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FINAL REPORT

DISTRIBUTION, ABUNDANCE, COMMUNITY STRUCTURE, AND TROPHIC RELATIONSHIPS OF THE BENTHIC INFAUNA OF THE NORTHEAST GULF OF ALASKA

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I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

The objectives of this study were: 1) a qualitative and quantitative inventory of benthic species within and adjacent to identified oil-lease sites in the northeast Gulf of Alaska (NEGOA), 2) a description of spatial and temporal distribution patterns of selected species in the designated study area, and 3) observations of biological interrelationships, specifically trophic interactions, between components of the benthic biota.

Forty-one widely dispersed sites for quantitative grab sampling were established in NEGOA, and these sites represent a reasonable nucleus around which a monitoring program could be developed.

The general patchiness of fauna initially observed at most sites in the Gulf of Alaska suggested that three to five replicates be taken per site. At least five replicates were taken at all sites during the latter part of the project period. An analysis of grab-sampling efficiency indicated that all but the rarer species were sampled with five replicates. Additional samples would have reduced the variability of abundance and biomass estimates, but five replicates represented the maximum number which could be processed within time and budget limitations.

Five hundred and fifteen invertebrate species were collected. It is probable that all species with numerical and biomass importance have been collected in all areas of investigation and that only rare species would be added by future sampling.

Basic information on diversity of the fauna is available for all permanent sites on the NEGOA grid. Diversity appears to increase in areas where the sedimentation rate is reduced and the presence of sand and gravel substrates increase environmental heterogeneity.

Numerical analysis of the benthic infauna delineated four major site groups and their species assemblages. One of these site groups, the Inshore Group, consisted of sites with predominantly silt-clay sediments located on the continental shelf. Its fauna was dominated by deposit-feeding species which were also present at all other sites in NEGOA except sites 29 and 30. The substrate at sites 29 and 30 was rocky (site 29) or sandy (site 30) with very low concentrations of silt and clay. Another major site group consisted of sites located in Hinchinbrook Entrance, the Hinchinbrook Entrance Group. The sediments of these sites consisted of about 28% sand mixed with silt and clay. The fauna of the Hinchinbrook Entrance Group was similar to that of the Inshore Group but the total abundance and biomass of the fauna appeared to be greater in the Hinchinbrook Entrance Group. Two other major site groups, the Shelf Break Group and the Tarr Bank Group, were located near the edge of the continental shelf and on Tarr Bank, respectively; the sediments at these sites contained increasing amounts of sand and gravel mixed with silt and clay. At the Shelf Break and Tarr Bank sites reduced sedimentation rates and the presence of gravel allowed the colonization of these sites by suspension feeding invertebrates and species which require solid substrate. The result was an increase in the abundance of suspension feeders at these sites and an increase in species richness and diversity.

An assessment of our data suggests that: 1) sufficient site and/or area uniqueness exist to permit development of monitoring programs based on species composition at selected sites, and 2) adequate numbers of biologically well-known, and abundant species are available to permit nomination of monitoring candidates once industrial activity is initiated.

II. INTRODUCTION

General Nature and Scope of Study

The operations connected with oil exploration, production, and transportation in the Gulf of Alaska present a wide spectrum of potential dangers to the marine environment (see Olson and Burgess, 1967; IMCO, 1973; Nelson-Smith, 1973; Boesch *et al*, 1974; for general discussions of marine pollution problems). Adverse effects on the marine environment of these areas cannot be quantitatively assessed, or even predicted, unless background data are recorded prior to industrial development.

Benthic organisms (primarily the infauna but also sessile and slow-moving epifauna) are particularly useful as indicator species for a disturbed area because they tend to remain in place, typically react to long-range environmental changes, and by their presence, generally reflect the nature of the substratum. Consequently, the organisms of the infaunal benthos have frequently been chosen to monitor long-term pollution effects, and are believed to reflect the biological health of a marine area (see Pearson, 1971, 1972, 1975; and Rosenberg, 1973, for discussion on long-term usage of benthic organisms for monitoring pollution).

The presence of large numbers of benthic epifaunal species of actual or potential commercial importance (crabs, shrimps, snails, fin fishes) in the Gulf of Alaska further dictates the necessity of understanding benthic communities since many of these species feed on infaunal and small epifaunal residents of the benthos (see Zenkevitch, 1963, for a discussion of the interaction of commercial species and the benthos; also see appropriate discussions in Feder, 1977; Feder *et al.*, 1978; Feder and Jewett, 1978). Any drastic changes in density of the food benthos could affect the health and numbers of these commercially important species.

Insufficient long-term information about an environment, and the basic biology and recruitment of species in that environment, can lead to erroneous interpretations of changes in types and density of species that might occur if the area becomes altered (see Nelson-Smith, 1973; Pearson, 1971, 1972, 1975; Rosenberg, 1973, for general discussions on benthic biological investigations in industrialized marine areas). Populations of marine species fluctuate over a time span of a few to 30 years (Lewis, 1970 and personal communication). Such fluctuations are typically unexplainable because of absence of long-term data on physical and chemical environmental parameters in association with biological information on the species involved (Lewis, 1970 and personal communication).

Experience in pollution-prone areas of England (Smith, 1968), Scotland (Pearson, 1972, 1975), and California (Straughan, 1971) suggests that at the completion of an initial study, selected stations should be examined regularly on a long-term basis to determine changes in species content, diversity, abundance and biomass. Such long-term data acquisition should make it possible to differentiate between normal ecosystem variation and pollutant-induced biological alteration. Intensive investigations of the benthos of the Gulf of Alaska are essential to understand the trophic interactions involved in this area and the changes that might take place once oil-related activities are initiated.

The benthic biological program in the northeast Gulf of Alaska (NEGOA), initiated in 1974, emphasized development of an inventory of species as part of the examination of biological, physical and chemical components of those portions of the shelf slated for oil exploration and drilling activity. In addition, initiation of a program designed to quantitatively assess assemblages (communities) of benthic species on the NEGOA shelf expanded our understanding of distribution patterns of species in NEGOA. Outer Continental Shelf Environmental Assessment Program (OCSEAP) investigations concerned with the biology (primarily concerned with feeding activity) of selected epifaunal species on the Kodiak shelf and lower Cook Inlet will further the understanding of the trophic dynamics of the Gulf of Alaska benthic system (Feder and Jewett, 1977; Feder *et al.*, 1978).

Relevance to Problems of Petroleum Development

Studies of the effects of oil pollution or other impacts caused by petroleum development fall into several categories. One approach is to monitor the response of selected organisms to varying levels of potential pollutants under laboratory and field conditions. While the laboratory approach is perhaps the most sensitive technique, results cannot be confidently extrapolated to responses that might occur under natural conditions. Furthermore, laboratory experiments are necessarily restricted to a limited subset of species, and it is virtually impossible to extrapolate results to total community response.

Field experiments involving addition of oil to experimental plots and comparing the response of the fauna to that of control plots, offer a solution to many problems inherent in laboratory bioassay procedures. Unfortunately, this technique cannot be practically applied to benthic environments below the reach of SCUBA divers.

Another approach to assessment of impact of oil on the marine environment is collection of sufficient background data on the physical environment and biota of an area so that the effects of industrial activity can be identified. However, as indicated above, it is generally not possible to obtain sufficient long-term information about the structure and function of an ecosystem to make accurate interpretations of changes in types and density of species which might occur if an area is altered (Nelson-Smith, 1973; Pearson, 1971, 1972; Rosenberg, 1973).

In the present study, we were unable to gather data over a sufficient time period (139 stations[1] were occupied at 41 sites [locations] over a 20 month period, Table I) to accurately predict long-term fluctuations in infaunal community composition. However, through the use of cluster and principal coordinate analysis routines we have been able to identify groups of sites with similar species compositions (Feder *et al.*, 1976). These site groups appear to be correlated with sediment type and deposition rate of glacially-derived particulate matter. The results of numerical analyses indicate that given a knowledge of the sediment type and the sedimentation rate, one could fairly accurately predict *a posteriori* what the community structure and composition of the infauna would have been like during this study (see also Boesch, 1973). Although possible long-term temporal fluctuations in infauna populations could make predictions of community composition in the future difficult, community structure would not be expected to undergo radical changes unless some major environmental alteration occurred.

As indicated previously, infaunal benthic organisms tend to remain in place and consequently have been useful as indicator species for disturbed areas. Thus, close examination of sites with substantial complements of infaunal species is warranted (see Feder and Mueller, 1975, and National Oceanographic Data Center [NODC] data on file for examples of such sites). Changes in the environment at sites with relatively large numbers of species might be reflected by a decrease in diversity with increased dominance

[1] For the purposes of this study a station was occupied every time a site [location] was sampled.

TABLE I

SITES SAMPLED BY VAN VEEN GRAB IN NORTHEAST GULF OF ALASKA (NEGOA), JULY 1974 TO MARCH 1976. THE NUMBER AT EACH ENTRY UNDER CRUISE NUMBER REFERS TO THE NUMBER OF REPLICATE SAMPLES.

				Jul. 74	Oct. 74	Nov. 74	Feb. 75	May 75	Sept. 76	Nov. 76	March 76
				Cruise Number							
Site	Latitude (N)	Longitude (W)	Approx. Depth (m)	193	200	202	805	807	811	816	001
1	59°50.2'	149°30.5'	263	3	-	3	-	-	5	-	5
2	59°41.5'	149°22.0'	219	-	-	-	-	5	5	-	5
3	59°33.0'	149°13.2'	220	3	-	-	-	-	5	-	5
4	59°24.5'	149°04.9'	200	-	-	-	-	4	10	-	5
5	59°16.0'	148°56.0'	174	-	-	-	-	4	5	-	5
6	59°07.2'	148°47.5'	151	3	-	-	-	-	5	-	5
7	58°58.7'	148°38.7'	220	-	-	-	-	1	5	5[a]	4
25	59°02.5'	140°49.8'	179	-	-	-	-	3	5[a]	10	5
26	59°10.8'	140°38.9'	148	3	-	-	-	4	5	5[a]	5
27	59°18.6'	140°27.9'	129	-	-	-	-	3	5	-	5
28	59°26.5'	140°16.9'	239	-	-	-	-	4	5	-	5
29	59°34.6'	140°06.0'	68	3	-	-	-	-	-	-	1[b]
30	59°44.1'	141°27.9'	43	1[b]	-	-	6[b]	-	10[b]	-	5[b]
31	59°35.2'	141°36.8'	117	-	-	-	4	-	5	-	5
32	59°26.3'	141°45.0'	179	3	-	-	4	-	5	-	5
33	59°17.5'	141°54.8'	219	-	-	-	1[b]	-	5	-	5
37	59°16.2'	142°59.2'	2,620	-	-	-	1[b]	-	-	-	-
39	59°35.7'	142°49.5'	549	1[b]	-	-	1[b]	-	3[a]	5	5
40	59°45.5'	142°44.5'	195	-	-	-	4	-	5	-	3
41	59°55.1'	142°39.5'	119	3	-	-	4	-	5	-	5
42	59°55.1'	143°51.2'	93	3	-	-	3	-	10	-	5
43	59°45.0'	143°52.8'	117	-	-	-	3	-	5	-	5
44	59°35.0'	143°54.2'	181	3	-	-	1[b]	-	3[b]	5	5
48	59°27.5'	145°11.5'	117	3	-	-	-	-	5[b]	10	5
49	59°37.5'	145°10.0'	186	-	-	-	4	4	5	-	5
50	59°47.7'	145°09.0'	164	2	3	-	-	-	5	-	5
51	59°57.6'	145°07.8'	135	-	-	-	4	-	5	-	5
52	60°07.6'	145°06.5'	53	3	3	-	-	4	5	-	5
53	60°23.0'	146°54.0'	279	-	3	-	2	2[b]	5	-	5
54	60°13.9'	146°48.6'	204	-	-	-	3	-	2[a]	5	5
55	60°04.5'	146°42.6'	117	3	-	-	4	-	5[a]	10	5
56	59°55.2'	146°36.8'	64	-	-	-	4	-	5	-	5
57	59°45.6'	146°31.0'	69	-	3	-	3	-	5	-	10
58	59°36.2'	146°25.5'	97	-	-	-	4	-	5	-	3
59	59°17.1'	146°14.0'	334	1[b]	-	-	-	-	4[a]	5	2
60	60°01.5'	145°51.2'	90	-	-	-	-	-	-	5[a]	5
61	59°34.2'	145°46.9'	170	-	-	-	-	-	-	5[a]	2
62	59°33.2'	142°16.0'	240	-	-	-	-	-	-	5[a]	5
63	59°49.5'	142°03.8'	80	-	-	-	-	-	-	5[a]	5
68	59°38.2'	147°36.5'	120	-	-	-	-	-	-	5[a]	5
69	59°20.0'	147°32.0'	120	-	-	-	-	-	-	5[a]	4

a = sample collected but not analyzed

b = qualitative sample only

of a few species (see Nelson-Smith, 1973 for further discussion of oil-related changes in diversity). Likewise, stations with substantial numbers of epifaunal species should be assessed on a continuing basis (see Feder and Mueller, 1975; Feder, 1977; for references to relevant stations). The potential effects of loss of species to the trophic structure in NEGOA cannot be assessed at this time; little data on food interactions are available for NEGOA (see Feder and Jewett, 1978). However the problem can be addressed by examination of benthic food studies resulting from OCSEAP projects in lower Cook Inlet and Kodiak (Feder, unpublished data from Cook Inlet; Jewett and Feder, 1976; Feder, 1977; Feder and Jewett, 1977; Feder *et al.*, 1978; Smith *et al.*, 1978).

A direct relationship between trophic structure (feeding type) and bottom stability has been demonstrated by Rhoads (see Rhoads, 1974 for review). A diesel fuel spill resulted in oil becoming adsorbed on sediment particles with resultant mortality of many deposit feeders on sublittoral muds. Bottom stability was altered with the death of these organisms, and a new complex of species became established in the altered substratum. The most common members of the infauna of the Gulf of Alaska and the Bering Sea are deposit feeders; thus, oil-related mortality of these species could result in a changed near-bottom sedimentary regime with subsequent alteration of species composition.

Lack of an adequate data base still makes it difficult to suggest the effect of oil-related activity on the subtidal benthos of NEGOA. However, the expansion of research activities in NEGOA has enabled us to point to certain species or areas that might bear closer scrutiny once industrial activity is initiated.

III. CURRENT STATE OF KNOWLEDGE

Gulf of Alaska

Little was known about the biology of the invertebrate benthos of the Gulf of Alaska at the time that Outer Continental Shelf Environmental Assessment Program (OCSEAP) studies were initiated there, although a compilation of some relevant data on the Gulf of Alaska was available

(Rosenberg, 1973). A short but intensive survey in the summer of 1975 added some benthic biological data for a specific area south of the Bering Glacier (Bakus and Chamberlain, 1975). Results of the latter study are similar to those reported by Feder and Mueller (1975) in their OCSEAP investigation.

Some scattered data based on trawl surveys by the Bureau of Commercial Fisheries (National Marine Fisheries Service) were available, but much of the information on the invertebrate fauna was so general that it was of limited value. In the summer and fall of 1961 and spring of 1962 otter trawls were used to survey the shellfishes and bottomfishes on the continental shelf and upper continental slope in the Gulf of Alaska (Hitz and Rathjen, 1965). The surveys were part of a long-range program begun in 1950 to determine the size of bottomfish stocks in the northeast Pacific Ocean between southern Oregon and northwest Alaska. Invertebrates taken in the trawls were of secondary interest, and only major groups and/or species were recorded. Invertebrates that comprised 27 percent of the total catch were grouped into eight categories; heart urchins (Echinoidea), snow crabs (*Chionoecetes bairdi*), sea stars (Asteroidea), Dungeness crabs (*Cancer magister*), scallops (*Pecten caurinus*), shrimps (*Pandalus borealis, P. platyceros*, and *Pandalopsis dispar*), king crabs (*Paralithodes camtschatica*), and miscellaneous invertebrates (Hitz and Rathjen, 1965). Heart urchins accounted for about 50 percent of the invertebrate catch and snow crabs ranked second, representing about 22 percent. Approximately 20 percent of the total invertebrate catch was composed of sea stars.

Data on the infauna collected in the first year (1974-1975) of the OCSEAP study in the northeast Gulf of Alaska (NEGOA) served as a springboard and an intensive data base for the studies in 1975-1977 (Feder and Mueller, 1975). The use of cluster and multivariate techniques for the analysis of infaunal data, which was applied to our data from the Gulf of Alaska and the Bering Sea (Feder *et al.*, 1976; Haflinger, 1978; present report), has been widely used by numerous investigators examining shallow-water marine environments. Techniques are reviewed in Clifford and Stephenson (1975).

Based on OCSEAP feeding studies initiated in NEGOA, lower Cook Inlet, and two bays on Kodiak Island (Feder, 1977; Feder *et al.*, 1978; Feder and Jewett, 1977), it is apparent that benthic infaunal invertebrates play a major role in the food dynamics of commercial crab and demersal fishes on the Kodiak shelf.

Data indicating the effects of oil on most subtidal benthic invertebrates are fragmentary (see Boesch *et al.*, 1974; Malins, 1977, for review; Baker, 1976, for a general review of marine ecology and oil pollution), but echinoderms are "notoriously sensitive to any reduction in water quality" (Nelson-Smith, 1973). Echinoderms (ophiuroids, asteroids, and holothuroids) are conspicuous members of the benthos of the Gulf of Alaska and the Bering Sea (see Feder, 1977, for references to relevant stations in NEGOA and Bering Sea), and could be affected by oil activities there. Asteroids (sea stars) and ophiuroids (brittle stars) are components of the diet of large crabs (for example king crabs feed on sea stars and brittle stars: unpub. data, Guy Powell, Alaska Dept. of Fish and Game; Feder, 1977) and demersal fishes. Snow crabs (*Chionoecetes* spp.) are conspicuous members of the shallow shelf of the Gulf of Alaska and the Bering Sea, and support commercial fisheries of considerable importance. Laboratory experiments with this species have shown that postmolt individuals lose most of their legs after exposure to Prudhoe Bay crude oil; obviously this aspect of the biology of the snow crab must be considered in the continuing assessment of this species (Karinen and Rice, 1974). Little other direct data based on laboratory experiments are available for subtidal benthic species (see Nelson-Smith, 1973). Experimentation on toxic effects of oil on other common members of the subtidal benthos should be strongly encouraged for future on OCSEAP programs.

IV. STUDY AREA

Thirty-four sites (Feder and Mueller, 1975) for sampling the infauna were selected from a grid established in conjunction with studies on the physical and chemical oceanography, hydrocarbon and heavy metal concentrations, and marine microbiota in the northeast Gulf of Alaska (NEGOA) (Fig. 1). The sites were dispersed over seven transects from Resurrection

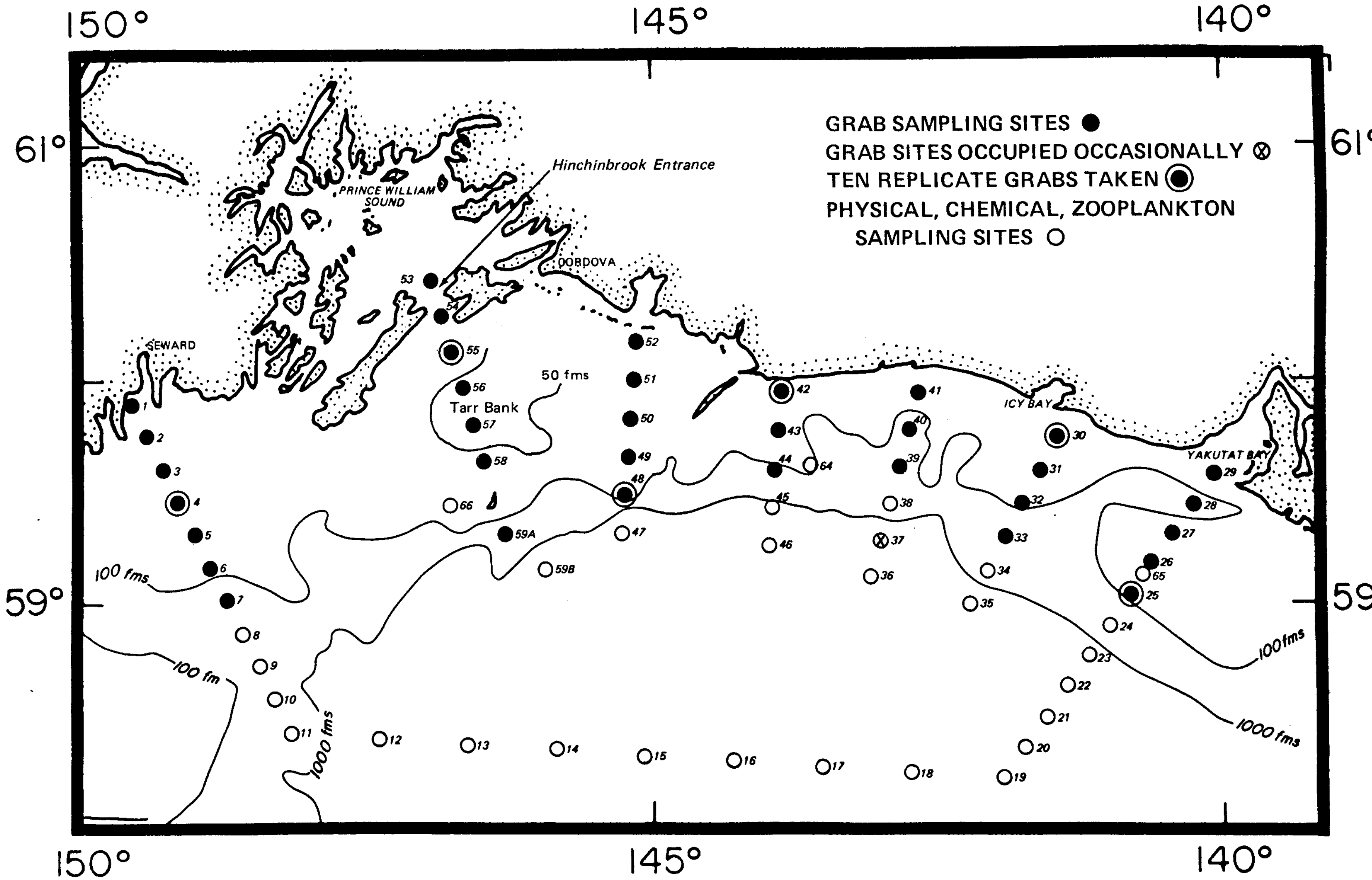

Figure 1. Site grid established for oceanographic investigations in the northeastern Gulf of Alaska.

Bay to Yakutat Bay, and extended from inshore to the vicinity of the shelf break (approximately 200 m). Seven additional sites were sampled on at least one occasion (Fig. 1).

Temperature and salinity data for NEGOA from July 1974 to June 1975 are available in Royer (1976). The temperature of the bottom water during this period ranged from 4.5 to 5.5°C, except at some of the shallower stations (Sta. 29, 68 m; 30, 43 m; 52, 53 m; 55, 117 m; 56, 54 m; 57, 67 m; 58, 97 m) where temperatures of 7.0° to 10.0°C were recorded in July and October 1974. Salinity of the bottom water ranged from 31.5 to 33.5°/₀₀.

Sediments in the study area were predominantly silts and clays. The principal sediment sources are the Copper River and the Bering and Malaspina Glaciers. The general transport of sediments, as they enter the Gulf of Alaska, is to the west. High sedimentation rates throughout most of the shelf area result in poorly consolidated sediments with a high water content. However, few sediments accumulate on Tarr Bank (Fig. 1, Stations 56 and 57), probably because of scouring by strong bottom currents and frequent winter storm waves (Molnia and Carlson, 1977).

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Field and Laboratory

At the outset of the study, thirty-four sites were established for seasonal sampling of the benthic infauna. Seven additional sites (Fig. 1, Table I) were occupied at least once to provide increased coverage. During the first year of the study three to four replicates were taken at each site. Subsequently five replicates were routinely taken. Samples were collected with a 0.1 m^2 van Veen grab weighted with 70 lbs of lead to facilitate penetration. Material from each grab was washed on a 1.0 mm stainless steel screen, and preserved in a 10% formalin seawater solution buffered with hexamine. In the laboratory, all samples were rinsed to remove the last traces of sediment, spread on a tray and rough sorted by hand. Material was then transferred to fresh preservative and identifications made. All organisms were counted, and wet weighed after excess moisture was removed with an absorbent towel.

Numerical Analysis

Site groups and species assemblages were identified using cluster analysis. Cluster analysis can be divided into three basic steps.

1. Calculation of a measure of similarity or dissimilarity between entities to be classified
2. Sorting through a matrix of similarity coefficients to arrange the entities in a hierarchy or dendrogram.
3. Recognition of classes within the hierarchy.

Data reduction prior to calculation of similarity coefficients consisted of elimination of taxa that could not be identified to genus and taxa that occurred at a single station in low numbers.

Two coefficients were used to calculate similarity matrices for cluster analysis routines: the Sørenson coefficient, based on the presence or absence of attributes, and the Czekanowski coefficient,[1] a quantitative modification of the Sørenson coefficient.

Sørenson

$$Cs_{1,2} = \frac{2C}{A + B}$$

where A = total number of attributes of entity one
B = total number of attributes of entity two
C = total attributes shared by entities one and two

Czekanowski

$$Cs_{1,2} = \frac{2W}{A + B}$$

where A = the sum of the measures of attributes of entity one
B = the sum of the measures of attributes of entity two
W = the sum of the lesser measures of attributes shared by entities one and two.

[1] The Czekanowski coefficient is synonymous with the Motyka (Mueller-Dombois and Ellenberg, 1974), and Bray-Curtis (Clifford and Stephenson, 1975) coefficients.

The Czekanowski coefficient has been used effectively in marine benthic studies by Field and MacFarlane (1968), Field (1969, 1970 and 1971), Day *et al.* (1971), Stephenson and Williams (1971), and Stephenson *et al.* (1972). This coefficient emphasizes the effect of dominant species on the classification, and is often used with some form of transformation. The Czekanowski coefficient was used to calculate similarity matrices for normal cluster analysis (with sites as the entities to be classified and species as their attributes) and inverse cluster analysis (with species as entities and sites as attributes) using both untransformed and natural logarithm transformed abundance data (individuals/m^2). The natural logarithm transformation, $Y = ln(X+1)$, reduces the influence that dominant species have on the similarity determination.

If only one sample was obtained or the volume of sediment collected was less than five liters per grab at any site, the site was not included in classifications using abundance data. For the purposes of this study, data obtained for these sites were considered to be qualitative. A similarity matrix was constructed for qualitative data using the Sørenson coefficient in order to examine the relationship of these sites to all other sites. Dendrograms were constructed from the similarity matrices using a group-average agglomerative hierarchical cluster analysis (Lance and Williams, 1966).

As an aid in the interpretation of dendrograms formed by cluster analyses, two-way coincidence tables comparing site groups formed by normal analysis and species groups formed by inverse analysis were constructed (Stephenson *et al.*, 1972). In each table the original species x sites data matrix was rearranged (based on the results of both normal and inverse analysis) so that the sites or species with the highest similarities were adjacent to each other. The two-way coincidence table was then divided into cells whose elements are the abundance of each of the species in a species group collected at each of the sites in a site group. The two-way coincidence tables were then reduced to create a table of average cell densities by summing all the elements in each cell and dividing the resulting sums by the number of species in the appropriate species group and the number of sites in the appropriate site group. Two-way tables of fidelity and constancy were also constructed (Stephenson *et al.*, 1972). Fidelity is the percentage of the total number of individuals of all species in a species group found in each site group, and is a reflection of the distribution of abundance of species in a species group among site groups. If all the individuals in a species group were found in only one site group, the fidelity of the species group in that site group would be 100%. Constancy, the percentage of the elements in each cell which had non-zero values, is a measure of the ubiquity of the species group members in each site group. If all the elements in a cell contain non-zero values (i.e. there is at least one individual of all species in the species group in each site of the site group) constancy would equal 100%.

Principal coordinate analysis (Gower, 1967, 1969) was used as an aid in interpreting the results of the cluster analyses (Stephenson and Williams, 1971; Boesch, 1973) and identifying misclassifications of sites by cluster analysis. Misclassifications in an agglomerative cluster analysis can occur by the early fusion of two sites and their subsequent incorporation into a group whose sites have a high similarity to only one member of the original pair (Boesch, 1973). In principal coordinate analysis an intersite similarity matrix is generated as in normal cluster analysis. The similarity matrix generated can be conceived of as a multi-dimensional space in which the sites are arranged in such a way that they are separated from one another according to their similarities. An ordination is then performed on the matrix to extract axes from this multidimensional space. The first axis extracted coincides with the longest axis, and accounts for the largest amount of variation in the similarity matrix. Subsequent axes account for successively smaller amounts of variation in the data. Both the Czekanowski and the Canberra "metric" similarity coefficients were used to calculate the similarity matrices used in principal coordinate analysis. The Canberra "metric" coefficient defines the similarity of two entities as:

$$Cs_{1,2} = 1 - \frac{1}{n} \sum_{i}^{n} \frac{|X_{1i} - X_{2i}|}{(X_{1i} + X_{2i})}$$

where X_{1i} = the measure of the i^{th} attribute in entity one

X_{2i} = the measure of the i^{th} attribute in entity two

Because the Canberra "metric" coefficient is a series of fractions, it gives a more equal weighting to all species and reduces the effect of the dominant species on the analysis. It was used as a means of comparison with the results of analyses using the Czekanowski coefficient which emphasizes dominant species.

Diversity

Species diversity can be thought of as a measurable attribute of a collection or a natural assemblage of species, and consists of two components: the number of species or "species richness" and the relative abundance of each species or "evenness". The two most widely used measures of diversity which include species richness and evenness are the Brillouin (1962) and Shannon (Shannon and Weaver, 1963) information measures of diversity (Nybakken, 1978). There is still disagreement on the applicability of these indices, and results are often difficult to interpret (Sager and Hasler, 1969; Hurlbert, 1971; Fager, 1972; Peet, 1974; Pielou, 1966a,b). Pielou (1966a,b, 1977) has outlined some of the conditions under which these indices are appropriate.

The Shannon Function

$$H' = -\sum_i p_i \log p_i \quad \text{where } p_i = \frac{n_i}{N}$$

where n_i = number of individuals in the i^{th} species
N = total number of individuals

assumes that a random sample has been taken from an infinitely large population whereas the Brillouin function

$$H = \frac{1}{N} \log \frac{N!}{n_1!n_2!\cdots n_s!}$$

is appropriate only if the entire population has been sampled. Thus, if we wish to estimate the diversity of the fauna at a sampling site the Shannon function is appropriate. The Brillouin function is merely a measure of the diversity of the five grab samples taken at each site, and makes no predictions about the diversity of the benthic community that the samples were drawn from. The evenness of samples taken at each site can be calculated using the Brillouin measure of evenness, $J = H/H_{maximum}$, where H = Brillouin diversity function. $H_{maximum}$, the maximum possible diversity for a given number of species, occurs if all species are equally common and is calculated as:

$$H_{maximum} = \frac{1}{N} \log \frac{N!}{\{[N/s]!\}^{s-r}\{([N/s]+1)!\}^{r}}$$

where [N/s] = the integer part of N/s
s = number of species in the censused community
r = N - s[N/s]

Theoretically the evenness component of the Shannon function can be calculated from the following:

$$J' = \frac{H'}{\log s^*}$$

where H' = Shannon diversity function
s* = the total number of species in the randomly sampled community

However, s*, the total number of species in a randomly sampled community, is seldom known for benthic infaunal communities. Therefore, the evenness component of the Shannon diversity index was not calculated (for a discussion see Pielou, 1977). Both the Shannon and Brillouin diversity indices were calculated in the present study, and they were closely correlated ($r = 0.97$; Fig. 2), indicating that either index would be acceptable as both Loya (1972) and Nybakken (1978) have suggested. Species richness (Margalef, 1958) was calculated as

$$SR = \frac{(S-1)}{\ln N}$$

where S = the number of species
N = the total number of individuals

The Simpson index (Simpson, 1949) was also calculated to enable comparison of the dominance structure in NEGOA with data collected in Port Valdez, Alaska (Feder *et al.*, 1973).

Trophic Structure

The trophic structure of each of the site groups formed by cluster analysis was determined by classifying the 50 most abundant species in each site group into 5 feeding classes: suspension feeders (SF), deposit

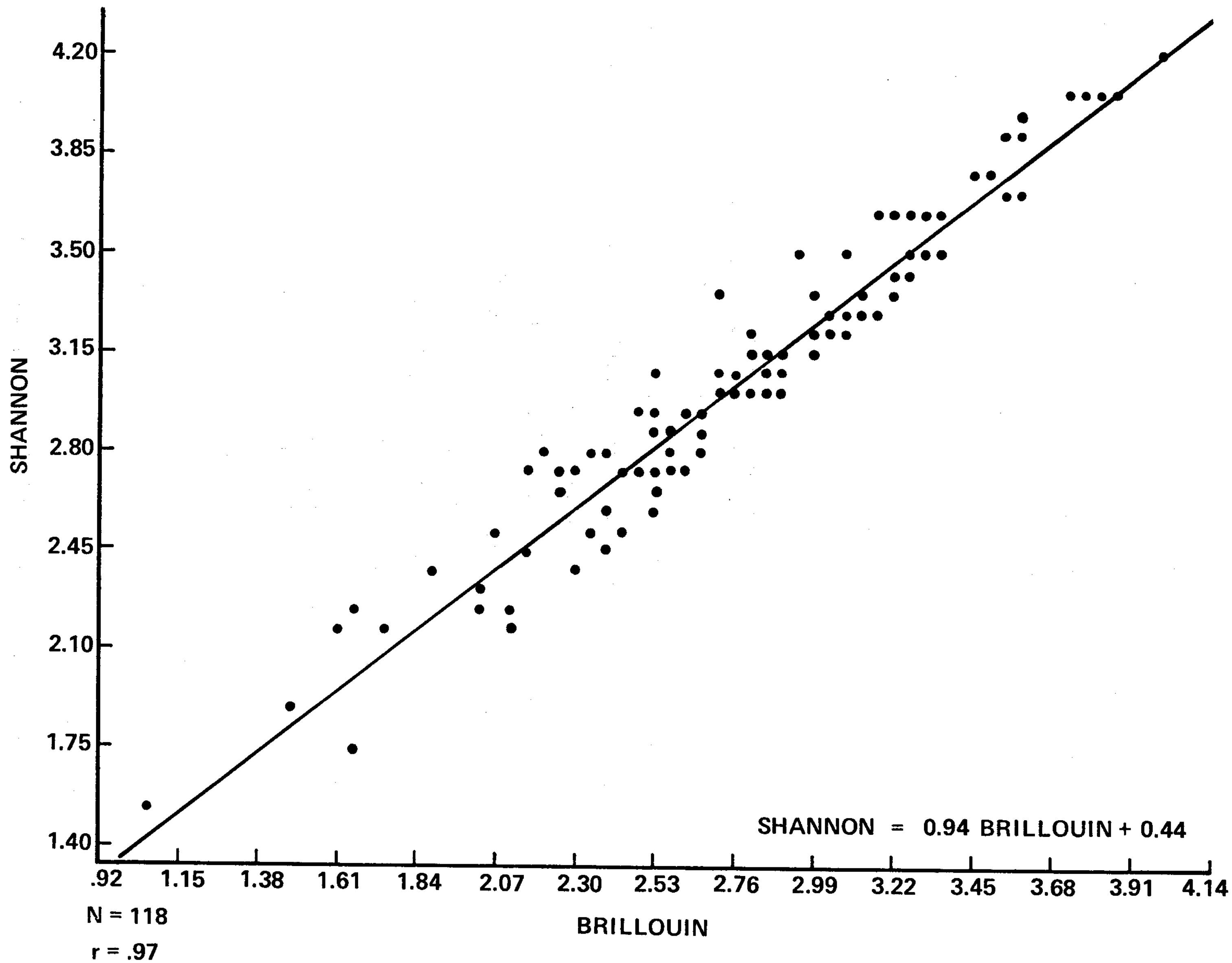

Figure 2. Relationship between Brillouin and Shannon index of diversity.

feeders (DF), predators (P), scavengers (S) and other (O). All species utilized for the determination of trophic structure were assigned to feeding classes (Table II) based on the literature (MacGinitie and MacGinitie, 1949; Morton, 1958; Fretter and Graham, 1962; Jørgensen, 1966; Day, 1967; Hyman, 1967; Mills, 1967; Purchon, 1968; Stanley, 1970; Eltringham, 1971; Feder *et al.*, 1973; Feder and Mueller, 1975; Abbott, 1974; Barnes, 1974; Trueman, 1975; Yonge and Thompson, 1976; Jumars and Fauchald, 1977) and personal observation. Since species are distributed along a continuum of feeding types and many organisms utilize several feeding modes, it is often difficult to place a species in a specific class. For example, protobranch molluscs, generally regarded as deposit feeders, may also utilize particles in suspension (Stasek, 1965; Stanley, 1970). However, since these molluscs probably obtain most of their nutritional requirements from the sediment, we classified them as deposit feeders. It is even more difficult to make a distinction between scavengers and deposit feeders, as for example, some of the larger polychaetes and amphipods that can ingest larger food particles as well as small detrital fragments. If these organisms were motile, and able to operate efficiently as scavengers, as well as incorporate sediment in their diet, they were classified as both scavengers and deposit feeders. Species whose feeding behavior was unknown, or uncertain, were classified as "other". The percentage of individuals belonging to each feeding classification was calculated for each site group. Where a species was assigned to two feeding classes we arbitrarily assigned one half of the individuals of that species to each class. Species were also classified into three classes of motility (Table II): sessile, discretely motile (generally sessile but capable of movement to escape unfavorable environmental conditions, after Jumars and Fauchald, 1977), and motile. The percentage of individuals belonging to each motility class was also calculated for each site group.

VI. RESULTS

Samples of the benthic infauna in the northeast Gulf of Alaska (NEGOA) area were obtained during eight cruises:

text continued on page 27.

TABLE II

FEEDING AND MOTILITY CLASSES OF BENTHIC INVERTEBRATES, FROM THE NORTHEAST GULF OF ALASKA, UTILIZED FOR THE DETERMINATION OF TROPHIC STRUCTURE

SF=suspension feeder; P=predator; S=scavenger; O=other; DF=deposit feeder; U=unknown, M=motile; DM=discretely motile[1]; SE=sedentary

ID. No.	Species	Feeding Class	Motility Class	ID. No.	Species	Feeding Class	Motility Class
1	HYDROZOA	SF	S	24	*Anaitides mucosa*	P/DF	M
	ANTHOZOA			25	*Eteone longa*	P	M
2	*Ptilosarcus gurneyi*	SF	S	26	*Ophiodromus pugettensis*	DF/S	M
3	*Peachia* sp.	SF	S	27	*Autolytus magnus*	P	M
4	*Virgulariidae*	SF	S	28	*Syllis spongiphila*	P	M
5	Zoantharia	SF	S	29	*Syllis sclerolema*	P	M
	RHYNCHOCOELA			30	*Typosyllis* sp.	P	M
6	*Amphiporidae*	P	M	31	*Typosyllis alternata*	P	M
	POLYCHAETA			32	*Typosyllis armillaris*	P	M
7	*Arcteobea spinelytris*	S	M	33	*Eusyllis blomstrandi*	P	M
8	*Eunoe depressa*	S	M	34	*Exogone* sp.	P	M
9	*Gattyana cirrosa*	S	M	35	*Exogone verugera*	P	M
10	*Gattyana brunnea*	S	M	36	*Langerhansia cornuta*	P	M
11	*Gattyana ciliata*	S	M	37	*Haplosyllis spongicola*	P	M
12	*Gattyana treadwelli*	S	M	38	*Cheilonereis cyclurus*	DF	M
13	*Harmothoe* sp.	S	M	39	*Ceratonereis paucidentata*	DF/P/S	M
14	*Harmothoe imbricata*	S	M	40	*Nereis* sp.	DF/P/ S/SF	M/DM
15	*Hermadion truncata*	S	M	41	*Nereis pelagica*	DF/P/S	M
16	*Lepidonotus squamatus*	S	M	42	*Nereis procera*	DF/P/S	M
17	*Hesperonoe complanata*	S	M	43	*Nereis zonata*	SF	DM
18	*Polyeunoe tuta*	S	M	44	*Nephtys* sp.	DF/P	M
19	*Polynoe* sp.	S	M	45	*Nephtys ciliata*	DF/P	M
20	*Peisidice aspera*	S	M	46	*Nephtys caeca*	DF/P	M
21	*Pholoe minuta*	S	M				
22	*Sthenealais fusca*	S	M				
23	*Anaitides maculata*	P/DF	M				

[1]Organisms which are generally sessile but are capable of movement to escape unfavorable environmental conditions (Jumars and Fauchald, 1977).

TABLE II

CONTINUED

ID. No.	Species	Feeding Class	Motility Class	ID. No.	Species	Feeding Class	Motility Class
47	*Nephtys cornuta*	DF/P	M	70	*Drilonereis filium*	DF	M
48	*Nephtys punctata*	DF/P	M	71	*Drilonereis falcata minor*	DF	M
49	*Nephtys longosetosa*	DF/P	M	72	*Haploscoloplos elongatus*	DF	M
50	*Nephtys ferruginea*	DF/P	M	73	*Aricidea* sp.	DF	M
51	*Aglaophamus rubella anops*	DF/P	M	74	*Aricidea suecica*	DF	M
52	*Glycera capitata*	DF/P	M	75	*Aricidea jeffreysi*	DF	M
53	*Glycinde picta*	DF/P	M	76	*Paraonis gracilis*	DF	M
54	*Glycinde armigera*	DF/P	M	77	*Apistobranchus* sp.	DF	DM
55	*Goniada annulata*	DF/P	M	78	*Polydora socialis*	DF	DM
56	*Goniada maculata*	DF/P	M	79	*Laonice cirrata*	DF	DM
57	*Onuphis* sp.	DF	M/S/DM	80	*Prionospio malmgreni*	DF	DM
58	*Onuphis conchylega*	DF	M	81	*Spio filicornis*	DF	DM
59	*Onuphis geophiliformis*	DF	S/DM	82	*Spiophanes bombyx*	DF	DM
60	*Onuphis iridescens*	DF	S/DM	83	*Spiophanes kroyeri*	DF	DM
61	*Onuphis parva*	DF	S/DM	84	*Spiophanes cirrata*	DF	DM
62	*Eunice valens*	DF	M	85	*Magelona japonica*	DF	DM
63	*Eunice kobiensis*	DF	M	86	*Magelona pacifica*	DF	DM
64	*Lumbrineris* sp.	DF/P	M	87	*Spiochaetopterus* sp.	SF	S
65	*Lumbrineris bicirrata*	DF/P	M	88	*Spiochaetopterus costarum*	SF	S
66	*Lumbrineris similabris*	DF/P	M	89	*Caulleriella* sp.	DF	DM
67	*Lumbrineris zonata*	DF/P	M	90	*Tharyx* sp.	DF	S/DM
68	*Ninoe gemmea*	DF	M				
69	*Drilonereis* sp.	DF	M				

TABLE II

CONTINUED

ID. No.	Species	Feeding Class	Motility Class
91	*Chaetozone setosa*	DF	DM
92	*Brada villosa*	DF	DM
93	*Pherusa (Stylarioides) papillata*	DF	DM
94	*Pherusa (Stylarioides) plumosa*	DF	DM
95	*Scalibregma inflatum*	DF	M
96	*Ammotrypane aulogaster*	DF	M
97	*Travisia pupa*	DF	M
98	*Sternaspis scutata*	DF	M
99	*Capitella capitata*	DF	M
100	*Heteromastus filiformis*	DF	M
101	*Asychis similis*	DF	S
102	*Maldane* sp.	DF	S
103	*Maldane sarsi*	DF	S
104	*Maldane glebiflex*	DF	S
105	*Maldanella robusta*	DF	S
106	*Nicomache lumbricalis*	DF	S
107	*Nicomache personata*	DF	S
108	*Notoproctus* sp.	DF	S
109	*Notoproctus pacificus*	DF	S
110	*Axiothella rubrocincta*	DF	S
111	*Praxillella gracilis*	DF	S
112	*Praxillella affinis*	DF	S
113	*Rhodine bitorquata*	DF	S
114	*Owenia fusiformis*	SF/DF	DM
115	*Myriochele heeri*	DF	S
116	*Idanthyrsus armatus*	SF	S
117	*Amphictene auricoma*	DF	M
118	*Cistenides brevicoma*	DF	M
119	*Amage anops*	DF	S
120	*Ampharete* sp.	DF	S
121	*Ampharete arctica*	DF	S
122	*Ampharete acutifrons*	DF	S
123	*Amphicteis* sp.	DF	S
124	*Amphicteis mucronata*	DF	S
125	*Lysippe labiata*	DF	S
126	*Melinna cristata*	DF	S
127	*Melinna elisabethae*	DF	S
128	*Pista* sp.	DF	S
129	*Pista cristata*	DF	S
130	*Pista fasciata*	DF	S
131	*Artacama conifera*	DF	DM
132	*Proclea emmi*	DF	S
133	*Terebellides stroemi*	DF	S
134	*Trichobranchus glacialis*	DF	S
135	*Chone* sp.	SF	DM
136	*Chone gracilis*	SF	DM

TABLE II

CONTINUED

ID. No.	Species	Feeding Class	Motility Class
137	*Chone infundibuliformis*	SF	DM
138	*Euchone analis*	SF	DM
139	*Megalomma splendida*	SF	S
140	*Potamilla neglecta*	SF	S
141	*Pseudopotamilla reniformis*	SF	S
142	*Chitinopoma groenlandica*	SF	S
143	*Crucigera irregularis*	SF	S
144	*Serpula vermicularis*	SF	S
145	*Spirorbis* sp.	SF	S
146	*Aphrodita parva*	DF	M
	APLACOPHORA		
147	*Chaetoderma robusta*	DF/P	M
	POLYPLACOPHORA		
148	*Ischnochiton albus*	S	M
149	*Mopalia* sp.	S/P	M
150	*Haneleya* sp.	S	M
	PELECYPODA		
151	*Nucula tenuis*	DF	M
152	*Malletia cuneata*	DF	M
153	*Nuculana fossa*	DF	M
154	*Nuculana minuta*	DF	M
155	*Portlandia arctica*	DF	M
156	*Yoldia* sp.	DF	M
157	*Yoldia amygdalea*	DF	M
158	*Yoldia secunda*	DF	M
159	*Mytilus edulis*	SF	S
160	*Crenella decussata*	SF	S
161	*Megacrenella columbiana*	SF	S
162	*Dacrydium* sp.	SF	S
163	*Dacrydium vitreum*	SF	S
164	*Propeamussium alaskense*	SF	S
165	*Delectopecten randolphi*	SF	S
166	*Lima hyperborea*	SF	S
167	*Astarte* sp.	SF	DM
168	*Astarte borealis*	SF	DM
169	*Astarte alaskensis*	SF	DM
170	*Astarte montegui*	SF	DM
171	*Astarte polaris*	SF	DM
172	*Astarte esquimaulti*	SF	DM
173	*Cyclocardia* sp.	SF	S
174	*Cyclocardia ventricosa*	SF	S
175	*Cyclocardia crebricostata*	SF	S
176	*Axinopsida serricata*	SF/DF	S
177	*Axinopsida viridis*	SF/DF	S
178	*Thyasira flexuosa*	SF/DF	S

TABLE II

CONTINUED

ID. No.	Species	Feeding Class	Motility Class	ID. No.	Species	Feeding Class	Motility Class
179	*Mysella* sp.	SF/DF	S	199	*Cardiomya oldroydi*	P/S/DF	S
180	*Odontogena borealis*	SF/DF	S		GASTROPODA		
181	*Clinocardium* sp.	SF	M	200	*Puncturella cooperi*	S	M
182	*Clinocardium ciliatum*	SF	M	201	*Lepeta caeca*	SF	M
183	*Clinocardium fucanum*	SF	M	202	*Solariella obscura*	S/P	M
184	*Psephidia lordi*	SF	S/DM	203	*Solariella varicosa*	S/P	M
185	*Spisula polynyma*	SF	M	204	*Solariella lewisai*	S/P	M
186	*Macoma calcarea*	DF	S	205	*Tachyrynchus reticulatus*	S/P	M
187	*Macoma brota*	DF	S	206	*Calyptraea fastigata*	SF	M
188	*Macoma moesta alaskana*	DF	S	207	*Natica clausa*	P	M
189	*Siliqua alta*	SF	M	208	*Polinices* sp.	P	M
190	*Hiatella arctica*	SF	S	209	*Polinices nanus*	P	M
191	*Pandora filosa*	SF	S	210	*Polinices pallidus*	P	M
192	*Pandora bilirata*	SF	S	211	*Trophonopsis lasius*	P	M
193	*Pandora grandis*	SF	S	212	*Amphissa columbiana*	P	M
194	*Thracia myopsis*	SF/DF	S	213	*Amphissa reticulata*	P	M
195	*Lyonsia norwegica*	SF	S	214	*Mitrella gouldi*	U	M
196	*Cardiomya* sp.	P/S/DF	S	215	*Suavodrilla* sp.	P	M
197	*Cardiomya pectinata*	P/S/DF	S	216	*Suavodrilla willetti*	P	M
198	*Cardiomya planetica*	P/S/DF	S	217	*Oenopota* sp.	P	M
				218	*Odostomia* sp.	O	M
				219	*Odostomia* c.f. *O. cyria*	O	M
				220	*Turbonilla* sp.	O	M

TABLE II

CONTINUED

ID. No.	Species	Feeding Class	Motility Class
221	*Retusa obtusa*	P	M
222	*Cylichna alba*	P	M
	SCAPHOPODA		
223	*Dentalium* sp.	DF/P	M
224	*Dentalium dalli*	DF/P	M
225	*Cadulus* sp.	DF/P	M
226	*Cadulus stearnsi*	DF/P	M
227	*Cadulus tolmei*	DF/P	M
	CUMACEA		
228	*Lamprops fuscata*	DF	M
229	*Leucon* sp.	DF	M
230	*Leucon acutirostris*	DF	M
231	*Leucon nasica*	DF	M
232	*Eudorella* sp.	DF	M
233	*Eudorella emarginata*	DF	M
234	*Eudorella pacifica*	DF	M
235	*Eudorellopsis integra*	DF	M
236	*Diastylis* sp.	DF	M
237	*Diastylis bidentata*	DF	M
238	*Diastylis paraspinu-losa*	DF	M
239	*Diastylis* c.f. *D. tetradon*	DF/S	M
240	*Diastylis hirsata*	DF	M
241	*Campylaspis* sp.	DF	M
242	*Campylaspis umbensis*	DF	M
	ISOPODA		
243	*Calathura branchiata*	DF/S	M
244	*Rocinela belliceps*	DF/S	M
245	*Gnathia* sp.	U	S
246	*Gnathia elongata*	U	S
247	*Hyssura* sp.	U	S
248	*Synidotea pettiboneae*	S	M
	AMPHIPODA		
249	*Acanthonato-zoma inflatum*	U	M
250	*Ampelisca* sp.	SF	DM
251	*Ampelisca macrocephala*	SF	DM
252	*Ampelisca birulai*	SF	DM
253	*Byblis* sp.	SF	DM
254	*Byblis crassicornis*	SF	DM
255	*Byblis gaimardi*	SF	DM
256	*Haploops tubicola*	SF	DM
257	*Ericthonius hunteri*	SF	DM
258	*Neohela monstrosa*	SF	DM
259	*Maera danae*	SF	M
260	*Maera loveni*	SF	M
261	*Melita* sp.	DF	M
262	*Melita dentata*	DF	M
263	*Urothoe denticulata*	SF	M

TABLE II

CONTINUED

ID. No.	Species	Feeding Class	Motility Class
264	*Photis* c.f. *P. reinhardi*	DF	M
265	*Protomedeia* sp.	DF	M
266	*Anonyx* sp.	S	M
267	*Anonyx ochoticus*	S	M
268	*Anonyx nugax*	S	M
269	*Hippomedon* sp.	S/DF	M
270	*Hippomedon kurilicus*	S/DF	M
271	*Hippomedon propinquus*	S/DF	M
272	*Lepidepecreum* sp.	S/DF	M
273	*Lepidepecreum kasatka*	S/DF	M
274	*Lepidepecreum comatum*	S/DF	M
275	*Orchomene* sp.	S	M
276	*Aceroides* sp.	DF/S	M
277	*Bathymedon* sp.	DF/S	M
278	*Bathymedon nanseni*	DF/S	M
279	*Monoculodes* sp.	DF/S	M
280	*Monoculodes diamesus*	DF/S	M
281	*Westwoodilla caecula*	DF/S	M
282	*Nicippe tumida*	SF	M
283	*Harpinia* sp.	SF	M
284	*Harpinia emeryi*	SF	M
285	*Harpinia kobjakovae*	SF	M
286	*Harpiniopsis sanpedroensis*	SF	M
287	*Heterophoxus occulatus*	SF	M
288	*Paraphoxus* sp.	SF	M
289	*Paraphoxus robustus*	SF	M
290	*Paraphoxus simplex*	SF	M
291	*Phoxocephalus* sp.	SF	M
292	*Phoxocephalus hamilis*	SF	M
293	*Podoceropsis* sp.	DF	M
294	*Metopa* sp.	SF	M
295	*Metopa alderi*	SF	M
296	*Syrrhoe crenulata*	SF	M
	CAPRELLIDAE		
297	*Caprella striata*	S/P	M
	CIRRIPEDIA		
298	*Scalpellum* sp.	SF	S
299	*Scalpellum columbiana*	SF	S
300	*Balanus crenatus*	SF	S
301	*Balanus nubilus*	SF	S
302	*Balanus rostratus*	SF	S
	DECAPODA		
303	*Chionoecetes* sp.	S/P	M
304	*Chionoecetes bairdi*	S/P	M
305	*Pinnixa* sp.	O	M
306	*Pinnixa occidentalis*	O	M
307	*Pinnixa schmitti*	O	M
308	*Cancer oregonenis*	S/P	M

TABLE II

CONTINUED

ID. No.	Species	Feeding Class	Motility Class
	SIPUNCULIDA		
309	*Golfingia* sp.	DF	S
310	*Golfingia margaritacea*	DF	S
311	*Golfingia vulgaris*	DF	S
312	*Phascolion stroembi*	DF	S
	PRIAPULIDA		
313	*Priapulus caudatus*	P	M
	ECTOPROCTA		
314	*Mieroporina borealis*	SF	S
315	*Clavipora occidentalis*	SF	S
	BRACHIOPODA		
316	*Hemithiris psittacea*	SF	S
317	*Terebratulina unguicula*	SF	S
318	*Terebratulina crossei*	SF	S
319	*Deistothyris frontalis*	SF	S
320	*Laqueus cali-fornianus*	SF	S
321	*Terebratalia transversa*	SF	S
	ASTEROIDEA		
322	*Ctenodiscus crispatus*	DF	M
323	*Henricia leviuscula*	SF	M
	ECHINOIDEA		
324	*Brisaster townsendi*	DF/S	M
325	*Strongylocen-trotus drobachiensis*	S	M
	OPHIUROIDEA		
326	*Diamphiodia* sp.	DF	M
327	*Diamphiodia craterodmeta*	DF	M
328	*Diamphiodia periercta*	DF	M
329	*Pandellia carchara*	DF	M
330	*Unioplus* sp.	DF	M
331	*Unioplus macraspis*	DF	M
332	*Ophiacantha cataleimmo-ida*	DF	M
333	*Ophiopolis aculeata*	SF	M
334	*Ophiopenia disacantha*	DF	M
335	*Ophiura* sp.	DF/P	M
336	*Ophiura sarsi*	DF/P	M
337	*Stegophiura* sp.	U	M
	HOLOTHUROIDEA		
338	*Molpadia intermedia*	DF	S
339	*Cucumaria calcigera*	DF	S
340	*Psolus phantapus*	DF	S

Cruise 193	R/V *Acona*	- July 1974
Cruise 200	R/V *Acona*	- October 1974
Cruise 202	R/V *Acona*	- November 1974
Cruise 805	OSS *Oceanographer*	- February 1975
Cruise 807	OSS *Townsend Cromwell*	- May 1975
Cruise 811	USNS *Silas Bent*	- September 1975
Cruise 816	OSS *Discoverer*	- November-December 1975
Cruise DS001	OSS *Discoverer*	- March 1976

Vessel scheduling and inclement weather prevented seasonal coverage of the sampling grid during the first year (Table I) and samples from the first five cruises (193-807) were pooled to obtain complete coverage of the sample grid. Samples obtained during cruises 811 and 816 were pooled to give complete coverage for the fall of 1975 and coverage for the spring of 1976 was provided by samples from cruise DS001. Numerical analysis of grab data collected during the first year of the study (1974-1975) and in the fall of 1975 have been reported elsewhere (Feder *et al.*, 1976; Feder, 1977; Matheke *et al.*, 1976) and are included as Appendices I and II of this report.

