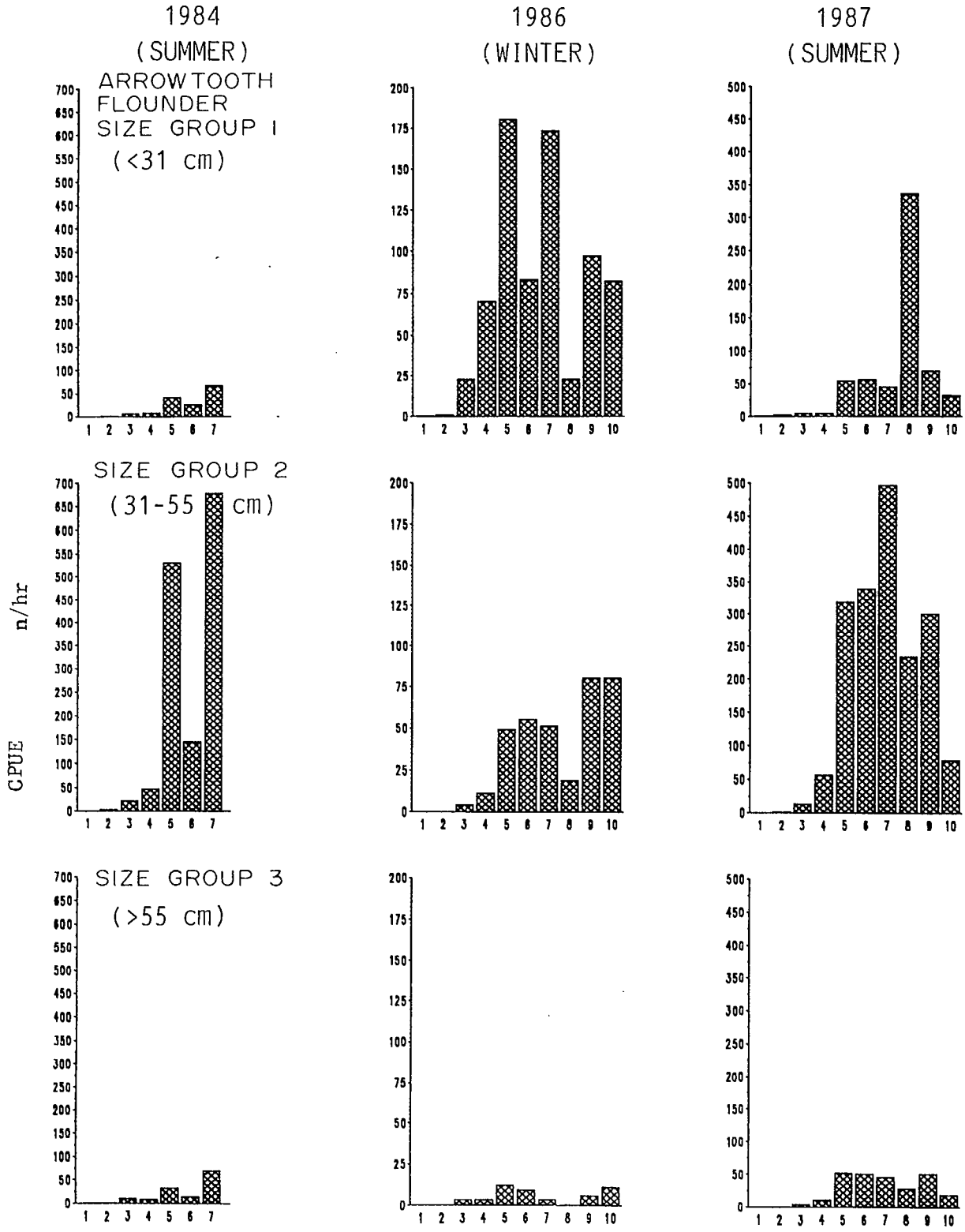
(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 36. Abundance of size groups of Pacific sanddab by depth interval in Hecate Strait, based on CPUE (n/hr) from bottom trawl surveys conducted from 1984-87.