Sampling Efficiency of the van Veen Grab

The van Veen grab functioned effectively in the fine sediments covering most of NEGOA, and typically delivered 15-19 liters of sediment. Penetration was reduced in sites with considerable concentrations of sand or gravel. The surface of all samples, examined through the top door of the grab, was relatively undisturbed as evidenced by the smooth detrital cover (see Feder *et al.*, 1973, for further discussion). Ten replicates were taken at Sites 4, 25, 30, 42, 48, 55 and 57 (Fig. 3) to determine the relative effectiveness of the grab. These samples were examined using a grab simulation program developed by Feder *et al.* (1973). This program provides an estimate of the cumulative percent of individuals and the cumulative percent of species collected in each step of a sequence of ten grabs, based on 100% obtained in ten grabs. The percentage of re-cruit individuals in the new species added at each subsequent grab was estimated; in this case, the percentage of recruits is the number of

text continued from page 18.

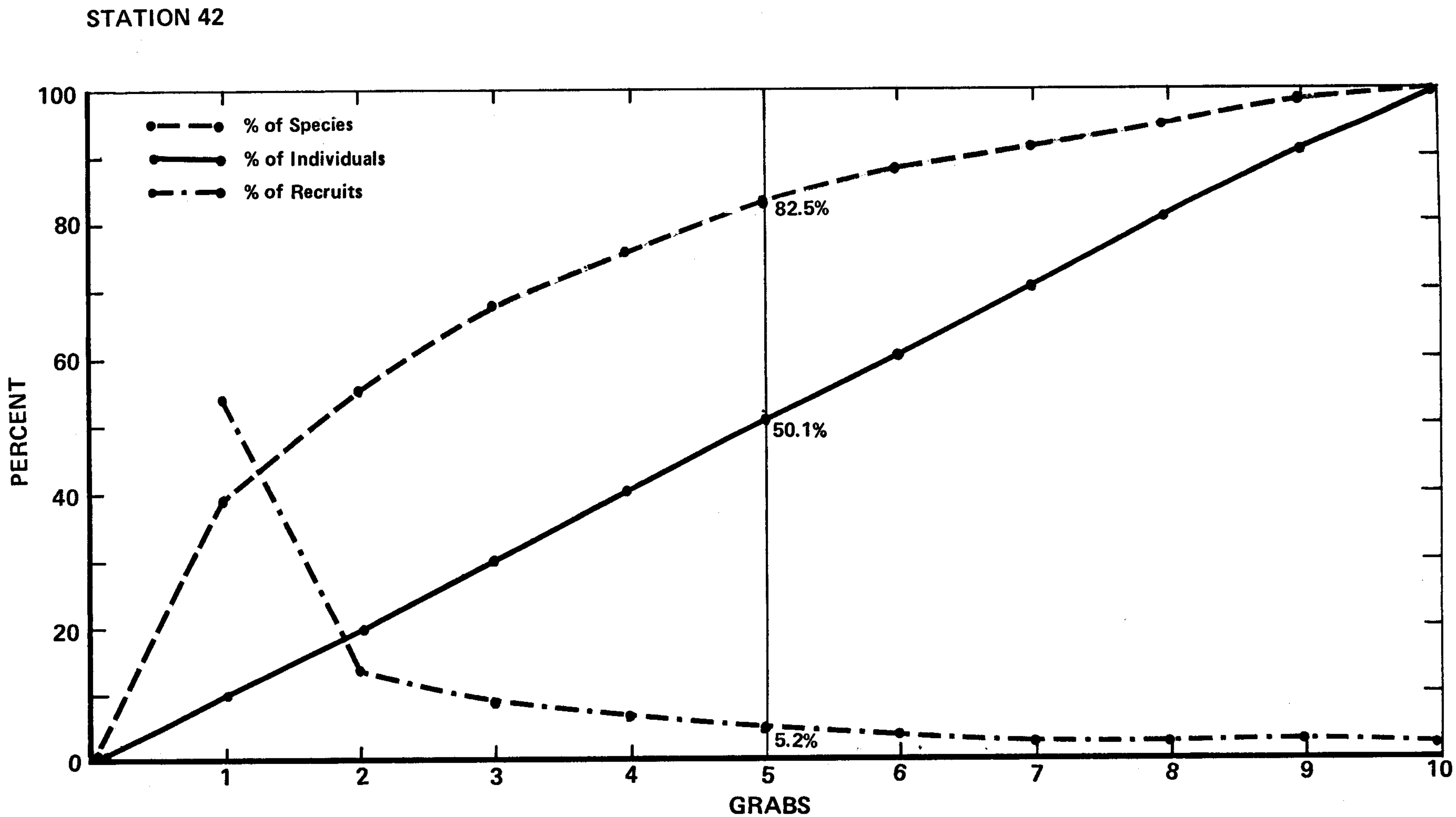

Figure 3. Plots of cumulative percentage of individuals and species, and percent of recruits added at each subsequent grab for Station 42. The total number of individuals and total of species collected in 10 grabs equals 100 percent.

individuals per new species added per grab divided by the sum, over all ten grabs, of the number of individuals per new species added per grab (for a detailed discussion see Feder *et al.*, 1973; Longhurst, 1964; Holme, 1964; Lie, 1968). The results of the grab simulation program were similar for each of the six sites analyzed. Figure 3 shows a representative plot of the results. The cumulative percent of species taken in five grabs at Sites 4, 25, 30, 42, 48, 55 and 57 ranged from 77.5 to 83.0%. The percent of recruit individuals obtained in the fifth grab ranged from 3.7 to 6.3%. This means that 93.7 to 96.3% of the recruit individuals found in 10 grabs were collected in the first five grabs. This indicates that the more abundant species were collected in the first five samples and recruitment of individuals of new species in subsequent samples represents only the less abundant species.

Numerical Analysis: Data Collected During OSS *Discoverer* Cruise DS001

In the spring of 1976 samples were collected at 41 sites during R/V *Discoverer* cruise DS001 (Table I). From these samples 438 taxa were identified (Appendix III). Prior to numerical analysis this data was reduced by eliminating all taxa which could not be identified to genera and all taxa which occurred at only one site in low abundance. This treatment reduced the number of species to 200 (Table III).

Numerical Analysis: Untransformed Abundance Data

A normal cluster analysis of untransformed abundance data produced six site groups at the 28% similarity level (Figs. 4 and 5; Table IV); three sites (2, 39 and 53) did not join any of the groups. Two major groups, identified as Inshore Group 1 and Inshore Group 2, consisted predominantly of sites located on the continental shelf. Two other groups (Shelf Break Groups 1 and 2) consisted of sites located at or near the 200-m contour. Smaller site groups consisted of Sites 56 and 57 (the Tarr Bank Group) located on Tarr Bank and Sites 54 and 63 (Group 5). An inverse cluster analysis identified 58 species groups at the 33% similarity level (Table V; distribution maps of numerically abundant species are presented in Appendix IV). A two-way coincidence table comparing site groups formed by the normal cluster analysis with the species groups formed

text continued on page 41.

TABLE III

SPECIES SELECTED FOR NUMERICAL ANALYSIS OF GRAB DATA COLLECTED DURING R/V *DISCOVERER* CRUISE DS 001

Species	Species
ANTHOZOA	*Laonice cirrata*
Ptilosarcus gurneyi	*Magelona japonica*
Peachia sp.	*Magelona pacifica*
	Spiochaetopterus costarum
POLYCHAETA	*Tharyx* sp.
Harmothoe sp.	*Chaetozone setosa*
Harmothoe imbricata	*Brada villosa*
Polynoe sp.	*Scalibregma inflatum*
Peisidice aspera	*Travisia pupa*
Pholoe minuta	*Sternaspis scutata*
Eteone longa	*Capitella capitata*
Autolytus magnus	*Heteromastus filiformis*
Syllis spongiphila	*Asychis similis*
Typosyllis sp.	*Maldane sarsi*
Typosyllis alternata	*Maldane glebifex*
Typosyllis armillaris	*Nicomache lumbricalis*
Eusyllis blomstrandi	*Notoproctus* sp.
Cheilonereis cyclurus	*Notoproctus pacifica*
Nereis sp.	*Axiothella rubrocincta*
Nereis pelagica	*Praxillella gracilis*
Nereis zonata	*Praxillella affinis*
Nephtys sp.	*Rhodine bitorquata*
Nephtys punctata	*Owenia fusiformis*
Nephtys longosetosa	*Myriochele heeri*
Aglaophamus rubella anops	*Idanthyrsus armatus*
Glycera capitata	*Amphictene auricoma*
Glycinde picta	*Ampharete* sp.
Goniada annulata	*Ampharete arctica*
Onuphis conchylega	*Ampharete acutifrons*
Onuphis geophiliformis	*Melinna cristata*
Onuphis iridescens	*Melinna elisabethae*
Onuphis parva	*Pista* sp.
Eunice valens	*Pista cristata*
Eunice kobiensis	*Artacama conifera*
Lumbrineris sp.	*Terebellides stroemii*
Lumbrineris zonata	*Trichobranchus glacialis*
Ninoe gemmea	*Chone* sp.
Drilonereis sp.	*Chone gracilis*
Drilonereis filum	*Euchone analis*
Drilonereis falcata minor	*Pseudopotamilla reniformis*
Haploscoloplos elongatus	*Chitinopoma groenlandica*
Aricidea sp.	*Crucigera irregularis*
Aricidea suecica	*Spirorbis* sp.
Paraonis gracilis	*Aphrodita parva*
Apistobranchus sp.	

TABLE III

CONTINUED

Species	Species
POLYPLACOPHORA	*Polinices pallida*
Ischnochiton albus	*Amphissa columbiana*
	Mitrella gouldi
PELECYPODA	*Odostomia* sp.
Nucula tenuis	
Nuculana pernula	SCAPHOPODA
Yoldia sp.	*Dentalium* sp.
Yoldia amygdalea	*Dentalium dalli*
Yoldia secunda	*Cadulus* sp.
Mytilus edulis	*Cadulus stearnsi*
Crenella dessucata	*Cadulus tolmei*
Megacrenella columbiana	
Dacrydium sp.	CIRRIPEDIA
Dacrydium vitreum	*Scalpellum* sp.
Propeamussium alaskense	*Balanus crenatus*
Delectopecten randolphi	*Balanus nubilis*
Lima hyperborea	*Balanus rostratus*
Astarte sp.	
Astarte borealis	CUMACEA
Astarte alaskensis	*Leucon* sp.
Astarte polaris	*Leucon nasica*
Astarte esquimaulti	*Eudorella emarginata*
Cyclocardia sp.	*Eudorellopsis integra*
Cyclocardia ventricosa	*Diastylis* sp.
Cyclocardia crebricostata	
Axinopsida serricata	ISOPODA
Axinopsida viridis	*Gnathia elongata*
Thyasira flexuosa	
Mysella sp.	AMPHIPODA
Odontogena borealis	*Ampelisca* sp.
Clinocardium sp.	*Ampelisca macrocephala*
Clinocardium ciliatum	*Ampelisca birulai*
Psephidia lordi	*Byblis* sp.
Spisula polynyma	*Byblis gaimardi*
Macoma calcarea	*Haploops tubicola*
Macoma brota	*Neohela monstrosa*
Hiatella arctica	*Urothoe denticulata*
Thracia myopsis	*Protomedeia* sp.
Cardiomya sp.	*Anonyx* sp.
Cardiomya pectinata	*Anonyx nugax*
Cardiomya planetica	*Hyppomedon* sp.
Puncturella cooperi	*Lepidepecreum comatum*
Solariella obscura	*Nicippe tumida*
Calyptraea fastigata	*Harpinia* sp.
Natica clausa	*Harpinia kobjakovae*
Polinices nanus	*Harpiniopsis sanpedroensis*

TABLE III

CONTINUED

Species	Species
DECAPODA	ECHINOIDEA
Chionoecetes bairdi	*Brisaster townsendi*
Pinnixa schmitti	
	OPHIUROIDEA
SIPUNCULA	*Diamphiodia craterodmeta*
Golfingia margaritacea	*Diamphiodia periercta*
Golfingia vulgaris	*Unioplus* sp.
Phascolion strombi	*Unioplus macraspis*
	Ophiacantha cataleimmoida
ECTOPROCTA	*Ophiopholis aculeata*
Clavipora occidentalis	*Ophiopenia disacantha*
	Ophiura sarsi
BRACHIOPODA	
Hemithiris psittacea	HOLOTHUROIDEA
Terebratulina unguicula	*Molpadia intermedia*
Terebratulina crossei	*Psolus phantapus*
Laqueus californianus	
Terebratalia transversa	
ASTEROIDEA	
Ctenodiscus crispatus	
Henricia leviuscula	

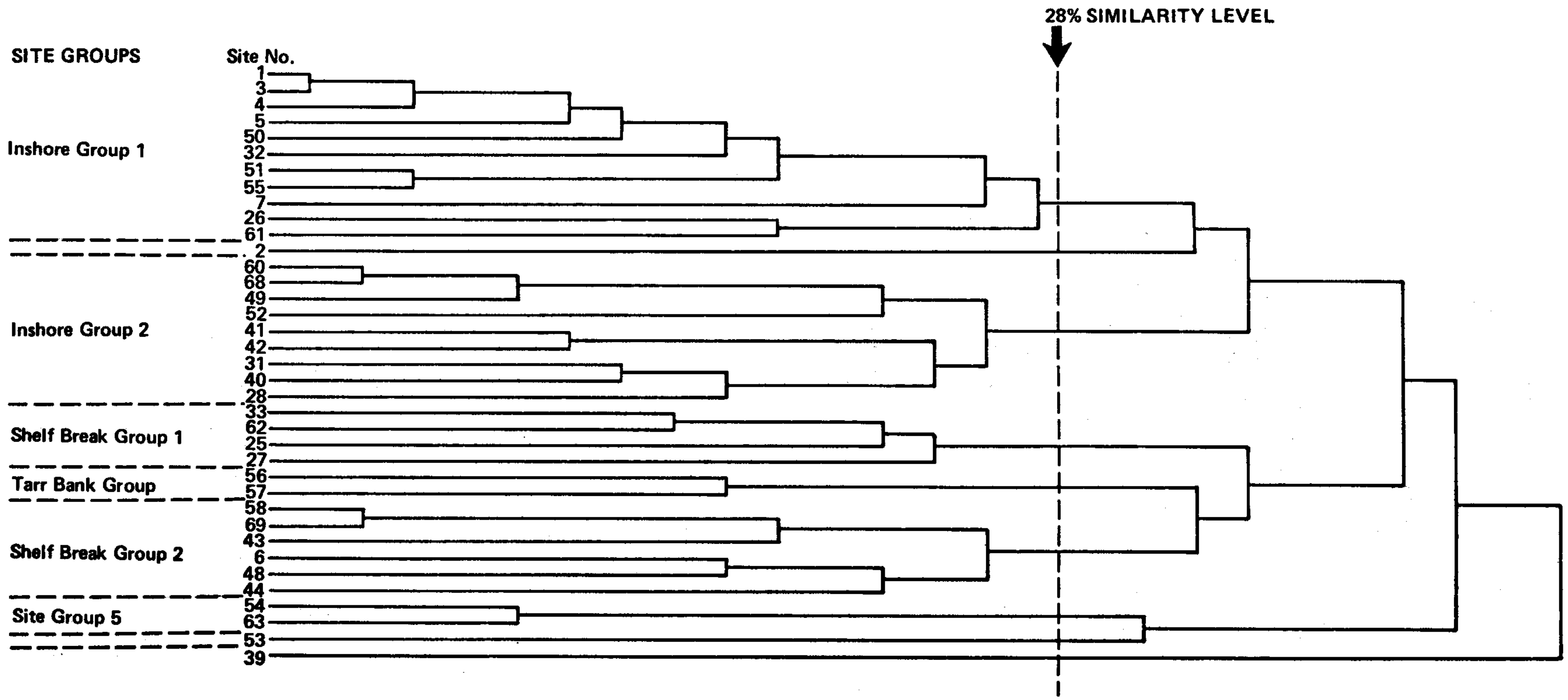

Figure 4. Dendrogram produced by cluster analysis using untransformed abundance data (No. of individuals/m^2) collected during OSS *Discoverer* Cruise DS001.

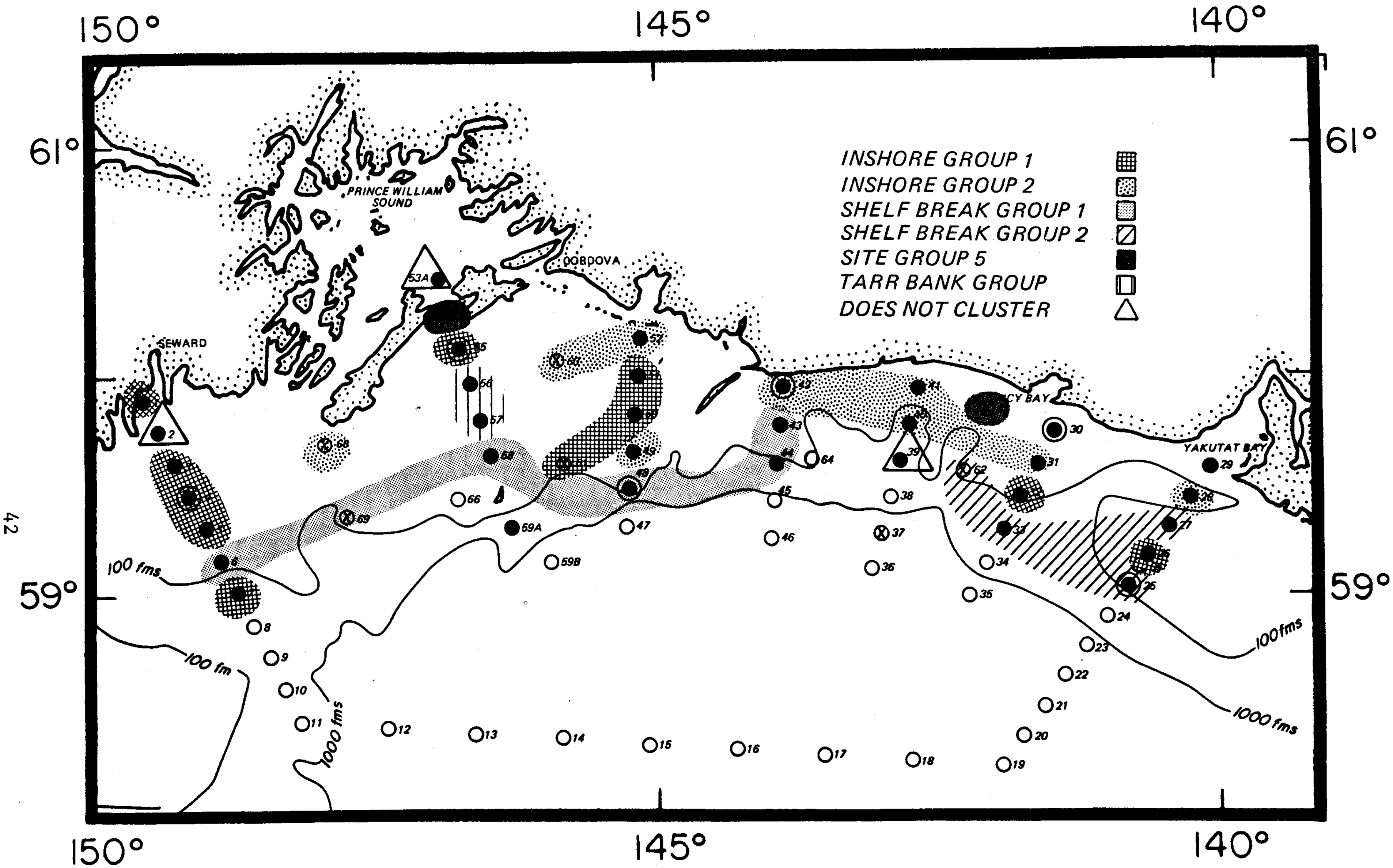

Figure 5. Station groups formed by a cluster analysis of untransformed abundance data (No. of individuals/m^2) collected during OSS *Discoverer* Cruise DS001.

TABLE IV-a

SITE GROUPS FORMED BY CLUSTER ANALYSIS OF DATA COLLECTED DURING R/V *DISCOVERER* CRUISE DS 001 MARCH 1976

Untransformed #/m^2 data

Site Group	Sites
Inshore Group 1	1, 3, 4, 5, 7, 26, 32, 50, 51, 55, 61
Inshore Group 2	28, 31, 40, 41, 42, 49, 60, 68
Shelf Break Group 1	6, 43, 44, 48, 58, 69
Shelf Break Group 2	25, 27, 33, 62
Site Group 5	54, 63
Tarr Bank Group	56, 57
Sites which did not join groups	2, 39, 53

Logarithm transformed #/m^2 data

Site Group	Sites
Inshore Group	1, 3, 4, 5, 26, 28, 32, 40, 50, 51, 55, 53, 54, 31, 41, 42, 43, 49, 61, 63
Shelf Break Group	6, 25, 27, 33, 44, 48, 58, 62, 69
Site Group 6	52, 60
Tarr Bank Group	56, 57
Sites which did not join groups	2, 7, 39

TABLE IV-b

COMPARISON OF SITE GROUPS FORMED BY CLUSTER ANALYSIS OF UNTRANSFORMED AND *ln* TRANSFORMED ABUNDANCE DATA

IG = Inshore Group, SBG = Shelf Break Group, TBG = Tarr Bank Group, G = Group, DNC = Did not join any station group

Site	Untransformed Data	Transformed Data
1	IG1	IG
3	IG1	IG
4	IG1	IG
5	IG1	IG
7	IG1	DNC
26	IG1	IG
32	IG1	IG
50	IG1	IG
51	IG1	IG
55	IG1	IG
61	IG1	IG
28	IG2	IG
31	IG2	IG
40	IG2	IG
41	IG2	IG
42	IG2	IG
49	IG2	IG
52	IG2	G6
60	IG2	G6
68	IG2	IG
6	SBG1	SBG
43	SBG1	IG2
44	SBG1	SBG
48	SBG1	SBG
58	SBG1	SBG
69	SBG1	SBG
25	SBG2	SBG
27	SBG2	SBG
33	SBG2	SBG
62	SBG2	SBG
54	G5	IG
63	G5	IG2
56	TBG	TBG
57	TBG	TBG
2	DNC	DNC
7	G1	DNC
39	DNC	DNC
53	DNC	IG

TABLE V

SPECIES GROUPS FORMED BY AN INVERSE CLUSTER ANALYSIS OF UNTRANSFORMED ABUNDANCE DATA (#/m^2) - R/V *DISCOVERER* CRUISE DS 001

Identification Numbers (ID) for Cross Reference with Table II are Included in Brackets

Group	Species
1	*Notoproctus* sp. (108), *Diamphiodia periercta* (328), *Psolus phantapus* (340), *Travisia pupa* (97), *Aphrodita parva* (146), *Megacrenella columbiana* (161), *Crucigera irregularis* (143)
2	*Capitella capitata* (99), *Brisaster townsendi* (324)
3	*Ampelisca birulai* (252), *Harpiniopsis sanpedroensis* (286), *Diastylis* sp. (236)
4	*Pseudopotamilla reniformis* (141), *Anonyx* sp. (266), *Aricidea suecica* (74), *Notoproctus pacificus* (109), *Phascolion stroembi* (312), *Golfingia margaritacea* (310), *Golfingia vulgaris* (311), *Typosyllis* sp. (30), *Typosyllis alternata* (31), *Idanthyrsus armatus* (116)
5	*Ampharete* sp. (120), *Ampharete arctica* (121)
6	*Syllis spongiphila* (28), *Harpinia* sp. (283), *Polinices nanus* (209), *Cardiomya pectinata* (196), *Byblis gaimardi* (255)
7	*Chone* sp. (135), *Anonyx nugax* (268), *Puncturella cooperi* (200), *Unioplus* sp. (330), *Glycinde picta* (53), *Rhodine bitorquata* (113), *Clavipora occidentalis* (315)
8	*Dentalium* sp. (223), *Cardiomya planetica* (198), *Byblis* sp. (253)
9	*Clinocardium ciliatum* (182), *Polinices pallidus* (210)
10	*Amphictene auricoma* (117), *Spirorbis* sp. (145), *Delectopecten randolphi* (165), *Ampelisca* sp. (250), *Mytilus edulis* (159), *Ophiacantha cataleimmodia* (332), *Apistobranchus* sp. (77), *Pista* sp. (128), *Euchone analis* (138), *Lima hyperborea* (166)
11	*Polynoe* sp. (19), *Henricia leviuscula* (323), *Calyptraea fastigata* (206), *Gnathia elongata* (246), *Clinocardium* sp. (181)

TABLE V

CONTINUED

Group	Species
12	*Nicomache lumbricalis* (106), *Praxillella affinis* (112)
13	*Peisidice aspera* (20), *Terebratulina unguicula* (317), *Astarte borealis* (168), *Terebratalia transversa* (321), *Balanus rostratus* (302), *Eunice valens* (62), *Astarte* sp. (167), *Lumbrineris zonata* (67), *Laqueus californianus* (321)
14	*Glycera capitata* (52), *Melinna cristata* (126), *Ischnochiton albus* (148)
15	*Harmothoe imbricata* (14), *Propeamussium alaskense* (164), *Terebratulina crossei* (318), *Typosyllis armillaris* (32), *Melinna elisabethae* (127), *Balanus nubilis* (301), *Drilonereis falcata minor* (71), *Onuphis conchylega* (58), *Drilonereis filum* (70), *Balanus crenatus* (300), *Natica clausa* (207), *Amphissa columbiana* (212), *Hemithiris psittacea* (316), *Nephtys longosetosa* (49), *Spiochaetopterus costarum* (88)
16	*Pholoe minuta* (21), *Haploscoloplos elongatus* (72), *Autolytus magnus* (27), *Ampelisca macrocephala* (251), *Metopa* sp. (294)
17	*Hiatella arctica* (190), *Eusyllis blomstrandi* (33), *Chone gracilis* (136), *Dacrydium* sp. (162)
18	*Chitinopoma groenlandica* (142), *Eunice kobiensis* (63), *Syrrhoe crenulata* (296), *Lepidepecreum comatum* (274), *Owenia fusiformis* (114)
19	*Laonice cirrata* (79)
20	*Haploops tubicola* (256)
21	*Paraonis gracilis* (76), *Phoxocephalus hamilis* (292),
22	*Cheilonereis cyclurus* (38), *Trichobranchus glacialis* (134), *Macoma calcarea* (186)
23	*Peachia* sp. (3), *Asychis similis* (101)

TABLE V

CONTINUED

Group	Species
24	*Cyclocardia* sp. (173), *Ophiopholis aculeata* (333), *Astarte alaskensis* (169), *Astarte esquimaulti* (172), *Astarte polaris* (171), *Urothoe denticulata* (263)
25	*Crenella dessucata* (160), *Cyclocardia ventricosa* (174), *Psephidia lordi* (184)
26	*Ophiura sarsi* (336)
27	*Myriochele heeri* (115)
28	*Eudorella emarginata* (233), *Eudorellopsis integra* (235), *Protomedeia* sp. (265), *Harpinia kobjakovae* (285), *Leucon* sp. (229), *Spiophanes cirrata* (84), *Heteromastus filiformis* (100), *Aglaophamus rulella anops* (51), *Tharyx* sp. (90)
29	*Chaetozone setosa* (91), *Ampharete acutifrons* (122), *Axiothella rubrocincta* (110), *Neohela monstrosa* (258), *Leucon nasica* (231), *Macoma brota* (187)
30	*Cyclocardia crebricostata* (175), *Cadulus stearnsi* (226)
31	*Dacrydium vitreum* (163)
32	*Nucula tenuis* (151), *Yoldia* sp. (156)
33	*Lumbrineris* sp. (64), *Nuculana fossa* (153), *Thyasira flexuosa* (178), *Sternaspis scutata* (98)
34	*Axinopsida serricata* (176)
35	*Goniada annulata* (55), *Molpadia intermedia* (338), *Nephtys punctata* (48), *Dentalium dalli* (224)
36	*Terebellides stroemi* (133), *Heterophoxus occulatus* (287), *Nereis zonata* (43), *Chaetoderma robusta* (147)
37	*Nephtys* sp. (44), *Ninoe gemmea* (68)
38	*Onuphis iridescens* (60), *Praxillella gracilis* (111), *Ctenodiscus crispatus* (322), *Pista cristata* (129)

TABLE V

CONTINUED

Group	Species
39	*Yoldia amygdalea* (157), *Cadulus tolmei* (227)
40	*Odontogena borealis* (180)
41	*Diamphiodia craterodmeta* (328)
42	*Mitrella gouldi* (214), *Pinnixa schmitti* (307), *Ptilosarcus gurneyi* (2), *Nereis pelagica* (41), *Megelona pacifica* (86)
43	*Maldane sarsi* (103), *Nicippe tumida* (282)
44	*Mysella* sp. (179), *Cardiomya* sp. (196), *Aricidea* sp. (73), *Hippomedon* sp. (269)
45	*Autolytus magnus* (27), *Axinopsida viridis* (177), *Nereis* sp. (40), *Maldane glebifex* (104)
46	*Unioplus macraspis* (331)
47	*Harmothoe* sp. (13), *Chionoecetes bairdi* (304)
48	*Cadulus* sp. (225)
49	*Brada villosa* (92), *Scalibregma inflatum* (95)
50	*Spisula polynyma* (185)
51	*Artacama conifera* (131)
52	*Drilonereis* sp. (69), *Thracia myopsis* (194), *Onuphis geophiliformis* (59)
53	*Solariella obscura* (202), *Odostomia* sp. (218)
54	*Yoldia secunda* (158)
55	*Ophiopenia disacantha* (334)
56	*Onuphis parva* (61)
57	*Spio filicornis* (81), *Magelona japonica* (85)
58	*Scalpellum* sp. (298)

by the inverse cluster analysis is presented in Appendix V. Reduced two-way tables of Average Cell Density (Table VI), Constancy (Table VII) and Fidelity (Table VIII) were utilized to determine the species and species groups which characterized and distinguished each of the site groups. Many species groups consisted of species present in only one or two sites, and these groups were eliminated from the graphical representation of species group distribution shown in Figure 6. The fidelity and constancy of the major species groups were arbitrarily divided into four classes: very high (VH), 95-100%; high (H), 66-94%; medium (M), 33-65%; low (L), 16-32%; and very low (VL), 0-15% (Fig. 6). A summary of the distribution of the major species groups follows (refer to Appendix V, Table I; Text, Tables V-VIII, Fig. 6):

Species Group 3. These species were most abundant in Shelf Break Group 2. They had a high constancy in that group.

Species Group 4. These species were found predominantly in Shelf Break Groups 1 and 2, and the Tarr Bank Group.

Species Groups 13, 14 and 15. Species in these groups were abundant in the Tarr Bank Group. Members of Species Group 14 were also common in Shelf Break Group 1.

Species Group 25. These species were abundant in the Tarr Bank Group, and in Shelf Break Group 2.

Species Group 26. *Ophiura sarsi*, the only species in this group, was found in all site groups except for Site 2. It was most abundant in Site Group 5 and Sites 54 and 63.

Species Groups 28 and 29. The species in this group were most abundant in Site 53. Species in Group 28 were also abundant in Site 54 of Site Group 5.

Species Groups 32 and 33. The species in these two groups were ubiquitous (medium to high constancy in all site groups).

Species Group 34. This species, *Axinopsida serricata*, was most abundant in Inshore Group 2. It was also abundant in some of the sites in Inshore Group 1.

Species Group 35. These species were most abundant in Site 53. They were also common in Inshore Groups 1 and 2. Members of this group were present in all site groups.

text continued from page 29.

TABLE VI

SITE GROUP/SPECIES GROUP COINCIDENCE TABLE SHOWING AVERAGE CELL DENSITIES OF GROUPS FORMED BY A CLUSTER ANALYSIS OF UNTRANSFORMED ABUNDANCE DATA - R/V *DISCOVERER*, MARCH 1976

IG = Inshore Group, SBG = Shelf Break Group, TBG = Tarr Bank Group

Species Group		Site Groups IG1 (11)†	Site* 2 (1)	IG2 (9)	SBG1 (4)	TBG (2)	SBG2 (6)	Group 5 (2)	Site* 53 (1)	Site* 39 (1)
1	(7)††	0.1	0.	0.0	0.1	0.1	0.7	0.	0.	0.
2	(2)	0.8	1.0	0.	0.3	0.8	0.3	0.	0.	0.
3	(3)	1.1	0.	0.4	0.3	0.7	7.5	1.3	1.3	2.2
4	(10)	0.	1.6	0.2	2.3	3.9	4.1	0.	0.	0.
5	(2)	0.2	1.0	0.3	1.0	0.5	1.2	3.0	1.0	0.
6	(5)	0.	0.	0.2	0.2	0.4	1.5	0.6	0.4	0.
7	(7)	0.1	0.	0.0	0.2	0.3	0.6	0.	0.	0.
8	(3)	0.2	0.	0.	0.	0.3	0.9	0.	0.7	0.
9	(2)	0.	1.0	0.3	0.	0.	0.3	0.	0.	0.
10	(10)	0.0	0.	0.0	1.0	0.3	0.2	0.	0.	0.
11	(5)	0.	0.	0.	0.	0.7	0.	0.2	0.	0.
12	(2)	0.2	0.	0.4	0.	1.0	0.	2.5	0.	0.
13	(9)	0.0	0.4	0.5	0.7	25.6	2.0	0.	0.	0.
14	(3)	0.4	0.	1.7	7.3	8.7	1.2	0.	0.	0.
15	(15)	0.0	0.	0.1	0.0	3.0	0.1	0.3	0.	0.
16	(5)	0.5	0.8	0.0	0.6	2.8	0.2	1.4	1.6	3.3
17	(4)	1.1	0.5	0.1	0.5	0.4	0.2	0.	0.	0.
18	(5)	0.	0.	0.0	0.7	0.2	0.1	0.2	0.	0.
19	(1)	0.9	0.	0.	2.0	1.5	1.3	0.	0.	0.
20	(1)	0.5	0.	0.4	4.0	0.	1.7	0.	0.	0.
21	(2)	1.1	0.	0.4	0.	0.	0.2	1.0	1.0	0.
22	(3)	0.	0.	0.1	0.	0.	0.1	2.0	0.	0.
23	(2)	0.2	0.	0.1	0.	10.8	2.3	0.	0.	0.
24	(6)	0.4	0.	0.6	0.6	2.2	4.6	0.	2.3	0.
25	(3)	2.8	0.	8.1	0.5	15.0	26.1	2.0	0.	0.
26	(1)	1.9	0.	12.2	10.5	5.5	62.4	300.0	22.0	3.3
27	(1)	0.	2.0	16.4	3.5	0.5	2.6	0.	0.	0.
28	(9)	0.8	0.4	0.3	0.2	0.5	0.3	12.0	39.6	0.
29	(6)	0.2	0.	0.0	0.	0.	0.1	0.5	5.0	0.6
30	(2)	1.6	0.	1.9	0.3	0.	0.2	0.	0.	0.
31	(1)	0.2	0.	3.6	0.	1.0	1.9	0.	0.	0.
32	(2)	13.2	1.0	54.4	5.0	3.0	9.1	22.0	4.0	5.0
33	(4)	15.0	3.5	13.9	3.6	7.1	3.8	18.8	79.5	1.7
34	(1)	8.6	0.	10.2	2.5	0.	5.0	0.	0.	0.
35	(4)	4.0	1.0	1.3	0.5	0.1	0.4	1.0	11.5	0.8
36	(4)	1.6	0.	3.3	0.5	0.5	1.8	10.8	11.5	0.8
37	(2)	1.5	0.	2.0	0.8	0.3	1.0	1.5	1.0	0.
38	(4)	5.2	2.0	3.9	3.6	0.5	3.3	3.5	1.0	0.8
39	(2)	1.6	2.0	6.7	0.	0.	0.2	9.5	4.0	0.
40	(1)	11.9	8.0	7.6	11.5	0.	15.9	1.0	0.	0.
41	(1)	0.4	0.	12.9	0.	2.5	0.	0.	0.	0.
42	(5)	0.	0.	1.9	0.	0.5	0.1	0.2	0.4	0.
43	(2)	0.	0.	0.4	0.	0.	2.3	0.	0.	6.7
44	(4)	0.1	0.	0.2	0.3	0.3	0.1	0.3	0.	5.0
45	(4)	0.1	0.	0.7	0.	1.5	1.5	1.3	0.	44.2
46	(1)	1.7	0.	4.2	8.0	1.0	3.0	0.	0.	26.7
47	(2)	0.3	0.	0.	0.	0.	0.	0.	0.	0.
48	(1)	1.3	0.	0.2	0.5	0.	0.	0.	0.	0.
49	(2)	0.2	0.	0.2	0.	1.0	0.6	0.	0.	0.
50	(1)	0.2	0.	0.	0.	0.	0.7	0.	0.	0.
51	(1)	0.	0.	0.7	0.5	0.	0.	0.	0.	0.
52	(3)	0.2	0.	1.0	0.	0.	0.1	0.	0.	0.
53	(2)	0.8	0.	0.7	0.	0.	0.	0.	0.	0.
54	(1)	1.6	0.	0.	0.	0.	0.	0.	0.	0.
55	(1)	0.7	2.0	0.4	0.	0.	0.8	0.	0.	0.
56	(1)	0.	0.	0.	0.	0.	4.7	0.	0.	0.
57	(2)	0.	0.	1.4	0.	0.	0.	0.	0.	0.
58	(1)	0.	14.0	0.	0.	0.	0.	0.	0.	0.

* Sites which did not join any site groups
† Number of sites in the group
†† Number of species in the group

TABLE VII

SITE GROUP/SPECIES GROUP COINCIDENCE TABLE SHOWING PERCENT CONSTANCY OF SPECIES GROUPS IN EACH SITE GROUP - R/V *DISCOVERER*, MARCH 1976

IG = Inshore Group, SBG = Shelf Break Group, TBG = Tarr Bank Group

Species Group		IG1 (11)†	Site* 2 (1)	IG2 (9)	SBG1 (4)	TBG (2)	SBG2 (6)	Group 5 (2)	Site* 53 (1)	Site* 39 (1)
1	(7)††	3.9	0.	1.6	3.6	7.1	23.8	0.	0.	0.
2	(2)	31.8	50.0	0.	12.5	50.0	16.7	0.	0.	0.
3	(3)	12.1	0.	11.1	16.7	33.3	66.7	16.7	33.3	33.3
4	(10)	0.	30.0	7.8	50.0	45.0	51.7	0.	0.	0.
5	(2)	9.1	50.0	11.1	37.5	25.0	33.3	50.0	50.0	0.
6	(5)	0.	0.	8.9	5.0	10.0	43.3	20.0	20.0	0.
7	(7)	2.6	0.	1.6	7.1	21.4	23.8	0.	0.	0.
8	(3)	6.1	0.	0.	0.	33.3	38.9	0.	33.3	0.
9	(2)	0.	50.0	16.7	0.	0.	16.7	0.	0.	0.
10	(10)	0.9	0.	1.1	30.0	20.0	10.0	0.	0.	0.
11	(5)	0.	0.	0.	0.	50.0	0.	10.0	0.	0.
12	(2)	9.1	0.	11.1	0.	50.0	0.	25.0	0.	0.
13	(9)	2.0	11.1	6.2	19.4	88.9	20.4	0.	0.	0.
14	(3)	9.1	0.	25.9	75.0	100.0	38.9	0.	0.	0.
15	(15)	0.6	0.	5.2	1.7	83.3	4.4	6.7	0.	0.
16	(5)	16.4	20.0	2.2	20.0	70.0	10.0	30.0	20.0	40.0
17	(4)	11.4	25.0	2.8	18.8	25.0	8.3	0.	0.	0.
18	(5)	0.	0.	2.2	25.0	10.0	6.7	10.0	0.	0.
19	(1)	18.2	0.	0.	25.0	100.0	16.7	0.	0.	0.
20	(1)	9.1	0.	22.2	25.0	0.	33.3	0.	0.	0.
21	(2)	9.1	0.	22.2	0.	0.	8.3	25.0	50.0	0.
22	(3)	0.	0.	7.4	0.	0.	5.6	50.0	0.	0.
23	(2)	4.5	0.	5.6	0.	50.0	41.7	0.	0.	0.
24	(6)	3.0	0.	9.3	16.7	41.7	41.7	0.	16.7	0.
25	(3)	21.2	0.	40.7	25.0	83.3	83.3	33.3	0.	0.
26	(1)	36.4	0.	77.8	100.0	50.0	100.0	100.0	100.0	100.0
27	(1)	0.	100.0	44.4	50.0	50.0	66.7	0.	0.	0.
28	(9)	14.1	11.1	9.9	11.1	16.7	11.1	55.6	100.0	0.
29	(6)	4.5	0.	1.9	0.	0.	5.6	16.7	100.0	16.7
30	(2)	18.2	0.	27.8	12.5	0.	8.3	0.	0.	0.
31	(1)	9.1	0.	22.2	0.	50.0	50.0	0.	0.	0.
32	(2)	100.0	50.0	66.7	62.5	75.0	58.3	75.0	100.0	100.0
33	(4)	75.0	50.0	83.3	62.5	75.0	62.5	100.0	75.0	25.0
34	(1)	27.3	0.	66.7	50.0	0.	33.3	0.	0.	0.
35	(4)	65.9	25.0	41.7	12.5	12.5	20.8	37.5	100.0	25.0
36	(4)	34.1	0.	61.1	18.8	25.0	50.0	87.5	100.0	25.0
37	(2)	45.5	0.	55.6	37.5	25.0	41.7	50.0	50.0	0.
38	(4)	65.9	50.0	66.7	87.5	37.5	45.8	37.5	50.0	25.0
39	(2)	22.7	50.0	16.7	0.	0.	8.3	25.0	50.0	0.
40	(1)	63.6	100.0	55.6	100.0	0.	50.0	50.0	0.	0.
41	(1)	9.1	0.	22.2	0.	100.0	0.	0.	0.	0.
42	(5)	0.	0.	20.0	0.	10.0	3.3	10.0	20.0	0.
43	(2)	0.	0.	16.7	0.	0.	33.3	0.	0.	100.0
44	(4)	2.3	0.	5.6	12.5	12.5	4.2	12.5	0.	100.0
45	(4)	2.3	0.	13.9	0.	25.0	29.2	25.0	0.	100.0
46	(1)	18.2	0.	33.3	50.0	50.0	33.3	0.	0.	100.0
47	(2)	13.6	0.	0.	0.	0.	0.	0.	0.	0.
48	(1)	18.2	0.	11.1	25.0	0.	0.	0.	0.	0.
49	(2)	4.5	0.	11.1	0.	25.0	25.0	0.	0.	0.
50	(1)	9.1	0.	0.	0.	0.	16.7	0.	0.	0.
51	(1)	0.	0.	33.3	25.0	0.	0.	0.	0.	0.
52	(3)	6.1	0.	18.5	0.	0.	5.6	0.	0.	0.
53	(2)	22.7	0.	16.7	0.	0.	0.	0.	0.	0.
54	(1)	9.1	0.	0.	0.	0.	0.	0.	0.	0.
55	(1)	27.3	100.0	22.2	0.	0.	33.3	0.	0.	0.
56	(1)	0.	0.	0.	0.	0.	16.7	0.	0.	0.
57	(2)	0.	0.	16.7	0.	0.	0.	0.	0.	0.
58	(1)	0.	100.0	0.	0.	0.	0.	0.	0.	0.

* Sites which did not join any site groups
† Number of sites in the group
†† Number of species in the group

TABLE VIII

SITE GROUP/SPECIES GROUP COINCIDENCE TABLE SHOWING PERCENT FIDELITY OF SPECIES GROUPS IN EACH SITE GROUP - R/V *DISCOVERER*, MARCH 1976

IG = Inshore Group, SBG = Shelf Break Group, TBG = Tar Bank Group

Species Group		Site Groups: IG1 (11)†	Site* 2 (1)	IG2 (9)	SBG1 (4)	TBG (2)	SBG2 (6)	Group 5 (2)	Site* 53 (1)	Site* 39 (1)
1	(7)††	8.5	0.	3.5	7.8	7.8	72.5	0.	0.	0.
2	(2)	24.3	32.4	0.	8.1	24.3	10.8	0.	0.	0.
3	(3)	7.3	0.	3.0	2.2	4.5	50.1	9.0	9.0	14.9
4	(10)	0.	13.3	1.3	18.7	32.5	34.2	0.	0.	0.
5	(2)	2.2	12.1	4.0	12.1	6.1	15.0	36.4	12.1	0.
6	(5)	0.	0.	5.4	6.0	12.0	46.5	18.1	12.0	0.
7	(7)	4.3	0.	2.6	17.8	23.8	51.5	0.	0.	0.
8	(3)	11.2	0.	0.	0.	15.4	42.5	0.	30.9	0.
9	(2)	0.	60.0	20.0	0.	0.	20.0	0.	0.	0.
10	(10)	1.3	0.	1.5	65.6	17.3	14.4	0.	0.	0.
11	(5)	0.	0.	0.	0.	77.8	0.	22.2	0.	0.
12	(2)	4.9	0.	10.7	0.	24.1	0.	60.3	0.	0.
13	(9)	0.1	1.5	1.6	2.5	87.3	7.0	0.	0.	0.
14	(3)	2.2	0.	8.8	38.0	44.9	6.1	0.	0.	0.
15	(15)	0.3	0.	2.9	0.9	85.4	2.9	7.5	0.	0.
16	(5)	4.8	7.0	0.4	5.3	24.6	2.2	12.3	14.1	29.3
17	(4)	41.0	17.9	2.0	17.9	13.4	7.9	0.	0.	0.
18	(5)	0.	0.	3.5	54.8	15.7	10.4	15.7	0.	0.
19	(1)	15.8	0.	0.	34.8	26.1	23.2	0.	0.	0.
20	(1)	6.9	0.	6.8	60.9	0.	25.4	0.	0.	0.
21	(2)	30.3	0.	11.9	0.	0.	4.4	26.7	26.7	0.
22	(3)	0.	0.	6.6	0.	0.	4.9	88.5	0.	0.
23	(2)	1.4	0.	0.8	0.	80.5	17.3	0.	0.	0.
24	(6)	3.7	0.	5.9	5.5	20.3	42.8	0.	21.8	0.
25	(3)	5.1	0.	14.8	0.9	27.6	47.9	3.7	0.	0.
26	(1)	0.4	0.	2.9	2.5	1.3	14.9	71.8	5.3	0.8
27	(1)	0.	8.0	65.8	14.0	2.0	10.2	0.	0.	0.
28	(9)	1.5	0.8	0.5	0.4	0.9	0.5	22.2	73.1	0.
29	(6)	2.6	0.	0.6	0.	0.	1.7	7.8	78.5	8.7
30	(2)	40.1	0.	48.2	6.4	0.	5.3	0.	0.	0.
31	(1)	3.4	0.	53.3	0.	15.0	28.3	0.	0.	0.
32	(2)	11.3	0.9	46.6	4.3	2.6	7.8	18.8	3.4	4.3
33	(4)	10.2	2.4	9.5	2.5	4.9	2.6	12.8	54.1	1.1
34	(1)	32.8	0.	38.8	9.5	0.	19.0	0.	0.	0.
35	(4)	19.1	4.8	6.5	2.4	0.6	2.0	4.8	55.7	4.0
36	(4)	5.2	0.	10.8	1.6	1.6	5.8	34.9	37.3	2.7
37	(2)	19.0	0.	25.0	9.4	3.1	12.3	18.7	12.5	0.
38	(4)	21.6	8.4	16.5	15.2	2.1	13.9	14.7	4.2	3.5
39	(2)	6.8	8.3	27.8	0.	0.	0.7	39.6	16.7	0.
40	(1)	21.2	14.3	13.5	20.6	0.	28.5	1.8	0.	0.
41	(1)	2.3	0.	81.8	0.	15.9	0.	0.	0.	0.
42	(5)	0.	0.	61.8	0.	16.2	2.7	6.5	12.9	0.
43	(2)	0.	0.	4.7	0.	0.	24.4	0.	0.	70.9
44	(4)	0.9	0.	2.7	4.1	4.1	1.7	4.1	0.	82.3
45	(4)	0.1	0.	1.4	0.	3.1	3.0	2.5	0.	89.9
46	(1)	3.9	0.	9.5	17.9	2.2	6.7	0.	0.	59.8
47	(2)	100.0	0.	0.	0.	0.	0.	0.	0.	0.
48	(1)	64.6	0.	10.8	24.5	0.	0.	0.	0.	0.
49	(2)	9.0	0.	11.0	0.	49.6	30.3	0.	0.	0.
50	(1)	21.4	0.	0.	0.	0.	79.6	0.	0.	0.
51	(1)	0.	0.	57.1	42.9	0.	0.	0.	0.	0.
52	(3)	13.7	0.	78.0	0.	0.	8.4	0.	0.	0.
53	(2)	55.1	0.	44.9	0.	0.	0.	0.	0.	0.
54	(1)	100.0	0.	0.	0.	0.	0.	0.	0.	0.
55	(1)	18.5	51.0	11.3	0.	0.	19.1	0.	0.	0.
56	(1)	0.	0.	0.	0.	0.	100.0	0.	0.	0.
57	(2)	0.	0.	100.0	0.	0.	0.	0.	0.	0.
58	(1)	0.	100.0	0.	0.	0.	0.	0.	0.	0.

* Sites which did not join any site groups
† Number of sites in the group
†† Number of species in the group

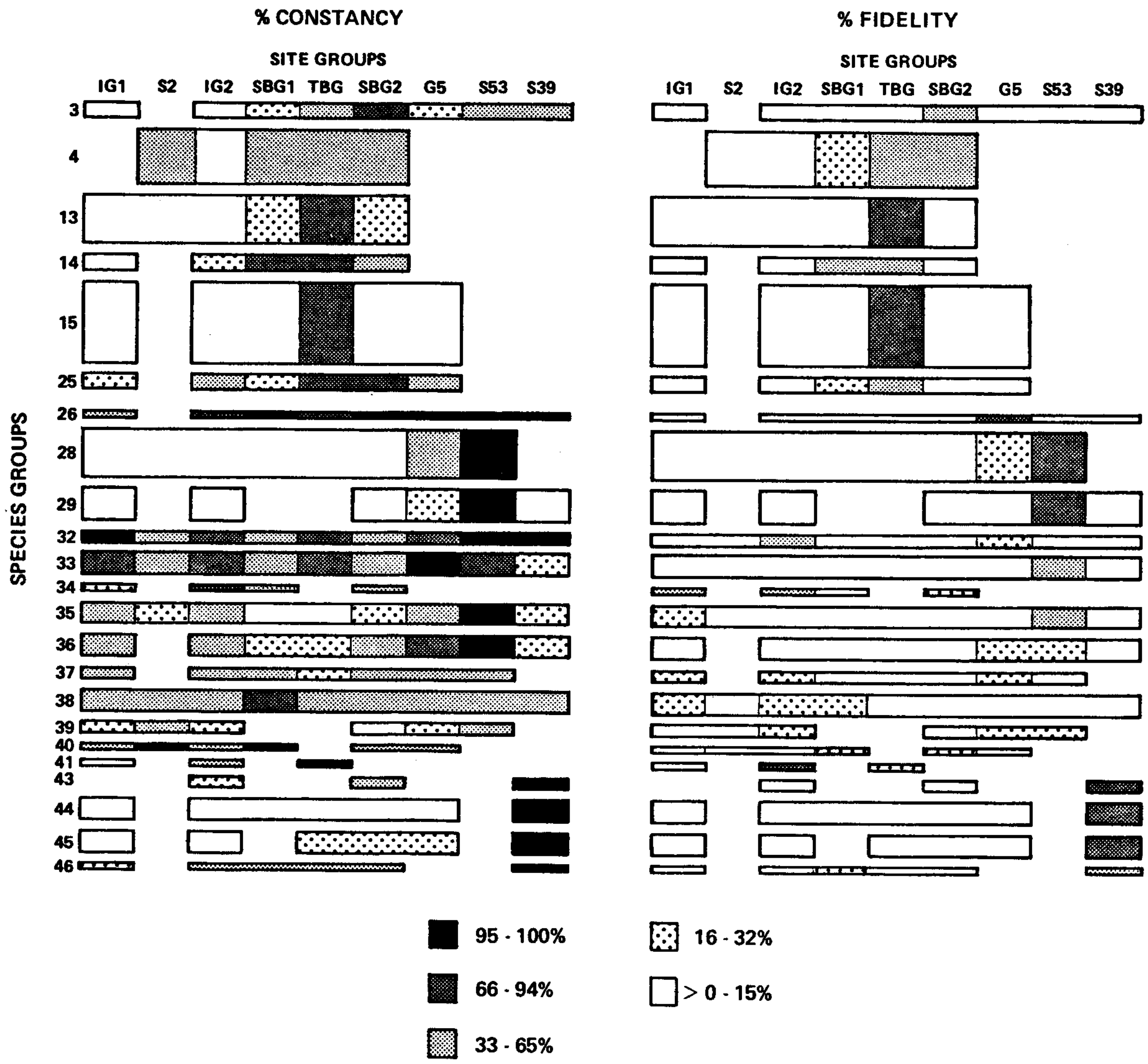

Figure 6. Constancy and fidelity of species groups formed by inverse cluster analysis using untransformed abundance data collected during OSS *Discoverer* Cruise DS001. The vertical dimension (height) of the bars is proportional to the number of species in the species group (Table V). S=Site, G=Group, IG=Inshore Group, SBG=Shelf Break Group, TBG=Tarr Bank Group.

Species Group 36. These species were most abundant in Site Group 5 and Site 53. They were present in medium constancy and reduced numbers in Inshore Groups 1 and 2 and Shelf Break Group 2. These species were present in all site groups except Site 2.

Species Groups 37 and 38. These species were found in most site groups with generally low to medium constancy. They were fairly evenly distributed in terms of density. Species in Group 37 were not found in Sites 2 and 53.

Species Group 39. These species were most abundant in Site Group 5, Inshore Group 2 and Site 53.

Species Group 40. This species, *Odontogena borealis*, was most abundant in Shelf Break Groups 1 and 2, Inshore Groups 1 and 2 and Site 2.

Species Group 41. This species, *Diamphiodia craterodmeta*, was most abundant in Inshore Group 2.

Species Groups 43, 44, 45 and 46. These species characterized Site 39.

The two-way tables (Tables VI-VIII and Fig. 6), in addition to providing information on the distribution of species groups, illustrate the differences between the site groups. The fauna in Inshore Groups 1 and 2 was composed of species in Species Groups 25, 26, 32, 33, 34, 35, 36, 37, 38 and 40 (Tables VI-VIII; Fig. 5). Most of these groups consisted of relatively ubiquitous species which were also present in most other site groups. Inshore Group 2 differed from Inshore Group 1 primarily on the basis of the increased abundance of members of Species Groups 25, 26, 27, 32 and 39 in Inshore Group 2 (Table VI). Site 2 was distinguished from Inshore Groups 1 and 2 by the low abundance and low species richness of its fauna. The fauna in the Shelf Break sites consisted of many of the species found in Inshore Groups 1 and 2 plus members of Species Groups 3, 4 and 14. Shelf Break Groups 1 and 2 were distinguished from each other on the basis of differences in abundance of Species Groups 3, 14, 25 and 26 (Table VI). The Tarr Bank Group sites (Sites 56 and 57) contained most of the species which characterized the Inshore and Shelf Break Group sites as well as members of Species Groups 13, 15 and 16 (Table VI). Sites 54 and 63 (Group 5) were linked together primarily by the high abundance of the brittle star, *Ophiura sarsi* (Table VI; Species Group 26) in these two sites. Site 54 of Site Group 5 has many affinities with Site 53 (Appendix

V, Table I); however, these sites were not classified together by this analysis because of differences in the abundance of *Ophiura sarsi*. Site 39 was characterized by Species Groups 43-46 (Table VI; Fig. 6).

A principal coordinate analysis using the Czekanowski coefficient with untransformed abundance data (Fig. 7) revealed groupings similar to those produced by cluster analysis (Figs. 4 and 5). Although some sites are contiguous, there is a visible separation between sites in Inshore Groups 1 and 2 and between sites in Shelf Break Groups 1 and 2 (Fig. 7). However, Sites 56 and 57 (Tarr Bank Group), which were classified as a separate group by cluster analysis, were closely associated with the Shelf Break Group on plots of all three axes (Fig. 7). The principal coordinate analysis (Fig. 7b and c) also indicated that Site 54 (Group 5; cluster analysis) was more closely associated with Site 53 than with Site 63 (Group 5; cluster analysis).

A principal coordinate analysis using untransformed abundance data and the Canberra "metric" similarity coefficient is shown in Figure 8. The Canberra metric coefficient reduced the effect of dominant species on the analysis and the segregation of Inshore Groups 1 and 2 was no longer apparent. Shelf Break Groups 1 and 2 exhibited a slight separation on the third coordinate axis (Fig. 8b). Sites 56 and 57 were quite distinct from all other sites on the first and second coordinate axes.

Numerical Analyses: Transformed Abundance Data

A cluster analysis of natural logarithm transformed abundance data delineated four site groups at the 33% similarity levels; Sites 2, 7 and 39 did not join any of the groups formed (Figs. 9 and 10). An inverse cluster analysis delineated 27 species groups at the 25% similarity level, the major species groups formed are listed in Table IX. Two-way coincidence tables (Appendix V, Table II; Text, Tables X-XII) were constructed comparing site groups and species groups formed by cluster analysis of *ln* transformed abundance data. Inshore Groups 1 and 2 delineated by a cluster analysis of untransformed abundance data merged to form a single large inshore group when *ln* transformed data were used (Table IV; Figs. 9 and 10).

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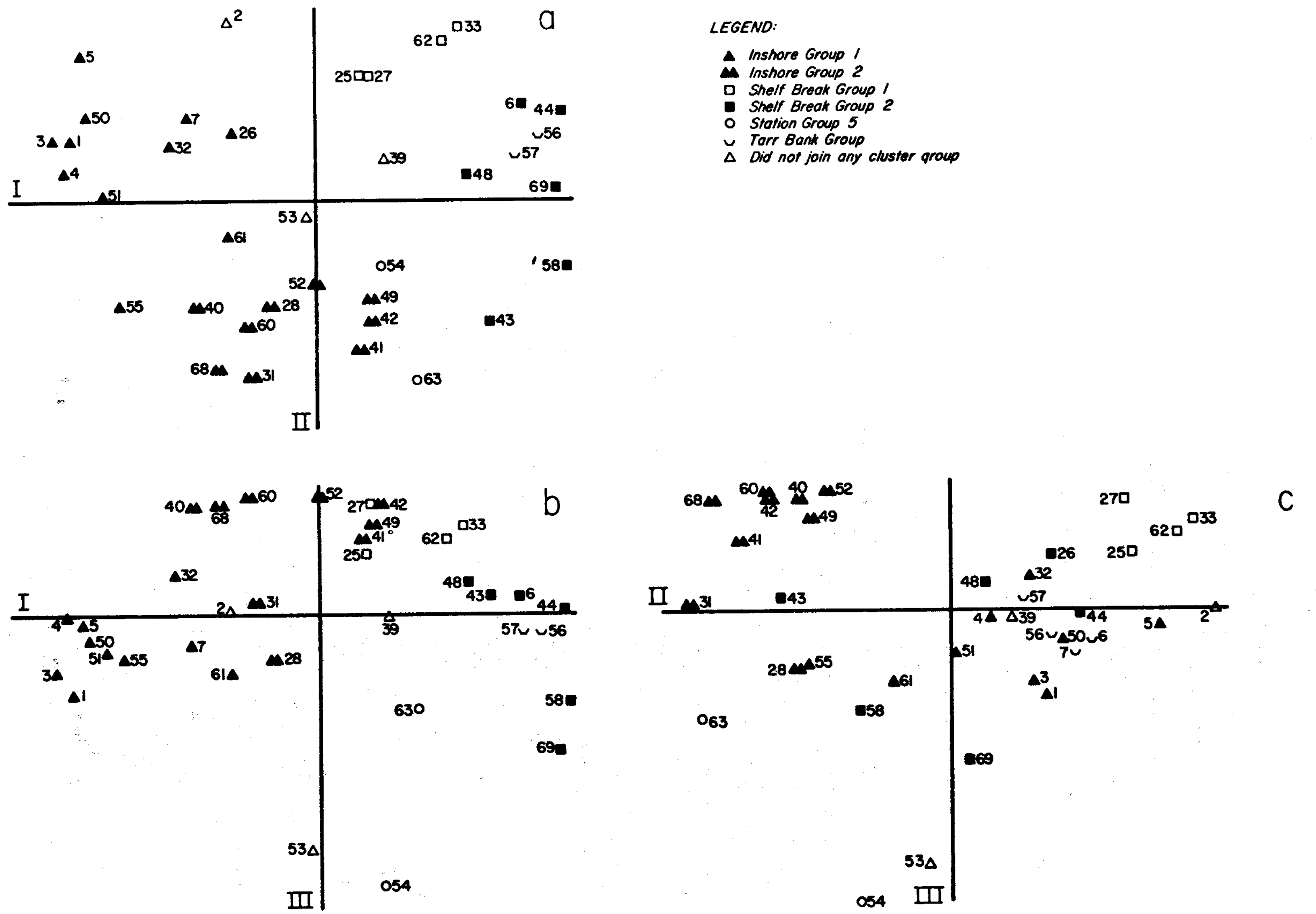

Figure 7. Plots of loadings on the first three coordinate axes extracted by principal coordinate analysis using untransformed abundance data and the Czekanowski similarity coefficient.

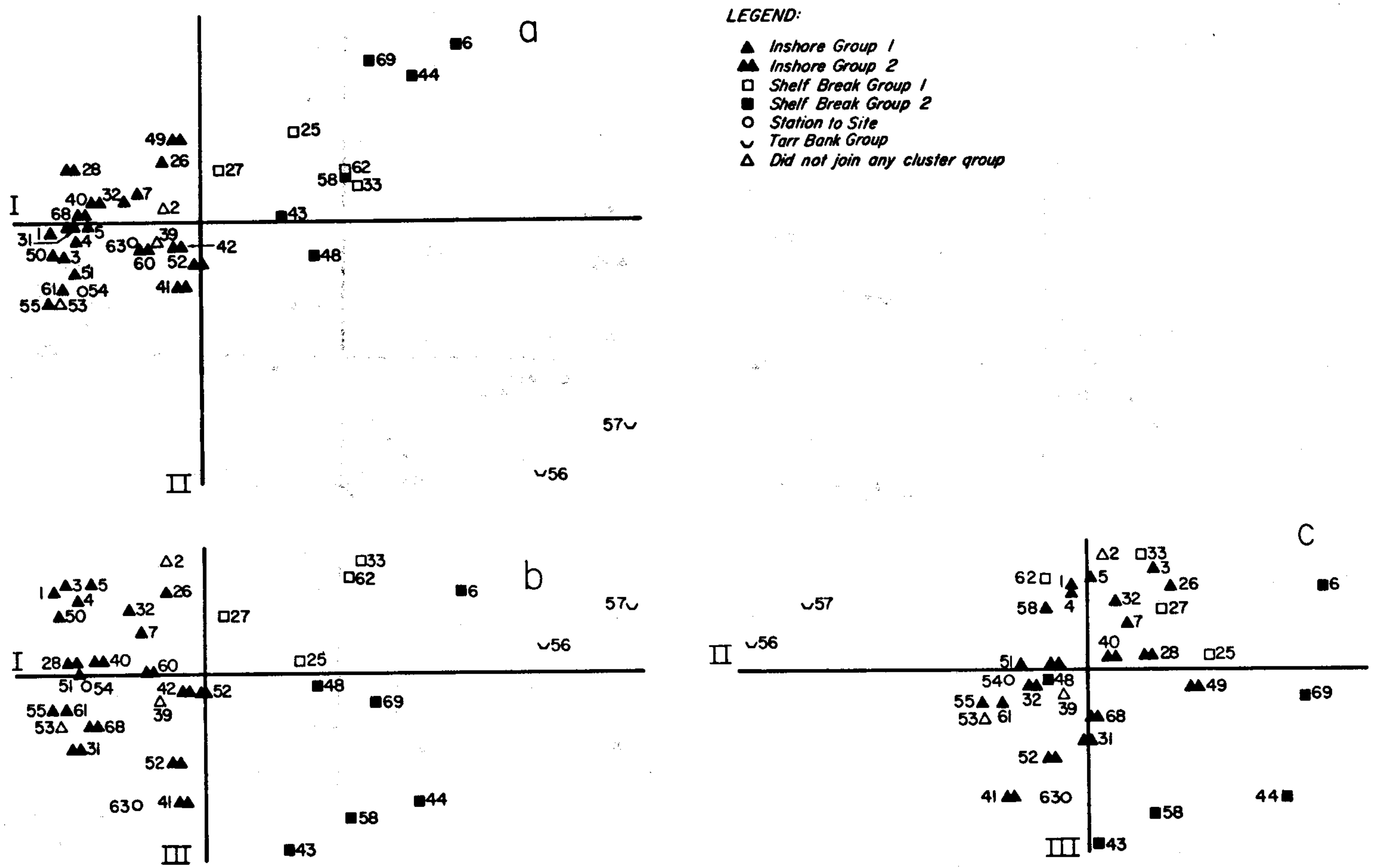

Figure 8. Plots of loadings on the first three coordinate axes extracted by principal coordinate analysis using untransformed abundance data and the Canberra metric similarity coefficient.

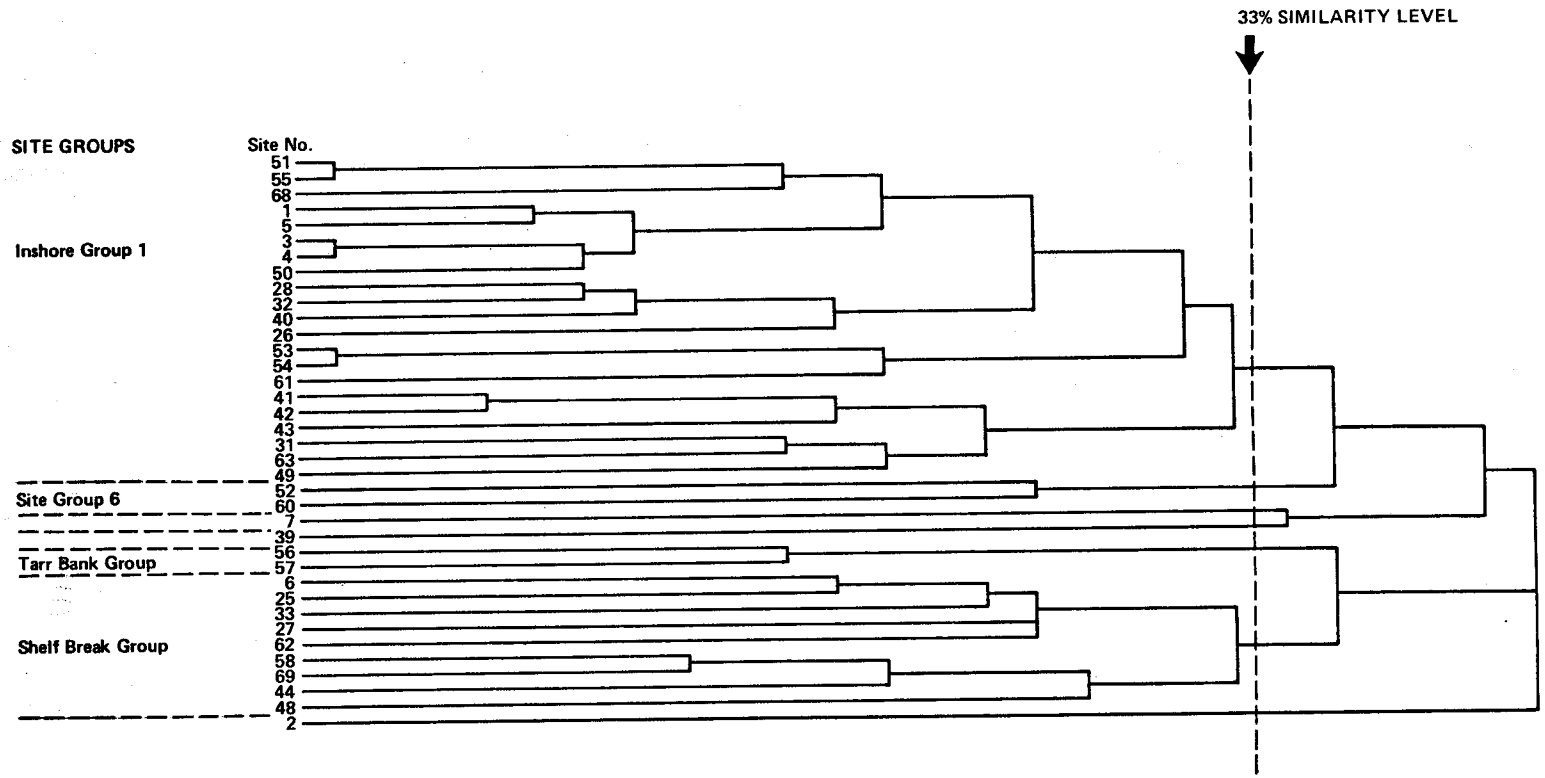

Figure 9. Dendrogram produced by cluster analysis using *ln* transformed abundance data (No. of individuals/m^2) collected during OSS *Discoverer* Cruise DS001.

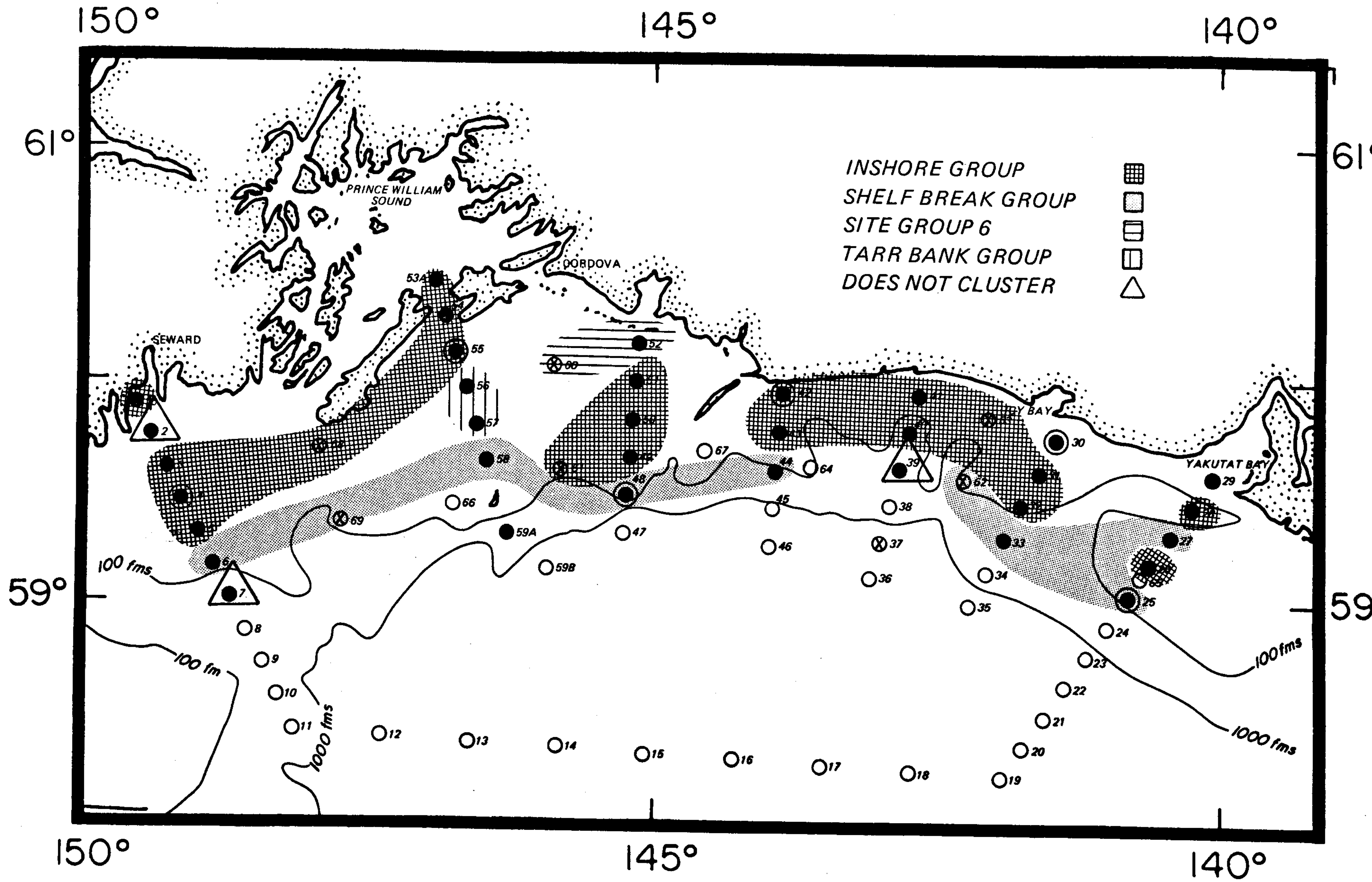

Figure 10. Station groups formed by a cluster analysis of *ln* transformed abundance data (No. of individuals/m^2) collected during OSS *Discoverer* Cruise DS001.

TABLE IX

MAJOR SPECIES GROUPS DELINEATED BY INVERSE CLUSTER ANALYSIS OF NATURAL LOGARITHM TRANSFORMED ABUNDANCE DATA, R/V *DISCOVERER* CRUISE DS 001

Numbers in parentheses are for cross reference with Table II.

Species Group	Species
3	*Ampharete* sp. (120), *Diastylis* sp. (236), *Ampharete arctica* (121), *Byblis gaimardi* (255)
4	*Myriochele heeri* (115), *Ophiopolus aculeata* (333), *Lumbrineris zonata* (67), *Melinna cristata* (126), *Glycera capitata* (52), *Unioplus macraspis* (331), *Astarte* sp. (167), *Laqueus californianus* (320), *Terebratulina unguicula* (317), *Ischnochitin albus* (148), *Metopa* sp. (294), *Crenella decussata* (160), *Cyclocardia ventricosa* (174), *Asychis similis* (101), *Astarte polaris* (171), *Urothoe denticulata* (263), *Typosyllis* sp. (30), *Idanthyrsus armatus* (116), *Typosyllis alternata* (31), *Aricidea suecica* (74), *Phascolion strombi* (312), *Peisidice aspera* (20), *Hapiniopsis sanpedroensis* (282), *Golfingia vulgaris* (311), *Golfingia margaritacea* (310), *Notoproctus pacificus* (109), *Ampelisca birulai* (252), *Anonyx* sp. (266)
5	*Nephtys* sp. (44), *Ninoe gemmea* (68), *Lumbrineris* sp. (64), *Nucula tenuis* (151), *Thyasira flexuosa* (178), *Nuculana fossa* (153), *Ophiura sarsi* (336), *Psephidia lordi* (184), *Sternaspis scutata* (98), *Yoldia* sp. (156), *Ctenodiscus crispatus* (323), *Onuphis iridescens* (60), *Odontogena borealis* (180), *Praxillella gracilis* (111), *Pista cristata* (129), *Axinopsida serricata* (176), *Terebellides stroemii* (133), *Heterophoxus occulatus* (287), *Nereis zonata* (43), *Dentalium dalli* (224), *Molpadia intermedia* (338), *Nephtys punctata* (48), *Chaetoderma robusta* (147)
13	*Autolytus magnus* (27), *Axinopsida viridis* (177), *Mysella* sp. (179), *Cardiomya* sp. (196), *Hippomedon* sp. (269), *Neries* sp. (40), *Ampelisca macrocephala* (251), *Maldane sarsi* (103), *Nicippe tumida* (282), *Maldane glebifex* (104)
16	*Eteone longa* (25), *Haploscoloplos elongatus* (72), *Phloe minuta* (21), *Onuphis conchylega* (58), *Drilonereis filium* (70), *Drilonereis falcata minor* (71), *Melinna elizabethae* (127), *Nephtys longosetosa* (49), *Balanus nubilis* (301), *Terebratulina crossei* (318), *Terebratalia transversa* (321), *Harmothoe imbricata* (14), *Propreomussum alaskense* (164), *Astarte borealis* (168), *Balanus rostratus* (302), *Eunice valens*

TABLE IX

CONTINUED

Species Group	Species
16 contd.	(62), *Balanus crenatus* (300), *Hemithiris psittacea* (316), *Amphissa columbiana* (212), *Natica clausa* (207), *Spiochaetopterus costarum* (88), *Astarte alaskensis* (169), *Astarte esquimalti* (172), *Typosyllis armillaris* (32), *Eusyllis bloomstrandi* (33), *Scalabregma inflatum* (95)
19	*Ampharete acutifrons* (122), *Neohela monstrosa* (258), *Chaetozone setosa* (91), *Heteromastus filiformis* (100), *Eudorellopsis integra* (234), *Leucon* sp. (229), *Spiophanes cirrata* (84), *Protomedeia* sp. (266), *Harpinia kobjakovae* (285), *Aglaophamus rubella anops* (51), *Axiothella rubrocincta* (110), *Tharyx* sp. (90), *Macoma brota* (187), *Yoldia amydalea* (157)

TABLE X

SITE GROUP/SPECIES GROUP COINCIDENCE TABLE SHOWING AVERAGE CELL DENSITIES OF GROUPS FORMED BY A CLUSTER ANALYSIS USING *ln* TRANSFORMED DATA, R/V *DISCOVERER*, MARCH 1976

IG = Inshore Group, SBG = Shelf Break Group, TBG = Tarr Bank Group

Species Group		Site Group IG (21)†	Group 6 (2)	Site 7* (1)	Site 39* (1)	TBG (2)	SBG (9)	Site 2* (1)
1	(8)††	0.1	0.	0.	0.	0.	1.0	0.
2	(3)	0.	0.	0.	0.	0.	0.7	0.
3	(4)	0.9	0.5	0.	0.	0.8	2.0	0.5
4	(28)	1.0	0.9	0.4	1.3	10.3	4.2	0.8
5	(25)	10.8	4.1	5.0	1.2	1.9	4.5	1.4
6	(6)	2.7	0.	1.3	0.	0.7	0.2	0.7
7	(7)	0.0	0.	0.	0.	0.3	0.5	0.
8	(2)	0.2	0.5	0.	0.	0.	0.	1.0
9	(5)	0.3	0.	0.	0.	0.2	0.9	0.
10	(4)	0.6	0.	0.6	0.	0.3	0.3	0.5
11	(6)	0.0	0.	0.	0.	0.2	0.4	0.
12	(1)	0.5	0.	0.	0.	1.5	1.8	0.
13	(10)	0.2	0.9	0.5	21.7	0.9	0.7	0.4
14	(11)	0.0	0.	0.	0.6	0.3	0.5	0.
15	(7)	0.0	0.	0.	0.	2.1	0.	0.
16	(26)	0.2	0.1	0.	0.	5.2	0.1	0.
17	(5)	0.2	0.	3.0	0.	0.3	0.2	0.4
18	(3)	0.8	0.	0.	0.	0.	0.	0.
19	(14)	2.0	0.1	0.	0.2	0.3	0.1	0.3
20	(13)	0.7	0.3	0.	0.	0.	0.	0.
21	(4)	0.5	0.	0.	0.	0.	0.2	0.5
22	(2)	0.1	0.	0.	0.	0.	0.3	0.
23	(1)	0.2	1.0	0.	0.	0.	0.2	0.
24	(3)	0.3	0.	0.	0.	0.	0.	0.
25	(2)	0.6	0.5	0.	0.	0.	0.	0.
26	(5)	0.1	7.8	0.	0.	0.5	0.1	0.
27	(1)	0.	0.	0.	0.	0.	0.	14.0

* Sites which did not join any site groups
† Number of sites in the group
†† Number of species in the group

TABLE XI

SITE GROUP/SPECIES GROUP COINCIDENCE TABLE SHOWING PERCENT CONSTANCY OF THE SPECIES GROUP IN EACH SITE GROUP, R/V *DISCOVERER*, MARCH 1976

IG = Inshore Group, SBG = Shelf Break Group, TBG = Tarr Bank Group

Species Group		Site Group: IG (21)†	Group 4 (2)	Site 7* (1)	Site 39* (1)	TBG (2)	SBC (9)	Site 2* (1)
1	(8)††	5.4	0.	0.	0.	0.	22.2	0.
2	(3)	0.	0.	0.	0.	0.	22.2	0.
3	(4)	17.9	25.0	0.	0.	25.0	41.7	25.0
4	(28)	9.4	14.3	7.1	10.7	69.6	50.8	17.9
5	(25)	64.4	42.0	32.0	28.0	36.0	48.9	28.0
6	(6)	16.7	0.	50.0	0.	33.3	9.3	16.7
7	(7)	2.0	0.	0.	0.	21.4	19.0	0.
8	(2)	9.5	25.0	0.	0.	0.	0.	50.0
9	(5)	7.6	0.	0.	0.	20.0	13.3	0.
10	(4)	7.1	0.	25.0	0.	25.0	13.9	25.0
11	(6)	1.6	0.	0.	0.	8.3	16.7	0.
12	(1)	9.5	0.	0.	0.	100.0	22.2	0.
13	(10)	7.6	15.0	20.0	100.0	20.0	13.3	10.0
14	(11)	1.3	0.	0.	9.1	22.7	19.2	0.
15	(7)	1.4	0.	0.	0.	50.0	0.	0.
16	(26)	3.7	3.8	0.	0.	73.1	4.3	0.
17	(5)	10.5	0.	40.0	0.	20.0	8.9	20.0
18	(3)	17.5	0.	0.	0.	0.	0.	0.
19	(14)	15.6	3.7	0.	7.1	10.7	4.8	7.1
20	(3)	12.7	16.7	0.	0.	0.	0.	0.
21	(4)	14.3	0.	0.	0.	0.	8.3	25.0
22	(2)	4.8	0.	0.	0.	0.	11.1	0.
23	(1)	9.5	50.0	0.	0.	0.	11.1	0.
24	(3)	9.5	0.	0.	0.	0.	0.	0.
25	(2)	4.8	24.0	0.	0.	0.	0.	0.
26	(5)	3.8	70.0	0.	0.	10.0	2.2	0.
27	(1)	0.	0.	0.	0.	0.	0.	100.0

* Sites which did not join any site groups
† Number of sites in the group
†† Number of species in the group

TABLE XII

SITE GROUP/SPECIES GROUP COINCIDENCE TABLE SHOWING PERCENT FIDELITY OF THE SPECIES GROUPS IN EACH SITE GROUP, R/V *DISCOVERER*, MARCH 1976

IG = Inshore Group, SBG = Shelf Break Group, TBG = Tarr Bank Group

Species Group		Site Group						
		IG (21)†	Group 4 (2)	Site 7* (1)	Site 39* (1)	TBG (2)	SBG (9)	Site 2* (1)
1	(8)††	11.7	0.	0.	0.	0.	88.3	0.
2	(3)	0.	0.	0.	0.	0.	100.0	0.
3	(4)	19.0	10.7	0.	0.	16.0	43.6	10.7
4	(28)	5.2	4.9	1.9	6.9	54.7	22.3	4.2
5	(25)	37.2	14.2	17.3	4.1	6.6	15.6	5.0
6	(6)	48.9	0.	22.8	0.	12.2	4.0	12.2
7	(7)	4.9	0.	0.	0.	34.2	60.9	0.
8	(2)	11.3	29.6	0.	0.	0.	0.	59.2
9	(5)	21.7	0.	0.	0.	14.2	64.1	0.
10	(4)	25.8	0.	27.1	0.	10.9	14.5	21.7
11	(6)	5.2	0.	0.	0.	27.5	67.2	0.
12	(1)	12.7	0.	0.	0.	40.0	47.4	0.
13	(10)	0.9	3.6	2.0	85.5	3.6	2.9	1.6
14	(11)	1.7	0.	0.	40.8	21.4	36.0	0.
15	(7)	1.9	0.	0.	0.	98.1	0.	0.
16	(26)	3.3	1.4	0.	0.	93.2	2.1	0.
17	(5)	5.6	0.	73.1	0.	7.3	4.3	9.7
18	(3)	100.0	0.	0.	0.	0.	0.	0.
19	(14)	66.7	2.4	0.	7.8	10.6	3.1	9.4
20	(3)	68.7	31.3	0.	0.	0.	0.	0.
21	(4)	44.6	0.	0.	0.	0.	14.7	40.7
22	(2)	22.2	0.	0.	0.	0.	77.8	0.
23	(1)	13.5	70.8	0.	0.	0.	15.7	0.
24	(3)	100.0	0.	0.	0.	0.	0.	0.
25	(2)	53.3	46.7	0.	0.	0.	0.	0.
26	(5)	1.3	92.1	0.	0.	5.9	0.7	0.
27	(1)	0.	0.	0.	0.	0.	0.	100.0

* Sites which did not join any site groups
† Number of sites in the group
†† Number of species in the group

The fauna in the Inshore Group was composed primarily of Species Group 5 (Tables IX-XII). Sites 52 and 60 (Group 6) were distinguished from Inshore Group sites by the absence of many of the species in Species Group 5. Sites 2 and 7 also differed from the inshore group by the absence of many of the species in Species Group 5. Site 39 was characterized by some of the species in Species Group 5 and by Species Group 13. Shelf Break Groups 1 and 2 formed by a cluster analysis of untransformed data also merged to form a single group, the Shelf Break Group, (Table IV; Figs. 9 and 10) when *ln* transformed data were used. The Shelf Break Group sites were characterized by Species Groups 4 and 5 (Table IX-XII). Sites 56 and 57 (Tarr Bank Group) were characterized by Species Groups 4, 5 and 16 (Table IX-XII).

The results of principal coordinate analysis of transformed abundance data using the Czekanowski coefficient is shown in Figure 11. The Shelf Break Group sites form a fairly tight grouping on plots of the first and second and first and third axes. Sites 56 and 57 (Tarr Bank Group) were closely associated with the Shelf Break Group sites. Inshore Group sites formed a rather loose grouping on all plots. Sites 52 and 60 (Site Group 6) were intermingled with the Inshore Group sites and Sites 7 and 39 were contiguous with the Inshore Group sites. Sites 53 and 54, classified as members of the Inshore Group sites by cluster analysis of transformed abundance data, were always closely associated with each other but exhibited considerable separation from all other sites in the Inshore Group on the third coordinate axis (Figs. 11b and c). Sites 53 and 54 differed from the inshore group sites by the presence of species in Species Groups 3 and 19 (Tables IX and X). Site 43, also classified as a member of the inshore group by cluster analysis of transformed data, appeared to have some affinities with the Shelf Break sites (Fig. 11).

The Inshore Group sites formed tight groupings on plots generated by a principal coordinate analysis of transformed abundance data using the Canberra metric similarity coefficient (Fig. 12). Sites 52 and 60 (Site Group 6) as well as Sites 2, 7 and 39 were closely associated with the Inshore Group sites on all plots. Site 43 again appeared to have some

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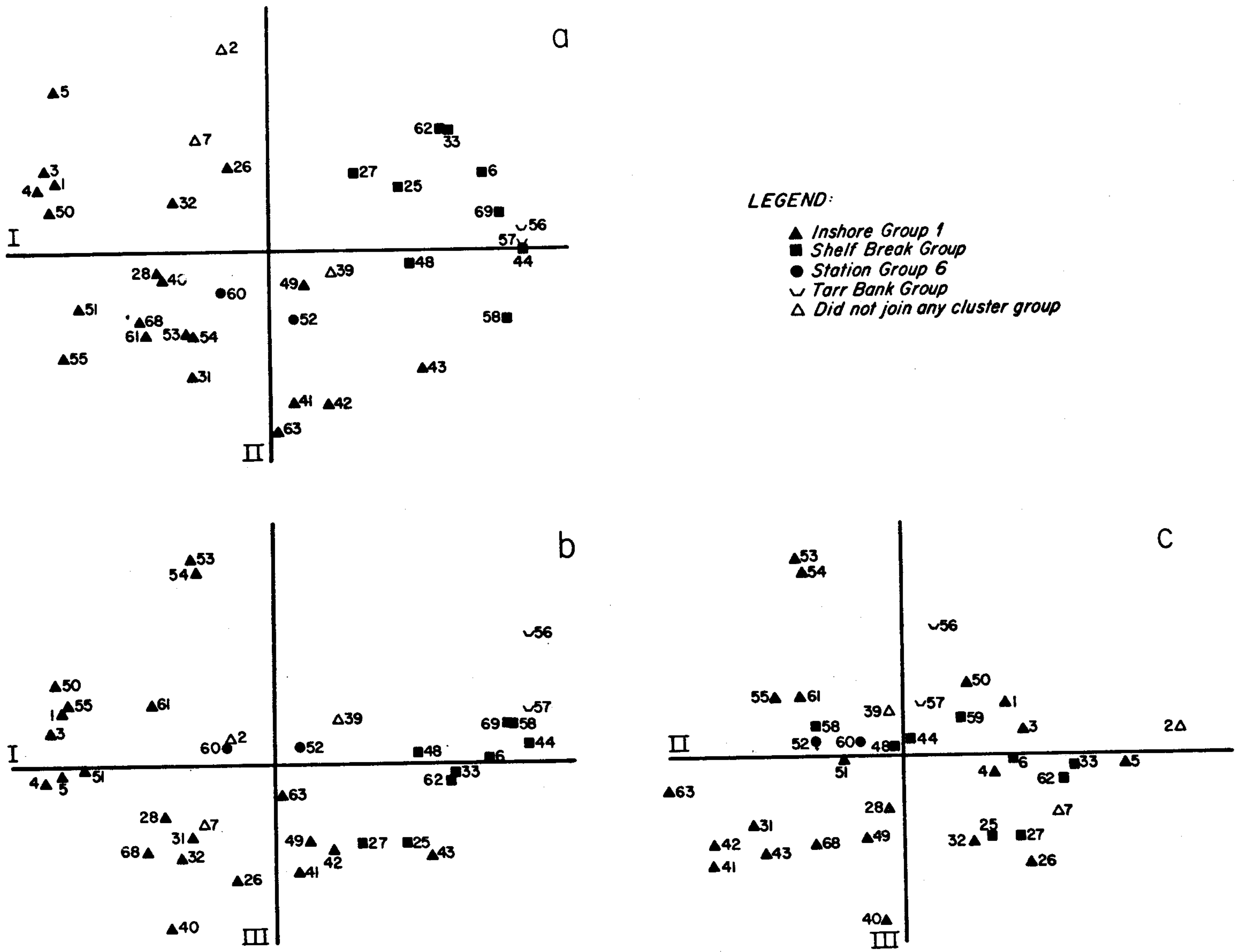

Figure 11. Plots of loadings on the first three coordinate axes extracted by principal coordinate analysis using *ln* transformed data and the Czekanowski similarity coefficient.

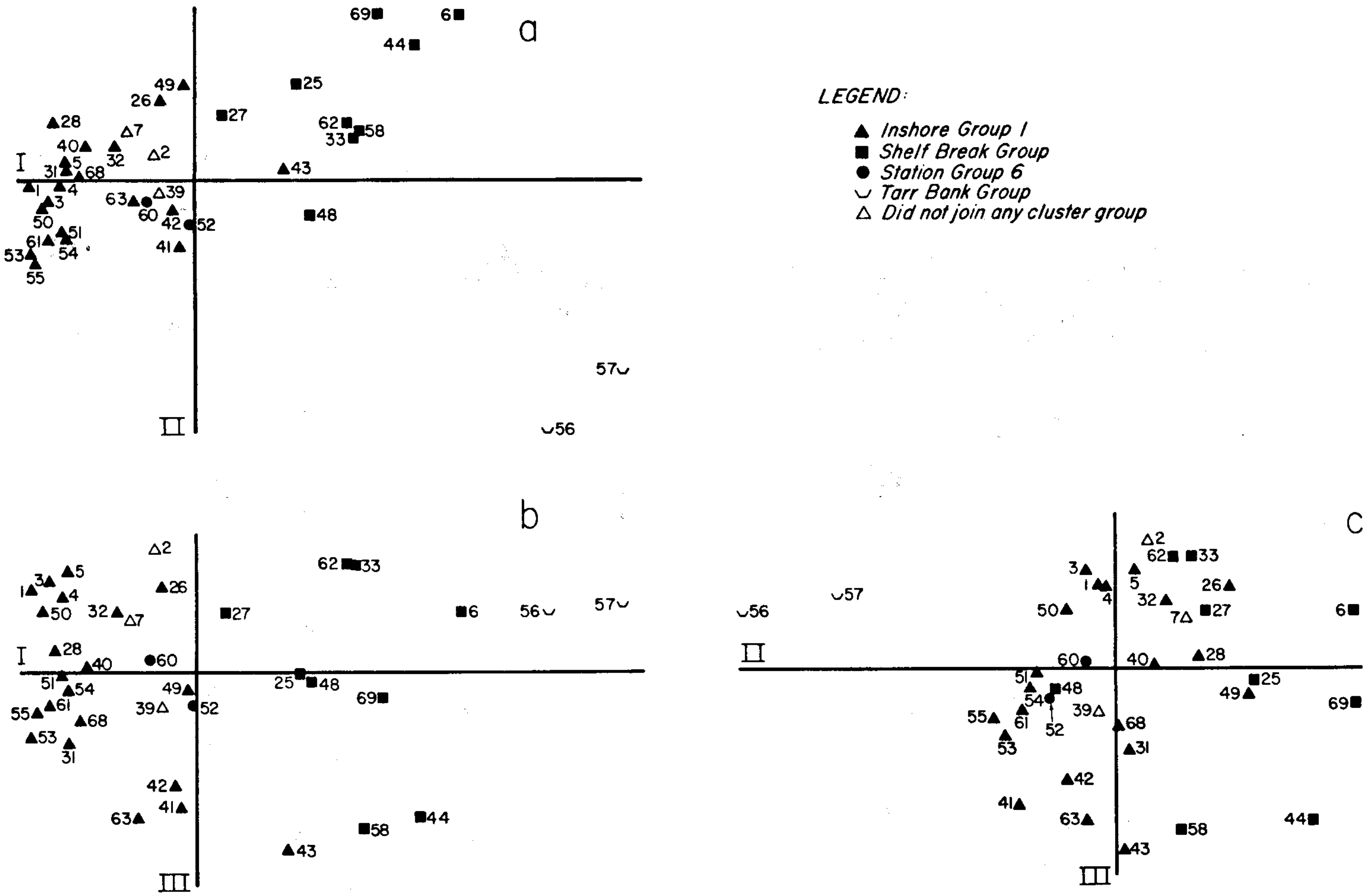

Figure 12. Plots of loadings on the first three coordinate axes extracted by principal coordinate analysis using *ln* transformed data and the Canberra metric similarity coefficient.

affinities to the Shelf Break Group sites. Sites 56 and 57 (Tarr Bank Group) showed considerable separation from all other sites on the first and second coordinate axes.