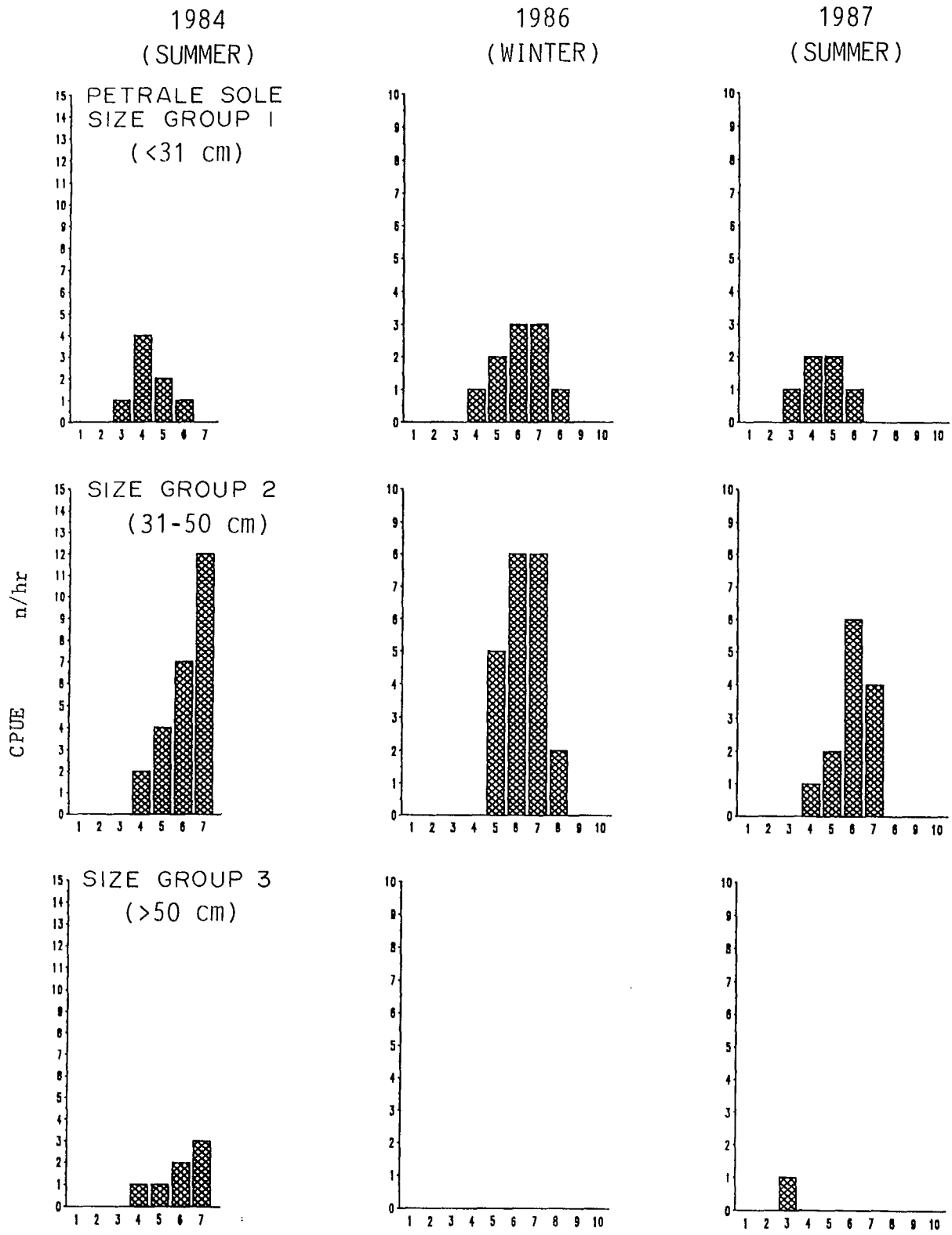
(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 37. Abundance of size groups of arrowtooth flounder by depth interval in Hecate Strait, based on CPUE (n/hr) from bottom trawl surveys conducted from 1984-87.



(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 38. Abundance of size groups of petrale sole by depth interval in Hecate Strait, based on CPUE (n/hr) from bottom trawl surveys conducted from 1984-87.



(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 39. Abundance of size groups of rex sole by depth interval in Hecate Strait, based on CPUE (n/hr) from bottom trawl surveys conducted from 1984-87.