Numerical Analysis: Presence-Absence Data

A cluster analysis was run using presence-absence data so that the similarity between the sites which were not sampled quantitatively and all other sites could be determined (Figs. 13 and 14). Sites 59, 30 and 29 (qualitative sites) were quite distinct from all other sites; they did not join the other sites until the 28, 18 and 1% similarity levels, respectively, were reached (Fig. 13). Because differences in the abundance of the species are not considered by this analysis, Sites 56 and 57 joined the Shelf Break Group and Sites 7 and 39 fused to form a site group (Site Group 8; Fig. 13).

Abundance, Biomass and Diversity

Abundance, biomass and diversity data arranged according to site groups delineated by cluster analysis of untransformed abundance data are presented in Table XIII. Abundance ranged from 118 individuals/m^2 in Site 5 (Inshore Group 1) to 1,038 individuals/m^2 in Site 53. Biomass values ranged from 7.37 g (wet weight)/m^2 in Site 68 to 638.17 g/m^2 in Site 56. There was no correlation between the abundance (number/m^2) and biomass of the fauna in the sampling sites ($P>0.05$). The Brillouin diversity ranged from 3.87 in Site 56 (Group 7) to 2.12 at Site 68 (Inshore Group 2) while the Brillouin evenness ranged from 0.66 at Sites 54 and 63 (Group 5) to 0.94 at Site 33 (Shelf Break Group 2).

A nested ANOVA was run comparing the variance associated with the abundance, biomass and diversity of the fauna between site groups, between sites within site groups and between samples (grabs) within sites (Tables XIV-XIX). For purposes of this analysis diversity indices were calculated for each grab instead of the pooled data for each site. There was a significant difference ($P<0.05$) between sites within site groups for Simpson and Brillouin diversity measures and the abundance and biomass of the fauna. There was no significant difference between sites within groups for Brillouin evenness. There was also a significant difference ($P<0.05$)

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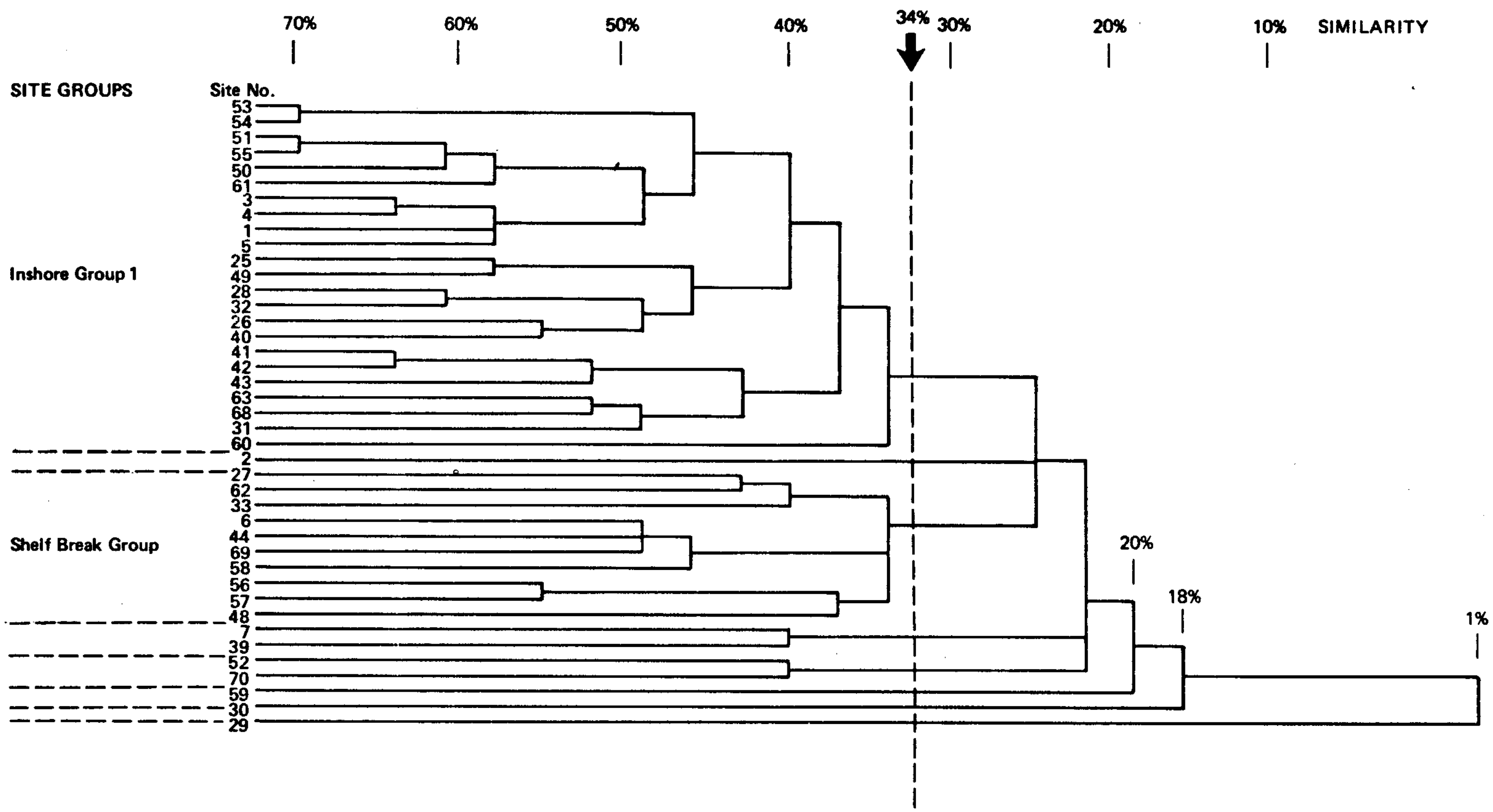

Figure 13. Dendrogram produced by a cluster analysis of binary data (presence-absence) using the Sørenson similarity coefficient. Data was collected during OSS *Discoverer* Cruse DS001.

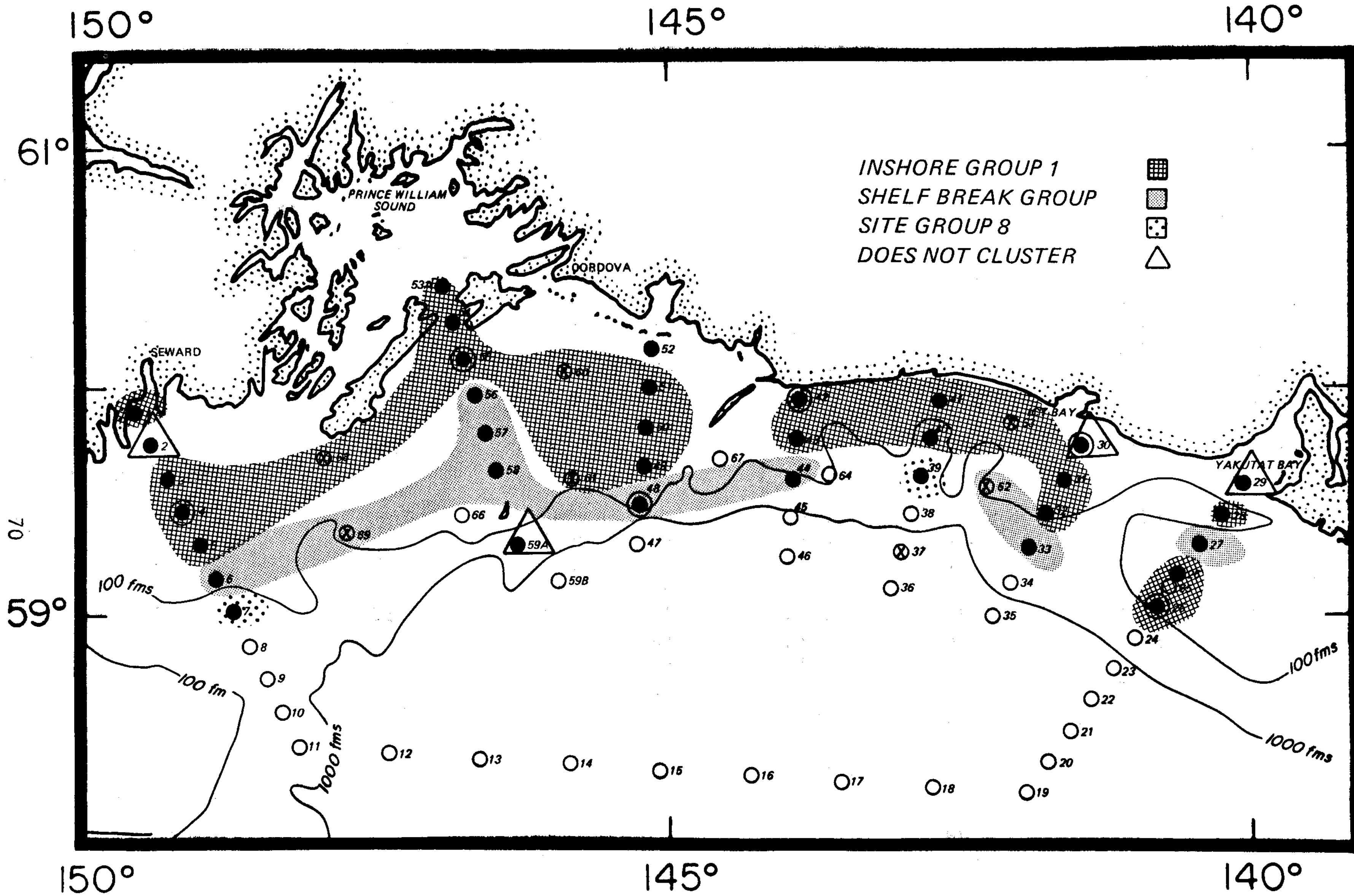

Figure 14. Site groups formed by a cluster analysis of binary (presence-absence) data using the Sørenson similarity coefficient. Data was collected during OSS *Discoverer* Cruise DS001.

TABLE XIII

ABUNDANCE, BIOMASS, AND DIVERSITY OF BENTHIC SAMPLING SITES

Sites are arranged according to the site groups delineated by a cluster analysis of untransformed abundance data

Site Number	Abundance (#/m^2)	Biomass ($gm/^2$)	No. of Species	Simpson Diversity	Shannon Diversity	Brillouin Diversity	Brillouin Evenness	Species Richness
Inshore Group 1								
1	204	157.59	32	0.07	3.00	2.76	0.86	5.83
3	286	218.80	34	0.07	2.98	2.79	0.85	6.98
4	186	199.30	25	0.08	2.76	2.53	0.85	4.59
5	118	108.94	23	0.10	2.70	2.42	0.86	4.61
7	215	41.47	31	0.11	2.82	2.60	0.82	5.59
26	370	65.84	47	0.05	3.35	3.13	0.87	7.78
32	280	48.00	36	0.04	3.31	3.11	0.93	6.21
50	232	352.17	34	0.06	3.12	2.88	0.88	6.06
51	254	73.23	30	0.06	3.01	2.81	0.89	5.24
55	290	138.41	34	0.09	2.84	2.65	0.81	5.82
61	540	502.41	38	0.05	3.27	3.13	0.90	5.88
Inshore Group 2								
28	922	50.55	64	0.09	2.98	2.88	0.71	9.23
31	528	169.56	46	0.07	3.06	2.92	0.80	7.18
40	382	38.84	43	0.08	3.04	2.86	0.81	7.06
41	584	56.74	43	0.14	2.64	2.51	0.70	6.59
42	296	80.78	38	0.06	3.10	2.88	0.85	6.50
40	290	60.95	40	0.06	3.10	2.88	0.85	6.50
52	362	156.31	40	0.15	2.69	2.51	0.72	6.62
60	198	10.28	24	0.11	2.55	2.37	0.80	4.35
68	242	7.37	27	0.20	2.27	2.12	0.68	4.92
Shelf Break Group 1								
6	492	48.87	95	0.03	4.06	3.78	0.89	15.17
43	670	40.84	56	0.06	3.22	3.09	0.80	8.45
44	372	47.41	70	0.04	3.77	3.48	0.88	11.66
48	288	42.63	60	0.04	3.67	3.36	0.90	10.42
58	590	39.30	58	0.07	3.31	3.15	0.82	8.93
69	645	69.17	72	0.06	3.48	3.29	0.81	10.97

TABLE XIII

CONTINUED

Site number	Abundance (#/m^2)	Biomass (gm/^{2})	No. of Species	Simpson Diversity	Shannon Diversity	Brillouin Diversity	Brillouin Evenness	Species Richness
Shelf Break Group 2								
25	274	29.81	55	0.04	3.62	3.32	0.90	9.62
27	370	65.84	33	0.06	3.14	2.79	0.90	5.75
33	260	65.19	70	0.02	3.99	3.59	0.94	12.41
62	294	29.84	68	0.03	3.89	3.55	0.92	11.79
Site Group 5								
54	896	246.34	57	0.20	2.66	2.53	0.66	8.24
63	580	45.92	43	0.20	2.49	2.37	0.66	6.60
Tarr Bank Group								
56	920	638.17	115	0.03	4.07	3.87	0.85	16.70
57	462	244.92	119	0.03	4.06	3.73	0.85	19.40
Site 2	174	34.23	37	0.07	3.14	2.83	0.87	6.98
Site 39	320	15.86	28	0.11	2.71	2.56	0.81	4.68
Site 53	1038	440.23	70	0.08	3.21	3.09	0.76	9.95

TABLE XIV

NESTED ANALYSIS OF VARIANCE, ABUNDANCE DATA (#/m^2). SITE GROUPS REFER TO THE SITE GROUPS FORMED BY CLUSTER ANALYSIS OF UNTRANSFORMED DATA.

A. ANOVA Table

	SS	DF	MS	F
Between site groups	5039343.0	8	629917.9	2.66 (NS)†
Between sites within groups	6091932.8	27	225627.1	12.11*
Within sites	2609021.0	140	18635.9	

B. Variance Components

	Variance component	Percent
Between site groups	21922.7	26.26
Between sites within groups	42913.5	51.41
Within sites	18635.9	22.33

C. Student-Newman-Keuls Multiple Range Test: Table of Means (sorted). Verticle bar indicates the range of non-significant differences.

Site Groups††	N	Mean	Std. deviation
Site 2	5	174.0	175.6
SBG 2	20	180.7	112.7
IG 1	51	255.7	156.0
Site 39	3	320.0	130.0
IG 2	40	406.0	274.8
SBG 1	27	428.7	215.3
G 5 (Sites 54 and 63)	10	506.0	422.0
TBG	15	614.7	292.7
Site 53	5	1038.0	183.1

* $P < 0.01$
† Not significant
†† IG=Inshore Group; SG=Site Group; SBG=Shelf Break Group, TBG=Tarr Bank Group

TABLE XV

NESTED ANALYSIS OF VARIANCE, BIOMASS DATA (WET WEIGHT/m^2). SITE GROUPS REFER TO THE SITE GROUPS FORMED BY CLUSTER ANALYSIS OF UNTRANSFORMED DATA.

A. ANOVA Table

	SS	DF	MS	F
Between site groups	2078683.3	8	259835.4	4.80*
Between sites within groups	1424854.5	27.	52772.4	2.02*
Within sites	3655931.6	140	26113.8	

B. Variance Components

	Variance component	Percent
Between site groups	11462.2	26.59
Between sites within groups	5526.9	12.82
Within sites	26113.8	60.59

C. Student-Newman-Keuls Multiple Range Test: Table of Means (sorted). Vertical bar indicates the range of non-significant differences.

Site Groups†	N	Mean	Std. Deviation
Site 39	3	15.9	9.0
Site 2	5	34.2	46.6
SBG 1	27	40.2	37.9
SBG 2	20	41.3	66.8
IG 2	40	58.6	67.6
G 5 (Sites 54 and 63)	10	127.8	269.4
IG 1	51	156.5	232.2
TBG	15	376.0	312.5
Site 53	5	440.2	116.7

* $P < 0.05$
† IG=Inshore Group, SG=Site Group, SBG=Shelf Break Group, TBG=Tarr Bank Group

TABLE XVI

NESTED ANALYSIS OF VARIANCE, BRILLOUIN DIVERSITY. SITE GROUPS REFER TO THE SITE GROUPS FORMED BY CLUSTER ANALYSIS OF UNTRANSFORMED DATA.

A. ANOVA Table

	SS	DF	MS	F
Between site groups	5.69	8	.711	4.11*
Between sites within groups	4.67	27 26.2	.173 .178	3.63*
Within sites	6.81	140	.049	

B. Variance Components

	Variance component	Percent
Between site groups	0.012	28.44
Between sites within groups	0.011	24.78
Within sites	0.021	46.78

C. Student-Newman-Keuls Multiple Range Test: Table of Means (sorted). Vertical bars indicate the range of non-significant differences.

Site Groups†	N	Mean	Std. Deviation
Site 2	5	1.38	.92
Site 39	3	1.89	.21
IG 2	40	1.89	.39
IG 1	51	1.98	.41
G 5 (Sites 54 and 63)	10	1.98	.23
SBG 2	20	2.16	.37
SBG 1	27	2.46	.32
Site 53	5	2.58	.14
TBG	15	2.60	.46

* $P < 0.05$
† IG=Inshore Group, SG=Site Group, SBG=Shelf Break Group, TGB=Tarr Bank Group

TABLE XVII

NESTED ANALYSIS OF VARIANCE, BRILLOUIN EVENNESS. SITE GROUPS REFER TO THE SITE GROUPS FORMED BY CLUSTER ANALYSIS OF UNTRANSFORMED DATA.

A. ANOVA Table

	SS	DF	MS	F
Between site groups	0.701	8	0.0870	11.51*
Between sites within groups	0.201	27. 24.3	0.0076 0.0076	0.98(NS)†
Within sites	1.08	140	0.0077	

B. Variance Components

	Variance component	Percent
Between site groups	0.0044	36.6252
Between sites within groups	-0.0000	-0.2042
Within sites	0.0077	63.5790

C. Student-Newman-Keuls Multiple Range Test: Table of Means (sorted). Vertical bars indicate the range of non-significant differences.

Site Groups††	N	Mean	Std. Deviation
G 5 (sites 54 & 63)	10	0.72	0.05
Site 2	5	0.74	0.42
Site 53	5	0.80	0.04
IG 2	40	0.83	0.08
Site 39	3	0.84	0.11
SBG 1	27	0.90	0.06
IG 1	51	0.92	0.05
TBG	15	0.93	0.04
SBG 2	20	0.95	0.04

* $P < 0.01$
† Not significant
†† IG=Inshore Group, SG=Site Group, SBG=Shelf Break Group, TBG=Tarr Bank Group

TABLE XVIII

NESTED ANALYSIS OF VARIANCE, SPECIES RICHNESS. SITE GROUPS REFER TO THE SITE GROUPS FORMED BY CLUSTER ANALYSIS OF UNTRANSFORMED DATA.

A. ANOVA Table

	SS	DF	MS	F
Between site groups	254.21	8	31.78	9.41*
Between sites within groups	91.27	28 27.2	3.26 3.38	3.40*
Within sites	138.18	144	0.96	

B. Variance Components

	Variance Component	Percent
Between site groups	1.54	51.83
Between sites within groups	0.48	15.98
Within sites	0.96	32.19

C. Student-Newman-Keuls Multiple Range Test: Table of Means (sorted). Vertical bars indicate the range of non-significant differences.

Site groups††	N	Mean	Std. Deviation
Site 2	5	2.3	1.6
Site 39	3	2.4	0.4
IG 2	45	3.2	1.0
IG 1	51	3.2	1.0
G 5 (Sites 54 and 63)	10	3.9	0.9
SBG 2	20	4.0	1.3
SBG 1	27	4.9	1.3
Site 53	5	6.0	0.6
TBG	15	7.0	1.6

* $P < 0.01$

†† IG=Inshore Group, SG=Site Group, SBG=Shelf Break Group, TBG=Tarr Bank Group

TABLE XIX

NESTED ANALYSIS OF VARIANCE, SIMPSON DIVERSITY. SITE GROUPS REFER TO SITE GROUPS FORMED BY CLUSTER ANALYSIS OF UNTRANSFORMED DATA.

A. ANOVA Table

	SS	DF	MS	F
Between site groups	0.28	7	0.0403	6.00**
Between sites within groups	0.18	27.0 25.5	0.0066 0.0067	1.81*
Within sites	0.49	136	0.0036	

B. Variance Components

	Variance Component	Percent
Between site groups	0.0017	28.74
Between sites within groups	0.0006	10.23
Within sites	0.0036	61.02

C. Student-Newman-Keuls Multiple Range Test: Table of Means (sorted). Bars indicate the range of non-significant differences.

Site Groups††	N	Mean	Std. Deviation
TBG	15	0.05	0.03
SBG 2	20	0.07	0.04
SBG 1	27	0.09	0.05
IG 1	51	0.11	0.08
Site 53	5	0.11	0.03
IG 2	40	0.15	0.07
Site 39	3	0.16	0.07
G 5 (Sites 54 and 63)	10	0.21	0.06
Site 2	5	0.30	0.40

* $P < 0.05$
** $P < 0.01$
†† IG=Inshore Group, G=Site Group, SBG=Shelf Break Group, TBG=Tarr Bank Group.

between site groups for all parameters tested except abundance. However, a Student-Newman-Keuls multiple range test comparing means of all parameters discussed indicated that only the most widely separated site group means were significantly different ($P<0.05$; Tables XIV-XIX). In all cases, except abundance data, the greatest percentage of the total variance was due to the within site (between grab) variation, and the percentage of the total variance attributed to differences between site groups was greater than that attributed to differences between sites within site groups (Tables XIV-XIX). For abundance data the greatest amount of variation was attributed to differences between sites within site groups. An examination of the two-way coincidence tables generated by cluster analysis (Tables VI, VII, VIII, X, XI and XII) indicates that there was an increase in diversity and species richness from the Inshore Groups to the Shelf Break Group to Sites 56 and 57. This increase was also apparent in the means listed in Tables XVI and XVIII. However, a Student-Newman-Keuls test indicated that these means were not significantly different from each other. Any actual difference in means appears to have been masked by the high within site variance (Tables XVI and XVIII).

Trophic Structure

The trophic structure of site groups formed by cluster analysis of untransformed and transformed abundance data is shown in Table XX. Deposit feeders dominated the fauna in the Inshore Groups, Shelf Break Group 2 (Cluster Analysis: Untransformed Data), and Site Groups 5 (Cluster Analysis: Untransformed Data) and 6 (Cluster Analysis: *ln* Transformed Data). The abundance of suspension feeders varied from 5 to 26% in these groups. In the Shelf Break Group (Cluster Analysis: *ln* Transformed Data) and Shelf Break Group 1 (Cluster Analysis: Untransformed Data) the percentage of deposit feeders was reduced and the percentage of suspension feeders increased (Table XX). The fauna in the Tarr Bank Group (Sites 56 and 57) was dominated by suspension feeders while the percentage of deposit feeders was reduced to 25%.

text continued from page 60.

TABLE XX

DISTRIBUTION OF MOTILITY AND FEEDING CLASSES IN SITE GROUPS FORMED BY CLUSTER ANALYSIS OF UNTRANSFORMED AND TRANSFORMED DATA

SE=Sessile, DM=Discretely Motile, M=Motile, DF=Deposit Feeder, SF=Suspension Feeder, P=Predator, S=Scavenger, O=Other, U=Unknown

	Motility Class (%)			Feeding Class (%)					
	SE	DM	M	DF	SF	P	S	O	U
Inshore Group 1 (Untrans.)	33	6	61	63	23	10	2	2	0
Inshore Group 2 (Untrans.)	31	9	59	62	26	8	3	1	0
Inshore Group (Trans.)									
Site Group 5 (Untrans.)	12	3	85	63	5	26	7	0	0
Site Group 5 (Trans.)	7	3	90	65	6	17	12	0	0
Site Group 6 (Trans.)	30	7	63	57	17	9	2	6	8
Shelf Break Group 1 (Untrans.)	47	9	44	40	42	11	6	1	0
Shelf Break Group 2 (Untrans.)	42	13	45	59	17	10	15	0	0
Shelf Break Group (Trans.)	47	7	46	48	31	11	11	0	0
Tarr Bank Group (Trans. & Untrans.)	53	12	35	25	55	8	13	0	0
Site 2*	52	11	37	58	29	11	2	0	0
Site 29*	25	0	75	11	31	11	46	0	0
Site 30*	68	3	29	55	36	9	1	0	0
Site 39*	43	12	45	62	18	16	5	0	0
Site 59*	32	21	47	65	21	15	0	0	0
Site 70*	20	10	70	75	6	15	1	1	3

* Sites which did not join any site groups.

The percentage of sessile organisms which was relatively low in the Inshore Group(s) and Site Groups 5 and 6, increased through the Shelf Break Group to the high values found in the Tarr Bank Group (Table XX). The increase in the percentage of sessile organisms from the low values found in the Inshore Group to the high values found in the Tarr Bank Group parallels the distribution of suspension feeders in these site groups.

Numerical Analysis: Combined Data; July 1974-March 1976

A cluster analysis was performed on all quantitative data collected in NEGOA during the 20 month sampling period of this study (July 1974-March 1976). Quantitative samples were obtained from 108 stations[1] taken at 38 sites; at 3 sites quantitative data were not obtained (Table I). Six of the quantitative sites were sampled once, five were sampled twice, nineteen were sampled three times, five were sampled on four occasions and three were sampled five times (Table I). A normal cluster analysis using *ln* transformed abundance data delineated 10 site groups at the 30% similarity level (Figs. 15 and 16). Three of these groups (labeled Site Group 39, Site Group 42 and Site Group 53; Table XXI, Fig. 15) were composed of 2 or 3 stations taken at the same site on different occasions which were linked together to form a site group (Table XXI). The largest group formed, the Inshore Group, consisted of 57 stations at 22 sites (Table XXI) located throughout the continental shelf in NEGOA (Fig. 16). The Shelf Break Group was composed of 18 stations occupied at 9 sites (Table XXI) at or near the shelf break (Fig. 16). Site Group 4 included Sites 44, 48 and 69 located near the shelf break as well as Sites 43 and 58 on the continental shelf (Fig. 16). Other groups consisted of Sites 53 and 54 (Hinchinbrook Entrance Group) in Hinchinbrook Entrance, Sites 7 and 59 (Site Group 5), Sites 52 and 60 (Site Group 6) and Sites 56 and 57 (Tarr Bank Group) located on Tarr Bank (Table XX; Fig. 15). One station each, occupied at Site 1, at Site 2 and at Site 57 did not join any site group (Table XX).

[1]For the purposes of this study a station was occupied every time a site (location) was sampled. Stations are identified by the site number and the season during which they were sampled (i.e., S76-1=Spring 1976, Sta. 1).

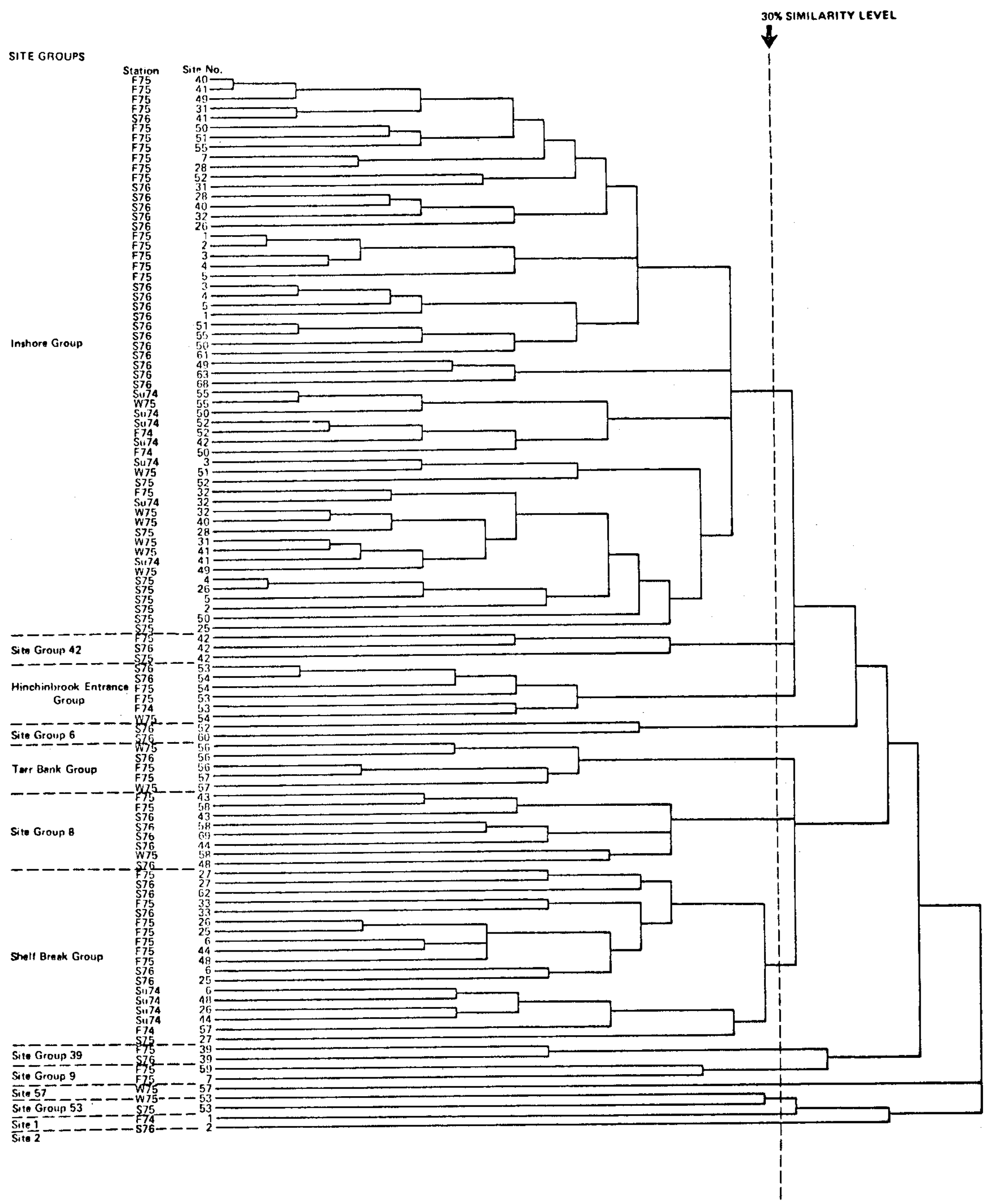

Figure 15. Dendrogram produced by a cluster analysis of all data collected during this study. The Czekanowski coefficient was used to create similarity matrices from *ln* transformed abundance data. Stations are coded as follows: F75=Fall of 1975, W=Winter, S=Spring, Su=Summer.

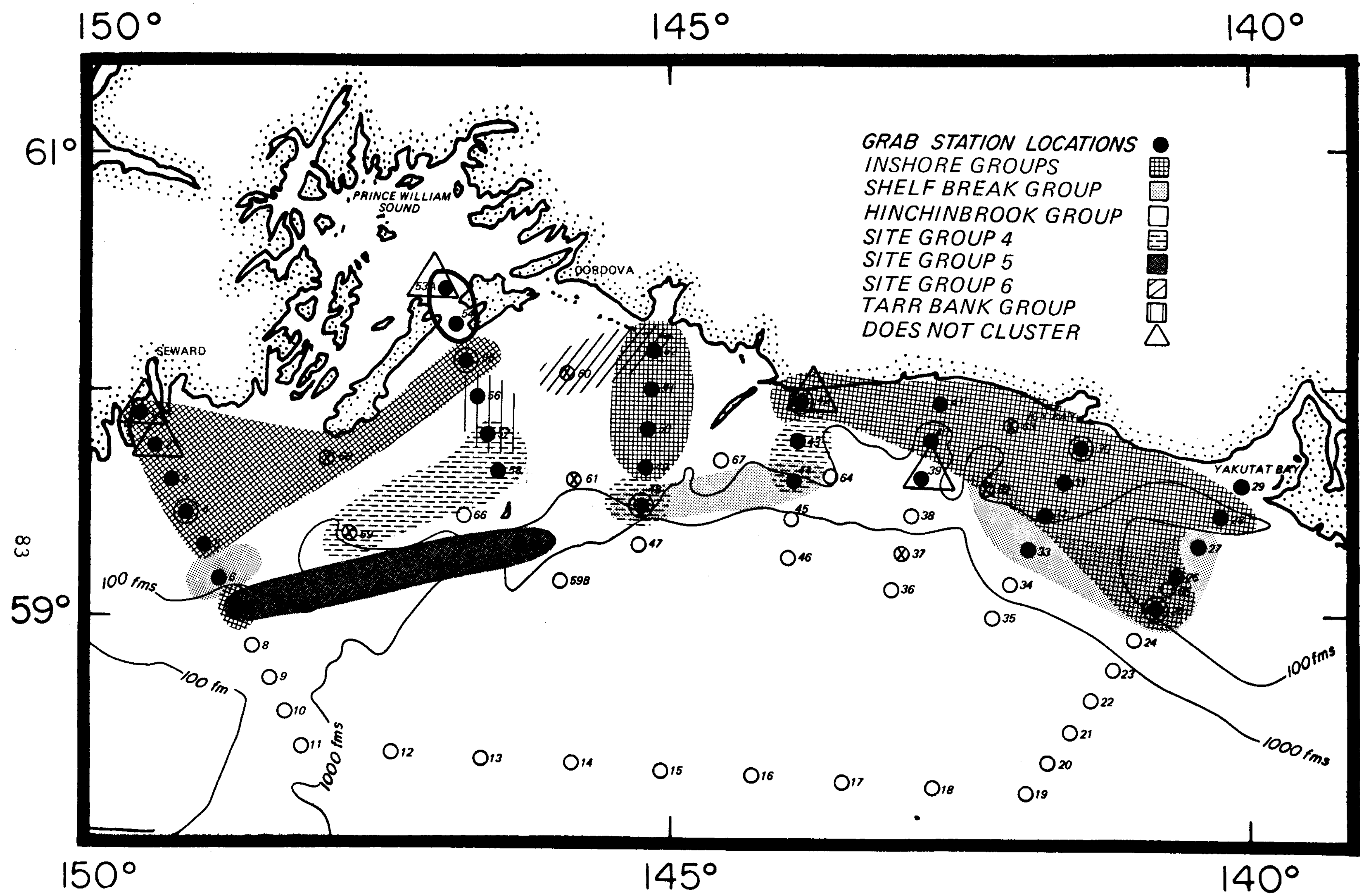

Figure 16. Station groups formed by a cluster analysis of all data collected during the study. The Czekanowski coefficient was used to create similarity matrices from *ln* transformed abundance data.

TABLE XXI

SITE GROUPS FORMED BY A CLUSTER ANALYSIS OF ALL QUANTITATIVELY SAMPLED STATIONS (JULY 1974-MARCH 1976)

Station Codes are Translated as Follows: F75-40 = Station Occupied During the Fall of 1975 at Site 40; W = Winter, S = Spring, Su = Summer, F = Fall

Inshore Group

F75-1	S75-25	S76-40	F75-51
S76-1	S75-26	S74-41	W75-51
S75-2	S76-26	S75-41	S76-51
F75-2	S75-28	F75-41	Su74-52
Su74-3	F75-28	W75-41	F74-52
F75-3	S76-28	Su74-42	S75-52
S76-3	F75-31	F75-49	F75-52
S75-4	W75-31	W75-49	Su74-55
F75-4	S76-31	S76-49	F75-55
S76-4	Su74-32	Su74-50	W75-55
S75-5	F75-32	F74-50	S76-55
F75-5	S76-32	S75-50	S76-61
S76-5	F75-40	F75-50	S76-63

Site Group 42

S75-42	F75-42	S76-42

Hinchinbrook Entrance Group

F74-53	F75-54
F75-53	W75-54
S76-53	S76-54

Site Group 6

S76-52	S76-60

Tarr Bank Group

F75-56	F75-57
W75-56	S76-57
S76-56	

Site Group 4

F75-43	F75-58
S76-43	W75-58
S76-44	S76-58
S76-48	S76-69

TABLE XXI

CONTINUED

Shelf Break Group

Su74-6	F75-26	Su74-44
F75-6	S75-27	F75-44
S76-6	F75-27	Su74-48
F75-25	S76-27	F75-48
S76-25	F75-33	F74-57
Su74-26	S76-33	S76-62

Site Group 39

F75-39	S76-39

Site Group 5

S76-7	F75-59

Site 57

W75-57

Site Group 53

S75-53	W75-53

Site 1

F74-1

Site 2

S76-2

An inverse cluster analysis of data collected from July 1974 to March 1976 yielded 53 species groups at the 25% similarity level (Table XXII). A two-way coincidence table comparing site groups and species groups is presented in Appendix V, Table III and reduced two-way tables of average cell density, constancy and fidelity are presented in Tables XXIII, XXIV and XXV. A summary of the major species groups identified by the two-way tables (Appendix V, Table III; text Tables XXIII, XXIV and XXV) is presented in Figure 17 and outlined below (refer to Appendix V, Table III; text Tables XXIII, XXIV and XXV; Fig. 17):

Species Group 9. The species in this group were most abundant in the Hinchinbrook Entrance Group (Sites 53 and 54).

Species Group 14. These species were most abundant in the Tarr Bank Group (Sites 56 and 57) and Site 57.

Species Group 20. These species were most abundant in the Tarr Bank Group (Sites 56 and 57) and in the Shelf Break Group.

Species Group 21. These species were most abundant in the Shelf Break Group, Tarr Bank Group (Sites 56 and 57) and Site Group 4 (Sites 43, 44, 48, 58 and 69).

Species Group 22. These species were most abundant in Site Group 39.

Species Group 23. These species were most abundant in Site Group 5 (Sites 7 and 59), the Inshore Group and Site Group 4.

Species Group 24. These species were most abundant in the Hinchinbrook Entrance Group (Sites 53 and 54).

Species Group 25. This group of 19 species was present in all site groups except Site 1. These species were most abundant in Site Group 7 (Sites 56 and 57) and Site Group 4 (Sites 43, 44, 48, 58 and 69).

Species Group 26. This large group of predominantly deposit feeding species was present in all site groups and was most abundant in the Hinchinbrook Entrance Group (Sites 53 and 54) and Site Group 4 (Sites 43, 44, 48, 58 and 69).

From an examination of the two-way coincidence tables (Appendix V, Table III; text Tables XXII-XXIV) the species groups which characterized and differentiated the various site groups were identified (distribution maps of numerically abundant species are presented in Appendix IV). The Inshore Group and Site Group 42 (Table XXI; Fig. 14) were both characterized by the presence of species in Species Group 26. Members of Species

text continued on page 89.

TABLE XXII

SPECIES GROUPS FORMED BY INVERSE CLUSTER ANALYSIS OF ABUNDANCE DATA. FEEDING CLASS, MOTILITY CLASS CODES AND IDENTIFICATION NUMBERS FOR CROSS REFERENCE TO TABLE II FOR EACH SPECIES ARE IN PARENTHESES

DF = Deposit Feeder, SF = Suspension Feeder, P = Predator, S = Scavenger, U = Unknown, O = Other, M = Motile, SE = Sedentary, DM = Discretely Motile

Species Group	Species
1	*Mytilus edulis* (159; SF, SE), *Ophiocantha cataleimmoida* (332; DF, M), *Apistobranchus* sp. (77; DF, DM), *Spirorbis* sp. (145; SF, SE), *Lima hyperborea* (166; SF, SE), *Amphictene auricoma* (117; DF, M), *Melinna elisabethae* (127; DF, SE), *Ampelisca* sp. (250; SF, DM)
2	*Balanus crenatus* (300; SF, SE), *Hemithiris psittacea* (316; SF, SE), *Balanus nubilis* (301; SF, SE), *Drilonereis filium* (70; DF, M), *Astarte borealis* (168; SF, DM), *Balanus rostratus* (303; SF, SE), *Typosyllis armillaris* (32; P, M), *Propeamussium alaskense* (164; SF, SE), *Terebratalia transversa* (322; SF, SE)
3	*Astarte alaskensis* (169; SF, DM), *Astarte esquimaulti* (172; SF, DM), *Cyclocardia* sp. (173; SF, SE), *Ophiopholis aculeata* (334; SF, M), *Trichobranchus glacialis* (134; DF, SE), *Cardiomya planetica* (198; P, S, DF?, SE)
4	*Hiatella arctica* (190; SF, SE), *Paraphoxus simplex* (290; SF, M), *Clinocardium fucanum* (183; SF, M?), *Lamprops fuscata* (287; DF/S, M), *Lepeta caeca* (201; SF, M), *Byblis crassicornis* (254; SF, DM)
5	*Pista fasciata* (130; DF, SE), *Goniada maculata* (56; DF/P, M)
6	*Proclea emmi* (132; DF, SE), *Acanthonatozoma inflatum* (249; U; M), *Megalomma splendida* (139; SF, SE), *Eteone longa* (25; P, M), *Scalibregma inflatum* (95; DF, M), *Gattyana treadwelli* (12; S, M), *Chone infundibuliformis* (137; SF, DM), *Harpinia* sp. (283; SF, M), *Ericthonius hunteri* (257; SF?, DM), *Microporina borealis* (314; SF, SE), *Hyssura* sp. (247; U, SE), *Caprella striata* (297; S/P, M), *Ampharete acutifrons* (122; DF, SE), *Langerhausia cornuta* (36; P, M), *Astarte montagui* (170; SF, DM), *Dacrydium* sp. (162; SF, SE), *Eusyllis blomstrandi* (33; P, M)
7	*Pandora grandis* (193; SF, SE), *Pinnixa occidentalis* (306; O, M), *Hesperonoe complanata* (17; S, M)

TABLE XXII

CONTINUED

Species Group	Species
8	*Rhodine bitorquata* (113; DF, SE), *Macoma calcarea* (186; DF, SE), *Pholoe minuta* (21; S, M)
9	*Heteromastus filiformis* (100; DF, M), *Eudorellopsis integra* (235; DF/S, M), *Yoldia amygdalea* (157; DF, M), *Haploscoloplos elongatus* (72; DF, M)
10	*Magelona japonica* (85; DF, DM)
11	*Spiophanes bombyx* (82; DF, DM), *Byblis* sp. (253; SF, DM)
12	*Onuphis conchylega* (58; DF, M), *Crucigera irregularis* (143; SF, SE)
13	*Cistenides brevicoma* (118; DF, M), *Cucumaria calcigera* (339; DF, SE), *Calathura branchiata* (243; DF/S, M)
14	*Eunoe depressa* (8; S, M), *Priapulus candatus* (313; P, M), *Natica clausa* (207; P, M), *Monoculodes diamensus* (280; DF/S, M), *Metopa alderi* (295; SF, M), *Diastylis bidentata* (236; DF/S, M), *Amphissa columbiana* (211; P, M), *Paraphoxus robustus* (289; SF, M), *Nephtys caeca* (46; P/DF, M)
15	*Clinocardium ciliatum* (182; SF, M?), *Oenopota* sp. (217; P, M)
16	*Cylichna alba* (222; P, M), *Maera loveni* (260; SF, M), *Melita dentata* (262; DF, M), *Maera danae* (2590; SF, M), *Lepidonotus squamatus* (16; S, M), *Onuphis parva* (61; DF, S/DM), *Monoculodes* sp. (279; DF/S, M), *Chone* sp. (135; SF, DM), *Anonyx nugax* (260; S, M), *Maldane* sp. (102; DF, SE), *Praxillella affinis* (112; DF, SE)
17	*Polinices pallidus* (210; P, M), *Phoxocephalus hamilis* (292; SF, M)
18	*Nereis zonata* (43; SF, DM), *Paraonis gracilis* (76; DF, M)
19	*Laonice cirrata* (79; DF, DM), *Diamphiodia craterodmeta* (327; DF, M)

TABLE XXII

CONTINUED

Species Group	Species
20	*Eunice kobiensis* (63; DF, M), *Terebratulina crossei* (318; SF, SE), *Harmothoe imbricata* (14; S, M), *Terebratulina unquicula* (317; SF, SE), *Laqueus californianus* (320; SF, SE), *Astarte* sp. (167; SF, DM), *Peisidice aspera* (20; S, M), *Golfingia margaritacea* (310; DF, SE)
21	*Notoproctus pacificus* (109; DF, SE), *Aricidea suecica* (74; DF, M), *Harpiniopsis sanpedroensis* (286; SF, M), *Ischnochiton albus* (148; S, M), *Clavipora occidentalis* (315; SF, SE), *Delectopecten randolphi* (165; SF, SE), *Chone gracilis* (136; SF, DM), *Euchone analis* (138; SF, DM), *Owenia fusiformis* (114; SF, DM), *Pseudopotamilla reniformis* (141; SF, SE), *Anonyx* sp. (266; S, M), *Idanthyrsus armatus* (116; SF, SE), *Golfingia vulgaris* (311; DF, SE), *Typosyllis alternata* (31; P, M), *Ampelisca birulai* (253; SF, DM), *Haploops tubicula* (256; SF, DM)
22	*Maldane sarsi* (103; DF, SE), *Maldane glebifex* (104; DF, SE), *Nicippe tumida* (282; SF, M)
23	*Cadulus* sp. (225; DF, P, M), *Brisaster townsendi* (324; DF/S, M)
24	*Spiochaetopterus* sp. (87; SF, SE), *Capitella capitata* (99; DF, M)
25	*Drilonereis falcata minor* (71; DF, M), *Metopa* sp. (294; SF, M), *Byblis gaimardi* (255; SF, DM), *Ampelisca macrocephala* (251; SF, DM), *Ampharete arctica* (121; DF, SE), *Diastylis* sp. (236; DF/S, M), *Leucon* sp. (229; DF/S, M), *Heterophoxus occulatus* (287; SF, M), *Lumbrineris zonata* (67; DF/P, M), *Asychis similis* (101; DF, SE), *Crenella decussata* (160; SF, SE), *Astarte polaris* (171; SF, DM), *Cyclocardia ventricosa* (174; SF, SE), *Urothoe denticulata* (263; SF, M), *Ninoe gemmea* (68; DF, M), *Yoldia secunda* (158; DF, M), *Cadulus stearnsi* (226; DF/P, M), *Cadulus tolmei* (227; DF/P, M), *Cyclocardia crebricostata* (175; SF, SE)
26	*Dentalium dalli* (224; DF/P, M), *Molpadia intermedia* (338; DF, SE), *Terebellides stroemi* (133; DF, SE), *Nuculana fossa* (153; DF, M), *Nucula tenuis* (151; DF, M), *Psephidia lordi* (184; SF, S/DM?), *Myriochele heeri* (115; DF, SE), *Ophiura sarsi* (336; DF/P, M), *Axinopsida serricata* (176; SF/DF?, SE), *Nephtys punctata* (49; DF/P, M), *Eudorella emarginata* (233; DF/S, M), *Chaetoderma robusta* (147; DF/P, M), *Onuphis iridescens* (60;

TABLE XXII

CONTINUED

Species Group	Species
26 cont'd.	DF, S/DM), *Sternaspis scutata* (98; DF, M), *Goniada annulata* (55; DF/P, M), *Ctenodiscus crispatus* (322; DF, M), *Praxillella gracilis* (111; DF, SE), *Thyasira flexuosa* (178; SF/DF?, SE), *Glycera capitata* (52; DF/P, M), *Lumbrineris similabris* (66; DF/P, M), *Tharyx* sp. (90; DF, S/DM), *Melinna cristata* (126; DF, SE), *Spiophanes kroyeri* (83; DF, DM), *Pista cristata* (129; DF, SE), *Unioplus macraspis* (331; DF, M), *Dacrydium vitreum* (163; SF, SE), *Odontogena borealis* (180; SF/DF?, SE?), *Yoldia* sp. (156; DF, M), *Cardiomya pectinata* (197; P/S/DF?, SE)
27	*Pherusa stylarioides papillata* (93; DF, DM), *Pherusa stylario-ides plumosa* (94; DF, DM), *Amage anops* (119; DF, SE), *Trophonopsis lasius* (211; P, M), *Polinices* sp. (208; P, M), *Campylaspis* sp. (241; DF/S, M)
28	*Eudorella* sp. (232; DF/S, M), *Lepidepcreum* sp. (272; S/DF?, M), *Lysippe labiata* (125; DF, SE), *Chitinopoma groenlandica* (142; SF, SE), *Maldanella robusta* (105; DF, SE), *Nephtys ciliata* (45; DF/P, M)
29	*Amphicteis macronata* (124; DF, SE), *Melita* sp. (262; DF/S, M), *Brada villosa* (92; DF, DM), *Arcteobea spinelytris* (7; S, M), *Hippomedon* sp. (269; S/DF?, M)
30	*Artacama conifera* (131; DF, DM)
31	*Suavodrilla willetti* (216; P, M), *Anonyx ochoticus* (267; S, M), *Polinices nanus* (209; P, M), *Rocinela belliceps* (244; S/DF, M), *Tachyrynchus reticulatus* (205; S/P, M)
32	*Pandora bilirata* (192; SF, SE), *Cardiomya oldroydi* (199; P/S/DF?, SE), *Sthenelais fusca* (22; S, M), *Stegophiura* sp. (337; U, M)
33	*Nereis procera* (42; DF/P/S, M), *Diastylis paraspinulosa* (238; DF/S, M), *Suavadrilla* sp. (215; P, M), *Nereis pelagica* (41; DF/P/S, M)
34	*Nephtys cornuta* (47; DF/P, M), *Turbonilla* sp. (220; O, M), *Macoma moesta alaskana* (188; DF, SE), *Pandora filosa* (191; SF, SE), *Retusa obtusa* (221; P, M), *Eudorella pacifica* (234; DF/S, M), *Odostomia* sp. (218; O, M)
35	*Neohela monstrosa* (258; SF?, DM), *Protomedeia* sp. (265; DF, M), *Axiothella rubrocincta* (110; DF, SE), *Macoma brota* (187; DF, SE), *Aglaophamus rubella anops* (51; DF/P, M)

TABLE XXII

CONTINUED

Species Group	Species
36	*Photis c.f. P. reinhardi* (264; DF, M), *Ordiomene* sp. (275; S, M), *Anaitides maculata* (23; P/DF, M), *Chaetozone setosa* (91; DF, DM), *Ophiodromus pugettensis* (26; DF/S, M), *Harpinia kobjakovae* (285; SF, M)
37	*Haplosyllis spongicola* (37; P, M), *Haneleya* sp. (150; S, M), *Syllis sclerolema* (29; P, M)
38	*Aphrodita parva* (146; DF, M), *Syrrhoe crenulata* (296; SF, M)
39	*Diamphiodia periercta* (328; DF, M), *Psolus* sp. (340; DF, SE), *Scalpellum columbiana* (299; SF, SE)
40	*Travisia pupa* (97; DF, M), *Puncturella cooperi* (200; S, M)
41	*Nephtys ferruginea* (50; DF/P, M), *Nuculana minuta* (154; DF, M), *Caulleriella* sp. (89; DF, DM), *Harpinia emeryi* (284; SF, M)
42	*Ophiopenia disacantha* (334; DF, M)
43	*Ophiura* sp. (335; DF/P, M)
44	*Mysella* sp. (179; SF/DF?, SE?), *Cardiomya* sp. (196; P/S/DF?, SE), *Axinopsida viridis* (177; SF/DF?, SE)
45	*Mitrella gouldi* (214; U, M), *Pinnixa schmitti* (307; O, M), *Ptilosarcus gurneyi* (2; SF, SE), *Magelona pacifica* (86; DF, DM)
46	*Peachia* sp. (3; SF, SE), *Calyptraea fastigata* (206; SF, M), *Nicomache lumbricalis* (106; DF, SE)
47	*Leucon acutirostris* (230; DF/S, M), *Aceroides* sp. (276; DF/S, M), *Mopadia* sp. (149; S/P, M)
48	*Gattyana ciliata* (11; S, M), *Leucon nasica* (231; DF/S, M), *Megacrenella columbiana* (161; SF, SE), *Amphissa reticulata* (213; P, M), *Ceratonereis paucidentata* (39; DF/P/S, M), *Pandellia carchara* (329; DF, M)
49	*Deistothyris frontalis* (319; SF, SE)
50	*Solariella lewisai* (204; S/P, M), *Pinnixa* sp. (305; O, M)

TABLE XXII

CONTINUED

Species Group	Species
51	*Spio filicornis* (81; DF, DM), *Portlandia arctica* (155; DF, M)
52	*Potamilla neglecta* (140; SF, SE), *Malletia cuneata* (152; DF, M), *Phoxocephalus* sp. (291; SF, M), *Diastylis hirsata* (240; DF/S, M), *Hippomedon propinquus* (271; S/DF?, M)
53	*Nephtys longasetosa* (49; DF/P, M)

TABLE XXIII

SITE GROUP/SPECIES GROUP COINCIDENCE TABLE SHOWING AVERAGE CELL DENSITIES OF GROUPS FORMED BY A CLUSTER ANALYSIS OF UNTRANSFORMED ABUNDANCE DATA (JULY 1974-MARCH 1976)

IG = Inshore Group, SBG = Shelf Break Group, TBG = Tarr Bank Group
HEC = Hinchinbrook Entrance Group, S = Site, G = Site Group

MATRIX OF AVERAGE CELL DENSITY

	Site Groups												
Species Group	IG (57)†	G42 (3)	HEG (6)	G6 (2)	TBG (5)	G4 (8)	SBG (18)	G39 (2)	G5 (2)	S57* (1)	G53 (2)	S1* (1)	S2* (1)
1 (8)††	0.0	0.5	0.1	0.1	0.3	0.	0.3	0.4	0.	0.	0.	0.	0.
2 (9)	0.0	0.	0.	0.	4.6	0.0	0.1	0.	0.	0.	0.	0.	0.
3 (6)	0.1	0.7	0.	0.	0.5	1.8	0.1	0.	0.	0.	0.	0.	0.
4 (6)	0.2	0.3	0.	0.	0.3	0.	1.6	0.	0.	0.	0.	0.	0.3
5 (2)	0.1	0.	0.	0.	0.	0.	0.2	0.	0.	0.	0.	0.	0.
6 (17)	0.2	0.1	0.1	0.	0.4	0.1	1.4	0.	0.1	0.	0.	0.	0.
7 (3)	0.1	0.	0.2	0.	0.2	0.	0.1	0.	0.	0.	0.	0.	0.
8 (3)	0.6	0.1	2.4	0.	0.6	0.3	0.6	0.	0.	0.	0.	0.	0.
9 (4)	0.6	0.	2.5	0.	1.5	0.1	0.2	0.	0.	0.8	0.6	0.	0.
10 (1)	4.7	16.0	0.	1.0	0.	0.	0.3	0.	0.	0.	0.	0.	0.
11 (2)	0.	0.	0.2	0.	0.5	0.5	0.8	0.	0.	0.	0.	0.	0.
12 (2)	0.1	0.	0.	0.	0.5	0.3	0.2	0.	0.	0.	0.	0.	0.
13 (3)	0.1	0.	0.	0.	0.3	0.	0.6	0.	0.3	0.	0.	0.	0.
14 (9)	0.1	0.	0.2	0.	3.4	0.0	0.1	0.	0.	1.9	0.	0.	0.
15 (2)	0.0	2.2	0.	0.5	2.4	0.4	0.2	0.	0.	0.	0.	0.	0.
16 (11)	0.0	0.2	0.4	0.	0.9	0.5	0.3	0.	0.3	0.	0.	0.	0.
17 (2)	0.2	0.2	0.2	0.	0.	0.3	0.0	0.	0.	0.	0.	0.	1.0
18 (2)	0.6	2.3	1.2	0.	1.2	0.4	0.3	0.5	0.	0.	0.	0.	0.
19 (2)	1.6	0.2	0.	0.	1.2	0.5	1.4	0.	0.5	0.	0.	0.	0.
20 (8)	0.3	0.0	0.0	1.4	0.1	2.5	10.8	0.	0.6	0.8	0.	0.	1.5
21 (18)	0.1	0.3	0.3	0.1	3.0	1.4	5.6	0.5	0.3	0.4	0.	0.	0.4
22 (3)	0.5	5.9	0.7	0.7	0.9	2.4	1.4	40.9	1.1	1.1	0.	0.	0.
23 (2)	1.9	0.	0.2	0.	0.	1.6	0.9	0.	4.3	0.	0.	3.3	1.0
24 (2)	1.0	1.2	8.3	0.	1.5	0.1	1.0	0.	0.	0.	1.3	0.	0.
25 (19)	1.8	2.5	3.8	0.3	8.8	9.1	1.9	0.9	1.2	0.7	0.1	0.	0.5
26 (29)	9.8	9.4	19.9	3.4	3.8	11.4	5.8	1.8	4.9	2.4	2.3	1.4	1.2
27 (6)	0.0	0.	0.	0.	0.2	0.0	0.2	0.	0.	0.	0.	0.	0.
28 (6)	0.1	0.1	0.1	0.	0.	0.0	0.4	0.3	0.	0.	0.	0.	0.
29 (5)	0.0	0.	0.1	0.	0.	0.1	0.1	2.5	0.4	0.	0.	0.	0.
30 (1)	0.3	0.	0.3	1.0	0.	0.	0.1	2.0	0.	0.	0.	0.	0.
31 (5)	0.0	0.1	0.1	0.	0.	1.1	0.2	0.	0.	0.	0.	0.	0.
32 (4)	0.3	0.	0.	0.	0.	0.3	0.0	0.	0.	0.	0.	0.	0.
33 (4)	0.0	0.4	0.	1.0	0.2	0.5	0.0	0.	0.	0.	0.	0.	0.
34 (7)	0.1	0.5	0.1	0.1	0.1	0.3	0.0	0.	0.	0.	0.	0.	0.
35 (5)	0.0	0.1	2.5	0.	0.	0.1	0.	0.5	0.	0.	0.	0.	0.
36 (6)	0.1	0.	3.1	0.	0.	0.	0.1	0.	0.3	0.	0.	0.	0.
37 (3)	0.	0.	0.	0.	0.2	0.3	0.8	0.	0.	0.	0.	0.	0.
38 (2)	0.	0.	0.	0.	0.	0.	0.2	0.	0.	0.	0.	0.	0.
39 (3)	0.1	0.	0.	0.	0.	0.1	0.3	0.	0.	0.	0.	0.	0.
40 (2)	0.1	0.	0.	0.	0.	0.2	0.2	0.	0.	0.	0.	0.	0.
41 (4)	0.5	0.	0.8	0.	0.	0.	0.0	0.	0.	0.	0.	1.7	0.
42 (1)	0.8	0.	0.	0.	0.	2.6	0.	0.	0.	0.	0.	0.	2.0
43 (1)	0.1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
44 (3)	0.	0.	0.	0.3	0.	0.	0.	5.6	0.4	0.	0.	0.	0.
45 (4)	0.0	0.	0.1	8.7	0.3	0.1	0.	0.	0.	0.	0.	0.	0.
46 (4)	0.1	0.	0.	0.	1.4	0.	0.0	0.	0.3	0.	0.	0.	0.
47 (3)	0.0	0.	0.	0.	0.3	0.	0.	0.	0.	0.	3.3	0.	0.
48 (6)	0.0	0.	0.4	0.	0.6	0.1	0.0	0.	0.	6.7	0.	0.	0.
49 (1)	0.0	0.	0.	0.	4.0	0.	0.	0.	0.	0.	0.	0.	0.
50 (2)	0.2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
51 (2)	2.7	9.0	0.	0.	0.	0.	0.	0.	0.	0.	1.3	0.	0.
52 (5)	0.2	0.	0.1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
53 (1)	0.3	0.	1.7	0.	0.4	0.	0.	0.	0.	0.	0.	0.	0.

* Sites which did not join any of the site groups
† Number of sites in the site group
†† Number of species in the species group

TABLE XXIV

SITE GROUP/SPECIES GROUP COINCIDENCE TABLE SHOWING % FIDELITY OF THE SPECIES GROUPS IN EACH SITE GROUP (JULY 1974-MARCH 1976)

IG = Inshore Group, SBG = Shelf Break Group, TBG = Tarr Bank Group
HEG = Hinchinbrook Entrance Group, S = Site, G = Site Group

MATRIX OF PERCENT FIDELITY

	Site Groups												
Species Group	IG (57)†	G42 (3)	HEG (6)	G6 (2)	TBG (5)	G4 (8)	SBG (18)	G39 (2)	G5 (2)	S57* (1)	G53 (2)	S1* (1)	S2* (1)
1 (8)††	0.4	26.9	4.9	7.3	19.1	0.	19.4	22.0	0.	0.	0.	0.	0.
2 (9)	0.1	0.	0.	0.	97.1	1.0	1.8	0.	0.	0.	0.	0.	0.
3 (6)	4.1	21.1	0.	0.	14.2	55.8	4.7	0.	0.	0.	0.	0.	0.
4 (6)	6.2	10.5	0.	0.	11.3	0.	59.3	0.	0.	0.	0.	0.	12.6
5 (2)	33.1	0.	0.	0.	0.	0.	66.9	0.	0.	0.	0.	0.	0.
6 (17)	7.4	5.5	4.7	0.	17.3	5.8	56.4	0.	2.9	0.	0.	0.	0.
7 (3)	15.9	0.	37.7	0.	33.9	0.	12.6	0.	0.	0.	0.	0.	0.
8 (3)	13.3	2.4	52.7	0.	12.9	5.8	12.8	0.	0.	0.	0.	0.	0.
9 (4)	2.5	0.	85.3	0.	5.7	0.2	0.8	0.	0.	3.2	2.4	0.	0.
10 (1)	21.4	72.6	0.	4.5	0.	0.	1.5	0.	0.	0.	0.	0.	0.
11 (2)	0.	0.	8.2	0.	24.7	26.3	40.8	0.	0.	0.	0.	0.	0.
12 (2)	6.7	0.	0.	0.	48.0	24.0	21.3	0.	0.	0.	0.	0.	0.
13 (3)	3.2	0.	30.7	0.	14.8	0.	32.8	0.	18.5	0.	0.	0.	0.
14 (9)	1.3	0.	3.3	0.	60.8	0.5	1.2	0.	0.	32.9	0.	0.	0.
15 (2)	0.8	38.0	0.	8.8	42.0	7.1	3.2	0.	0.	0.	0.	0.	0.
16 (11)	1.1	5.9	14.3	0.	36.0	19.4	12.5	0.	10.7	0.	0.	0.	0.
17 (2)	12.0	9.1	9.1	0.	0.	3.7	1.5	0.	0.	0.	0.	0.	4.6
18 (2)	9.7	35.4	18.6	0.	18.2	5.7	4.8	7.6	0.	0.	0.	0.	0.
19 (2)	29.5	3.2	0.	0.	22.7	9.5	25.6	0.	9.5	0.	0.	0.	0.
20 (8)	0.7	0.1	0.1	3.6	52.7	6.5	28.4	0.	1.6	2.2	0.	0.	3.9
21 (18)	1.2	2.1	2.2	0.9	24.2	11.6	44.9	4.3	2.0	3.0	0.	0.	3.6
22 (3)	0.8	10.6	1.2	1.2	1.7	4.3	2.6	73.6	2.0	2.0	0.	0.	0.
23 (2)	14.6	0.	1.3	0.	0.	12.3	6.6	0.	32.3	0.	0.	25.3	7.6
24 (2)	6.8	8.1	58.2	0.	10.5	0.9	6.8	0.	0.	0.	8.7	0.	0.
25 (19)	5.6	7.8	12.0	0.8	27.9	28.9	6.1	2.8	3.8	2.2	0.4	0.	1.7
26 (29)	12.6	12.2	25.7	4.4	4.9	14.7	7.5	2.3	6.4	3.1	3.0	1.8	1.5
27 (6)	5.0	0.	0.	0.	42.7	8.9	43.4	0.	0.	0.	0.	0.	0.
28 (6)	7.4	5.5	9.1	0.	0.	4.1	41.1	32.9	0.	0.	0.	0.	0.
29 (5)	1.5	0.	4.2	0.	0.	1.6	3.1	77.1	12.5	0.	0.	0.	0.
30 (1)	7.1	0.	9.0	27.0	0.	0.	3.0	53.9	0.	0.	0.	0.	0.
31 (5)	3.2	4.3	4.3	0.	0.	73.3	14.9	0.	0.	0.	0.	0.	0.
32 (4)	45.2	0.	0.	0.	0.	50.3	4.5	0.	0.	0.	0.	0.	0.
33 (4)	1.8	19.2	0.	46.1	9.2	23.0	0.6	0.	0.	0.	0.	0.	0.
34 (7)	10.7	38.6	10.5	10.5	4.2	23.7	1.8	0.	0.	0.	0.	0.	0.
35 (5)	1.2	3.3	61.8	0.	0.	1.2	0.	13.0	0.	0.	0.	0.	19.5
36 (6)	2.6	0.	85.9	0.	0.	0.	2.1	0.	9.4	0.	0.	0.	0.
37 (3)	0.	0.	0.	0.	13.1	24.0	63.0	0.	0.	0.	0.	0.	0.
38 (2)	0.	0.	0.	0.	0.	0.	100.0	0.	0.	0.	0.	0.	0.
39 (3)	11.6	0.	0.	0.	0.	17.7	70.7	0.	0.	0.	0.	0.	0.
40 (2)	13.1	0.	0.	0.	0.	38.8	48.2	0.	0.	0.	0.	0.	0.
41 (4)	17.5	0.	27.0	0.	0.	0.	1.5	0.	0.	0.	0.	54.0	0.
42 (1)	15.0	0.	0.	0.	0.	47.7	0.	0.	0.	0.	0.	0.	37.3
43 (1)	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
44 (3)	0.	0.	0.	5.3	0.	0.	0.	88.1	6.6	0.	0.	0.	0.
45 (4)	0.2	0.	0.9	95.3	2.7	0.9	0.	0.	0.	0.	0.	0.	0.
46 (4)	4.8	0.	0.	0.	76.0	0.	2.3	0.	17.0	0.	0.	0.	0.
47 (3)	0.5	0.	0.	0.	9.0	0.	0.	0.	0.	0.	90.4	0.	0.
48 (6)	0.5	0.	5.7	0.	7.5	0.7	0.2	0.	0.	85.4	0.	0.	0.
49 (1)	0.	0.	0.	0.	100.0	0.	0.	0.	0.	0.	0.	0.	0.
50 (2)	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
51 (2)	21.1	69.3	0.	0.	0.	0.	0.	0.	0.	0.	9.6	0.	0.
52 (5)	63.3	0.	36.7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
53 (1)	11.0	0.	71.8	0.	17.2	0.	0.	0.	0.	0.	0.	0.	0.

* Sites which did not join any of the site groups
† Number of sites in the site group
†† Number of species in the species group

TABLE XXV

SITE GROUP/SPECIES GROUP COINCIDENCE TABLE SHOWING % FIDELITY OF THE SPECIES GROUPS IN EACH SITE GROUP (JULY 1974-MARCH 1976)

IG = Inshore Group, SBG = Shelf Break Group, TBG = Tarr Bank Group
HEG = Hinchinbrook Entrance Group, S = Site, G = Site Group

MATRIX OF PERCENT CONSTANCY

	Site Groups												
Species Group	IG (57)†	G42 (3)	HEG (6)	G6 (2)	TBG (5)	G4 (8)	SBG (18)	G39 (2)	G5 (2)	S57* (1)	G53 (2)	S1* (1)	S2* (1)
1 (8)††	0.4	8.3	2.1	6.3	17.5	0.	11.8	6.3	0.	0.	0.	0.	0.
2 (9)	0.2	0.	0.	0.	37.8	1.4	1.2	0.	0.	0.	0.	0.	0.
3 (6)	2.6	5.6	0.	0.	13.3	22.9	1.9	0.	0.	0.	0.	0.	0.
4 (6)	2.9	5.6	0.	0.	10.	0.	13.9	0.	0.	0.	0.	0.	16.7
5 (2)	3.5	0.	0.	0.	0.	0.	8.3	0.	0.	0.	0.	0.	0.
6 (17)	2.8	5.9	3.9	0.	9.4	5.9	16.3	0.	2.9	0.	0.	0.	0.
7 (3)	2.3	2.3	0.	5.6	0.	6.7	0.	1.9	0.	0.	0.	0.	0.
8 (3)	14.0	11.1	38.9	0.	20.0	8.3	13.0	0.	0.	0.	0.	0.	0.
9 (4)	8.3	0.	66.7	0.	20.0	3.1	4.2	0.	0.	25.0	12.5	0.	0.
10 (1)	7.0	66.7	0.	50.0	0.	0.	11.1	0.	0.	0.	0.	0.	0.
11 (2)	0.	0.	8.3	0.	20.0	8.8	11.1	0.	0.	0.	0.	0.	0.
12 (2)	3.5	0.	0.	0.	30.0	12.5	5.6	0.	0.	0.	0.	0.	0.
13 (3)	2.3	0.	11.1	0.	13.3	0.	7.4	0.	16.7	0.	0.	0.	0.
14 (9)	1.8	0.	7.4	0.	46.7	1.4	2.5	0.	0.	22.2	0.	0.	0.
15 (2)	2.6	33.3	0.	25.0	20.7	18.8	2.8	0.	0.	0.	0.	0.	0.
16 (11)	1.3	9.1	4.5	0.	27.3	6.8	9.1	0.	9.1	0.	0.	0.	0.
17 (2)	5.3	16.7	8.3	0.	0.	12.5	2.8	0.	0.	0.	0.	0.	50.0
18 (2)	12.3	16.7	33.3	0.	30.0	18.8	11.1	25.0	0.	0.	0.	0.	0.
19 (2)	11.4	16.7	0.	0.	50.0	6.3	13.9	0.	5.0	0.	0.	0.	0.
20 (8)	5.9	4.2	2.1	18.8	92.5	18.8	42.4	0.	6.3	12.5	0.	0.	25.0
21 (18)	4.6	7.4	4.6	5.6	42.2	23.6	45.7	13.9	8.3	11.1	0.	0.	11.1
22 (3)	10.5	11.1	11.1	16.7	33.3	41.7	20.4	100.0	50.0	33.3	0.	0.	0.
23 (2)	25.4	0.	8.3	0.	0.	12.5	25.0	0.	75.0	0.	0.	50.0	50.0
24 (2)	9.4	16.7	25.0	0.	50.0	6.3	22.2	0.	0.	0.	25.0	0.	0.
25 (19)	18.0	17.5	31.6	13.2	49.5	47.4	28.9	18.4	13.2	10.5	2.6	0.	15.8
26 (29)	56.9	55.2	56.3	32.8	42.8	42.7	51.1	25.9	34.5	27.6	15.5	17.2	24.1
27 (6)	1.2	0.	0.	0.	10.0	2.1	7.4	0.	0.	0.	0.	0.	0.
28 (6)	2.3	5.6	2.8	0.	0.	2.1	15.7	16.7	0.	0.	0.	0.	0.
29 (5)	1.8	0.	6.7	0.	0.	2.5	5.6	60.0	20.0	0.	0.	0.	0.
30 (1)	10.5	0.	16.7	50.0	0.	0.	5.6	50.0	0.	0.	0.	0.	0.
31 (5)	2.1	6.7	3.3	0.	0.	15.0	6.7	0.	0.	0.	0.	0.	0.
32 (4)	6.1	0.	0.	0.	0.	3.1	1.4	0.	0.	0.	0.	0.	0.
33 (4)	1.3	16.7	0.	12.5	5.0	12.5	1.4	0.	0.	0.	0.	0.	0.
34 (7)	4.5	23.8	4.8	7.1	2.9	8.9	0.8	0.	0.	0.	0.	0.	0.
35 (5)	2.1	6.7	26.7	0.	0.	2.5	0.	20.0	0.	0.	0.	0.	20.0
36 (6)	2.9	0.	22.2	0.	0.	0.	0.9	0.	8.3	0.	0.	0.	0.
37 (3)	0.	0.	0.	0.	6.7	8.3	9.3	0.	0.	0.	0.	0.	0.
38 (2)	0.	0.	0.	0.	0.	0.	8.3	0.	0.	0.	0.	0.	0.
39 (3)	1.2	0.	0.	0.	0.	4.2	9.3	0.	0.	0.	0.	0.	0.
40 (2)	2.6	0.	0.	0.	0.	6.3	8.3	0.	0.	0.	0.	0.	0.
41 (4)	4.4	0.	4.2	0.	0.	0.	1.4	0.	0.	0.	0.	25.0	0.
42 (1)	17.5	0.	0.	0.	0.	37.5	0.	0.	0.	0.	0.	0.	100.0
43 (1)	1.8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
44 (3)	0.	0.	0.	6.7	0.	0.	0.	50.0	16.7	0.	0.	0.	0.
45 (4)	0.9	0.	4.2	75.0	5.0	3.1	0.	0.	0.	0.	0.	0.	0.
46 (4)	1.8	0.	0.	0.	25.0	0.	1.4	0.	12.5	0.	0.	0.	0.
47 (3)	0.6	0.	0.	0.	6.7	0.	0.	0.	0.	0.	50.0	0.	0.
48 (6)	1.5	0.	11.1	0.	10.0	2.1	0.9	0.	0.	100.0	0.	0.	0.
49 (1)	0.	0.	0.	0.	20.0	0.	0.	0.	0.	0.	0.	0.	0.
50 (2)	3.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
51 (2)	16.7	33.3	0.	0.	0.	0.	0.	0.	0.	0.	25.0	0.	0.
52 (5)	5.3	0.	3.3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
53 (1)	10.5	0.	16.7	0.	20.0	0.	0.	0.	0.	0.	0.	0.	0.

* Sites which did not join any of the site groups
† Number of sites in the site group
†† Number of species in the species group

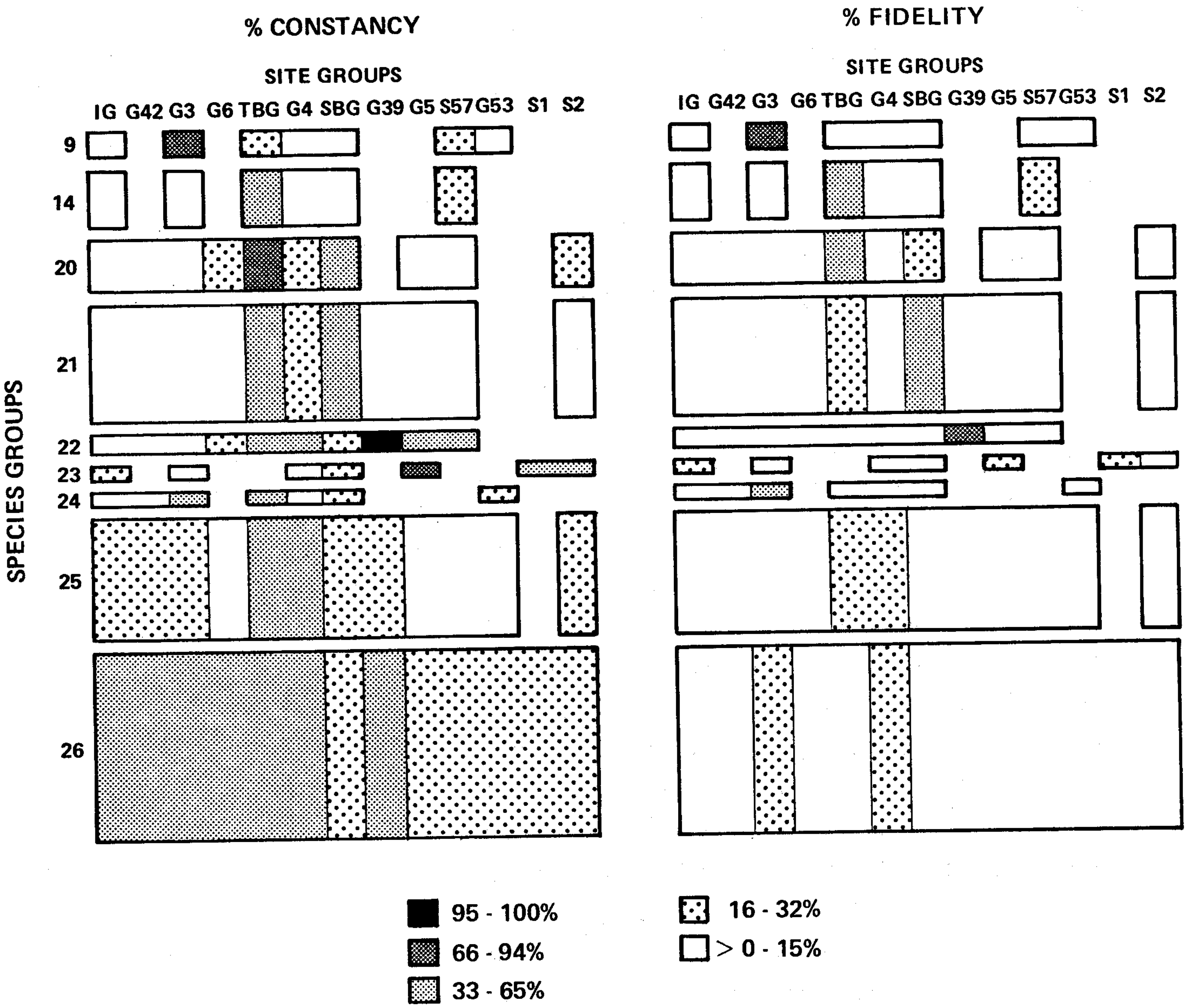

Figure 17. Constancy and fidelity of species groups formed by inverse cluster analysis of all data collected during this study. The Czekanowski coefficient was utilized to create similarity matrices from *ln* transformed abundance data. The vertical dimension of the bars (height) is proportional to the number of species in the species group (Table XXI). IG=Inshore Group, SBG=Shelf Break Group, TBG=Tarr Bank Group, HEG=Hinchinbrook Entrance Group, S=Site, G=Site Group.

Group 25 were also present in some of the stations in the Inshore Group and Site Group 42 (Appendix V, Table III; text, Table XXV). The increased abundance of five members (*Nucula tenuis, Psephidia lordi, Myriochele heeri, Ophiura sarsi* and *Axinopsida serricata*) of Species Group 26 in Site Group 42 was the principal difference between Site Group 42 and the Inshore Group (Appendix V, Table III). *Myriochele heeri, Nucula tenuis, Psephidia lordi,* and *Axinopsida serricata* have aggregated distributions in Site Group 42 (Morisita's index of dispersion, $P<0.05$; Pielou, 1977). Abundance estimates of species with aggregated distributions have a high variance and it is not at all certain that a distinction between these groups is valid. The Hinchinbrook Entrance Group (Sites 53 and 54) was characterized by Species Groups 9, 24, 25 and 26. Species in Species Group 26, particularly the brittle star, *Ophiura sarsi*, were more abundant in the Hinchinbrook Entrance Group than in the Inshore Group and Site Group 42 (Appendix V, Table III; Text, Tables XXIII-XXV). The Shelf Break Group was characterized by Species Groups 20, 21 and 26 (Fig. 17; Tables XXIII-XXV). The fauna of Site Group 4 (Species Groups 20, 21, 25 and 26) was similar to that of the Shelf Break Group (Fig. 17) except that members of Species Groups 20 and 21 were not as abundant (Table XXIII) or as ubiquitous (Table XXV) in Site Group 4. In addition, species in Species Group 25 were more abundant in Site Group 4 than in the Shelf Break Group (Table XXIII). The Tarr Bank Group (Sites 56 and 57) was characterized by Species Groups 14, 20, 21, 22, 25 and 26 (Fig. 17; Tables XXIII-XXV). Site Group 39 was characterized by the three members of Species Group 22, the maldanid polychaetes, *Maldane sarsi* and *Maldane glebifex*, and the amphipod, *Nicippe tumida* (Appendix V, Table III; text, Fig. 17). The remaining site groups (Site Groups 5, 6 and 53) and single sites (Sites 1 and 2) were distinguished primarily by the low abundance and diversity of their fauna (Appendix V, Table III).

There was some partitioning by cluster analysis of the stations within the Inshore Group into subgroups of stations taken in the fall of 1975, the spring of 1976; the spring of 1975 (Fig. 15). Stations in the Shelf Break Group also could be partitioned into subgroups which included a group of four stations taken during the fall of 1975 and another group of stations taken during the summer of 1974. However, these subgroups were

text continued from page 78.

formed at relatively high similarity levels (Fig. 15), and are based primarily on slight differences in the abundance of the fauna rather than changes in the species composition of the stations (Appendix V, Table III).

At least one of the stations occupied at each of ten sampling sites was not classified in the same site group as the other stations taken at that site (Table XXVI). For example, stations occupied at Site 57 were classified as members of both the Shelf Break Group, and the Tarr Bank Group (Sites 56 and 57) and on one occasion a station occupied at Site 57 did not join any site group (Table XXVI). In most cases, changes in the classification of a sampling site were not due to major changes in the species assemblages at that site; instead, they were caused by changes in the species richness and abundance of the fauna (Appendix V, Table III).

Abundance, Biomass and Diversity: Combined Data; July 1974-March 1976

The results of nested ANOVA's comparing the between site group, between stations within site groups, and within station (sample) variance of the abundance, biomass and diversity of the fauna are presented in Tables XXVII-XXXII. There were significant differences ($P<0.05$) between site groups in biomass, species richness and Brillouin diversity. However, a Student-Newman-Keuls multiple range test indicated that there were no significant differences ($P>0.05$) between individual means. There were also significant differences ($P<0.05$) between stations within groups for all parameters tested. In all cases, except for species richness and abundance, the greatest percentage of the total variance in the data was attributed to within station (between sample) variation (Tables XXVII-XXX). For abundance data the greatest amount of variation occurred between stations within groups (Table XXVIII). The greatest variance in species richness data was between site groups.

Although there were few statistically significant differences in site group means, there appear to be several trends worth noting. Both the abundance and biomass of the fauna was highest in the Hinchinbrook Entrance Group (Site 53 and 54; Tables XXVII and XXVIII). The biomass (Table XXVIII) in the Shelf Break Group and Site Group 4 stations (see Table XXI for site

text continued on page 98.

TABLE XXVI

STATIONS[†] WHICH WERE CLASSIFIED AS MEMBERS OF MORE THAN ONE SITE GROUP

IG = Inshore Group, SBG = Shelf Break Group, TBG = Tarr Bank Group, HEG = Hinchinbrook Entrance Group, S = Site, G = Site Group, DNC = Did Not Join Any Site Group

	Cruise Dates (Date station was occupied)					
Site	Summer 1974	Fall 1974	Winter 1975	Spring 1975	Fall 1975	Spring 1976
1	-	DNC	-	-	IG	IG
2	-	-	-	IG	IG	DNC
25	-	-	-	IG	SBG	SBG
26	SBG	-	-	IG	SBG	IG
42	IG	-	S42	-	S42	S42
44	SBG	-	QS	-	SBG	G8
48	SBG	-	-	-	SBG	G8
52	IG	IG	-	IG	IG	IG
53	-	HEG	G53	G53	HEG	HEG
57	-	SBG	-	DNC	TBG	TBG

† Each station is a site occupied on a specific cruise (date).

TABLE XXVII

NESTED ANALYSIS OF VARIANCE, ABUNDANCE DATA ($\#/m^2$). SITE GROUPS ARE THE SITE GROUPS FORMED BY A CLUSTER ANALYSIS OF NATURAL LOGARITHM TRANSFORMED ABUNDANCE DATA COLLECTED FROM JULY 1974-MARCH 1976.

A. ANOVA Table

	SS	DF	MS	F
Between site groups	8850616.0	12	737551.3	1.55(NS)†
Between sites within groups	44710948.0	95	474515.0	10.57**
Within sites	17181602.0	386	44511.9	

B. Variance Components

	Variance component	Percent
Between site groups	9364.8	6.4
Between sites within groups	93366.7	63.4
Within sites	44511.9	30.2

C. Student-Newman-Keuls Multiple Range Test: Table of Means (sorted). Bar represents the ranges of non-significant ($P > 0.05$) differences in means.

Site Groups	N	Mean	Std. Deviation
Site 1	3	66.66	25.2
Site Group 53	3	123.3	92.9
Site Group 3	9	129.1	85.4
Site Group 39	8	162.4	149.6
Site 2	5	174.0	175.6
Site 57	3	219.9	103.9
Site Group 6	10	280.0	178.3
Inshore Group	258	402.4	334.1
Shelf Break Group	87	453.8	464.3
Site Group 4	36	544.2	309.9
Tarr Bank Group	29	548.9	331.9
Site Group 42	17	650.0	375.6
Hinchinbrook Entrance Group	26	833.7	460.4

† Not Significant, $P > 0.05$
** $P < 0.01$
* $P < 0.05$

TABLE XXVIII

NESTED ANALYSIS OF VARIANCE, BIOMASS DATA (WWT/m^2). SITE GROUPS ARE THE SITE GROUPS FORMED BY A CLUSTER ANALYSIS OF NATURAL LOGARITHM TRANSFORMED ABUNDANCE DATA COLLECTED FROM JULY 1974-MARCH 1976

A. ANOVA Table

	SS	DF	MS	F
Between site groups	2830742.5	12	235895.2	3.37**
Between site within groups	6616547.1	95.4 94.4	69647.9 70049.0	2.73**
Within sites	9849455.0	386.	25516.7	

B. Variance Components

	Variance Component	Percent
Between site groups	5904.6	14.3
Between site within groups	9669.3	23.53
Within sites	25516.7	62.10

C. Student-Newman-Keuls Multiple Range Test: Table of Means (sorted). Bar represents the range of non-significant (P > 0.05) differences in means.

Site Groups	N	Mean	Std. Deviation
Site Group 39	8	9.4	7.5
Site Group 3	9	22.7	39.8
Site 2	5	34.2	46.6
Shelf Break Group	87	34.8	51.2
Site Group 4	36	54.6	42.5
Site 57	3	65.7	35.0
Site Group 42	17	71.4	38.4
Site Group 6	10	83.3	129.8
Inshore Group	258	142.9	203.5
Tarr Bank Group	29	242.6	275.0
Site Group 53	3	243.5	385.0
Hinchinbrook Entrance Group	26	329.4	341.4

** P < 0.01

TABLE XXIX

NESTED ANALYSIS OF VARIANCE, SPECIES RICHNESS. SITE GROUPS ARE THE SITE GROUPS FORMED BY A CLUSTER ANALYSIS OF NATURAL LOGARITHM TRANSFORMED ABUNDANCE DATA COLLECTED FROM JULY 1974-MARCH 1976

A. ANOVA Table

	SS	DF	MS	F
Between site groups	683.1	12	56.92	10.40**
Between sites within groups	515.9	95. 44.7	5.43 5.47	6.57**
Within sites	318.9	386.	0.82	

B. Variance Components

	Variance Component	Percent
Between site groups	1.83	49.96
Between sites within groups	1.01	27.51
Within sites	0.83	22.53

C. Student-Newman-Keuls multiple Range Test: Table of Means (sorted). Bars represent the ranges of non-significant (P > 0.05) differences in means.

Site Groups	N	Mean	Std. Deviation
Site 1	3	1.4	0.2
Site Group 53	3	1.5	1.1
Site Group 6	10	2.3	0.7
Site 2	5	2.3	1.6
Site Group 39	8	2.7	0.6
Site 57	3	3.1	0.9
Site Group 3	9	3.3	0.7
Inshore Group	258	3.6	1.1
Site Group 4	36	4.2	1.3
Site Group 42	17	4.3	1.7
Hinchinbrook Entrance Group	26	4.7	1.2
Shelf Break Group	87	5.7	1.8
Tarr Bank Group	29	7.2	1.7

** $P < 0.01$

TABLE XXX

NESTED ANALYSIS OF VARIANCE, BRILLOUIN DIVERSITY. SITE GROUPS ARE THE SITE GROUPS FORMED BY A CLUSTER ANALYSIS OF NATURAL LOCARITHM TRANSFORMED ABUNDANCE DATA COLLECTED FROM JULY 1974-MARCH 1976

A. ANOVA Table

	SS	DF	MS	F
Between site groups	14.46	12.	1.20	4.80*
Between sites within groups	23.58	95.	0.25	3.12*
		94.4	0.25	
Within sites	32.62	386.	0.04	
			0.08	

B. Variance Components

	Variance Component	Percent
Between site groups	0.022	22.03
Between sites within groups	0.016	23.22
Within sites	0.037	54.75

C. Student-Newman-Keuls Multiple Range Test: Table of Means (sorted) Bar represents the range of non-significant ($p > 0.05$) differences in means

Site Groups	N	Mean	Std. Deviation
Site 1	3	1.31	0.21
Site 2	5	1.38	0.92
Site Group 6	10	1.54	0.44
Site Group 53	3	1.59	0.48
Site Group 39	8	1.77	0.25
Site Group 3	9	2.03	0.25
Site Group 42	17	2.05	0.58
Inshore Group	258	2.07	0.60
Site 57	3	2.16	0.37
Site Group 4	36	2.28	0.37
Hinchinbrook Entrance Group	26	2.28	0.30
Shelf Break Group	87	2.51	0.39
Tarr Bank Group	29	2.69	0.48

* $P < 0.01$

TABLE XXXI

NESTED ANALYSIS OF VARIANCE, BRILLOUIN EVENNESS. SITE GROUPS ARE THE SITE GROUPS FORMED BY A CLUSTER ANALYSIS OF NATURAL LOGARITHM TRANSFORMED ABUNDANCE DATA COLLECTED FROM JULY 1974-MARCH 1976

A. ANOVA Table

	SS	DF	MS	F
Between site groups	0.79	12.	0.0657	1.33(NS)†
Between sites within groups	4.68	95. 94.3	0.0492 0.0495	2.34*
Within sites	8.14	386.	0.0211	

B. Variance Components

	Variance Component	Percent
Between site groups	0.0006	2.08
Between sites within groups	0.0062	22.17
Within sites	0.0211	75.75

C. Student-Newman-Keuls Multiple Range Test: Table of Means (sorted). Bar represents the range of non-significant ($p > 0.05$) differences in means.

Site Groups	N	Mean	Std. Deviation
Site 2	5	0.74	0.42
Hinchinbrook Entrance Group	26	0.76	0.08
Site Group 6	10	0.78	0.19
Site Group 42	17	0.78	0.21
Site Group 39	8	0.80	0.11
Site Group 4	36	0.84	0.10
Tarr Bank Group	29	0.87	0.12
Inshore Group	258	0.87	0.19
Site Group 3	9	0.89	0.05
Shelf Break Group	87	0.90	0.08
Site 57	3	0.93	0.04
Site Group 53	3	0.94	0.05
Site 1	3	0.97	0.04

† (NS) = Not significant, $P > 0.05$
* $P < 0.01$

TABLE XXXII

NESTED ANALYSIS OF VARIANCE, SIMPSON DIVERSITY. SITE GROUPS ARE THE SITE GROUPS FORMED BY A CLUSTER ANALYSIS OF NATURAL LOGARITHM TRANSFORMED ABUNDANCE DATA COLLECTED FROM JULY 1974-MARCH 1976

A. ANOVA Table

	SS	DF	MS	F
Between site groups	0.68	12.	0.0574	4.63*
Between sites within groups	1.17	95.	0.0123	1.95*
Within sites	2.44	386.	0.0063	

B. Variance Components

	Variance Component	Percent
Between site groups	0.0016	17.33
Between sites within groups	0.0013	14.23
Within sites	0.0063	68.44

C. Student-Newman-Keuls Multiple Range Test: Table of Means (sorted). Bars represent the ranges of non-significant ($p > 0.05$) differences in means.

Site Groups	N	Mean	Std. Deviation
Shelf Break Group	87	0.07	0.05
Tarr Bank Group	29	0.08	0.11
Site 57	3	0.10	0.05
Inshore Group	258	0.11	0.06
Site Group 4	36	0.12	0.06
Site Group 3	9	0.12	0.06
Hinchinbrook Entrance Group	26	0.16	0.07
Site Group 42	17	0.17	0.22
Site 1	3	0.17	0.03
Site Group 53	3	0.20	0.06
Site Group 39	8	0.20	0.09
Site Group 6	10	0.24	0.19
Site 2	5	0.29	0.40

* $P < 0.01$

group composition) appeared to be substantially lower than in the other major site groups (Inshore Group, Tarr Bank Group, Hinchinbrook Entrance Group). Among the major station groups, species richness and Brillouin diversity increase from the low values found in the Inshore Group through Site Group 4, Hinchinbrook Entrance Group (Sites 53 and 54), the Shelf Break Group to the high values in the Tarr Bank Group (Sites 56 and 57).

VII. DISCUSSION

Numerical Analysis

Numerical analysis makes the evaluation of large data sets feasible, and its use has greatly reduced the subjective element in the analysis of benthic faunal distributions. However, numerical techniques have not completely eliminated subjectivity. Among the subjective decisions required during the development of the numerical analysis protocols used in this study were the selection of (1) a method of data standardization of transformation (if any were desired); (2) a similarity coefficient; and (3) a clustering strategy and method of ordination. A subjective judgement delimiting the groups formed by the analysis must also be made, either by examining a dendrogram (classification) or loadings of points on coordinate or component axes (ordination). Rather than make an *a priori* selection of any single method of analysis we decided to use a range of analytical strategies. The effectiveness of each analysis was then evaluated by using two-way coincidence tables and examining the extent to which the groupings that were formed by cluster analysis reflected environmental (physical, chemical, biological) conditions.

Some form of data transformation or standardization has often been utilized in the analysis of benthic communities (Field and MacFarlane, 1968; Field and Robb, 1970; Ebeling *et al.*, 1970; Day *et al.*, 1971; Thorrington-Smith, 1971; Stephenson and Williams, 1971; Stephenson *et al.*, 1972; Raphael and Stephenson, 1972; Williams and Stephenson, 1973; Levings, 1975; Maurer *et al.*, 1978). Boesch (1973) used a double standardization to eliminate the effects of differences in abundance between individuals. He argued that two species which might have "similar habitat

text continued from page 90.

requirements, yet one is always much more abundant than the other", would be segregated by the analysis unless abundances are standardized. We agree that some form of standardization or transformation should be utilized; however, differences in abundance may also imply that differences in the suitability of the habitat for the species in question may, in fact, exist. In the absence of a thorough knowledge of the habitat requirements of the species utilized for the analysis we feel that both unaltered and transformed or standardized data should be examined.

The Czekanowski coefficient was used in the present study to calculate similarity matrices for cluster analysis because it tends to emphasize the effect of dominant species on the classification. Raphael and Stephenson (1972) found that the Czekanowski coefficient, with its emphasis on dominant species, produced station groups that were more closely correlated with abiotic attributes. The Canberra "metric" similarity coefficient has also been used extensively in studies of benthic infaunal community structure (Boesch, 1973; Maurer *et al.*, 1978). Unlike the Czekanowski coefficient, the Canberra metric coefficient tends to reduce the effect of dominant species on the analysis. Both the Czekanowski and Canberra "metric" similarity coefficients were used to calculate similarity matrices for principal coordinate analyses. The use of the two coefficients in principal coordinate analyses enabled us to compare the relative similarity of stations as delineated by analyses ranging from one which placed a strong emphasis on the numerically dominant species (Czekanowski coefficient, untransformed data) to one placing a more equal emphasis on all species in spite of differences in their abundance (Canberra "metric" coefficient, *ln* transformed data).

A hierarchical agglomerative clustering strategy was used to create dendrograms from similarity matrices. We have found that the group-average sorting strategy gives useful results, and we have used it almost exclusively here. Boesch (1973) and Stephenson *et al.* (1972) used both group average and "flexible" sorting strategies (Lance and Williams, 1966). Boesch (1973) found the flexible strategy yielded "the more instructive classification" while Stephenson *et al.* (1972), using a variety of criteria, found both strategies to have merit. We experimented with the use of the flexible sorting strategy with $\alpha = 0.85$ and found that the results were not appreciably different from those obtained using the group average strategy.

Separate analyses of data collected during three sampling periods (July 1974-May 1975, September-December 1975 and March 1977), as well as an analysis of all data combined, yielded similar results (Appendix I, Figs. 2 and 3; Appendix II, Figs. 4 and 9; Text, Figs. 4, 9 and 15). Four major site groups were identified: the Inshore Group, the Shelf Break Group, the Tarr Bank Group (Sites 56 and 57) and the Hinchinbrook Entrance Group (Sites 53 and 54). Although the composition of the groups changed slightly with time and with the method of analysis, the same basic groups were consistently identified (Appendix I, Figs. 2 and 3; Appendix II, Figs. 4 and 9; Text, Figs. 4, 9 and 15). When untransformed data were used in the analysis the Inshore Group was consistently split into two subgroups, Inshore Groups 1 and 2 (Appendix I, Fig. 2; Appendix II, Fig. 4; Text, Fig. 4). The division of the Inshore Group into subgroups by numerical analyses of untransformed data was the result of differences in the abundance of many of the species common to both groups. We have not yet found a satisfactory method of determining if a distinction between Inshore Group 1 and 2 based on these slight differences in the abundance and composition of their species complement is statistically valid. However, the fact that Sites 31, 40, 41 and 42 were consistently classified as members of Inshore Group 2 by cluster analysis of untransformed data suggests that there may be differences in the environment at these stations that are reflected in the compositions of their fauna.

Cluster analysis of untransformed abundance data collected during OSS *Discoverer* cruise DS001 split the Shelf Break Group sites into two subgroups, Shelf Break Groups 1 and 2 (Fig. 4). An analysis of the combined data (July 1974-March 1976) also defined a separate group, Site Group 4, which contained many of the same stations (S76-43, S76-44, S76-48, S76-58, S76-69; Table XXI; Fig. 15) as Shelf Break Group 1 (cluster analysis, untransformed data, OSS *Discoverer* cruise DS001; Fig. 4). A principal coordinate analysis (Figs. 6 and 7) indicates that the fauna of sites in Shelf Break Group 1 (DS001; Fig. 4) and Site Group 4 (combined data; Fig.

15) may be transitional between that found in the Inshore Group(s) and Shelf Break 2. However, the fauna in Shelf Break Group 1 sites is much more similar to that of Shelf Break Group 2 than that of the Inshore Group.