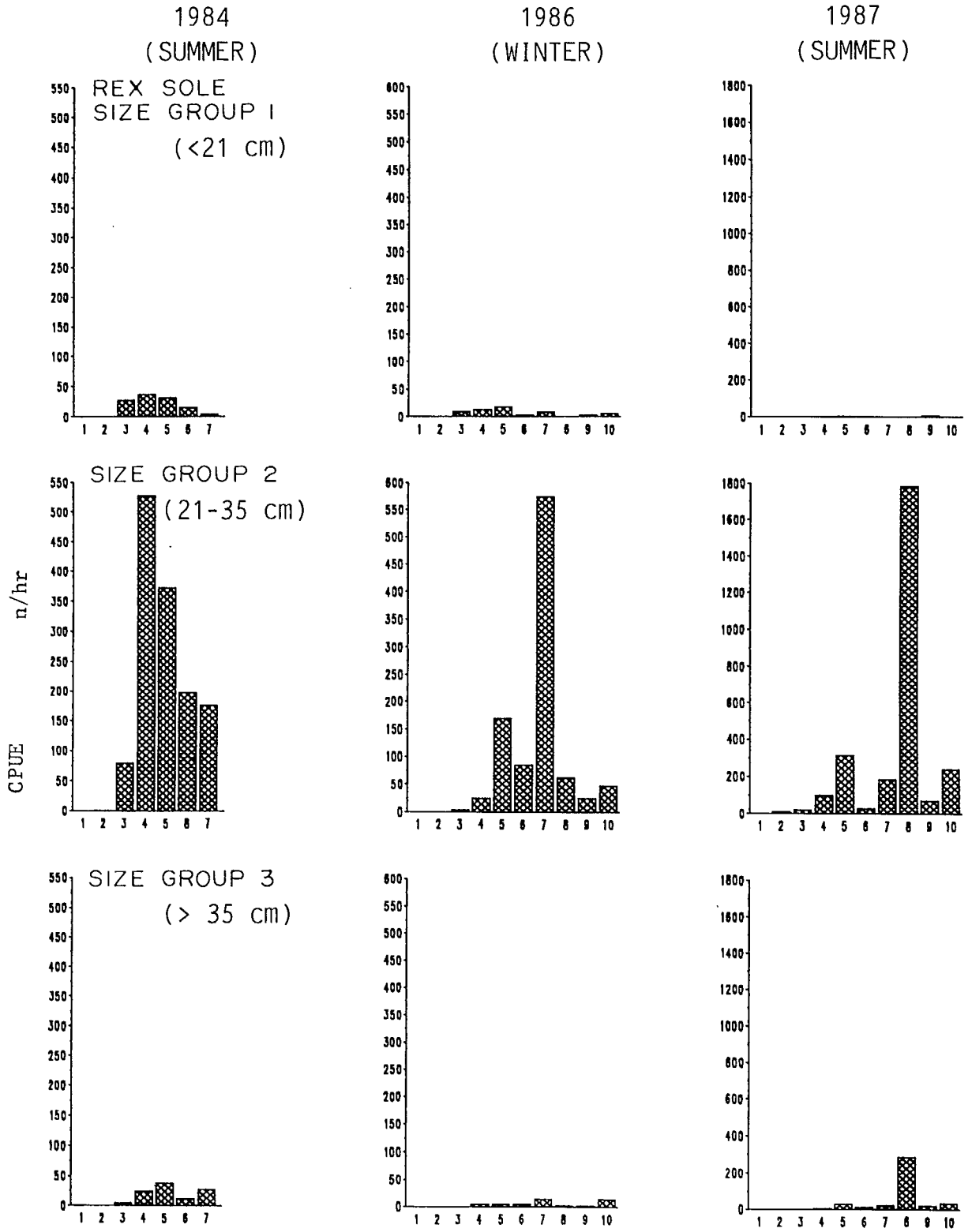

1984
(SUMMER)
1986
(WINTER)
1987
(SUMMER)
REX SOLE
SIZE GROUP 1
(<21 cm)
SIZE GROUP 2
(21-35 cm)
SIZE GROUP 3
(> 35 cm)
CPUE n/hr
DEPTH INTERVAL (fathoms)[1]
(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59,
6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 40. Abundance of size groups of Pacific halibut by depth interval in Hecate Strait, based on CPUE (n/hr) from bottom trawl surveys conducted from 1984-87.