An examination of the dendrogram produced by cluster analysis of the combined data (Fig. 15) indicates the presence of seasonal subgroups within two of the major site groups, the Inshore Group and the Shelf Break Group. However, the differences in the faunal complement of these subgroups were slight in comparison to differences between the site groups. In addition, at several sites, stations occupied during different cruises were not always classified as members of the same group (Table XXVI). In most of these cases, the shift in the classification of these sites was due to a decrease in the abundance and species richness of the fauna rather than a major change in the species assemblage at the site. Although, the slight temporal fluctuations indicated by a cluster analysis of combined data may be due to seasonal or long-term temporal variations in the fauna there are several alternate explanations. During the first year of this study only three or occasionally four grabs were taken at each station; after that five grabs were routinely collected. Therefore, distinctions between stations occupied from July 1974 to May 1975 (Su74-S75; Fig. 15) and those occupied subsequently (F75 and S76; Fig. 15) are at least partly due to new species collected by the additional grabs. Other factors which might be partially responsible for apparent temporal fluctuations noted by cluster analysis include navigational difficulties in precisely relocating the same site and the high spatial variability of the fauna.

Factors Affecting the Distribution of the Fauna

The major discontinuities in faunal distributions in NEGOA appear to be related to changes in sediment size distributions (Fig. 18; Table XXXIII) which in turn are controlled by the deposition of predominantly glacially derived fine sediments (Fig. 19; Feely and Cline, 1977; Molnia and Carlson, 1977). The principal sediment sources in NEGOA are the Copper River and coastal streams draining the Bering, Guyot, and Malaspina Glaciers. As this material enters the Gulf of Alaska, westward currents deflect it to

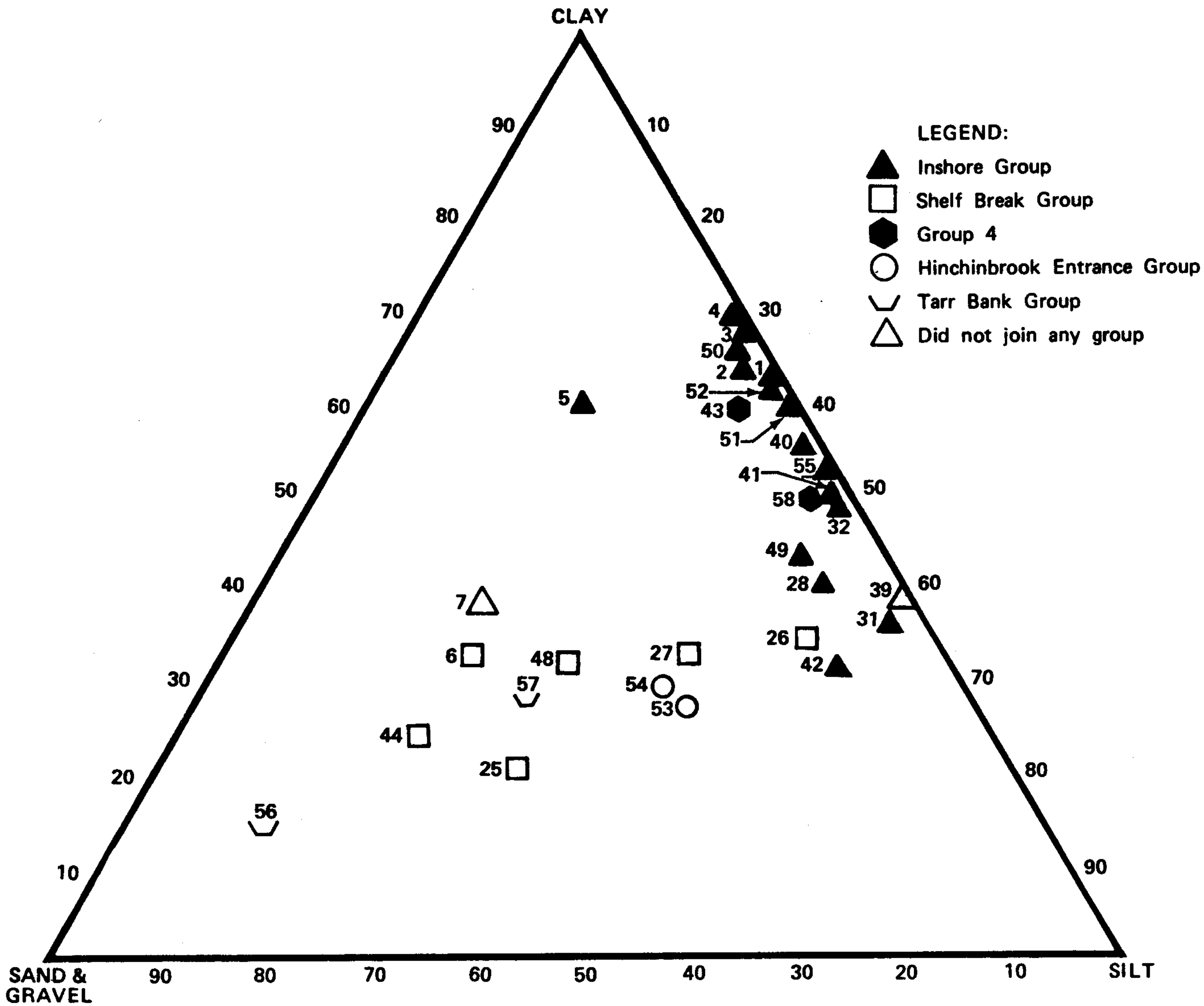

Figure 18. Ternary diagram of gravel-sand, silt and clay contents. Stations are symbolized following the groupings formed by cluster analysis of number of individuals/m^2 data collected from July to March 1976.

TABLE XXXIII

SEDIMENT SIZE DISTRIBUTION BY SITE GROUP

Site Number	Depth	% Gravel	% Sand	% Silt	% Clay
Inshore Group					
1	263	0	1.08	37.10	61.82
2	219	0	3.35	33.85	62.80
3	220	0	0.40	31.92	67.68
4	200	0	0.42	30.70	68.87
5	174	3.12	16.84	20.25	59.80
28	239	0.27	6.87	52.66	40.20
32	179	0	0.42	51.09	48.49
49	186	0	7.71	49.53	42.75
50	164	0	2.50	33.30	64.20
51	135	0	0.27	39.54	60.19
52	53	0	0.44	37.83	51.72
55	117	0	1.26	48.22	50.52
31	117	0	1.68	62.70	35.62
40	195	0	0.23	44.53	55.24
41	119	0	0.31	49.37	50.12
42	93	0	10.58	58.88	30.54
Site Group 4					
43	117	0	4.39	35.85	59.76
58	97	0	3.41	47.00	49.59
Hinchinbrook Entrance Group					
53	279	0	28.07	46.02	25.91
54	204	0	27.94	43.47	28.49
Site Group 3					
7	220	0	36.11	21.59	42.29
59	334	-	-	-	-
Tarr Bank Group					
56	64	24.39	42.49	18.05	15.07
57	67	26.59	14.20	29.39	26.83
Shelf Break Group					
6	151	6.27	37.69	23.42	32.62
26	148	4.32	8.47	53.64	33.57
27	129	13.17	10.49	43.56	32.88
33	219	-	-	-	-
35	179	1.18	44.96	33.42	20.44
44	181	3.01	50.64	22.95	23.40
48	117	19.95	15.54	33.51	31.00
Station 30	43	-	-	-	-
Station 39	549	0	0.10	61.15	38.75

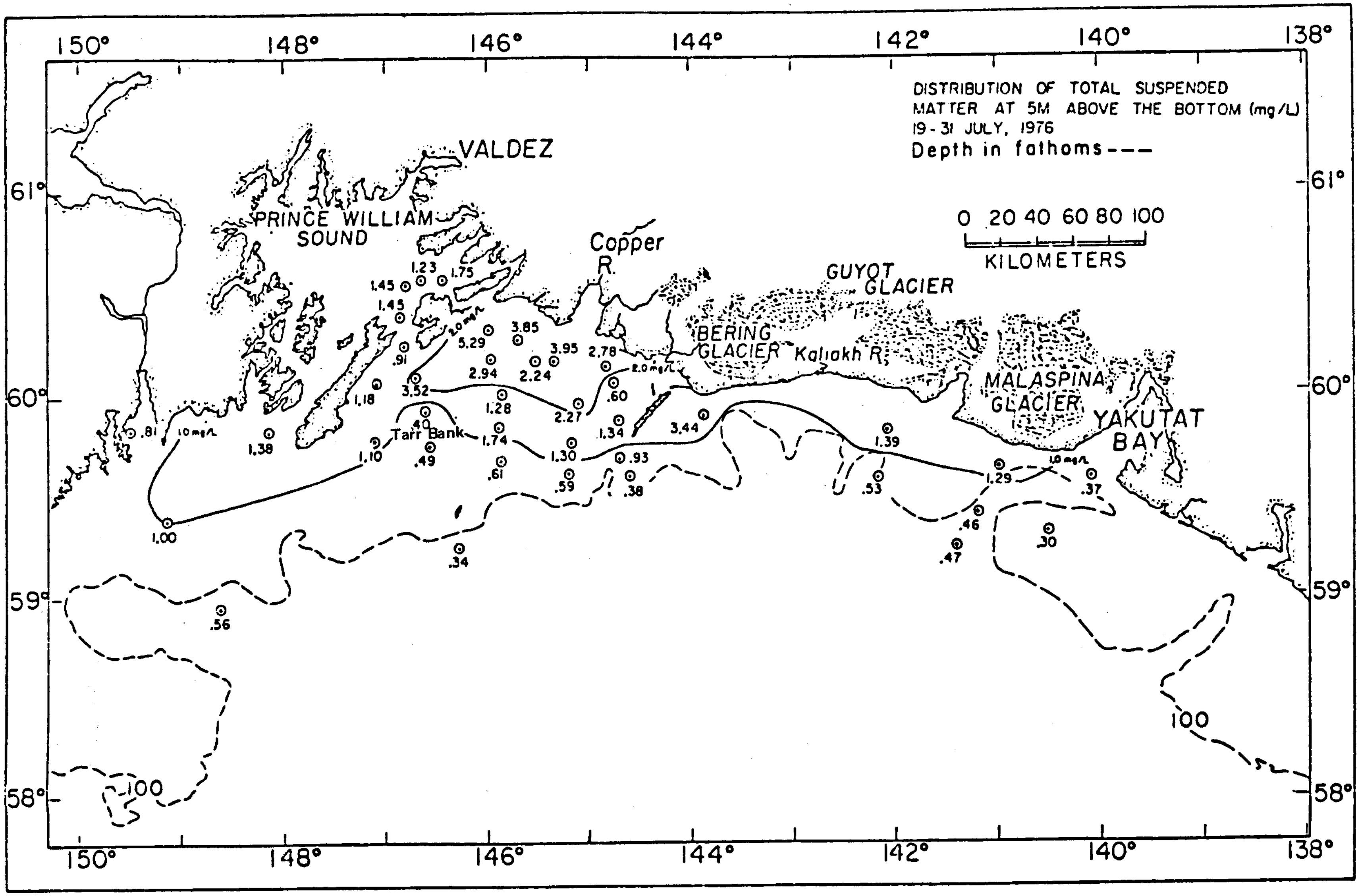

Figure 19. Distribution of total suspended matter at 5 m above the bottom in the northeastern Gulf of Alaska, 19-31 July 1976 (Figure from Feely and Cline, 1977).

the west except near Kayak Island where it is deflected to the southwest and then trapped in a counterclockwise gyre west of Kayak Island (Sharma *et al.*, 1974; Burbank, 1974; Feely and Cline, 1977). This results in high sedimentation rates and a high suspended sediment load throughout much of the shelf area west of Yakutat Bay except on topographic highs such as Tarr Bank where scouring by strong bottom currents and frequent winter storm waves probably prevents sediment accumulation (Fig. 19; Molnia and Carlson, 1977). The westward transport of suspended sediment by the Alaska Stream prevents the accumulation of sediment along the shelf break and on the continental slope. Sediment deposition on the vicinity of Hinchinbrook Entrance is probably limited by currents (up to ca. 50 cm/sec, T. Royer, Inst. Mar. Sci., Univ. Alaska, person. commun.) moving in and out of Prince William Sound.

The sediments in the major site groups ranged from predominantly silts and clays in most of the sites in the Inshore Group to about 25% gravel mixed with sand, silt and clay in the Tarr Bank Group (Sites 56 and 57; Fig. 18; Table XXXIII). The sediments in the Hinchinbrook Entrance Group (Sites 53 and 54), about 28% sand mixed with silt and clay, and the Shelf Break Group, from 3 to 19% gravel mixed with sand (8-50%), silt and clay, were intermediate in terms of mean grain size (Fig. 18; Table XXXIII).

The fauna of the Inshore Group, where sediments were fine and the sedimentation rate (as indicated by the suspended load above the bottom; Fig. 19) was high, consisted primarily of motile deposit-feeding organisms (Table XX; Species Group 26, Tables XXII and XXIII) which were widely distributed throughout NEGOA. Since all sites contained at least 30% silt and clay (Table XXXIII), it is not surprising that many of the species which successfully occupied the muddy environment of the Inshore Group sites were widely distributed. The fauna of the Hinchinbrook Entrance Group (Sites 53 and 54) was also dominated by deposit feeding organisms (Table XXII). However, the abundance (Table XXVII), biomass (XXVIII), species richness (Table XXIX) and diversity (Table XXX) of the fauna appeared to be greater in the Hinchinbrook Entrance Group than in the Inshore Group.

As the sediment changed from silt and clay in the Inshore Group to sand and gravel mixed with silt and clay in the Shelf Break Group and the Tarr Bank Group (Sites 56 and 57), greater numbers of sessile and suspension feeding organisms were collected (Appendix V, Table III; Appendix II, Table VIII; text Table XX). The diversity and species richness of the fauna in the Tarr Bank and the Shelf Break stations were among the highest found in NEGOA (Tables XXIX and XXX). There are several possible explanations for the increase in diversity in the Shelf Break and Tarr Bank sites. The most obvious one is the increase in environmental heterogeneity provided by the presence of sand and gravel. Among the organisms found in the Tarr Bank Group and to a lesser extent in the Shelf Break Group were brachiopods, bryozoans and other organisms which require a solid substrate for attachment.

The reduction in the abundance of suspension feeding organisms in muddy sediments, noted by many investigators (Davis, 1925; Jones, 1950; Sanders, 1956, 1958; Thorson, 1957; McNulty *et al.*, 1962), may be partly responsible for the reduced diversity in the Inshore Group. Rhoads and Young (1970) hypothesized that the activities of deposit feeding organisms will tend to exclude suspension feeders by creating an easily-resuspended, unstable, sedimentwater interface which tends to clog the gills of suspension feeders, and bury or inhibit settling of their larvae. In addition, sediment instability may act to exclude suspension feeders by requiring excessive energy expenditure to maintain contact with the overlying waters (Myers, 1977). Throughout much of the shelf of NEGOA high sedimentation rates result in poorly consolidated fine deposits (Molnia and Carlson, 1977) which are easily resuspended (Feely and Cline, 1977). Thus, as suggested by Rhoads and Young (1970), these conditions should tend to exclude suspension feeding organisms.

Jumars and Fauchald (1977) postulated that sessile species would tend to be excluded from areas with disturbed sediments or high sedimentation rates due to the effects of burial and "alteration of local sediment characteristics, probably giving an advantage to those individuals who can move to locally optimum conditions". They further hypothesized that the relative abundance of sessile individuals would decrease as the flux of organic material to the substrate decreased. They reasoned that in areas with a limited food supply "the foraging radius required for adequate nutrition exceeds the reach of most sessile individuals". Since much of the sediment deposited in NEGOA is of glacial origin, it might be expected that these sediments would be relatively low in organic carbon. For example, the relatively low carbon values in the outwash deltaic complex formed by the Lowe River and Valdez Glacier stream in Port Valdez, an embayment of Prince William Sound, indicate that the glacially derived sediments deposited by these rivers contain low organic carbon concentrations (Sharma and Burbank, 1973). Thus, the reduced abundance of sessile organisms from areas with high rates of deposition of glacially derived sediments in the Gulf of Alaska may be due, in part, to low concentrations of organic material in the sediments.

The Community Concept

There was no evidence that discrete communities such as those described by Petersen (1911) and Thorson (1957) could be identified in the northeast Gulf of Alaska (NEGOA). In fact, our data suggest that the species found in NEGOA distribute themselves independently along environmental gradients (also see Whittaker, 1970).

A minimum of 28 species groups were required to describe the spatial distribution patterns found during a single cruise and 53 species groups were required to describe spatial and temporal distribution patterns over a 21 month period. Moreover, there was considerable variation in the abundance patterns of the species within these groups. The change in the faunal composition and the increase in diversity and species richness that occurs as the amount of sand and gravel in the sediment increases indicates that sediment size is a major factor in controlling species distributions. We can identify groups of species which are characteristic of different sedimentary environments in NEGOA. However, the variation between individual species distribution patterns, especially within the species groups which characterize silt-clay environments, indicate that environmental conditions other than grain size and deposition rate also affect their distributions.

The variance structure of the data also suggest that discrete communities do not exist in NEGOA. Although there was a significant difference between site groups for most parameters tested (biomass, Brillouin diversity, species richness, Simpson diversity; Tables XV-XIX, XXVII-XXXI), there was also a significant, but generally smaller, difference between stations within the site groups for these parameters. The formation of site groups by cluster analysis was successful in partitioning the between site variance so that a greater percentage of the variance was attributed to differences between site groups than to differences between sites within site groups. However there was still a considerable amount of variance associated with differences between sites. Thus, it appears that the delineation of site groups by cluster analysis has identified the largest discontinuities in a near continuation of species distributions (also see Stephenson, 1973; Boesch, 1973). Principal coordinate analyses have also identified sites and site groups which appear to be transitional between the major site groups.

VIII. CONCLUSIONS

Forty-one widely dispersed permanent sites have been established in the northeast Gulf of Alaska (NEGOA) in conjunction with the physical, chemical, heavy metals and hydrocarbon programs. These sites represent a reasonable nucleus around which a monitoring program can be developed.

The sampling device chosen, the van Veen grab, adequately sampled the infauna at most sites. Penetration was excellent in the soft sediments characteristic of the majority of sites; poor penetration occurred at a few sites where substratum was sandy or gravelly.

The general patchiness of infaunal species initially observed suggested that at least five replicate grabs be taken per site. An analysis of grab-sampling efficiency indicated that all but the rarer species were sampled with five replicates.

There is now a satisfactory knowledge, for grab stations, of invertebrate species (infauna and epifauna) present and general species distribution on the shelf in the northeast Gulf of Alaska study area. Approximately 515 taxa have been identified. Fourteen marine phyla are represented in the collections. The important groups, in terms of number of species in descending order, are the polychaetous annelids, molluscs, arthropods (crustaceans), and echinoderms. It is probable that all species of numerical and biomass importance have been collected during the intensive sampling accomplished on OCSEAP cruises in NEGOA and that only rare species will be added to the list in the future.

The diversity indices included in the 1976 Annual Report (Feder *et al.*, 1976) and this Final Report, Simpson, Brillouin, and Shannon-Wiener are complementary to each other since the former reflects dominance of a few species and the latter two are weighted in favor of rare species. Values calculated, in general, reflect these weightings. A preliminary examination of the two measures of evenness (or equitability) indicates a reasonable relationship to the calculated diversity values. In general, high measures of evenness show numerical codominance of many species (with low Simpson index and high Shannon-Wiener and Brillouin indices) while low evenness measures must still be interpreted with considerable caution until more data is available, and further detailed assessment of the meaning of the calculated values can be made.

Information on feeding biology of most species has been compiled. Most of the information for the northeast Gulf of Alaska is from literature source material; it is suggested that experimental work on feeding biology of selected species be encouraged for this region.

Clustering techniques have supplied us with valuable insights into species distributions on the shelf of the northeast Gulf of Alaska. The preliminary grouping of stations by three different classification schemes has delineated four basic site groups. Further insight into the meaning of stations clustered by our analysis is gained by means of the two-way coincidence table of site groups vs. species groups. Specific groupings of species can be related to site groups, and intermediate positions of stations (or site groups) can be determined by the particular groupings of species they have in common.

Initial qualitative assessment of data printouts of infaunal species (data to be stored at the National Environmental Data Center) indicates that, (1) sufficient station uniqueness exists to permit development of an adequate monitoring program based on species composition at selected sites, and (2) adequate numbers of unique, abundant, and/or large species are available to ultimately permit nomination of likely monitoring candidates.

The National Marine Fisheries Service trawl charter for investigation of demersal fishes and epifaunal benthos was effective and maximum spatial coverage was achieved. Integration of this information with the infaunal benthic data will enhance our understanding of the shelf ecosystem.

Availability of many readily identifiable, biologically well-understood organisms is a preliminary to the development of monitoring programs. Sizeable biomasses of taxonomically well-known molluscs, crustaceans, and echinoderms were typical of most of our stations, and many species of these phyla were sufficiently abundant to represent organisms potentially useful as monitoring tools. The present investigation should clarify some aspects of the biology of many of these organisms, and should increase the reliability of future monitoring programs for the Gulf of Alaska.

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APPENDIX I

NUMERICAL ANALYSIS OF GRAB DATA COLLECTED DURING THE FIRST YEAR OF SAMPLING IN THE NORTHEASTERN GULF OF ALASKA (FROM FEDER *ET AL.*, 1977)

APPENDIX I - CLUSTER ANALYSIS OF BENTHIC INVERTEBRATE DATA

Cluster analysis was utilized to define groups of stations which had a similar faunal composition and groups of species which were characteristic of the station groups. We feel that this technique provides an excellent tool for proper selection of monitoring sites and for detection of changes in the fauna caused by environmental disturbances (Feder *et al.*, 1976).

Methods

A brief summary of the methods of analysis will be presented here. More detailed information is available in Feder *et al.*, (1976). Since research vessel scheduling and inclement weather prevented seasonal coverage of the entire station grid during the first year of the study, data from the five cruises listed below had to be pooled to obtain complete coverage: Cruise 193 R/V *Acona* - July 1974; Cruise 200 R/V *Acona* - October 1974; Cruise 202 R/V *Acona* - November 1974; Cruise 805 R/V *Oceanographer* - February 1975; Cruise 807 R/V *Townsend Cromwell* - May 1975

This data includes samples from part of cruise 805 and all of cruise 807, which were not available for inclusion in Feder *et al.*, (1976). Analysis of the data collected on all of these cruises yielded 315 taxa collected from 50 stations (several stations were sampled on more than one occasion). The data matrix of 50 stations x 315 taxons was reduced by eliminating all organisms which occurred only at one station and in such low numbers that they would have little effect on the analysis. In addition, several stations which were inadequately sampled for reliable quantitative data (Stations 7, 29, 30, 33, 37, 39, 43, and 59; Fig. 1) were excluded from analyses using quantitative data. Five separate cluster analyses were run using the following data:

1. Untransformed number of individuals/m^2.
2. Natural logarithm transformed number of individuals/m^2.
3. Untransformed wet weight/m^2 data.
4. Natural logarithm transformed wet weight/m^2 data.
5. Presence-absence data (all stations were included).

Both normal (comparing stations) and inverse (comparing species) cluster analysis were run on all data.

Samples from cruise 811, USNS *Silas Bent*, September 1975 and cruise 816, *Discoverer*, November-December 1975 have been processed by the Marine Sorting Center, and are now being prepared for submission to NODC. A listing of the stations occupied and the species identified are included in Tables I and II. These two cruises gave us complete coverage of the station grid established for the lease area. Cluster analyses have been run on this data, but they have not been examined in sufficiant detail for inclusion in this report.

A more detailed evaluation of this data will be included either in the next quarterly report or as a special data report.

Results

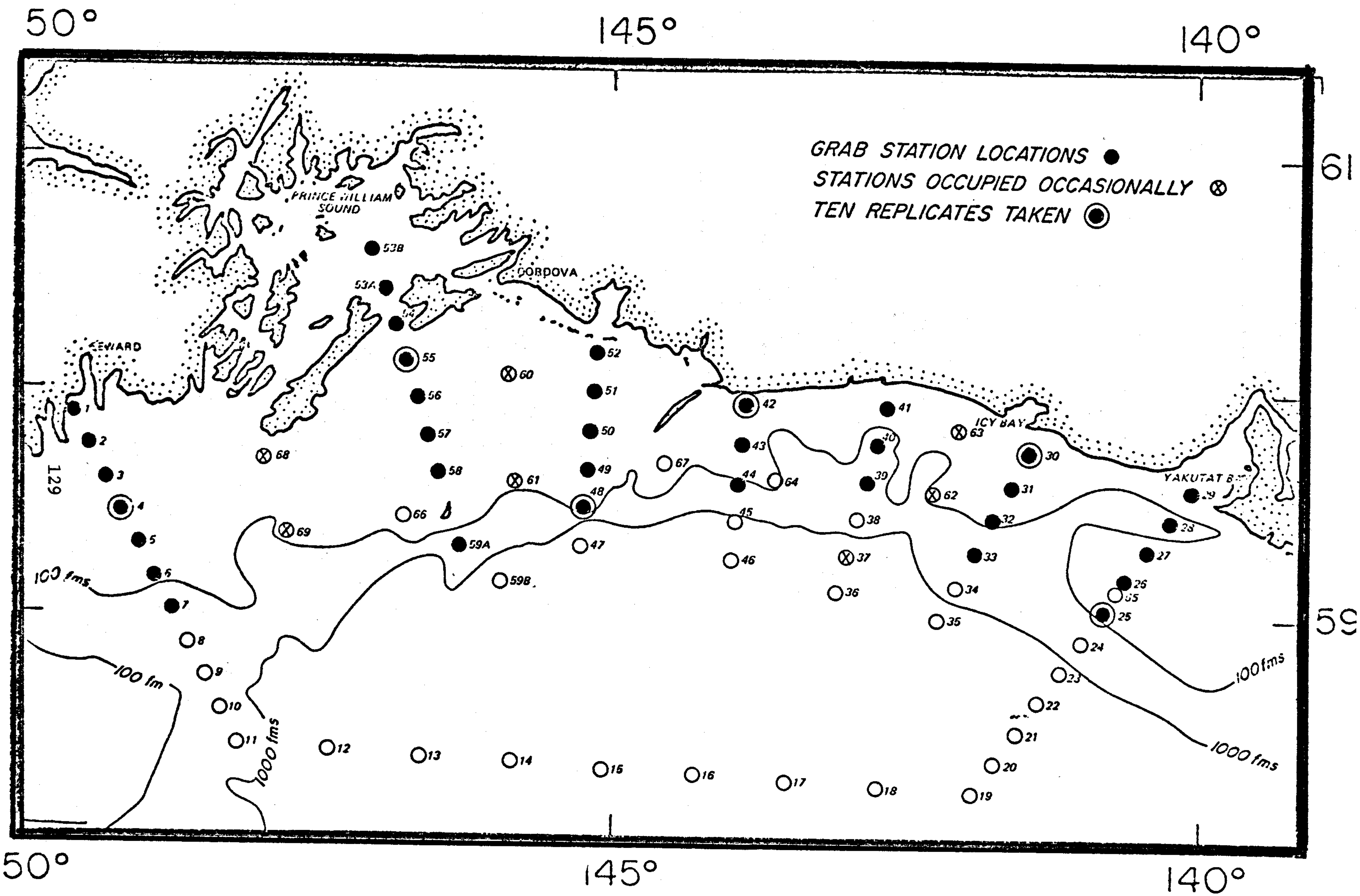
Station groups formed by normal cluster analysis are shown in Figures 1 through 5. To avoid confusion, only the major station groups were plotted. Tables III through VII list all the station groups formed by the five cluster analyses utilized. A normal cluster analysis delineated three major station groups at the 30 percent similarity level (Fig. 2). One group of stations (labeled Inshore Group I) is located south of Prince William Sound and Cordova. Inshore Group II consists of a large block of stations to the east of Inshore Group I and several stations south of Resurrection Bay. A third group (labeled Shelf Break Group) consists of stations located at or near the 200-m contour. Several stations including stations 56 and 57 have a unique enough fauna so that they do not enter any of the cluster groups formed (Fig. 2; Table III). The species groups formed by an inverse analysis of untransformed number/m^2 data are listed in Table VIII.

Tables III and IX list some of the properties of the stations in the various station groups. The values listed in Table IX are mean values for all stations in each group. The sediments in both of the inshore station groups are predominantly silts and clays while the shelf break stations and stations 56 and 57 have considerable quantities of sand and gravel mixed with silt and clay. An analysis of variance demonstrated that the diversity of the shelf break stations and stations 56 and 57 is significantly higher ($P < 0.05$) than that of the inshore stations (Table IX). Coincident with the difference in sediment types between the inshore station groups and the shelf break stations as well as stations 56 and 57, there is a shift in the distribution of feeding types within the fauna. The fauna of the inshore station groups is dominated by deposit feeders whereas suspension feeders are dominant in the shelf break stations and in stations 56 and 57 (Table IX).

The major station groups delineated by cluster analyses using *ln* transformed number/m^2 data, untransformed and *ln* transformed wet weight/m^2 data and presence-absence data are shown in Figures 3 through 6. Although the boundaries of the major station groups change somewhat when different data bases are used, the major station groups illustrated in Figure 2 are still recognizable. When wet weight/m^2 data was used in the analysis, Inshore Group II was greatly reduced in size (Fig. 4). Species which have a large biomass but are present in low numbers will have little effect on station grouping when abundance data is used, but they will have a very great effect on those groupings when wet weight/m^2 data is used. The fragmentation of larger station groups into several smaller ones are caused by the distribution of these large species. The use of a natural log transformation reduces the effect of these species. When natural log transformed wet weight/m^2 data was used, Inshore Groups I and II merged to form a single large inshore station group (Fig. 5). Cluster analysis of presence-absence data included those stations which could not be sampled quantitatively. The addition of these stations to the analysis added two new station groups seaward of the Shelf Break Group (Fig. 6).

Since the data from four different cruises had to be pooled to get complete coverage of the lease area, seasonal changes in the fauna may be confusing the results. For example, some of the stations which have been sampled on more than one occasion are classified into different station groups when sampled at different times. A great deal of caution must be applied in interpreting these results until they can be compared with data from the *Silas Bent* cruise of September 1975 and the *Discoverer* cruise of March 1976. However, a preliminary analysis of the data collected in the fall of 1975 (cruises 811 and 816) seems to indicate that there has been very little change in the structure of the station groupings (Fig. 7).

The results of the analyses appear to indicate that there is a change in the infaunal community along a gradient that is related to changes in depth and sediment grain size distribution.



Appendix I - Figure 1. Station grid established for oceanographic investigations in the northeastern Gulf of Alaska.

APPENDIX I - TABLE I

LIST OF THE STATIONS PROCESSED FROM CRUISE 811 USNS *SILAS BENT*, SEPTEMBER 1975 AND CRUISE 816 R/V *DISCOVERER* NOVEMBER-DECEMBER 1975

GULF OF ALASKA BENTHIC GRAB DATA -- SEPTEMBER-DECEMBER 1975 03/04/77 PAGE 1

STATION-SAMPLE LISTING

		TOT CNT	TOT WWGT	CNT/SQM	WWGT/SQM	GRABS
CRUISE 811	STATION 001	166.	17.711	332.	35.423	0001 0002 0003 0005 0004
CRUISE 811	STATION 002	116.	14.146	232.	28.291	0001 0005 0004 0002 0003
CRUISE 811	STATION 003	230.	20.450	460.	40.900	0003 0002 0001 0004 0005
CRUISE 811	STATION 004	264.	11.825	264.	11.825	0001 0003 0007 0006 0005 0004 0010 0002 0009 0008
CRUISE 811	STATION 005	208.	5.719	416.	11.437	0001 0004 0003 0002 0005
CRUISE 811	STATION 006	724.	2.154	1448.	4.309	0002 0005 0004 0003 0001
CRUISE 811	STATION 007	370.	5.132	740.	10.265	0001 0002 0005 0004 0003
CRUISE 811	STATION 026	207.	0.953	518.	2.382	0002 0003 0001 0005
CRUISE 811	STATION 027	300.	1.321	600.	2.643	0001 0004 0005 0002 0003
CRUISE 811	STATION 028	272.	3.371	544.	6.743	0005 0004 0002 0001 0003
CRUISE 811	STATION 030	905.	4.100	905.	4.100	2. 5 9 7 4 6 10 8 3 1
CRUISE 811	STATION 031	492.	9.733	984.	19.465	0001 0002 0005 0004 0003
CRUISE 811	STATION 032	206.	6.757	412.	13.514	0001 0002 0005 0004 0003
CRUISE 811	STATION 033	315.	2.672	630.	5.343	0003 0001 0005 0004 0002
CRUISE 811	STATION 040	406.	4.947	812.	9.894	0003 0005 0002 0001 0004
CRUISE 811	STATION 041	722.	6.960	1444.	13.920	0003 0002 0004 0005 0001
CRUISE 811	STATION 042	914.	7.362	914.	7.362	0001 0002 0010 0008 0009 0007 0005 0006 0004 0003
CRUISE 811	STATION 043	556.	5.630	1112.	11.259	0002 0005 0004 0003 0001
CRUISE 811	STATION 048	143.	4.303	286.	8.606	0001 0005 0003 0004 0002
CRUISE 811	STATION 049	325.	8.691	650.	17.381	0005 0002 0004 0001 0003
CRUISE 811	STATION 050	208.	9.029	416.	18.058	0002 0005 0001 0003 0004
CRUISE 811	STATION 051	147.	9.928	294.	19.856	0001 0002 0005 0003 0004
CRUISE 811	STATION 052	97.	1.991	194.	3.983	0005 0003 0001 0004 0002
CRUISE 811	STATION 053	718.	10.607	1436.	21.213	0004 0002 0003 0005 0001
CRUISE 811	STATION 056	795.	9.717	1590.	19.434	0003 0004 0005 0002 0001
CRUISE 811	STATION 057	635.	8.935	1270.	17.869	0004 0002 0003 0005 0001
CRUISE 811	STATION 058	827.	7.189	1654.	14.377	0003 0001 0004 0002 0005
CRUISE 816	STATION 025	498.	2.453	498.	2.453	0003 0002 0001 0006 0004 0008 0010 0005 0009 0007
CRUISE 816	STATION 039	170.	1.367	340.	2.735	0002 0003 0004 0005 0001
CRUISE 816	STATION 044	490.	2.568	980.	5.135	0002 0001 0003 0004 0005
CRUISE 816	STATION 048	755.	3.212	755.	3.212	0010 0006 0004 0002 0008 0001 0003 0007 0005 0009
CRUISE 816	STATION 054	528.	18.510	1056.	37.019	0005 0004 0001 0002 0003
CRUISE 816	STATION 055	463.	22.591	463.	22.591	0007 0006 0002 0005 0009 0008 0001 0003 0004 0010
CRUISE 816	STATION 059	151.	1.911	302.	3.822	0002 0005 0003 0001 0004

TOTAL NUMBER OF STATIONS = 34.

APPENDIX I - TABLE II

LIST OF SPECIES IDENTIFIED FROM SAMPLES COLLECTED DURING CRUISE 811 USNS *SILAS BENT* SEPTEMBER 1975 AND CRUISE 816 R/V *DISCOVERER* NOVEMBER-DECEMBER 1975

GULF OF ALASKA BENTHIC GRAB DATA -- SEPTEMBER-DECEMBER 1975 03/04/77 PAGE 2

LIST OF ALL TAXONOMIC GROUPS FOUND

CRITERIA 1- TAXON OCCURS IN 50 PCT OR MORE OF STATIONS
CRITERIA 2- AT LEAST 10 PCT OF INDIVIDUALS AT SOME STATION
CRITERIA 3- AT LEAST 10 PCT OF WET BIOMASS AT SOME STATION
CRITERIA 4- ABUNDANT WRT NO. INDIVIDUALS AT SOME STATION
CRITERIA 5- ABUNDANT WRT TOTAL BIOMASS AT SOME STATION

TAXON CODE	TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
320000000000	PORIFERA			X	X	X	10
330100000000	HYDROZOA						7
330300000000	ANTHOZOA						1
330347000000	PENNATULACEA VIRGULARIIDAE		X		X		11
330350000000	ZOANTHINIARIA			X		X	4
400000000000	RHYNCHOCOELA	X					27
440000000000	NEMATODA			X			9
480100000000	POLYCHAETA	X			X		34
480101000000	POLYNOIDAE						11
480101020100	ANTINOELLA MACROLEPIDA						1
480101030000	ARCTEOBIA						1
480101030200	ARCTEOBIA SPINELYTRIS						4
480101050200	EUNOE DEPRESSA						2
480101060400	GATTYANA BRUNNEA						2
480101060500	GATTYANA IPHIONELLOIDES						1
480101060600	GATTYANA TREADWELLI						3
480101080000	HARMOTHOE SP						1
480101080600	HARMOTHOE IMBRICATA						5
480101110300	LEPIDONOTUS SQUAMATUS						2
480101150200	POLYNOE GRACILIS						1
480102000000	POLYNODONTIDAE						1
480102010000	PEISIDICE SP						1
480102010100	PEISIDICE ASPERA				X		9
480105000000	SIGALIONIDAE						3
480105010100	PHLOE MINUTA						7
480105030100	STHENELAIS FUSCA						3
480110000000	EUPROSINIDAE						0
480110010100	EUPHROSINE ARCTICA						1
480110010200	EUPHROSINE BICIRRATA						1
480112000000	PHYLLODOCIDAE						1
480112010000	ANAITIDES						3
480112010200	ANAITIDES GROENLANDICA						1
480112010400	ANAITIDES MUCOSA						1
480112010600	ANAITIDES MACULATA						4
480112020000	ETEONE SP.						1
480112020500	ETEONE LONGA						2
480112030000	EULALIA SP						1
480112030400	EULALIA BILINEATA						1
480120000000	HESIONIDAE						0
480120040100	OPHIODROMUS PUGETTENSIS						2
480121000000	PILARIGIDAE						0
480121020100	SIGAMBRA TENTACULATA						1
480122000000	SYLLIDAE						6
480122030400	SYLLIS SPONGIPHILA						1
480122050000	TYPOSYLLIS SP.				X		9
480122050100	TYPOSYLLIS ALTERNATA						4
480122050200	TYPOSYLLIS ARMILLARIS						2
480122050900	TYPOSYLLIS ADAMANTEA						1

LIST OF ALL TAXONOMIC GROUPS FOUND

CRITERIA 1- TAXON OCCURS IN 50 PCT OR MORE OF STATIONS
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CRITERIA 5- ABUNDANT WRT TOTAL BIOMASS AT SOME STATION

TAXON CODE	TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
480122051200	TYPOSYLLIS VARIEGATA						1
480122060200	EUSYLLIS BLOMSTRANDI						1
480122070000	EXOGONE SP				X		5
480122070600	EXOGONE VERRUGERA						2
480123000000	NEREIDAE						0
480123040000	NEREIS SP.						5
480123040300	NEREIS PELAGICA						4
480123040400	NEREIS PROCERA						2
480123040600	NEREIS ZONATA						5
480123060100	CERATOCEPHALE LOVENI		X		X		1
480124000000	NEPHTYIDAE						5
480124010000	NEPTHYS SP.	X					19
480124010200	NEPHTYS CILIATA						6
480124010300	NEPHTYS CAECA						2
480124010400	NEPHTYS CORNUTA						3
480124010500	NEPHTYS PUNCTATA	X			X		20
480124010600	NEPHTYS RICKETTSI						1
480124020000	MICRONEPTHYS SP						1
480124030200	AGLAOPHOMUS RUBELLA ANOPS						3
480125000000	SPHAERODORIDAE						0
480125020100	SPHAERODOROPSIS MINUTA						1
480125020300	SPHAERODOROPSIS SPHAERULIFER						1
480126000000	GLYCERIDAE						1
480126010000	GLYCERA SP.						1
480126010100	GLYCERA CAPITATA	X					21
480127000000	GONIADIDAE						0
480127010100	GLYCINDE PICTA						2
480127010300	GLYCINDE ARMIGERA						3
480127020100	GONIADA ANNULATA	X			X		21
480127020200	GONIADA MACULATA						2
480128000000	ONUPHIDAE						0
480128010000	ONUPHIS SP.						5
480128010100	ONUPHIS CONCHYLEGA						2
480128010200	ONUPHIS GEOPHILIFORMIS						4
480128010300	ONUPHIS IRIDESCENS	X			X		24
480128010500	ONUPHIS PARVA						3
480129000000	EUNICIDAE						0
480129010000	EUNICE SP						1
480129010200	EUNICE VALENS						3
480129010400	EUNICE KOBIENSIS						2
480130000000	LUMBRINERIDAE						0
480130010000	LUMBRINEREIS SP.	X			X		29
480130010100	LUMBRINEREIS BICIRRATA						4
480130010500	LUMBRINEREIS SIMILABRIS						7
480130010600	LUMBRINEREIS ZONATA	X			X		28
480130020200	NINOE GEMMEA	X			X		17
480132000000	ARABELLIDAE						0
480132010000	DRILONEREIS SP.						1

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TAXON CODE	TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
480132010400	DRILONEREIS FALCATA MINOR						15
480135000000	DORVILLEIDAE						0
480135010100	DORVILLEA PSEUDORUBROVITTATA						1
480139000000	PARAONIDAE						0
480139010200	HAPLOSCOLOPLOS ELONGATUS						4
480140020000	ARICIDEA SP.						3
480140020100	ARICIDEA SUECICA				X		8
480140020400	ARICIDEA JEFFREYSII						3
480140030000	PARAONIS SP.						1
480140030100	PARAONIS GRACILIS						5
480142000000	SPIONIDAE						2
480142020100	LAONICE CIRRATA				X		9
480142040000	POLYDORA SP.						2
480142050000	PRIONOSPIO SP.						1
480142050200	PRIONOSPIO CIRRIFERA						1
480142080200	BOCCARDIA NATRIX						1
480142100100	SPIOPHANES BOMBYX						2
480142100200	SPIOPHANES KROYERI				X		7
480142100300	SPIOPHANES CIRRATA		X		X		7
480142130200	PYGOSPIO ELEGANS						1
480143000000	MAGELONIDAE						0
480143010100	MAGELONA JAPONICA						5
480143010200	MAGELONA PACIFICA						1
480148000000	CHAETOPTERIDAE						0
480148030000	SPIOCHAETOPTERUS SP.						6
480148030200	SPIOCHAETOPTERUS COSTARUM				X		7
480149000000	CIRRATULIDAE						0
480149030000	THARYX SP.	X					18
480149040100	CHAETOZONE SETOSA						3
480152000000	FLABELLIGERIDAE						0
480152010000	BRADA SP.						1
480152010200	BRADA VILLOSA						4
480152020200	FLABELLIGERA AFFINIS						1
480152030000	PHERUSA SP.						1
480152030100	PHERUSA PAPILLATA						2
480152030200	PHERUSA PLUMOSA						3
480155000000	SCALIBREGMIDAE						0
480155010100	SCALIBREGMA INFLATUM						5
480156000000	OPHELIIDAE						1
480156010100	AMMOTRYPANE AULOGASTER						2
480156040100	TRAVISIA BREVIS			X			1
480156040200	TRAVISIA FORBESII						1
480156040300	TRAVISIA PUPA			X			2
480157000000	STERNASPIDAE						0
480157010100	STERNASPIS SCUTATA	X	X	X	X		25
480158000000	CAPITELLIDAE						1
480158010000	CAPITELLA SP						1
480158010100	CAPITELLA CAPITATA						14

LIST OF ALL TAXONOMIC GROUPS FOUND

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TAXON CODE	TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
480158030300	NOTOMASTUS LINEATUS						1
480161000000	MALDANIDAE	X					21
480161010000	ASYSCHIS S.						1
480161010200	ASYCHIS SIMILIS				X		6
480161030000	MALDANE SP.						3
480161030100	MALDANE SARSI				X		12
480161030200	MALDANE GLEBIFEX		X		X		12
480161040000	MALDANELLA SP						1
480161040100	MALDANELLA ROBUSTA						2
480161050000	NICOMACHE SP.						1
480161050100	NICOMACHE LUMBRICALIS						2
480161050200	NICOMACHE PERSONATA						2
480161060000	NOTOPROCTUS SP.						1
480161060100	NOTOPROCTUS PACIFICUS				X		9
480161090100	PRAXILLELLA GRACILIS	X			X		23
480161090200	PRAXILLELLA PRAETERMISSA						9
480161100100	RHODINE BIRORQUATA						6
480162000000	OWENIDAE						0
480162010200	OWENIA FUSIFORMIS		X		X		8
480162020000	MYRIOCHELE SP						1
480162020100	MYRIOCHELE HEERI	X	X		X		30
480163000000	SABELLARIDAE						0
480163010200	IDANTHYRSUS ARMATUS				X		5
480164000000	PECTINARIDAE						0
480164010100	AMPHICTENE AURICOMA						3
480164020100	CISTENIDES BREVICOMA						4
480164020300	CISTENIDES HYPERBOREA						1
480164030000	PECTINARIA SP.						1
480165000000	AMPHARETIDAE						11
480165010100	AMAGE ANOPS						3
480165020000	AMPHARETE SP.						8
480165020100	AMPHARETE ARCTICA	X			X		19
480165020800	AMPHARETE ACUTIFRONS						2
480165030000	AMPHICTEIS SP						2
480165030300	AMPHICTEIS ALASKANA						1
480165030600	AMPHICTEIS MACRONATA						2
480165040100	LYSIPPE LABIATA						7
480165050000	MELINNA SP	X					17
480165050100	MELINNA CRISTATA						4
480165050300	MELINNA ELIZABETHA						10
480166000000	TEREBELLIDAE						7
480166070000	PISTA SP.				X		16
480166070100	PISTA CRISTATA						1
480166070200	PISTA FASCIATA						1
480166070600	PISTA PACIFICA						1
480166080000	POLYCIRRUS SP.						4
480166120100	ARTACAMA CONIFERI						1
480167000000	TRICHOBRANCHIDAE						

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TAXON CODE	TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
480167010100	TEREBELLIDES STROEMII	X					26
480167020100	TRICHOBRANCHUS GLACIALIS						1
480168000000	SABELLIDAE						13
480168010000	CHONE SP.						6
480168010100	CHONE GRACILIS						8
480168010200	CHONE INFUNDIBULIFORMIS						2
480168020100	EUCHONE ANALIS				X		8
480168040100	MEGALOMMA SPLENDIDA						2
480168060000	POTAMILLA SP						1
480168060100	POTAMILLA NEGLECTA						1
480168070300	PSEUDOPOTAMILLA RENIFORMIS						3
480168080100	SABELLA CRASSICORNIS						1
480168130000	FABRICIA SP						1
480170000000	SERPULIDAE						1
480170010200	CHITINOPOMA GROENLANDICA						5
480170020100	CRUCIGERA IRREGULARIS						1
480170040100	SERPULA VERMICULARIS						2
480170050000	SPIRORBIS SP				X		1
480174000000	APHRODITIDAE						0
480174010100	APHRODITA JAPONICA				-		1
480174010300	APHRODITA PARVA						1
480175000000	COSSURIDAE						0
480175010100	COSSURA LONGOCIRRATA						1
480179000000	AMPHINOMIDAE						0
480179010100	CHLOEIA SP.						1
482000000000	OLIGOCHAETA						2
484000000000	ARCHIANNELIDA						1
490000000000	MOLLUSCA				X		15
490100000000	APLACOPHORA						1
490103010100	CHAETODERMA ROBUSTA						16
490300000000	POLYPLACOPHORA						0
490302030200	ISCHNOCHITON ALBUS				X		8
490305040000	MOPALIA SP						1
490400000000	PELECYPODA	X					18
490402020100	NUCULA TENUIS	X	X		X		32
490403020000	NUCULANA SP.						1
490403020100	NUCULANA PERNULA	X	X		X		26
490403020200	NUCULANA MINUTA						1
490403020600	NUCULANA CONCEPTIONIS						1
490403050000	YOLDIA SP.		X		X		15
490403050100	YOLDIA AMYGDAIEA			X		X	5
490403050400	YOLDIA SCISSURATA			X		X	1
490403050800	YOLDIA SECUNDA	X	X		X		17
490407010100	MYTILUS EDULIS						1
490407020100	CRENELLA DECUSSATA		X		X		10
490407030100	MEGACRENELLA COLUMBIANA						1
490407040100	MUSCULUS NIGER						1
490407050100	DACRYDIUM VITREUM	-			X		19

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TAXON CODE	TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
490407060100	MODIOLUS MODIOLUS						1
490408050200	PROPEAMUSSIUM ALASKENSE						3
490408060100	DELECTOPECTEN RANDOLPHI						7
490409010300	LIMA HYPERBOREA						1
490411010000	ASTARTE SP.						5
490411010200	ASTARTE ALASKENSIS						1
490411010300	ASTARTE MONTEGUI						2
490411010400	ASTARTE POLARIS			X	X	X	9
490412010100	CYCLOCARDIA VENTRICOSA						7
490412010200	CYCLOCARDIA CREBRICOSTATA	X	X		X		19
490415020100	AXINOPSIDA SERRICATA	X	X		X		20
490415030000	THYASIRA SP						2
490415030100	THYASIRA FLEXUOSA	X	X		X		23
490418010000	MYSELLA SP.						1
490418020100	ODONTOGENA BOREALIS	X	X		X		24
490420010000	CLINOCARDIUM SP.						1
490420010100	CLINOCARDIUM CILIATUM						2
490420010200	CLINOCARDIUM NUTTALLII						1
490420020200	SERRIPES LAPEROUSII						1
490421030100	COMPSOMYAX SUBDIAPHANA						1
490421050100	PSEPHIDIA LORDI	X	X		X		22
490423010100	SPISULA POLYNYMA						1
490424010000	MACOMA SP.						2
490424010100	MACOMA CALCAREA						3
490424010300	MACOMA BROTA			X			1
490424010800	MACOMA MOESTA ALASKANA						9
490427010200	SILIQUA ALTA						1
490429020100	HIATELLA ARCTICA						2
490432010200	PANDORA FILOSA						5
490432010300	PANDORA BILIRATA						3
490433020400	LYONSIA NORVEGICA			X		X	2
490437010000	CARDIOMYA SP.						1
490437010100	CARDIOMYA PECTINATA						13
490437010200	CARDIOMYA PLANETICA						2
490437010300	CARDIOMYA OLDROYDI						4
490500000000	GASTROPODA						14
490503020000	PUNCTURELLA SP						2
490503020500	PUNCTURELLA COOPERI						1
490505010100	CRYPTOBRANCHIA CONCENTRICA						1
490505020100	LEPETA CAECA						2
490506040000	SOLARIELLA SP.						1
490506040200	SOLARIELLA OBSCURA				X		4
490506040300	SOLARIELLA VARICOSA						2
490511010000	ALVINIA SP						1
490511010600	ALVINIA COMPACTA						1
490518010200	TACHYRYNCHUS RETICULATUS						4
490523010100	CALYPTRAEA FASTIGATA						1
490525020000	NATICA SP.						1

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TAXON CODE	TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
490525020100	NATICA CLAUSA						4
490525040000	POLINICES SP.						2
490525040100	POLINICES NANUS						3
490525040200	POLINICES PALLIDUS						3
490530041600	TROPHONOPSIS LASIUS						2
490533030000	COLUS SP						1
490534010100	AMPHISSA COLUMBIANA						2
490534020100	MITRELLA ROSACEA						1
490541000000	TURRIDAE						2
490541010000	SUAVODRILLA						3
490541010200	SUAVODRILLA WILLETTI						4
490541030100	MANGELIA ALEUTICA						1
490541040000	OENOPOTA SP.						4
490541042000	OENOPOTA DECUSSATA						1
490541071700	LORA RETICULATA						1
490542010000	ODOSTOMIA SP.						5
490542020000	TURBONILLA SP.						4
490545010100	RETUSA OBTUSA						2
490546010000	DIAPHANA SP						1
490549020000	CYLICHNA SP						1
490549020300	CYLICHNA ALBA						7
490600000000	SCAPHOPODA						0
490601010000	DENTALIUM SP.				X		8
490601010100	DENTALIUM DALLI				X		12
490601010200	DENTALIUM INVERSUM						1
490602010000	CADULUS SP.						14
490602010200	CADULUS STEARNSI	X					17
490602010300	CADULUS TOLMEI				X		11
520000000000	PYCNOGONIDA						0
520002010100	PSEUDOPALLENE CIRCULARIS						1
530000000000	CRUSTACEA						2
530700000000	PODOCOPA	X			X		19
531700000000	BRANCHIURA						1
531700010000	ARGULUS SP						1
531800000000	THORACICA						1
531802010400	BALANUS CRENATUS						1
532800000000	CUMACEA						13
532802000000	LAMPROPIDAE						2
532802010500	LAMPROPS QUADRIPLICATA						1
532802010700	LAMPROPS SERRATA						1
532802020000	HEMILAMPROPS SP						2
532804000000	LEUCONIDAE						1
532804010000	LEUCON SP.	X					19
532804020000	EUDORELLA SP.						3
532804020100	EUDORELLA EMARGINATA	X			X		20
532804020200	EUDORELLA PACIFICA						5
532804030100	EUDORELLOPSIS INTEGRA						2
532804030400	EUDORELLOPSIS DEFORMIS						1

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TAXON CODE	TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
532805000000	DIASTYLIDAE						1
532805010000	DIASTYLIS SP.						15
532805010300	DIASTYLIS BIDENTATA						4
532805011500	DIASTYLIS PARASPINULOSA						2
532805012500	DIASTYLIS CF. D. TETRADON						3
532805012600	DIASTYLIS LORICATA						1
532805020000	DIASTYLOPSIS SP						1
532805020100	DIASTYLOPSIS DAWSONI						1
532807000000	CAMPYLASPIDAE						0
532807010000	CAMPYLASPIS SP						5
532807010100	CAMPYLASPIS RUFA						1
532807010300	CAMPYLASPIS RUBICUNDA						1
532807010900	CAMPYLASPIS UMBENSIS						3
532900000000	TANAIDACEA						0
532901000000	TANAIDAE						1
533000000000	ISOPODA						3
533001020300	ARCTURUS GLABER						1
533001030100	CALATHURA BRANCHIATA						2
533005010000	AEGA SP						1
533005020200	ROCINELA BELLICEPS						2
533011010000	GNATHIA SP.				X		12
533012000000	ANTHURIDAE						3
533100000000	AMPHIPODA	X					22
533102010000	AMPELISCA SP.						5
533102010100	AMPELISCA MACROCEPHALA	X	X		X		18
533102010200	AMPELISCA BIRULAI				X		4
533102010500	AMPELISCA ESCHRICHTI						1
533102020000	BYBLIS SP						4
533102020200	BYBLIS GAIMARDI				X		10
533102030100	HAPLOOPS TUBICULA						7
533104010000	AMPITHOE						1
533107010100	ARGISSA HAMATIPES						1
533112090100	OLIGOCHINUS LIGHTI						1
533115000000	COROPHIIDAE						1
533115030000	ERICTHONIUS SP						1
533115050100	NEOHELA MONSTROSA						1
533120000000	EUSIRIDAE						1
533120010000	ACCEDOMOERA						1
533120130700	RHACHOTROPIS OCULATA						1
533121000000	GAMMARIDAE						1
533121080000	MAERA SP						1
533121080100	MAERA DANAE						2
533121080200	MAERA LOVENI						4
533121100000	MELITA SP.						2
533121100200	MELITA DENTATA						2
533122040200	UROTHOE DENTICULATA				X		9
533126000000	ISAEIDAE						1
533126020000	PHOTIS SP.						1

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533126020200	PHOTIS CF. P. REINHARDI				X		2
533126030000	PROTOMEDEIA SP.						4
533133020000	LILJEBORGIA						1
533134000000	LYSIANASSIDAE						1
533134030000	ANONYX SP.						7
533134030100	ANONYX OCHOTICUS						4
533134030200	ANONYX NUGAX						6
533134031200	ANONYX CF. A. LATICOXAE						1
533134031300	ANONYX MAGNUS						1
533134110100	CYPHOCARIS CHALLENGERI						1
533134140000	HIPPOMEDON SP						3
533134140500	HIPPOMEDON PROPINQUUS						1
533134140600	HIPPOMEDON KURILICUS						3
533134210300	LIPIDEPECREUM KASATKA						2
533134210400	LEPIDEPECREUM COMATUM						4
533134290000	ORCHOMENE SP.						2
533134290700	ORCHOMENE LEPIDULA						1
533134380100	SCHISTURELLA PULCHRA						1
533135010000	MELPHIDIPPA SP						1
533135010100	MELPHIDIPPA GOESI						1
533137000000	OEDICEROTIDAE						3
533137020100	ACEROIDES LATIPES						1
533137050000	BATHYMEDON SP.						3
533137050200	BATHYMEDON LANGSDORFI						1
533137050400	BATHYMEDON NANSENI						1
533137080000	MONOCULODES SP.						3
533137080500	MONOCLADES DIAMENSUS						4
533137080600	MONOCLADES LATIMANUS						1
533137080900	MONOCLADES MERTENSI						1
533137081600	MONOCLADES ZERNOVI						1
533137150200	WESTWOODILLA COECULA						2
533140010100	HALICE ABYSSI						1
533140020100	NICIPPE TUMIDA						7
533140030300	PARADALISCA TENUIPES						1
533142000000	PHOXOCEPHALIDAE				X		6
533142010200	HARPINIA KOBJAKOVAE						4
533142020100	HARPINIOPSIS SANPEDROENSIS				X		14
533142030100	HETEROPHOXUS OCULATUS	X			X		19
533142070000	PARAPHOXUS SP.						3
533142070100	PARAPHOXUS ROBUSTUS						2
533142070200	PARAPHOXUS SIMPLIX						5
533142080000	PHOXOCEPHALUS						1
533143030400	PARAPLEUSTES ASSIMILIS						1
533143060100	STENOPLEASTES UNCITGERA						1
533148000000	STENOTHOIDAE						2
533148020000	METOPA SP.				X		12
533148020100	METOPA ALDERI						2
533150000000	SYNOPIIDAE						1

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LIST OF ALL TAXONOMIC GROUPS FOUND

CRITERIA 1- TAXON OCCURS IN 50 PCT OR MORE OF STATIONS
CRITERIA 2- AT LEAST 10 PCT OF INDIVIDUALS AT SOME STATION
CRITERIA 3- AT LEAST 10 PCT OF WET BIOMASS AT SOME STATION
CRITERIA 4- ABUNDANT WRT NO. INDIVIDUALS AT SOME STATION
CRITERIA 5- ABUNDANT WRT TOTAL BIOMASS AT SOME STATION

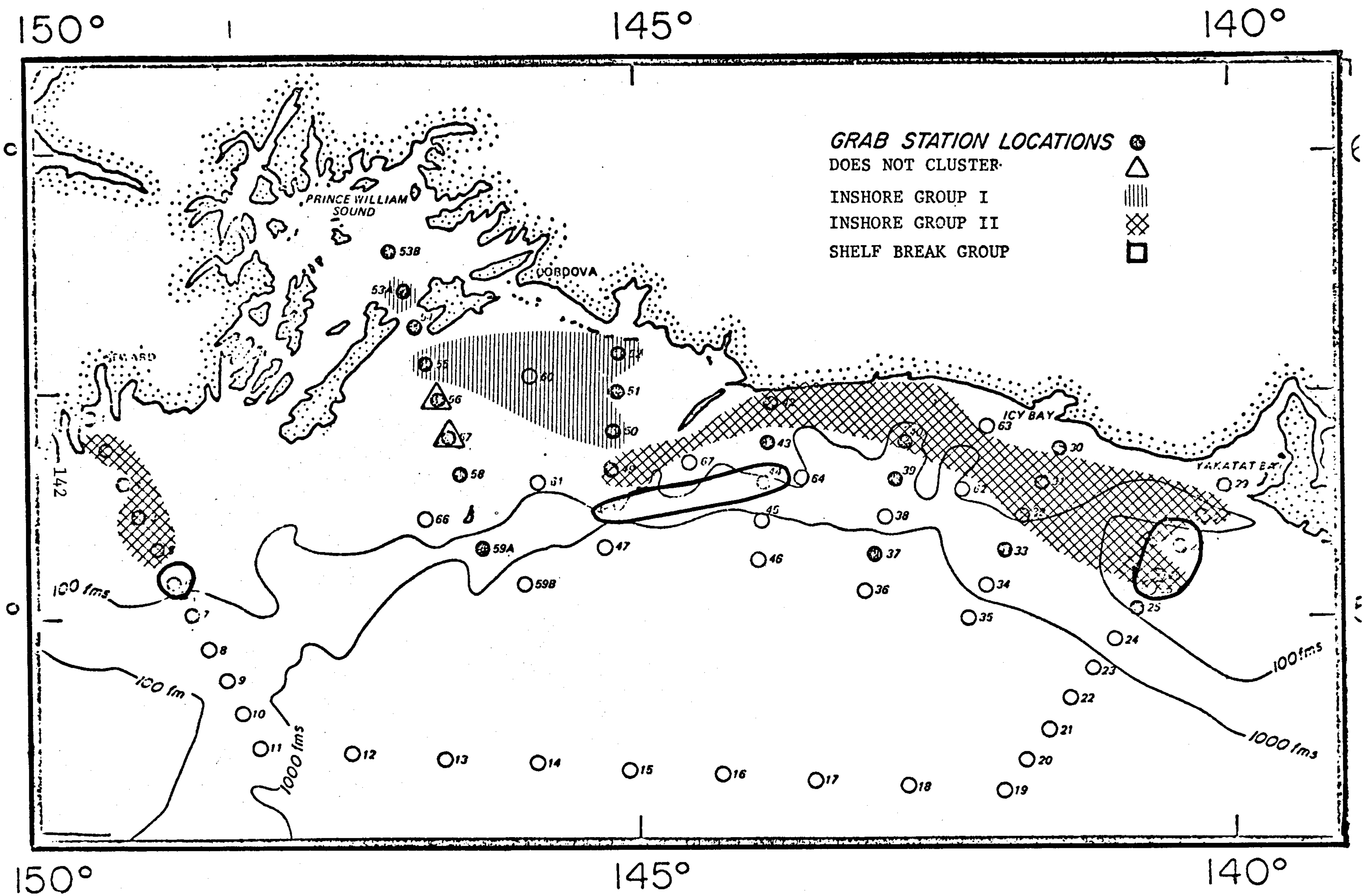
TAXON CODE	TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
533150030100	SYRRHOE CRENULATA						1
533150050200	TIRON BIOCULATA						1
533180100000	PARATHEMISTO SP						1
533198000000	CAPRELLIDAE						5
533200000000	EUPHAUSIACEA						0
533202000000	EUPHAUSIIDAE						1
533202090000	THYSANOESSA SP						1
533202090200	THYSANOESSA INERMIS						1
533202090600	THYSANOESSA RASCHII						1
533300000000	DECAPODA						2
533305000000	HIPPOLYTIDAE						1
533305041100	EUALUS AVINA						1
533306011100	CRANGON COMMUNIS						1
533311020000	PAGURUS SP.						2
533311050100	DISCORSOPAGURUS SCHMITTI						1
533317030000	CHIONOECETES SP.						10
533318010600	CANCER OREGONENSIS						1
590000000000	SIPUNCULIDA						0
590101010100	GOLFINGIA MARGARITACEA	X	X		X		22
590101010200	GOLFINGIA VULGARIS						10
590101020100	PHASCOLION STROMBI				X		13
610000000000	PRIAPULIDA						3
610101020200	PRIAPULUS CAUDATUS						2
660000000000	ECTOPROCTA		X	X	X	X	15
660306010100	CLAVIPORA OCCIDENTALIS				X		6
670000000000	BRACHIOPODA						0
670200000000	ARTICULATA			X		X	5
670203010000	TEREBRATULINA SP						1
670203010100	TEREBRATULINA UNGUICULA			X	X	X	7
670203010300	TEREBRATULINA CROSSEI				X		2
670205010100	DIESTOTHYRIS FRONTALIS						1
670205030100	LAQUEUS CALIFORNIANUS			X	X	X	8
670205040100	TEREBRATALINA TRANSVERSA			X		X	2
680000000000	ECHINODERMATA						0
680100000000	ASTEROIDEA						4
680104060200	PSEUDARCHASTER PARELII						1
680106000000	PORCELLANASTERIDAE						1
680106010100	CTENODISCUS CRISPATUS	X		X	X	X	19
680202010100	ECHINARACHNIUS PARMA						1
680203010100	BRISASTER TOWNSENDI			X	X	X	9
680204010100	ALLOCENTROTUS FRAGILIS						1
680300000000	OPHIUROIDEA						16
680302030100	DIAMPHIODIA CRATERODMETA						5
680302080100	UNIOPLUS MACRASPIS	X	X	X	X	X	21
680304020000	GORGONOCEPHALUS SP						1
680306010100	OPHIOPHOLIS ACULEATA						2
680309000000	OPHIURIDAE						1
680309050100	OPHIOPENIA DISACANTHA						2

LIST OF ALL TAXONOMIC GROUPS FOUND

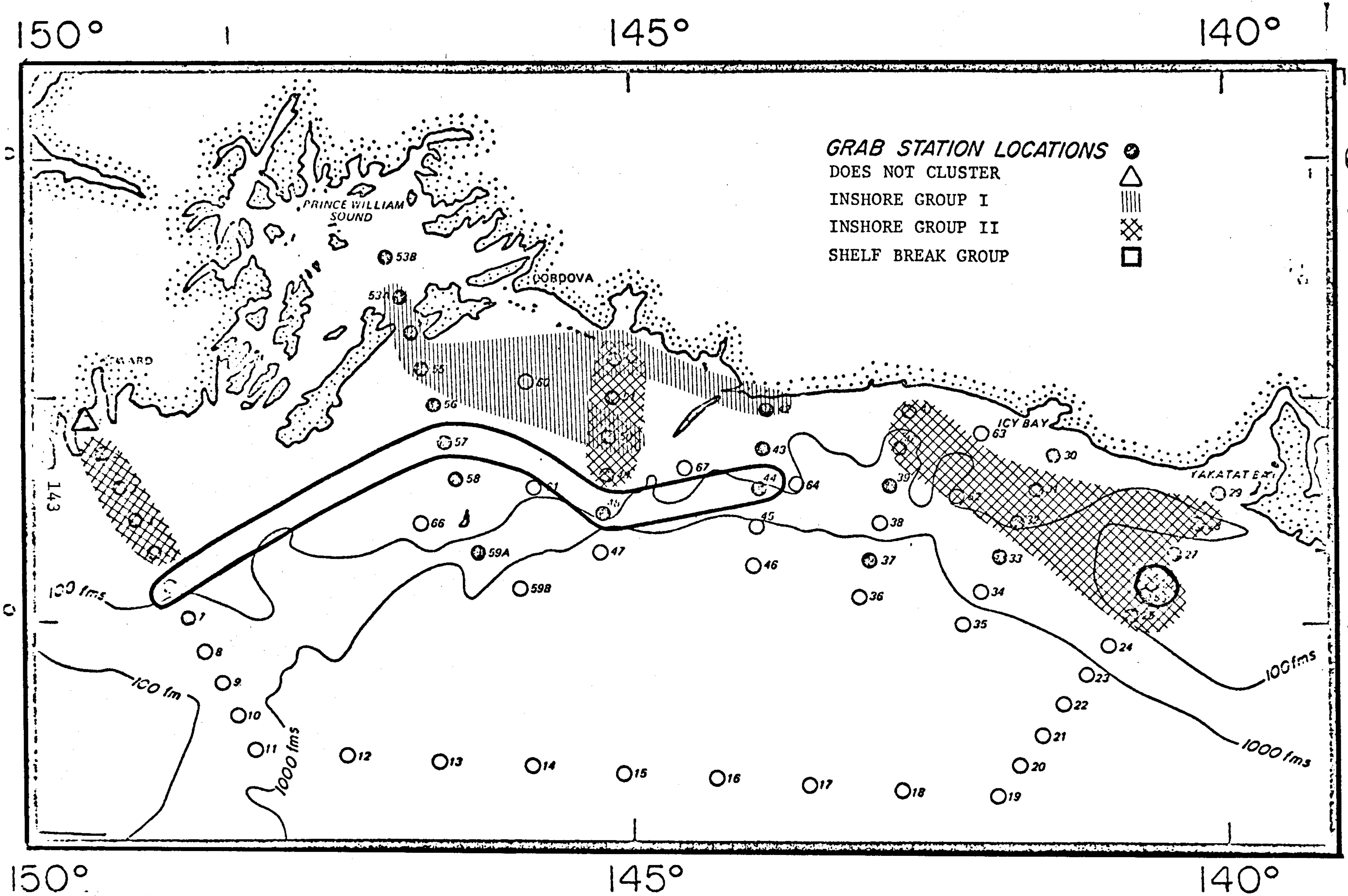
CRITERIA 1- TAXON OCCURS IN 50 PCT OR MORE OF STATIONS
CRITERIA 2- AT LEAST 10 PCT OF INDIVIDUALS AT SOME STATION
CRITERIA 3- AT LEAST 10 PCT OF WET BIOMASS AT SOME STATION
CRITERIA 4- ABUNDANT WRT NO. INDIVIDUALS AT SOME STATION
CRITERIA 5- ABUNDANT WRT TOTAL BIOMASS AT SOME STATION

TAXON CODE	TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
680309061100	OPHIURA SARSI	X	X	X	X	X	30
680309080000	STEGOPHIURA SP						6
680400000000	HOLOTHUROIDEA			X		X	9
680405010100	MOLPADIA INTERMEDIA	X		X		X	19
680410010100	CUCUMARIA CALCIGERA						7
680412020000	PSOLUS SP.						2
680500000000	CRINOIDEA						4
720000000000	UROCHORDATA						8
999900000000	EGG CASES				X		9
999999999900	UNIDENTIFIBLE						11

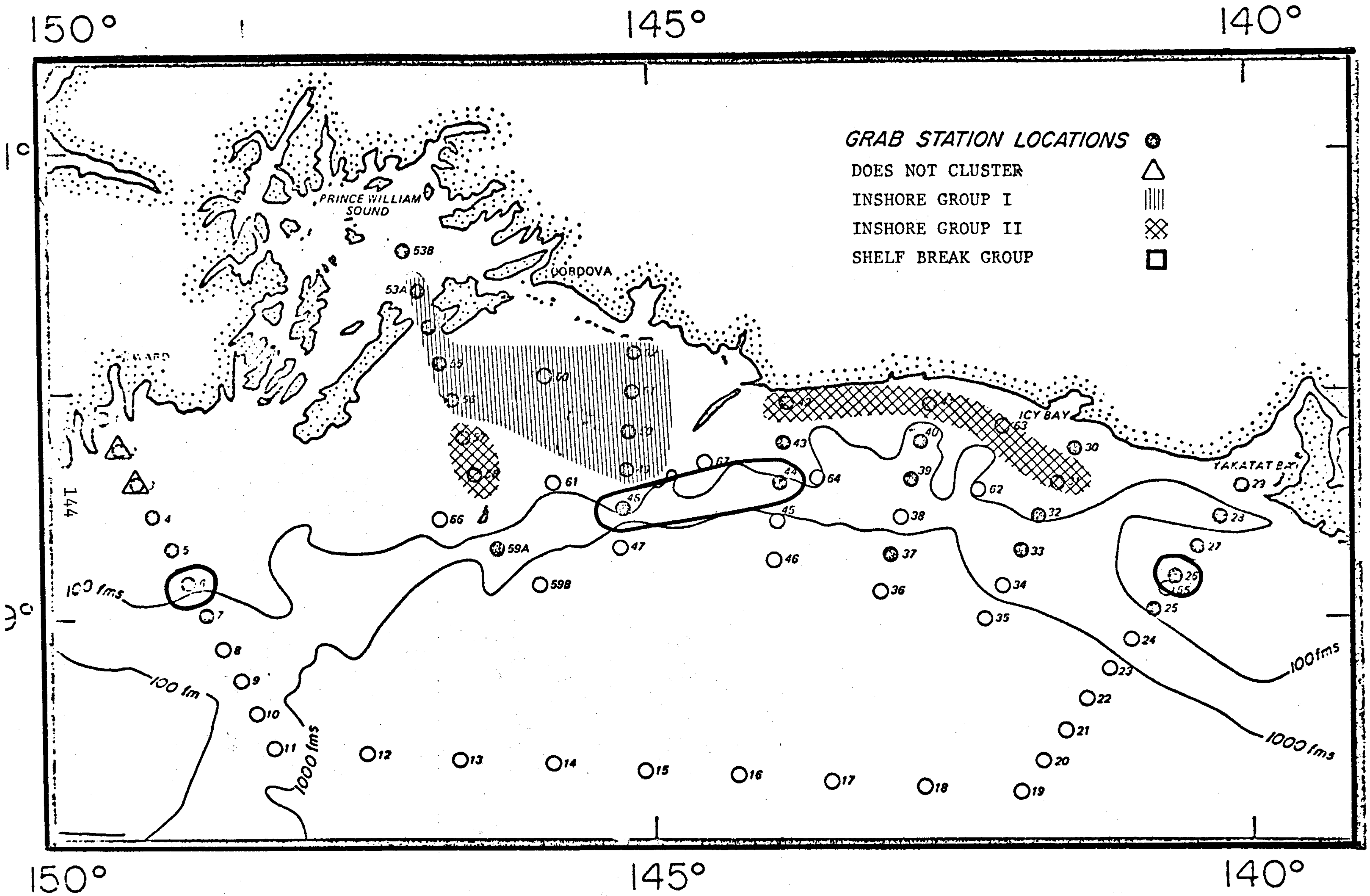
TOTAL NUMBER OF TAXONS = 457



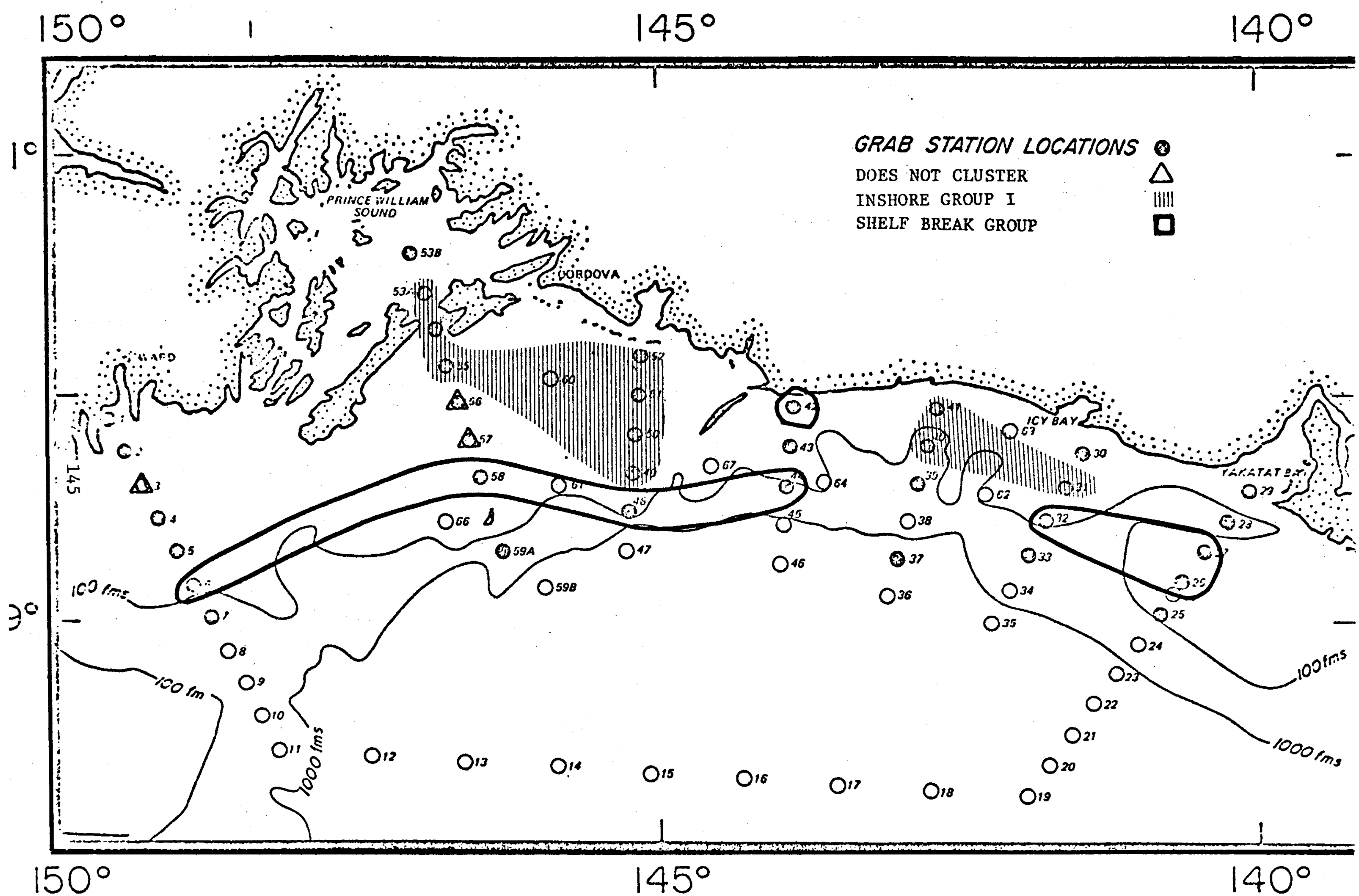
Appendix I - Figure 2. Station groups formed by cluster analysis of quantitative stations using the number of individuals/ m^2. Only major station clusters are shown.



Appendix I - Figure 3. Station groups formed by cluster analysis of quantitative stations using a natural log transformation of the number of individuals/m^2. Only major station clusters are shown.



Appendix I - Figure 4. Station groups formed by cluster analysis of quantitative stations using wet weight/m^2. Only major station clusters are shown.



Appendix I - Figure 5. Station groups formed by cluster analysis of quantitative stations using a natural log transformation of wet weight/m^2. Only major station clusters are shown.

APPENDIX I - TABLE III

STATION GROUPS DELINEATED BY CLUSTER ANALYSIS BASED ON THE NUMBER OF INDIVIDUALS PER SQUARE METER. FEEDING TYPES AS FOLLOWS: DF = DEPOSIT FEEDER, E = ECTOPARASITE, P = PREDATOR, S = SCAVENGER, SF = SUSPENSION FEEDER.

ID #	Station #	Brillouin Diversity	Brillouin Evenness	Simpson Diversity	Sediment %Gravel	Sediment %Sand	Sediment %Silt	Sediment %Clay	%Feeding Type
Station Group 1 (Inshore Group I)									
10	193052*	1.036	0.715	0.125	Trace	0.44	37.83	61.72	DF 61%
13	200052	1.159	0.817	0.084	Trace	0.44	37.83	61.72	P 21%
12	200050	1.184	0.860	0.059	Trace	2.50	33.30	64.20	S 14%
14	200053	1.097	0.752	0.018	0	28.07	46.02	25.91	SF 4%
11	193055	1.104	0.825	0.091	0	1.26	48.22	50.52	
26	805055	1.098	0.895	0.057	0	1.26	48.22	50.52	
9	193050	1.098	0.933	0.041	Trace	2.50	33.30	64.20	
Station Group 2									
5	193041	1.012	0.727	0.127	Trace	0.31	49.57	50.12	DF 50%, SF 24%
6	193042	1.021	0.683	0.135	Trace	10.58	58.88	30.54	P 17%, S 9%
Station Group 3									
15	200057	1.416	0.824	0.047	26.59	14.20	29.39	26.83	SF 38%, DF 34% S 20%, P 8%
Station Group 4 (Shelf Break Group)									
3	193026	1.292	0.902	0.039	4.32	8.47	53.64	33.57	SF 32%
7	193044	1.335	0.884	0.040	3.01	50.64	22.95	23.40	S 30%
2	193006	1.507	0.870	0.031	6.27	37.69	23.42	32.62	DF 26%
8	193048	1.407	0.901	0.033	19.95	15.54	33.51	31.00	P 12%
35	807027	.871	0.583	0.279	13.17	10.49	43.46	32.88	
Station Group 5									
1	193003	0.993	0.991	0.061	Trace	0.40	31.92	67.68	
23	805051	0.987	0.881	0.071	0	0.27	39.54	60.19	
38	807052	0.948	0.936	0.052	Trace	0.44	37.83	61.72	

* The first three digits of the station code represent the cruise number and the last three represent the station name, i.e. 193003=Cruise 193 Station 3.

APPENDIX I - TABLE III (cont'd)

ID #	Station #	Brillouin Diversity	Brillouin Evenness	Simpson Diversity	Sediment %Gravel	Sediment %Sand	Sediment %Silt	Sediment %Clay	%Feeding Type
Station Group 6 (Inshore Group II)									
33	807025	1.015	0.906	0.062	1.18	44.96	33.42	20.44	DF 65%
37	807050	1.032	0.886	0.070	Trace	2.50	33.30	64.20	SF 15%
4	193032	1.223	0.931	0.036	Trace	0.42	51.09	48.49	P 12%
18	805032	1.388	0.925	0.028	Trace	0.42	51.09	48.49	E 6%
19	805040	1.212	0.892	0.048	Trace	0.23	44.53	55.24	S 3%
36	807028	1.177	0.851	0.064	0.27	6.87	52.66	40.20	
20	805041	1.086	0.811	0.088	Trace	0.31	49.57	50.12	
22	805049	1.203	0.847	0.065	0	7.71	49.53	42.75	
17	805031	1.133	0.883	0.060	Trace	1.68	62.70	35.62	
31	807004	0.985	0.830	0.094	Trace	0.42	30.70	68.87	
34	807026	1.088	0.871	0.067	4.32	8.47	53.64	33.57	
30	807002	1.282	0.941	0.027	0	3.35	33.85	62.80	
32	807005	1.072	0.767	0.109	3.12	16.84	20.25	59.80	
21	805042	0.902	0.863	0.091	Trace	10.58	58.88	30.54	
Station Group 7									
25	805054	0.940	0.765	0.158	0	27.94	43.47	28.59	DF 44%, SF 31%
29	805058	0.883	0.692	0.185	0	3.41	47.00	49.59	P 13%, S 13%
Station Group 8									
27	805056	1.311	0.765	0.102	24.39	42.49	18.05	15.07	P 34%, SF 28% DF 21%, S 17%
Station Group 9									
28	805057	1.189	0.941	0.031	26.59	14.20	29.39	26.83	DF 50%, S 25% P 13%, E 13%
Station Group 10									
24	805053	0.817	0.886	0.093	0	28.07	46.02	25.91	
39	807053	0.463	1.000	0.107	0	28.07	46.02	25.91	
16	202001	0.707	0.902	0.105	Trace	1.08	37.10	61.82	

APPENDIX I - TABLE IV

STATION GROUPS DELINEATED BY CLUSTER ANALYSIS BASED ON A NATURAL LOG TRANSFORMATION OF THE NUMBER OF INDIVIDUALS/M^2 DATA

Station Group 1 (Inshore Group I)
193052*
200052
193042
200050
193055
193050
200053
805054

Station Group 2 (Inshore Group II)
193003
805051
807052
805032
805040
807028
805031
805041
193041
805049
193032
807004
807026
807005
807002
807050
807025

Station Group 3 (Shelf Break Group)
193006
193048
193026
193044
200057

Station Group 4
805054
807027

Station Group 6
805056
805057

Stations which do not join clusters
807042
805053
807053
202001

* The first three digits of the station code represent the cruise number and the last three represent the station name, i.e. 193003=Cruise 193 Station 3.

APPENDIX I - TABLE V

STATION GROUPS DELINEATED BY CLUSTER ANALYSIS BASED ON WET BIOMASS PER SQUARE METER

Station Group 1 (Inshore Group I)
200053*
805049
805054
805056
805051
807052
193055
193050
805040

Station Group 2 (Inshore Group II)
193041
805031
805041
805042
805058
805057

Station Group 3 (Shelf Break Group)
193006
193026
193044
193048

Station Group 4
200050
807050

Station Group 5
200057
807027

Station Group 6
193042
193052

Station Group 7
202001
807004
807028

Stations which do not join clusters
805056
193003
807002
807053
200052
805053

* The first three digits of the station code represent the cruise number and the last three represent the station name, i.e. 193003=Cruise 193 Station 3.

APPENDIX I - TABLE VI

STATION GROUPS DELINEATED BY CLUSTER ANALYSIS BASED ON A NATURAL LOG TRANSFORMATION OF WET WEIGHT/M^2 DATA

Station Group 1 (Inshore Group I)
193041*
805031
805041
805040
807050
200053
805054
805051
807052
193055
805055
805049
193050

Station Group 2 (Shelf Break Group)
193006
193048
193042
805042
805058
807027
193026
193044
193032
805032

Station Group 3
807025
807026
807005
200050

Station Group 4
202001
807004
807028
807002

Station Group 5
193052
200052

Stations which do not join clusters
193003
805056
200057
805058
807053
805053

* The first three digits of the station code represent the cruise number and the last three represent the station name, i.e. 193003=Cruise 193 Station 3.

APPENDIX I - TABLE VII

STATION GROUPS FORMED BY CLUSTER ANALYSIS OF BOTH QUANTITATIVE AND AND QUALITATIVE STATIONS USING PRESENCE-ABSENCE DATA

Station Group 1 (Inshore Group I)
193055
805055
193050
805051
200050
200053
807052
805054
807050
193032
193041
193003
807004
807026
807005
805031
805049
805032
805040
805041
807028

Station Group 2 (Inshore Group II)
193042
193052
200052
805042
193029

Station Group 3 (Shelf Break Group)
193006
193048
193044
193026
200057

Station Group 4 (Deep Water I)
805033
807025
807007

Station Group 5 (Deep Water II)
193059
805037

Station Group 6
805043
805058

Station Group 7
805056
805057

Station Group 8
193030
805030

Stations which do not join clusters
807027
807053
202001
805053
805044
193039
805039

APPENDIX I - TABLE VIII

SPECIES GROUPS DELINEATED BY CLUSTER ANALYSIS BASED ON THE NUMBER OF INDIVIDUALS PER SQUARE METER. FEEDING TYPES ARE AS FOLLOWS: DF = DEPOSIT FEEDER, E = ECTOPARASITE, P = PREDATOR, S = SCAVENGER AND SF = SUSPENSION FEEDER

ID No.	Species Groups	Station Groups ≥30%	Feeding Type
	Species Group # 1	8(70%)	
94	Pelecypoda *Astarte esquimaulti*		SF
132	Amphipoda *Ampeliscida birulai*		S?
31	Eunicidae *Eunice* sp.		DF
105	Pelecypoda *Thriacia beringi*		SF
111	Gastropoda *Cylichna albd*		P
117	Thoracica *Balanus rostratus*		SF
159	Brachiopoda *Terrebratulina frossei*		SF
160	Brachiopoda *Deistrothyris frontalis*		SF
161	Brachiopoda *Laques californianus*		SF
135	Amphipoda *Byblis gaimandi*		S
34	Orbiniidae *Haplosoloplos panamensis*		DF
93	Pelecypoda *Astarte polaris*		SF
75	Polyplacophora *Ischnochiton albus*		DF?
146	Amphipoda *Paraphoxus robustus*		S
11	Phyllodocidae *Eteone langa*		P
8	Sigaloinidae *Phloe minuta*		S
108	Gastropoda *Amphissa columbiana*		P
167	Amphiuridae *Pandellia charchara*		DF
109	Gastropoda *Amphissa reticulata*		P
19	Nereidae *Ceratonereis paucidentata*		P
87	Pelecypoda *Megacrenella columbiana*		SF
21	Nepthyidae *Nepthys* sp.		P
23	Nepthyidae *Nepthys coeca*		P
	Species Group # 2	8(40%)	
77	Polyplacophora *Hanleya* sp.		DF
78	Polyplacophora *Hanleya hanleyi*		DF
13	Syllidae *Syllis* sp.		P
14	Syllidae *Syllis sclerolema*		P
12	Syllidae		P
4	Polynoidae *Harmothoe imbricata*		S
	Species Group # 3	9(51%)	
2	Polynoidae *Gattyana iliata*		S
120	Cumacea *Leucon nasica*		DF
22	Nepthnyidae *Nepthys ciliata*		P
152	Decapoda *Pinnixia occidentalis*		S

TABLE VIII (cont'd)

ID No.	Species Groups	Station Groups ≥30%	Feeding Type
	Species Group # 4	6(100%)	
139	Amphipoda *Hippomedon propinguus*		S
148	Amphipoda *Phoxocephalus* sp.		S
	Species Group # 5	7(32%)	
125	Cumacea *Diastylis hirsata*		DF?
145	Amphipoda *Heterophoxus occulatus*		S
66	Terebellidae *Arctecama conifera*		DF
119	Cumacea *Leucon* sp.		DF
73	Sabellidae *Potamilla neglecta*		SF
80	Pelecypoda *Malletia cuneata*		DF SF?
	Species Group # 6	7(91%)	
25	Nepthyidae *Nepthys longasetosa*		P
85	Pelecypoda *Yoldia amygdaiea*		DF SF
	Species Group # 7	9(50%)	
46	Scalibreamidae *Travista* sp.	6(31%)	DF
128	Isopoda *Gnathia* sp.		E
32	Lumbrineridae *Lumbrineris* sp.		DF
35	Paraonidae *Aricidea suecica*		DF
	Species Group # 8	6(32%)	
67	Terebellidae *Proclea emmi*		DF
110	Gastropoda *Oenopota* sp.		P
54	Maldanidae *Praxillella* sp.		DF
	Species Group # 9	4(76%)	
69	Sabellidae *Chone gracilis*		SF
114	Amphipoda *Halosoma* sp.		S
72	Sabellidae *Megalomma splendida*		SF
130	Amphipoda *Acanthonatozoma inflatum*		S
3	Polynoidae *Gattyana treadwelli*		S
	Species Group # 10	4(52%)	
100	Pelecypoda *Clinocardium ciliatum*		SF
125	Cumacea *Diastylis* sp.		DF
57	Owenidae *Owenia fusiformis*		DF SF
65	Terebellidae *Pista fasciata*		DF
18	Syllidae *Haplosyllis spongicola*		P
60	Ampharetidae *Ampharete arctica*		DF

TABLE VIII (cont'd)

ID No.	Species Groups	Station Groups ≥30%	Feeding Type
	Species Group # 11	4(30%)	
71	Sabellidae *Euchone analis*		SF
156	Bryozoa *Microporina borealis*		SF
133	Amphipoda *Byblis* sp.		S
158	Brachipoda *Terebratulina unguicula*		SF
26	Nepthyidae *Nepthys ferruginea*		P
134	Amphipoda *Byblis crassicornis*		S
	Species Group # 12	4(46%)	
17	Syllidae *Langerhansia cornuta*		P
144	Amphipoda *Harpiniopsis sandpedroensis*		S
7	Polydontidae *Peisidice aspera*		S
90	Pelecypoda *Cyclopecten randolphi*		SF
153	Sipunculida *Golfingia margaritacea*		DF
53	Maldanidae *Notoproctus pacificus*		DF
88	Pelecypoda *Dacrydium* sp.		SF
36	Paraonidae *Aricidea jeffreysii*	(selected deposit)	SDF
127	Isopoda *Gnathia* sp.		E
115	Copepoda *Harpacticoidea*		S
136	Amphipoda *Haploops tubicula*		S
52	Maldanidae *Maldane glebifex*		DF
15	Syllidae *Eusyllis bloomstrandi*		P
137	Amphipoda *Ericthonius heunteri*		S
142	Amphipoda *Harpinia* sp.		S
	Species Group # 13	3(67%)	
86	Pelecypoda *Crenella dessucata*		SF
95	Pelecypoda *Cyclocardia ventricosa*		SF
	Species Group # 14	3(82%)	
101	Pelecypoda *Clinocardium fucanum*		SF
157	Bryozoa *Clavopora occidentalis*		SF
131	Amphipoda *Ampelisca macrocephala*		S
92	Pelecypoda *Astarte montegui*		SF
107	Gastropoda *Lepeta caeca*		S?
118	Cumacea *Lamprops fuscata*		DF
50	Maldanidae *Asychis similis*		DF
70	Sabellidae *Chone infundibuliformis*		SF
61	Ampharetidae *Ampharete goesi*		SDF
149	Caprellidae *Caprella striata*		SF
129	Amphipoda *Hyssura* sp.		S
16	Syllidae *Exogene* sp.		P
45	Scalibregmidae *Scalibregma inflatum*		DF
147	Amphipoda *Paraphoxus simplex*		S
59	Sabellariidae *Idanthyrsus armatus*		SF

TABLE VIII (cont'd)

ID No.	Species Groups	Station Groups ≥30%	Feeding Type
	Species Group # 15	3(47%)	
6	Polynoidae *Hesperonoe complanata*	1(46%)	S
155	Priapulidae *Priapulus caudatus*		DF
1	Cnidaria Anthozoa "Sea Pan"		SF
56	Maldanidae *Rhodine bitorquata*		DF
	Species Group # 16	1(76%)	
43	Cirratulidae *Caulleriella* sp.		DF
18	Syllidae *Haplosyllis spongicola*		P
	Species Group # 17	1(40%)	
103	Pelecypoda *Macoma calcarea*		DF SF
143	Amphipoda *Harpinia emeryi*		S
37	Paraonidae *Paraonis gracilis*		DF
48	Capitellidae *Capitella capitata*		DF
49	Capitellidae *Heteromastis filiformis*		DF
122	Cumacea *Eudorella emarginata*		DF? S?
123	Cumacea *Eudorellopsis integra*		DF? S?
	Species Group # 18	2(42%)	
44	Cirratulidae *Tharyx* sp.		DF
62	Ampharetidae *Melinna cristata*		SDF
27	Glyceridae *Glycera capitata*		P
68	Terebellidae *Terebellides stromata*		SDF
24	Nepthyidae *Nepthys punctata*		DF
74	Aplacaphora *Chaetoderma robusta*		DF
98	Pelecyploda *Thyasira flexuosa*		SF
55	Maldanidae *Praxillella gracilis*		DF
112	Scaphapoda *Dentalium* sp.		SDF
172	Holothuroidea *Molpadia* sp.		DF
40	Spionidae *Spiophanes cirrata*		SDF
8	Sigalionidae *Phloe minuta*		S
79	Pelecypoda *Nucula tenuis*		SF DF
102	Pelecypoda *Psephidia lordi*		SF
33	Lumbrineridae *Lumbrineris similabris*		P
47	Sternaspidae *Sternaspis scutata*		DF
58	Owenidae *Myriochele heeri*		SDF
96	Pelecypoda *Axinopsida serricata*		SF
30	Onuphidae *Onuphis geofiliformis*		DF SF?
171	Echinodermata *Ophiura sarsi*		P

TABLE VIII (cont'd)

ID No.	Species Groups	Station Groups ≥30%	Feeding Type
	Species Group # 19	2(41%)	
106	Pelecypoda *Cardiomya serricata*		SF
113	Scaphopoda *Cadulus* sp.		DF P
89	Pelecypoda *Dacryduum pacificum*		SF
64	Terebellidae *Pista cristata*		DF
	Species Group # 20	6(39%)	
83	Pelecypoda *Portlandia arctica*		DF SF
163	Echinodermata *Ctenodiscus crispatus*		DF
168	Echinodermata *Pandellia carchara*		DF
28	Goniadidae *Goniada annulata*		P
	Species Group # 21	6(83%)	
99	Pelecypoda *Odontogenia borealis*		SF
164	Echinoidea *Brisaster townsendi*		DF
	Species Group # 22	6(69%)	
39	Spionidae *Spio filicornis*		DF
	Species Group # 23	1(96%)	
41	Megalonidae *Megalona japonica*		DF
	Species Group # 24	6(100%)	
121	Cumacea *Leucon acutirostris*		DF S
141	Amphipoda *Aceroides* sp.		S
76	Polyplacophora *Molpalia* sp.		DF
	Species Group # 25	3(76%)	
29	Coniadidae *Goniada maculata*		P
165	Echinodermata *Diamphiodia craterodermata*		DF
38	Spionidae *Laonice cirrata*		DF
84	Pelecypoda *Yoldia* sp.		DF SF
	Species Group # 26	4(66%)	
63	Terrebellidae *Pista cristata*		DF
116	Thoracica *Scapellum columbianum*		SF
166	Echinodermata *Diamphiodia periercta*		DF
173	Echinodermata *Psolus* sp.		SF
138	Amphipoda *Anonyx ochoticus*		S

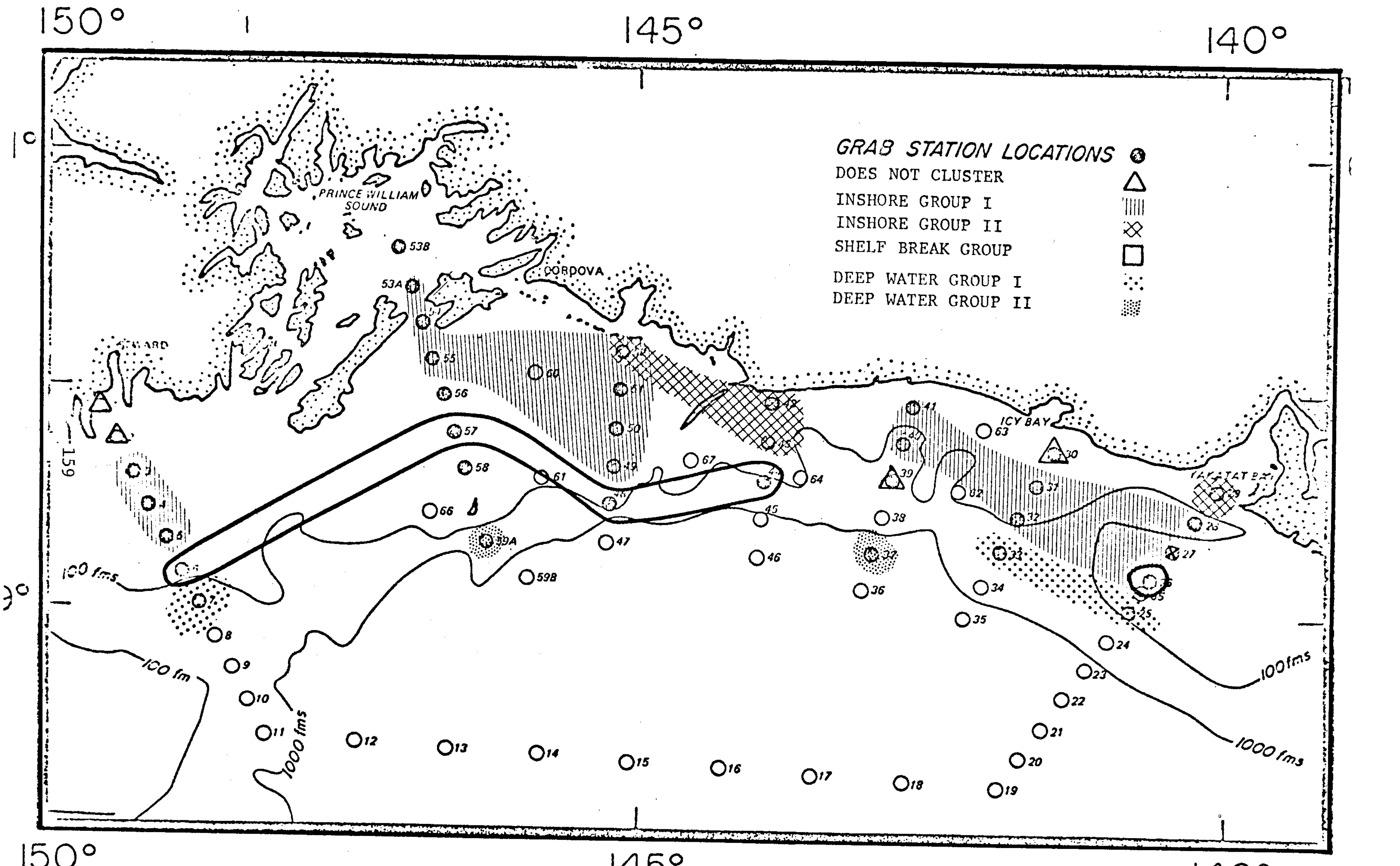
TABLE VIII (cont'd)

ID No.	Species Groups	Station Groups ≥30%	Feeding Type
	Species Group # 27	2(98%)	
20	Nereidae *Nereis* sp.		P
150	Decopoda *Chionoecetes bairdi*		P S
	Species Group # 28	1(63%)	
42	Goniadidae *Goniada anulata*		P
140	Amphipoda *Lepideprecum comatum*		S
	Species Group # 29	2(72%)	
151	Decapoda *Pinnixia* sp.		S
154	Priajoulida *Halicryptus spinulosus*		SF
104	Pelecypoda *Hiatella arctica*		SF
	Species Group # 30	1(88%)	
162	Echinodermata *Ctenodiscus* sp.		DF
170	Echinodermata *Ophiura* sp.		P
169	Echinodermata *Ophiopenia disacantha*		DF
	Species Group # 31	5(70%)	
5	Polynoidae *Lepidonotus squamatus*		S
10	Phyllodocidae *Araitides mucosa*		P
9	Phyllodoridae *Phylodoce groenlandica*		P
	Species Group # 32	1(100%)	
97	Pelecypoda *Thyasira* sp.		SF

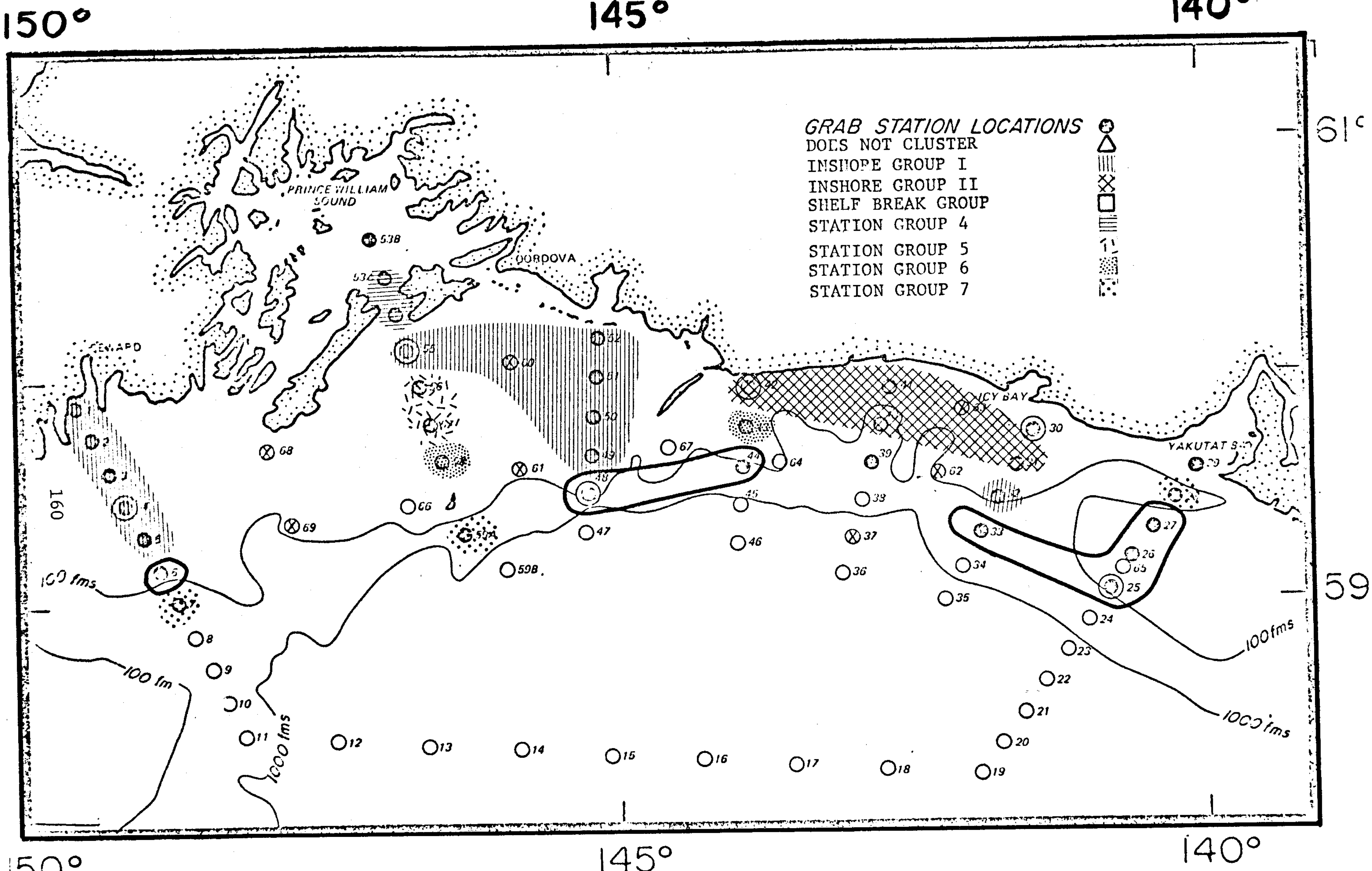
APPENDIX I - TABLE IX

SOME CHARACTERISTICS OF STATION GROUPS FORMED BY CLUSTER ANALYSIS OF UNTRANSFORMED NUMBER/M^2 DATA. DIVERSITY INDICES AND SEDIMENT DISTRIBUTIONS ARE MEAN VALUES FOR ALL STATIONS WITHIN THE STATION GROUP

STATION GROUPS	BRILLOUIN INDEX OF DIVERSITY	SEDIMENT % GRAVEL	% SAND	% SILT	% CLAY	FEEDING TYPE % SF	% DF	% P	% S
Inshore Group 1	1.11 ± 0.05	0	5.21	40.67	59.92	4	61	21	14
Inshore Group 2	1.12 ± 0.12	0.63	7.48	40.55	47.22	15	65	12	3
Station 56	1.31	26.59	14.20	29.39	26.83	28	21	34	7
Station 57	1.42	24.39	42.49	18.05	15.07	38	34	8	20
Shelf Break Group	1.38 ± .09	9.39	24.56	35.39	30.69	32	26	12	30



Appendix I - Figure 6. Station groups formed by cluster analysis of both quantitative and qualitative stations using presence-absence data. Only major station clusters are shown.