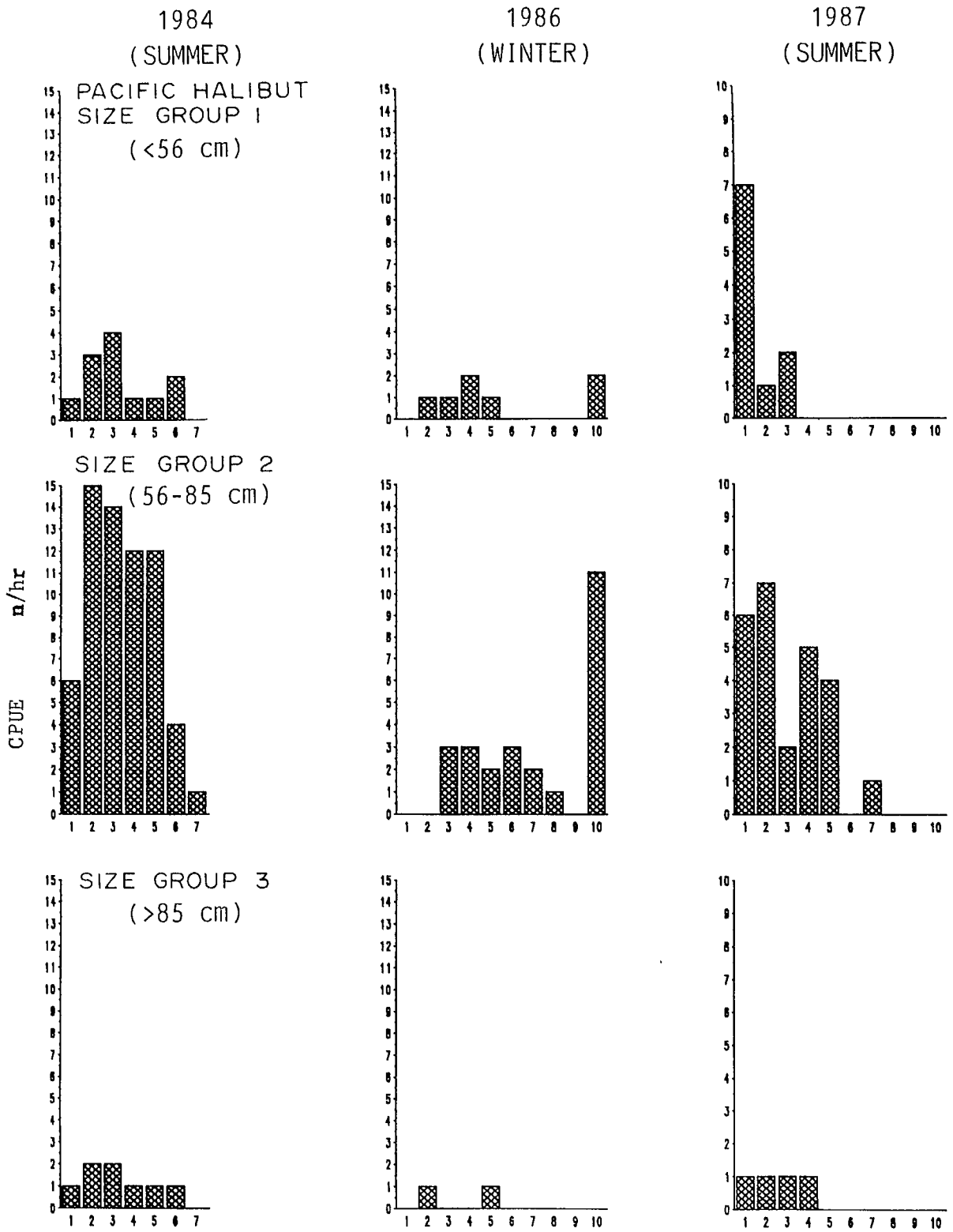
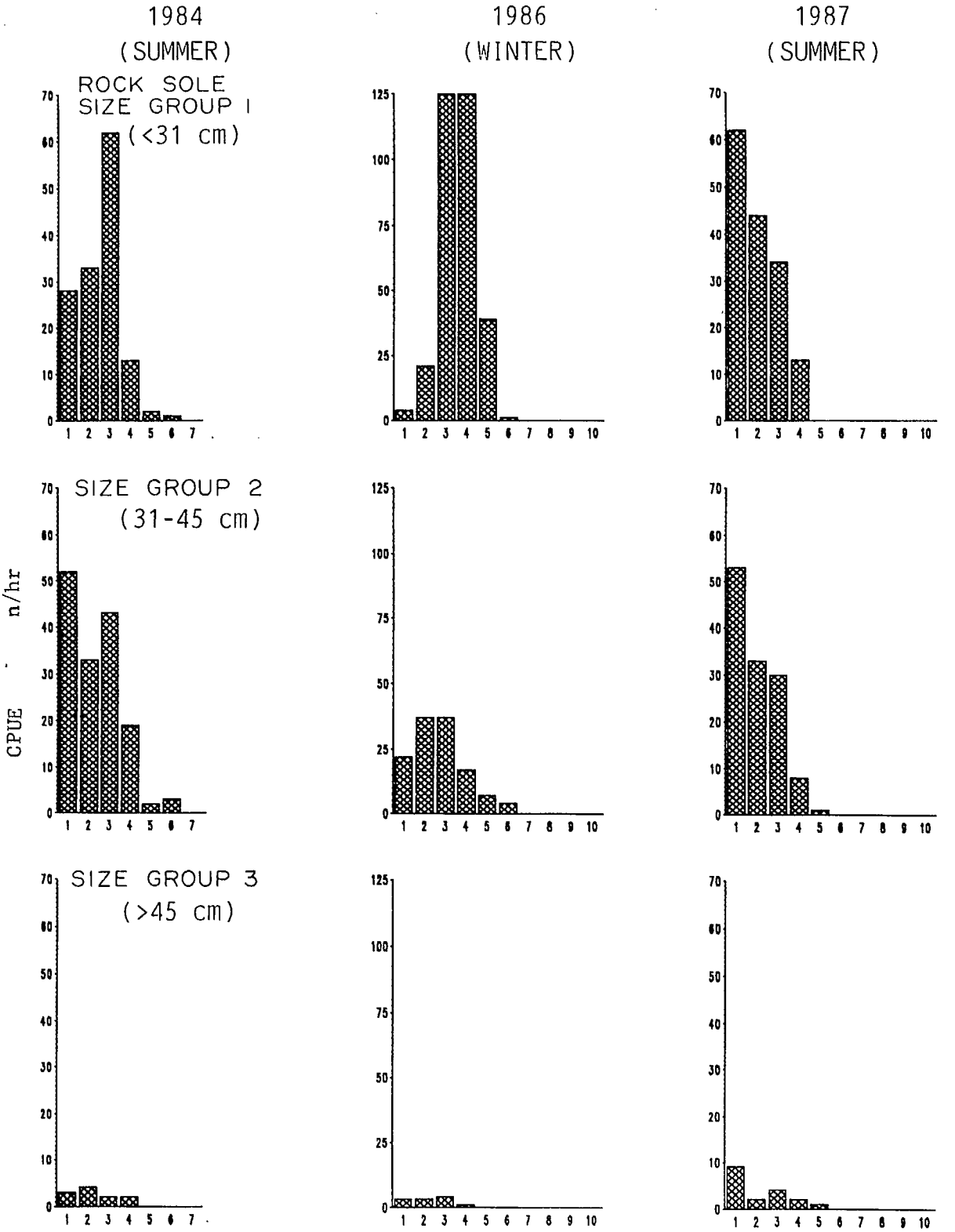
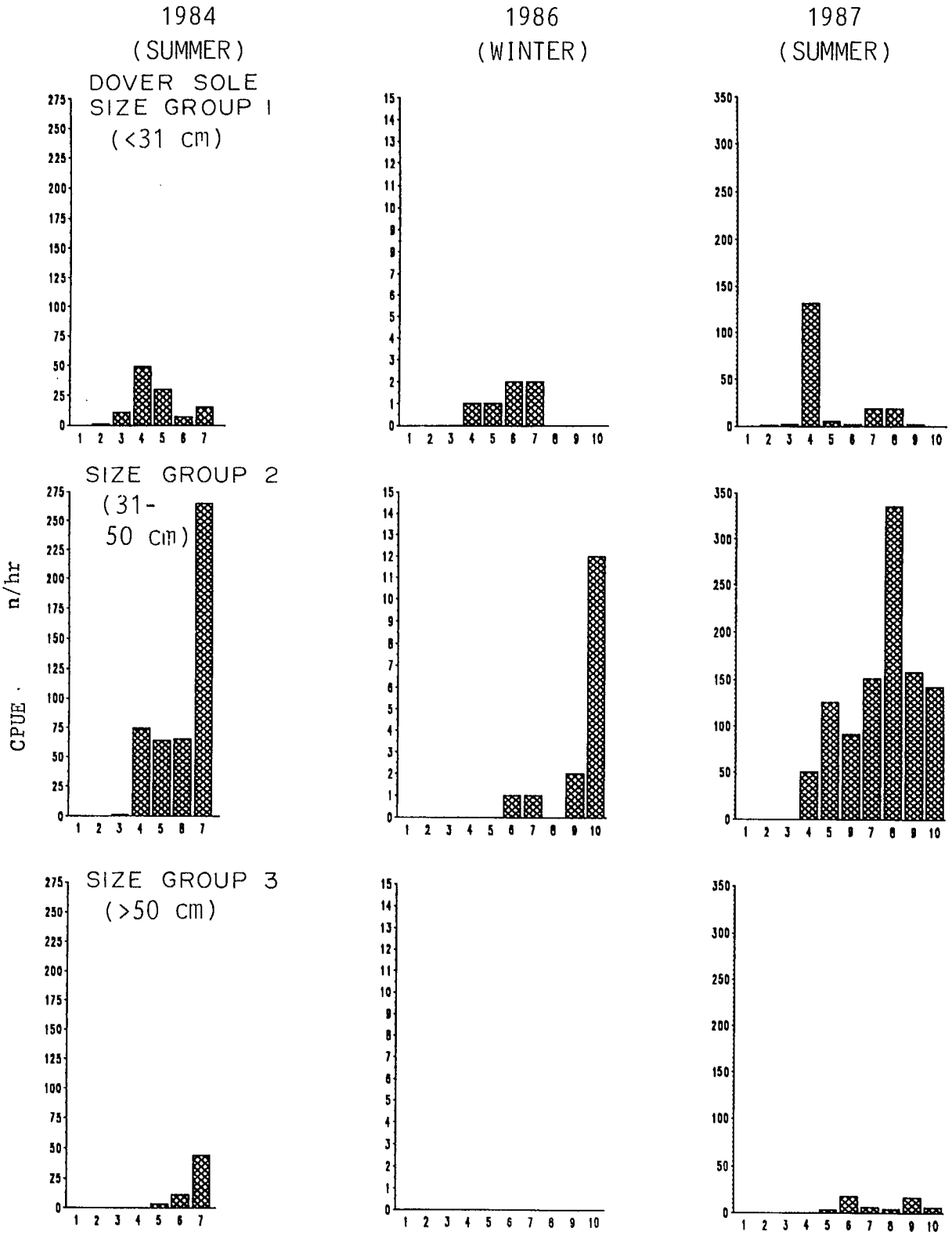

1984
(SUMMER)
1986
(WINTER)
1987
(SUMMER)
PACIFIC HALIBUT
SIZE GROUP 1
(<56 cm)
SIZE GROUP 2
(56-85 cm)
SIZE GROUP 3
(>85 cm)
CPUE n/hr
DEPTH INTERVAL (fathoms)[1]
(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59,
6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 41. Abundance of size groups of rock sole by depth interval in Hecate Strait, based on CPUE (n/hr) from bottom trawl surveys conducted from 1984-87.



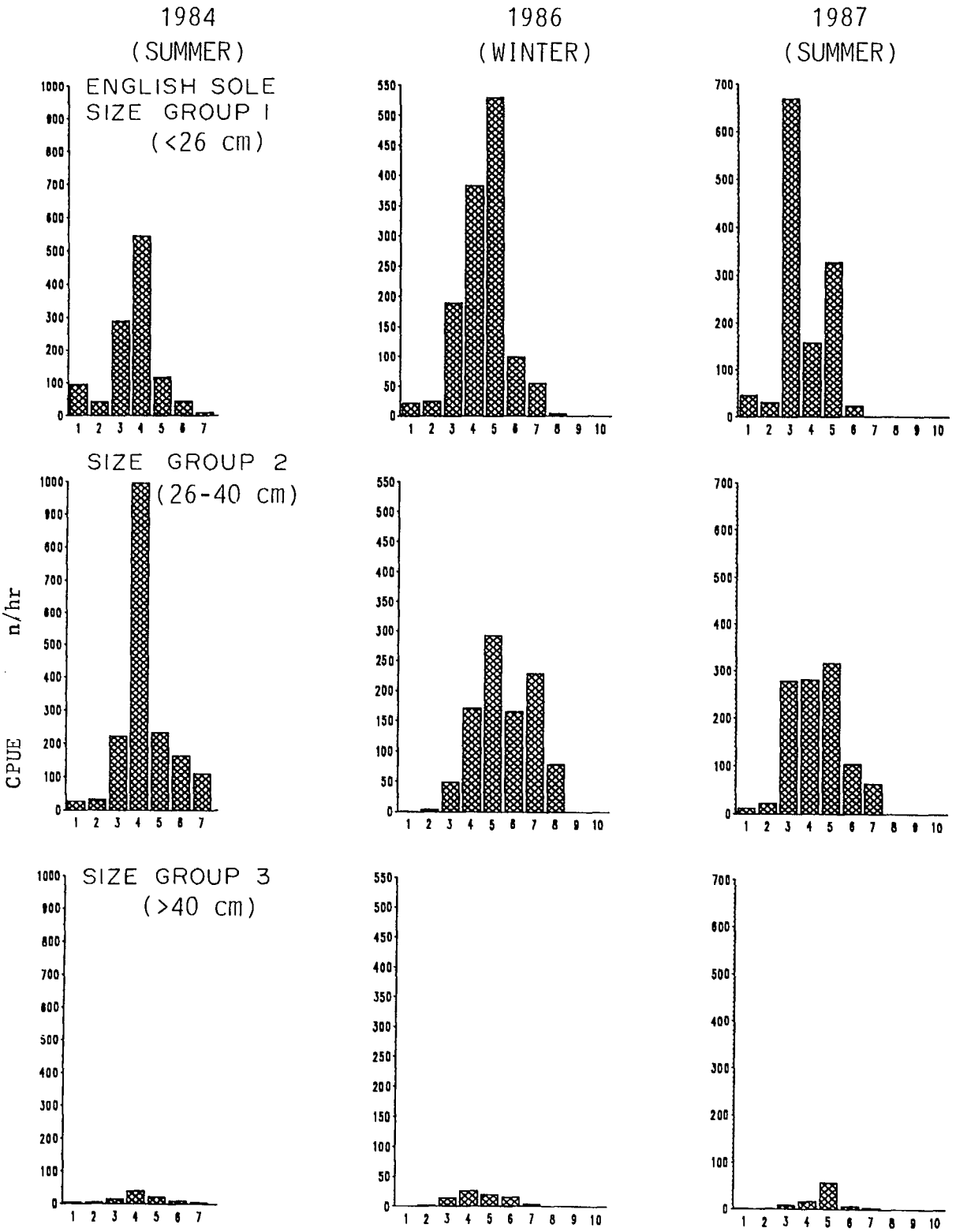
(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 42. Abundance of size groups of Dover sole by depth interval in Hecate Strait, based on CPUE (n/hr) from bottom trawl surveys conducted from 1984-87.



(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139

Fig. 43. Abundance of size groups of English sole by depth interval in Hecate Strait, based on CPUE (n/hr) from bottom trawl surveys conducted from 1984-87.



(1) 1=10-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79, 8=80-99, 9=100-119, 10=120-139