Appendix I - Figure 7. Station groups formed by cluster analysis of quantitative stations using number of individuals/m^2. Data collected during September and November-December 1975.

APPENDIX II

NUMERICAL ANALYSIS OF THE BENTHIC INFAUNA IN THE NORTHEASTERN GULF OF ALASKA, FALL, 1976

NUMERICAL ANALYSIS OF THE BENTHIC INFAUNA IN THE NORTHEASTERN GULF OF ALASKA

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INTRODUCTION

In 1974 a two-year study was initiated to assess the distribution, abundance and diversity of the benthic infauna in the northeastern Gulf of Alaska (NEGOA). Among the goals of this study was a description of spatial and seasonal distribution patterns of the benthic infauna, and a comparison of these patterns with available data on physical, chemical and especially geological features. In addition, we wished to develop a basis for selecting representative sites for (1) intensive investigations of the trophic structure and productivity of the infauna, (2) long term studies of species content, diversity and abundance, and (3) monitoring potential impacts of oil related development in the NEGOA area.

Various techniques of numerical classification have been utilized to recognize patterns in the complex data created by collections of multi-species populations of benthic organisms (see Clifford and Stephenson, 1975 for a review). We utilized normal cluster analysis and principal coordinate analysis to define station groups based on their fauna and inverse cluster analysis to define species groups based on their distribution within the series of stations sampled (Clifford and Stephenson, 1975). These groupings were then examined in comparison with available data on the environmental parameters in the NEGOA area. A preliminary analysis of data collected during the first year of the study is included in Feder _et al_. (1975, 1976). This chapter presents an analysis of data collected in the fall of 1975. The results of an examination of seasonal as well as spatial patterns in the distribution and abundance of the benthic infauna during the two-year study period will be included in a final report to NOAA.

STUDY AREA

Thirty-three stations (Feder _et al_., 1975) were selected from a grid established in conjunction with studies on the physical and chemical oceanography, hydrocarbon and heavy metal concentrations, and marine microbiota in the NEGOA (Fig. 1). The stations were dispersed over seven transects from Resurrection Bay to Yakutat Bay and they extended from inshore to the 200 m contour.

Temperature and salinity data for the northeastern Gulf of Alaska from July 1974 to June 1975 are available in Royer (1976). The temperature of the bottom water during this period ranged from 4.5 to 5.5°C except at some of the shallower stations (Sta. 29, 68 m; 30, 43 m; 52,

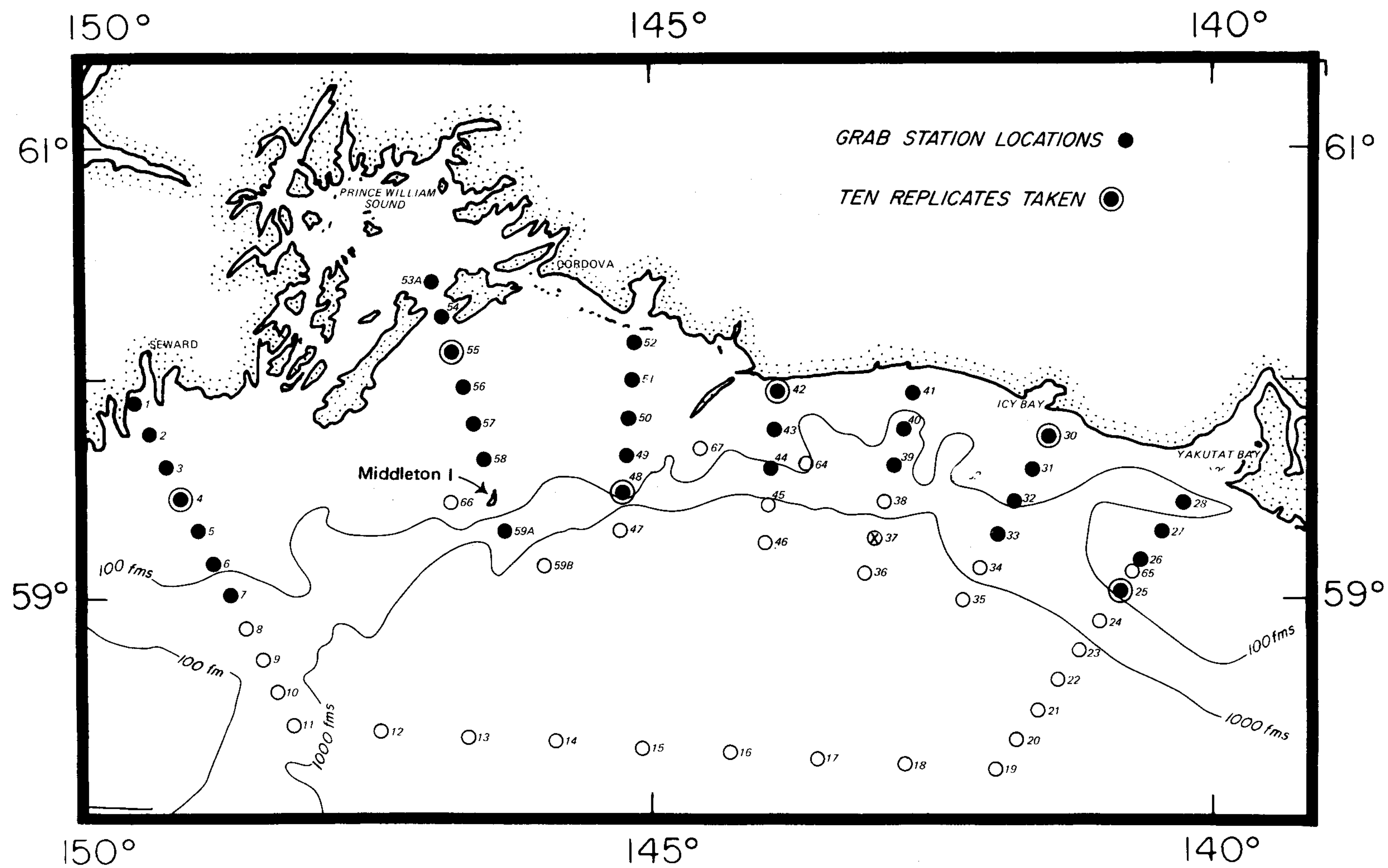

Figure 1. Station grid established for oceanographic investigations in the northeastern Gulf of Alaska. Shaded circles = major stations sampled with van Veen grab. Open circles = physical chemical and zooplankton stations.

53 m; 55, 117 m; 56, 54 m; 57, 67 m; 58, 97 m) where temperatures of 7.0° to 10.0°C were recorded in July and October 1974. Salinity of the bottom water ranged from 31.5 to 33.5 °/oo.

Sediments in the study area are predominantly silts and clays. The principal sources for these sediments are the Copper River and the Bering and Malaspina Glaciers. The general transport of the sediments as they enter the Gulf of Alaska is to the west. High sedimentation rates throughout most of the shelf area result in poorly consolidated sediments with high pore water pressures. However, few sediments accumulate on Tarr Bank (Fig. 1, Stations 56 and 57) probably because of scouring by strong bottom currents and frequent winter storm waves (Molnia and Carlson, 1977).

METHODS

Field and Laboratory

The thirty-three stations (Fig. 1) were sampled during USNS *Silas Bent* cruise 811, September 1975 and R/V *Discoverer* cruise 816, November-December 1975. Five replicates were routinely taken at each station with a 0.1 m^2 van Veen grab weighted with 70 lbs of lead to facilitate bottom penetration. The grab functioned effectively in the fine sediments covering most of the Gulf of Alaska, and typically delivered from 15-19 liters of sediment. Penetration was reduced in stations with considerable sand or gravel concentrations. At station 30 less than 5 liters of sediment was obtained per grab, and data from this station was considered to be qualitative only. The surface of all samples, examined through the top door of the grab, was relatively undisturbed as evidenced by the smooth detrital cover. Ten replicates were taken at stations 4, 25, 30, 42, 48 and 55 (Fig. 1) to determine the relative effectiveness of the grab. These samples were examined using a grab simulation program developed by Feder *et al.* (1973). This program provides an estimate of the cumulative percent of individuals and the cumulative percent of species collected in each step of a sequence of ten grabs, based on 100% obtained in ten grabs. The percentage of recruits in the new species added at each subsequent grab was estimated; in this case, the fraction of recruits is the number of individuals per new species added per grab divided by the sum over all ten grabs of the number of individuals per new species added per grab (for a detailed discussion see Feder *et al.*, 1973; Longhurst 1959; Holme 1964; Lie 1968). The results of the grab simulation program were similar for each of the six stations analyzed. Figure 2 shows a representative plot of the results. The cumulative percent of species taken in five grabs at stations 4, 25, 30, 42, 48 and 55 ranged from 77.5 to 83.0%. The percent of recruit individuals obtained in the fifth grab ranged from 3.7 to 6.7%. This means that 93.7 to 96.3% of the recruit individuals found in 10 grabs were collected in the first five grabs. This indicates that more abundant species are adequately sampled in the first five samples and recruitment in the subsequent samples represents only the less abundant species.

Material from each grab was washed on a 1.0 mm stainless steel screen, and preserved in 10% formalin seawater solution buffered with hexamine. In the laboratory all samples were rinsed to remove the last traces of sediment, spread on a tray and rough sorted by hand. The material was then transferred to fresh preservative and identifications made. All organisms were counted and wet weighed after excess moisture was removed with an absorbent towel.

Numerical Analysis

Station groups and species assemblages were identified using cluster analysis. Cluster analysis can be divided into three basic steps.

1. Calculation of a measure of similarity or dissimilarity between entities to be classified.

2. Sorting through a matrix of similarity coefficients to arrange the entities in a hierarchy or dendrogram.

3. Recognition of classes within the hierarchy.

Four hundred and nineteen taxa were identified from the 33 stations sampled (Feder *et al.*, 1976). Data reduction prior to calculation of similarity coefficients consisted of elimination of taxa that could not be identified to genus and taxa that occurred at a single station in such low numbers that they would have little effect on the classification. This procedure reduced the number of taxa used in the analysis to 224 (Table 1).

Two similarity coefficients were used to calculate the similarity matrices used for cluster analysis routines, the Sørenson coefficient which is based on the presence or absence of attributes and the Czenkanowski quantitative modification of the Sørenson coefficient. The Czenkanowski coefficient is synonymous with the Motyka (Mueller-Dombois and Ellenberg, 1974), and Bray-Curtis (Clifford and Stephenson, 1975) coefficients.

Sørenson

$$Cs_{1,2} = \frac{2C}{A + B}$$

where A = total number of attributes of entity one
B = total number of attributes of entity two
C = total attributes shared by entities one and two

Czekanowski

$$Cs_{1,2} = \frac{2W}{A + B}$$

where A = the sum of the measures of attributes of entity one
B = the sum of the measures of attributes of entity two
W = the sum of the lesser measures of attributes shared by entities one and two.

The Czekanowski coefficient has been used effectively in marine benthic studies by Field and MacFarlane (1968), Field (1969, 1970 and 1971), Day *et al.* (1971), Stephenson and Williams (1971), and Stephenson *et al.* (1972). This coefficient emphasizes the effect of dominant species on the classifica-

TABLE 1. Species selected for numerical analysis and their feeding type. SF= suspension feeder; DF=deposit feeder; P=predator; S=scavenger.

ID. NO.	SPECIES	FEEDING TYPE
	POLYCHAETA	
1	*Arcteobea spinelytris*	S
2	*Eunoe depressa*	S
3	*Gattyana brunnea*	S
4	*Gattyana treadwelli*	S
5	*Harmothoe imbricata*	S
6	*Lepidonotus squamatus*	S
7	*Peisidice aspera*	S
8	*Pholoe minuta*	S
9	*Sthenelais fusca*	S
10	*Anaitides maculata*	P
11	*Eteone longa*	P
12	*Ophiodromus pugettensis*	DF,S
13	*Typosyllis* sp.	P
14	*Typosyllis alternata*	P
15	*Typosyllis armillaris*	P
16	*Exogone* sp.	P
17	*Exogone verugera*	P
18	*Nereis* sp.	P,S
19	*Nereis pelagica*	P,S
20	*Nereis procera*	P,S
21	*Nereis zonata*	SF
22	*Nephtys* sp.	P
23	*Nephtys ciliata*	P
24	*Nephtys caeca*	P
25	*Nephtys cornuta*	P
26	*Nephtys punctata*	P
27	*Aglaophamus rubella anops*	P
28	*Glycera capitata*	P
29	*Glycinde picta*	P
30	*Glycinde armigera*	P
31	*Goniada annulata*	P
32	*Goniada maculata*	P
33	*Onuphis* sp.	DF
34	*Onuphis conchylega*	DF
35	*Onuphis geophiliformis*	DF
36	*Onuphis iridescens*	DF
37	*Onuphis parva*	DF
38	*Eunice valens*	DF
39	*Eunice kobiensis*	DF
40	*Lumbrineris* sp.	DF
41	*Lumbrineris bicirrata*	DF
42	*Lumbrineris similabris*	DF
43	*Lumbrineris zonata*	DF
44	*Ninoe gemmea*	DF
45	*Drilonereis falcata minor*	DF
46	*Haploscoloplos elongatus*	DF
47	*Aricidea* sp.	DF
48	*Aricidea suecica*	DF
49	*Aricidea jeffreysi*	DF
50	*Paraonis gracilis*	DF
51	*Laonice cirrata*	DF
52	*Spiophanes bombyx*	DF
53	*Spiophanes kroyeri*	DF
54	*Spiophanes cirrata*	DF
55	*Magelona japonica*	DF
56	*Spiochaetopterus* sp.	SF
57	*Spiochaetopterus costarum*	SF
58	*Tharyx* sp.	DF
59	*Chaetozone setosa*	DF
60	*Brada villosa*	DF
61	*Pherusa papillata*	DF
62	*Pherusa plumusa*	DF
63	*Scalibregma inflatum*	DF
64	*Ammotrypane aulogaster*	DF
65	*Travisia pupa*	DF
66	*Sternaspis scutata*	DF
67	*Capitella capitata*	DF
68	*Asychis similis*	DF
69	*Maldane* sp.	DF
70	*Maldane sarsi*	DF
71	*Maldane glebifex*	DF
72	*Maldanella robusta*	DF
73	*Nicomache lumbricalis*	DF
74	*Nicomache personata*	DF
75	*Notoproctus pacificus*	DF
76	*Praxillella gracilis*	DF
77	*Praxillella praetermissa*	DF
78	*Rhodine bitorquata*	DF
79	*Owenia fusiformis*	SF,DF
80	*Myriochele heeri*	DF

TABLE 1. Continued.

ID. NO.	SPECIES	FEEDING TYPE
81	*Myriochele heeri*	DF
82	*Idanthyrsus armatus*	DF
83	*Cistenides brevicoma*	DF
84	*Amage anops*	DF
85	*Ampharete* sp.	DF
86	*Ampharete arctica*	DF
87	*Ampharete acutifrons*	DF
88	*Amphicteis* sp.	DF
89	*Amphicteis macronata*	DF
90	*Lysippe labiata*	DF
91	*Melinna cristata*	DF
92	*Melinna elizabethae*	DF
93	*Pista* sp.	DF
94	*Pista cristata*	DF
95	*Artacama coniferi*	DF
96	*Terebellides stroemi*	DF
97	*Chone* sp.	SF
98	*Chone gracilis*	SF
99	*Chone infundibuliformis*	SF
100	*Euchone analis*	SF
101	*Megalomma splendida*	SF
102	*Pseudopotamilla reniformis*	SF
103	*Chitinopoma groenlandica*	SF
104	*Serpula vermicularis*	SF
	APLACOPHORA	
105	*Chaetoderma rubostum*	DF,P
	POLYPLACOPHORA	
106	*Ischnochiton albus*	S
	PELECYPODA	
107	*Nucula tenuis*	S
108	*Nuculana pernula*	DF
109	*Yoldia* sp.	DF
110	*Yoldia amygdalea*	DF
111	*Yoldia secunda*	DF
112	*Crenella decussata*	SF
113	*Dacrydium vitreum*	SF
114	*Propeamussium alaskense*	SF
115	*Delectopecten randolphi*	SF
116	*Astarte* sp.	SF
117	*Astarte montegui*	SF
118	*Astarte polaris*	SF
119	*Cyclocardia ventricosa*	SF
120	*Cyclocardia crebricostata*	SF
121	*Axinopsida sericata*	SF
122	*Thyasira flexuosa*	SF
123	*Odontogena borealis*	SF
124	*Clinocardium ciliatum*	SF
125	*Psephidia lordi*	SF
126	*Macoma calcarea*	DF
127	*Macoma moesta alaskana*	DF
128	*Hiatella arctica*	SF
129	*Pandora filosa*	SF
130	*Pandora bilirata*	SF
131	*Lyonsia norwegica*	SF
132	*Cardiomya pectinata*	P-S
133	*Cardiomya planetica*	P-S
134	*Cardiomya oldroydi*	P-S
	GASTROPODA	
135	*Lepeta caeca*	SF
136	*Solariella obscura*	S,P
137	*Solariella varicosa*	S,P
138	*Tachyrynchus reticulatus*	S,P
139	*Natica clausa*	P
140	*Policices* sp.	P
141	*Polinices nanus*	P
142	*Polinices pallidus*	P
143	*Trophonopsis lasius*	P
144	*Amphissa columbiana*	P
145	*Suavodrilla*	P
146	*Suavodrilla willetti*	P
147	*Oenopota* sp.	P
148	*Odostomia* sp.	OTHER
149	*Turbonilla* sp.	OTHER
150	*Retusa obtusa*	P
151	*Cylichna alba*	P
	SCAPHOPODA	
152	*Dentalium* sp.	DF,P
153	*Dentalium dalli*	DF,P
154	*Cadulus* sp.	DF,P
155	*Cadulus stearnsi*	DF,P
156	*Cadulus tolmei*	DF,P
	CUMACEA	
157	*Leucon* sp.	DF,S

TABLE 1. Continued.

ID. NO.	SPECIES	FEEDING TYPE
158	*Eudorella* sp.	DF,S
159	*Eudorella emarginata*	DF,S
160	*Eudorella pacifica*	DF,S
161	*Eudorellopsis integra*	DF,S
162	*Diastylis* sp.	DF,S
163	*Diastylis bidentata*	DF,S
164	*Diastylis paraspinulosa*	DF,S
165	*Diastylis* cf. *D. tetradon*	DF,S
166	*Campylaspis* sp.	DF,S
167	*Campylaspis umbensis*	DF,S
	ISOPODA	
168	*Calathura branchiata*	S,DF
169	*Rocinela belliceps*	S,DF
170	*Gnathia* sp.	OTHER
	AMPHIPODA	
171	*Ampelisca* sp.	SF
172	*Ampelisca macrocephala*	SF
173	*Ampelisca birulai*	SF
174	*Byblis* sp.	SF
175	*Byblis gaimardi*	SF
176	*Haploops tubicula*	SF
177	*Maera danae*	DF,S
178	*Maera loveni*	DF,S
179	*Melita* sp.	DF
180	*Melita dentata*	DF
181	*Urothoe denticulata*	SF
182	*Photis* cf. *P. reinhardi*	DF
183	*Protomedeia* sp.	DF
184	*Anonyx* sp.	S
185	*Anonyx ochoticus*	S
186	*Anonyx nugax*	S
187	*Hippomedon* sp.	S(DF?)
188	*Hippomedon kurilicus*	S(DF?)
189	*Lepidepecreum kasatka*	S(DF?)
190	*Lepidepecreum comatum*	S(DF?)
191	*Orchomene* sp.	S
192	*Bathymedon* sp.	DF,S
193	*Monoculodes* sp.	DF,S
194	*Monoculodes diamesus*	DF,S
195	*Westwoodilla coecula*	DF,S
196	*Nicippe tumida*	SF
197	*Harpinia kobjakovae*	SF
198	*Harpiniopsis sanpedroensis*	SF SF
199	*Heterophoxus oculatus*	SF
200	*Paraphoxus* sp.	SF
201	*Paraphoxus robustus*	SF
202	*Paraphoxus simplix*	SF
203	*Metopa* sp.	DF
204	*Metopa alderi*	DF
	DECAPODA	
205	*Chionoecetes* sp.	S,P
	SIPUNCULIDA	
206	*Golfingia margaritaces*	DF
207	*Golfingia vulgaris*	DF
208	*Phascolion strombi*	DF
	PRIAPULIDA	
209	*Priapulus caudatus*	P
	ECTOPROCTA	
210	*Clavipora occidentalis*	SF
	BRACHIOPODA	
211	*Terebratulina unguicula*	SF
212	*Terebratulina crossei*	SF
213	*Laqueus californianus*	SF
214	*Terebratalia transversa*	SF
	ASTEROIDEA	
215	*Ctenodiscus crispatus*	DF,S
	ECHINOIDEA	
216	*Brisaster townsendi*	DF,S
	OPHIUROIDEA	
217	*Diamphiodia craterodmeta*	DF
218	*Unioplus macraspis*	DF
219	*Ophiopholis aculeata*	SF
220	*Ophiopenia disacantha*	DF
221	*Ophiura sarsi*	DF,P
222	*Stegophiura* sp.	OTHER
	HOLOTHUROIDEA	
223	*Molpadia intermedia*	DF
224	*Cucumaria calcigera*	DF

tion and is often used with some form of transformation. The Czekanowski coefficient was used to calculate similarity matrices for normal cluster analysis (with stations as entities and species as attributes) and inverse cluster analysis (with species as entities and stations as attributes). Normal and inverse cluster analyses were run on untransformed and natural logarithm transformed abundance data (individuals/m^2). The natural logarithm transformation $Y = \ln(X+1)$ reduces the influence that dominant species have on the similarity determination. Station 30 was not included in classifications using abundance data because the data obtained for this station was considered to be qualitative only. A similarity matrix was constructed using the Sørenson coefficient in order to examine the relationship of station 30 to other stations. Dendrograms were constructed from the similarity matrices using a group-average agglomerative hierarchical cluster analysis (Lance and Williams, 1966).

As an aid in the interpretation of the dendrograms formed by cluster analyses a two-way coincidence table comparing the station groups formed by normal analysis and the species groups formed by inverse analysis was constructed. In this table the original species x stations data matrix was rearranged according to both normal and inverse analysis so that all stations or species within each group are adjacent to each other. The two-way coincidence table can then be divided into cells whose elements are the abundance of each of the species in a species group in each of the stations in a station group. The two-way table produced in this study (224 species x 32 stations) was too large to be reproduced here. It was reduced by summing all the elements in each cell and standardized by dividing the resulting sums by the number of species in the appropriate species group and the number of stations in the appropriate station group. The resulting table of average cell densities is presented in Table 2. Two-way tables of fidelity and constancy were also constructed (Tables 3 and 4). Fidelity is the percentage of the total number of individuals of all species in a species group which are found in each station group. In essence it is a measure of how faithful that species group is to each station group. Constancy, the percentage of the elements in each cell which had non-zero values, is a measure of the ubiquity of the species group members in each station group.

Principal coordinate analysis (Gower 1967, 1969) was used as an aid in interpreting the results of the cluster analyses and identifying misclassifications of stations by cluster analysis. In principal coordinate analysis an interstation similarity matrix is generated as in normal cluster analysis. The similarity matrix generated can be conceived of as a multidimensional space in which the stations are arranged in such a way that they are separated from one another according to their similarities. An ordination is then performed on the matrix to extract axes from this multidimensional space. The first axis extracted coincides with the longest axis, and accounts for the largest amount of variation in the similarity matrix. Subsequent axes account for successively smaller amounts of variation in the data. Both the Czekanowski and the Canberra "metric" similarity coefficients were used to calculate the similarity matrices used in principal coordinate analysis. The Canberra "metric" coefficient defines the similarity of two entities as:

TABLE 2. Station group/species group coincidence table showing average cell densities. Station group and species group size is in brackets.

		STATION GROUPS						
SPECIES GROUPS	IG 2 (4)	Group 4 (2)	Group 5 (2)	Group 6 (3)	IG 1 (11)	Group 7 (2)	SBG (7)	Station 39 (1)
1 (13)	0.2	0.1	0.1	0.0	0.2	4.8	0.2	0.5
2 (1)	4.0	0.0	0.0	0.0	1.2	2.0	0.0	0.0
3 (2)	0.0	0.0	4.0	0.0	0.5	1.0	0.0	0.0
4 (5)	0.2	0.0	0.0	0.0	0.1	1.2	0.1	0.0
5 (7)	0.6	1.1	1.0	1.3	0.3	17.0	2.5	0.6
6 (10)	0.3	0.3	0.5	0.3	0.1	4.5	1.0	0.0
7 (3)	0.7	0.7	0.3	0.2	2.1	0.0	0.8	0.0
8 (11)	0.2	0.1	0.0	0.5	0.1	0.6	1.4	0.0
9 (1)	0.0	1.0	0.0	0.7	0.0	0.0	4.4	0.0
10 (3)	0.0	0.0	0.0	0.0	0.2	1.3	0.9	0.0
11 (5)	0.2	0.0	0.0	0.0	0.1	0.0	0.7	0.0
12 (7)	0.0	0.1	0.0	0.1	0.1	0.6	0.4	0.0
13 (3)	0.0	0.0	0.0	0.0	0.1	0.7	0.7	0.0
14 (1)	1.0	0.0	1.0	0.7	0.0	1.0	0.6	0.0
15 (3)	13.9	0.0	0.3	0.4	0.4	1.3	0.7	0.0
16 (1)	0.0	1.0	0.0	2.0	0.6	1.0	1.1	118.0
17 (3)	0.2	18.0	1.0	0.0	1.8	0.0	1.3	0.0
18 (3)	1.3	94.3	0.0	0.4	2.4	38.7	1.8	0.0
19 (3)	15.2	4.3	1.3	51.1	5.2	0.0	5.3	0.0
20 (2)	6.0	5.0	9.0	38.4	10.55	15.0	77.5	0.0
21 (5)	118.4	135.2	74.8	12.3	13.0	14.2	16.2	1.2
22 (1)	10.5	0.0	42.0	2.0	17.4	0.0	3.7	0.0
23 (5)	0.4	10.4	49.4	0.2	0.9	0.8	1.2	0.0
24 (3)	2.8	0.3	2.3	0.0	0.9	2.7	0.5	2.7
25 (2)	0.5	0.0	0.0	0.4	0.1	5.0	5.4	1.0
26 (7)	6.1	3.1	4.9	2.5	1.7	7.6	3.2	0.6
27 (13)	3.9	3.1	8.2	2.9	5.3	6.3	0.1	0.2
28 (2)	19.0	4.0	54.0	29.7	23.6	17.0	2.0	3.0
29 (5)	16.2	5.6	5.6	6.3	10.2	9.6	8.2	9.2
30 (4)	0.4	1.3	2.7	0.2	0.2	42.2	7.9	0.0
31 (9)	0.2	1.3	1.3	0.3	0.4	4.7	13.0	0.0
32 (1)	0.0	0.0	0.0	0.7	0.4	0.0	3.4	0.0
33 (2)	0.1	0.0	0.0	0.4	0.2	0.0	4.2	0.0
34 (1)	0.0	0.0	0.0	0.0	0.0	4.0	5.7	0.0
35 (3)	1.3	7.0	0.0	0.0	0.7	0.0	0.2	0.0
36 (1)	0.5	0.0	0.0	0.0	1.2	0.0	0.0	0.0
37 (4)	0.3	4.0	2.0	0.0	0.1	0.5	0.0	0.0
38 (5)	0.9	2.8	1.4	0.0	0.6	0.2	0.0	0.0
39 (2)	0.1	1.0	0.0	0.0	0.2	0.0	0.0	0.0
40 (1)	0.0	1.0	0.0	0.0	0.2	0.0	1.0	0.0
41 (4)	2.4	0.2	0.0	0.0	0.2	0.8	0.0	0.0
42 (2)	0.2	0.0	0.5	0.0	0.0	0.5	0.0	0.0
43 (4)	0.1	0.8	0.0	0.0	0.0	0.5	0.4	0.0
44 (6)	0.1	0.0	0.2	0.9	0.0	0.0	0.7	1.0
45 (4)	0.2	0.0	0.0	0.2	0.0	0.0	0.4	5.0
46 (2)	0.6	0.0	2.5	0.0	0.2	0.0	0.2	2.0

TABLE 2. Continued

SPECIES GROUPS		IG 2 (4)	STATION GROUPS Group 4 (2)	Group 5 (2)	Group 6 (3)	IG 1 (11)	Group 7 (2)	SBG (7)	Station 39 (1)
47	(7)	0.6	0.7	8.0	0.6	0.6	0.7	0.7	0.0
48	(4)	0.0	0.0	1.5	1.3	0.0	0.5	0.2	0.0
49	(4)	0.0	0.0	1.8	0.0	0.4	0.0	0.0	0.0
50	(3)	0.7	0.7	0.0	0.4	2.3	0.3	0.0	0.0
51	(2)	0.0	0.0	0.5	0.0	0.3	0.0	0.0	0.0
52	(2)	0.0	0.0	0.5	0.0	0.3	0.5	0.0	0.0
53	(6)	0.1	0.7	0.0	0.0	0.1	0.0	0.5	0.0
54	(2)	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0
55	(1)	1.5	0.0	0.0	0.0	1.7	0.0	0.0	0.0
56	(2)	0.0	0.0	0.0	0.4	0.6	0.0	0.2	0.0
57	(3)	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.0
58	(1)	0.5	0.0	0.0	0.0	0.0	0.0	0.1	0.0
59	(1)	0.0	0.0	1.0	0.0	0.0	0.0	0.4	0.0
60	(1)	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0

TABLE 3. Station group/species group coincidence table showing % fidelity of the species groups in each station group.

	IG2	Group 4	Group 5	Group 6	IG1	Group 7	SBG	Sta. 39
1	3.2	1.6	1.6	0.0	3.2	78.7	3.2	8.2
2	55.5	0.0	0.0	0.0	16.7	27.8	0.0	0.0
3	0.0	0.0	72.7	0.0	9.1	18.1	0.0	0.0
4	12.5	0.0	0.0	0.0	6.2	75.0	6.2	0.0
5	2.5	4.5	4.1	5.3	1.2	69.7	10.2	2.5
6	4.3	4.3	7.1	4.3	1.4	64.3	14.3	0.0
7	14.5	14.5	6.2	4.2	43.8	0.0	16.7	0.0
8	6.9	3.4	0.0	17.2	3.4	20.7	48.2	0.0
9	0.0	16.4	0.0	11.5	0.0	0.0	72.2	0.0
10	0.0	0.0	0.0	0.0	8.3	54.2	37.5	0.0
11	20.0	0.0	0.0	0.0	10.3	0.0	70.0	0.0
12	0.0	7.7	0.0	7.7	7.7	46.2	30.8	0.0
13	0.0	0.0	0.0	0.0	6.7	46.7	46.7	0.0
14	23.3	0.0	23.3	16.3	0.0	23.3	13.9	0.0
15	81.8	0.0	1.8	2.3	2.3	7.7	4.1	0.0
16	0.0	0.8	0.0	1.6	0.5	0.8	0.9	95.3
17	0.9	80.7	4.5	0.0	8.0	0.0	5.8	0.0
18	0.9	67.8	0.0	0.3	1.8	27.8	1.3	0.0
19	18.4	5.2	1.6	62.0	6.3	0.0	6.4	0.0
20	3.7	3.1	3.5	23.8	6.5	9.3	47.7	0.0
21	30.7	35.1	19.4	3.2	3.3	3.7	4.2	0.3
22	13.9	0.0	55.6	2.6	23.0	0.0	4.9	0.0
23	0.6	16.4	78.0	0.3	1.4	1.3	1.9	0.0
24	22.9	2.5	18.8	0.0	7.4	22.1	4.1	22.1
25	4.0	0.0	0.0	3.2	0.8	40.3	43.6	8.1
26	20.5	10.4	16.5	8.4	5.7	25.6	10.8	2.0
27	13.0	10.4	27.4	9.4	17.7	21.1	0.3	0.7
28	12.4	2.6	35.4	19.5	15.5	11.2	1.3	2.0
29	22.8	7.9	7.9	8.9	14.4	13.5	11.6	12.9
30	0.7	2.3	4.8	0.4	0.4	75.5	14.1	0.0
31	0.9	6.1	6.1	1.4	1.9	22.2	61.3	0.0
32	0.0	0.0	0.0	15.5	8.9	0.0	75.6	0.0
33	2.0	0.0	0.0	8.2	4.1	0.0	85.7	0.0
34	0.0	0.0	0.0	0.0	0.0	41.2	58.8	0.0
35	14.1	76.1	0.0	0.0	7.6	0.0	2.2	0.0
36	29.4	0.0	0.0	0.0	70.6	0.0	0.0	0.0
37	4.4	58.0	29.0	0.0	1.4	7.3	0.0	0.0
38	15.2	47.5	23.7	0.0	10.2	3.4	0.0	0.0
39	7.7	76.9	15.4	0.0	0.0	0.0	0.0	0.0
40	0.0	45.4	0.0	0.0	9.1	0.0	45.4	0.0
41	66.7	5.6	0.0	0.0	5.6	22.2	0.0	0.0
42	16.7	0.0	41.7	0.0	0.0	41.7	0.0	0.0
43	5.6	44.4	0.0	0.0	0.0	27.7	22.2	0.0
44	3.4	0.0	6.9	31.0	0.0	0.0	24.1	34.5
45	3.4	0.0	0.0	3.4	0.0	0.0	6.9	86.2

TABLE 3. Continued

	IG2	Group 4	Group 5	Group 6	IG1	Group 7	SBG	Sta. 39
46	10.9	0.0	45.4	0.0	3.6	0.0	3.6	36.4
47	5.0	5.8	67.2	5.0	5.0	5.8	5.8	0.0
48	0.0	0.0	42.8	37.1	0.0	14.3	5.7	0.0
49	0.0	0.0	81.8	0.0	18.2	0.0	0.0	0.0
50	15.9	15.9	0.0	9.1	52.3	6.8	0.0	0.0
51	0.0	0.0	62.5	0.0	37.5	0.0	0.0	0.0
52	0.0	0.0	38.4	0.0	23.1	38.4	0.0	0.0
53	7.1	50.0	0.0	0.0	7.1	0.0	35.7	0.0
54	40.0	0.0	0.0	0.0	60.0	0.0	0.0	0.0
55	46.9	0.0	0.0	0.0	53.1	0.0	0.0	0.0
56	0.0	0.0	0.0	33.3	50.0	0.0	16.7	0.0
57	0.0	0.0	0.0	0.0	75.0	0.0	25.0	0.0
58	83.3	0.0	0.0	0.0	0.0	0.0	16.7	0.0
59	0.0	0.0	71.4	0.0	0.0	0.0	28.6	0.0
60	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0

TABLE 4. Station group/species group coincidence table showing % constancy of species groups within each station group.

	IG2	Group 4	Group 5	Group 6	IG1	Group 7	SBG	Sta. 39
1	5.77	3.8	3.8	5.1	8.4	61.5	8.8	15.4
2	25.0	0.0	0.0	0.0	18.2	50.0	0.0	0.0
3	0.0	0.0	50.0	0.0	18.2	25.0	0.0	0.0
4	15.0	0.0	0.0	13.3	6.1	60.0	8.6	0.0
5	21.4	35.7	28.6	28.6	7.8	100.0	20.8	0.0
6	7.5	10.0	20.0	13.3	3.6	75.0	27.2	0.0
7	16.7	16.7	16.7	11.1	24.2	0.0	23.8	0.0
8	11.3	4.5	0.0	3.0	2.5	31.8	28.6	0.0
9	0.0	50.0	0.0	33.0	0.0	0.0	71.4	0.0
10	0.0	0.0	0.0	0.0	6.01	50.0	23.8	0.0
11	10.0	0.0	0.0	0.0	1.8	0.0	34.2	0.0
12	0.0	7.2	0.0	4.8	3.9	28.6	20.4	0.0
13	0.0	0.0	0.0	0.0	3.0	33.0	19.0	0.0
14	50.0	0.0	50.0	33.3	0.0	50.0	28.6	0.0
15	41.7	0.0	16.7	22.2	18.2	50.0	19.0	33.3
16	0.0	50.0	0.0	100.0	9.1	50.0	57.1	100.0
17	8.3	66.7	50.0	0.0	24.2	0.0	38.1	0.0
18	25.0	83.3	0.0	11.1	33.3	100.0	47.6	0.0
19	66.7	16.7	33.3	100.0	45.5	0.0	47.6	0.0
20	50.0	50.0	50.0	100.0	63.6	50.0	100.0	0.0
21	100.0	80.0	80.0	80.0	76.4	80.0	74.3	20.0
22	75.0	0.0	50.0	66.7	63.6	0.0	28.6	0.0
23	10.0	50.0	70.0	6.7	23.6	10.0	22.9	0.0
24	41.7	16.7	50.0	0.0	21.2	50.0	19.0	66.7
25	25.0	0.0	0.0	16.7	4.5	75.0	57.1	50.0
26	71.4	57.1	64.3	47.6	36.4	78.6	67.3	28.6
27	61.5	46.2	82.6	56.4	67.1	38.5	40.7	15.4
28	62.5	75.0	100.0	66.7	100.0	50.0	64.3	50.0
29	90.0	60.0	70.0	66.7	72.7	80.0	77.1	80.0
30	16.7	25.0	12.5	8.3	4.5	75.0	57.1	0.0
31	5.6	22.2	11.1	14.8	10.1	55.6	76.2	22.2
32	0.0	0.0	0.0	33.3	0.0	0.0	14.3	0.0
33	12.5	0.0	0.0	16.7	13.6	25.0	28.6	0.0
34	0.0	0.0	0.0	0.0	0.0	50.0	14.3	0.0
35	41.7	66.7	0.0	0.0	21.2	0.0	21.2	0.0
36	25.0	0.0	0.0	0.0	18.2	0.0	0.0	0.0
37	12.5	50.0	0.0	0.0	4.5	12.5	3.6	0.0
38	35.0	40.0	20.0	6.7	16.4	0.0	0.0	0.0
39	12.5	50.0	0.0	0.0	4.5	0.0	0.0	0.0
40	0.0	50.0	0.0	0.0	9.1	0.0	28.6	0.0
41	37.5	0.0	0.0	0.0	11.4	12.5	17.9	0.0
42	25.0	0.0	25.0	0.0	0.0	0.0	14.3	0.0
43	6.3	25.0	0.0	0.0	2.3	25.0	14.3	0.0
44	8.3	0.0	8.3	38.9	0.0	0.0	4.8	50.0
45	6.3	0.0	12.5	8.3	0.0	0.0	21.4	100.0

TABLE 4. Continued

	IG2	Group 4	Group 5	Group 6	IG1	Group 7	SBG	Sta. 39
46	37.5	0.0	75.0	0.0	14.3	25.0	0.0	50.0
47	7.1	21.4	54.3	19.0	13.0	14.3	16.3	14.3
48	0.0	0.0	62.5	41.7	2.3	12.5	7.1	0.0
49	0.0	0.0	50.0	0.0	15.9	12.5	0.0	0.0
50	33.3	33.3	0.0	22.2	39.4	16.7	4.9	0.0
51	0.0	0.0	25.0	0.0	13.6	0.0	0.0	0.0
52	0.0	0.0	25.0	0.0	13.6	25.0	0.0	0.0
53	4.2	25.0	0.0	0.0	6.1	0.0	19.1	0.0
54	12.5	0.0	0.0	0.0	9.1	0.0	0.0	0.0
55	25.0	0.0	0.0	0.0	27.3	0.0	0.0	0.0
56	0.0	0.0	0.0	16.7	27.3	0.0	21.4	0.0
57	0.0	0.0	0.0	0.0	12.1	0.0	9.5	0.0
58	25.0	0.0	0.0	0.0	0.0	0.0	14.3	0.0
59	0.0	0.0	50.0	0.0	0.0	0.0	14.3	0.0
60	0.0	0.0	0.0	0.0	9.1	0.0	0.0	0.0

$$Cs_{1,2} = 1 - \frac{1}{n} \sum_{i}^{n} \frac{|X_{1i} - X_{2i}|}{(X_{1i} + X_{21})}$$

where X_{1i} = the measure of the ith attribute in entity one
X_{2i} = the measure of the ith attribute in entity two

The Canberra "metric" coefficient is a series of fractions and gives equal weighting to all species and reduces the effect of the dominant species on the analysis. It was used as a means of comparison with the results of analyses using the Czekanowski coefficient.

Diversity

Species diversity was calculated by the use of three indices; the Simpson index (a measure of dominance) and the Shannon and Brillouin indices (information measures of diversity). The Brillouin evenness function was also calculated.

The Simpson index

$$S = \sum_{i} \frac{n_i (n_i - 1)}{N (N-1)}$$

where n_i = number of individuals in the ith species
N = total number of individuals

is an index of dominance since the maximum value, one, is obtained when there is a single species (total dominance) and values approaching zero are obtained when there are numerous species, each a very small fraction of the total abundance. The Shannon

$$H' = -\sum_{i} p_i \log p_i \qquad \text{where } p_i = \frac{n_i}{N}$$

and Brillouin

$$H = \frac{1}{N} \log \frac{N!}{n_1! n_2! \cdots n_s!}$$

information measures of diversity were also used. The Shannon function assumes that a random sample has been taken from a infinitely large population whereas the Brillouin function is appropriate only if the entire population has been sampled. Thus, if we wish to estimate the diversity of the fauna at a sampling station the Shannon function is appropriate. The Brillouin function is merely a measure of the diversity of the five grab samples taken at each station and makes no predictions about the diversity of the benthic community that the samples were drawn from. Diversity, as measured by both the Shannon and the Brillouin diversity indices, can be divided into two components. One component is simply the number of species represented and the other is the relative abundance of each species. The relative number of individuals per species is called the evenness component of the diversity index. The evenness of the five grab samples taken at each station can be calculated using the Brillouin measure of evenness $J = H/H_{maximum}$ where H = Brillouin diversity function. $H_{maximum}$, the maximum possible diversity for a given number of species, occurs if all species are equally common and is calculated as:

$$H_{maximum} = \frac{1}{N} \log \frac{N!}{\{[N/s]!\}^{s-r}\{([N/s]+1)!\}^{r}}$$

where $[N/s]$ = the integer part of N/s
s = number of species in the censused population
r = $N - s[N/s]$

Theoretically the evenness component of Shannon function can be calculated from the following

$$J' = \frac{H'}{\log s^*}$$

where H' = Shannon diversity function
s^* = the total number species in the randomly sampled population.

However, s^* is seldom known for benthic infaunal communities, and it is obvious from Figure 2 that the number of species obtained in 5 grabs is a poor estimate of the total number of species found in 10 grabs. For this reason the evenness component of the Shannon diversity index was not calculated (for a discussion see Pielou, 1977). The Brillouin measures of diversity and evenness, although not appropriate as estimators of community structure, provide a means of assessing the fitness of classifactory routines by measuring the structure of the samples which provided the data for classification.

Trophic Structure

The trophic structure of each of the station groups formed by cluster analysis was determined by classifying the 50 most abundant species in each station group into 5 feeding classes: suspension feeders (SF), deposit feeders (DF), predators (P), scavengers (S) and other (O). Species were assigned to feeding classes (Table 1) based on literature reports and personal observations on the species in question or on closely related species (Feder et al. 1973, 1975; Jumars and Fauchald 1977; unpub. observations). Since species are distributed along a continuum of feeding types and many organisms utilize several feeding modes, it is often difficult to place a species in a specific class. For example, protobranch molluscs, generally regarded as deposit feeders, also utilize particles in suspension (Stasek 1965; Stanley, 1970). However, since these molluscs probably obtain most of their nutritional requirements from the sediment, we classified them as deposit feeders. It is even more difficult to make a distinction between scavengers and deposit feeders in organisms such as cumaceans and amphipods that can ingest larger food particles and or small detrital fragments. If such organisms were motile, and able to operate efficiently as scavengers, they were classified as both scavengers and deposit feeders. Species whose feeding behavior was unknown, or uncertain, were classified as "other". The percentage of individuals belonging to each feeding classification (Table 1) was calculated for each station group. In those cases where a species was assigned to two feeding classes we assigned one half of the individuals of that species to each class. Species were also classified into three classes of motility: sessile, discretely motile, and motile (after Jumars and Fauchald, 1977). The percentage of individuals belonging to each motility class was also calculated for each station group.

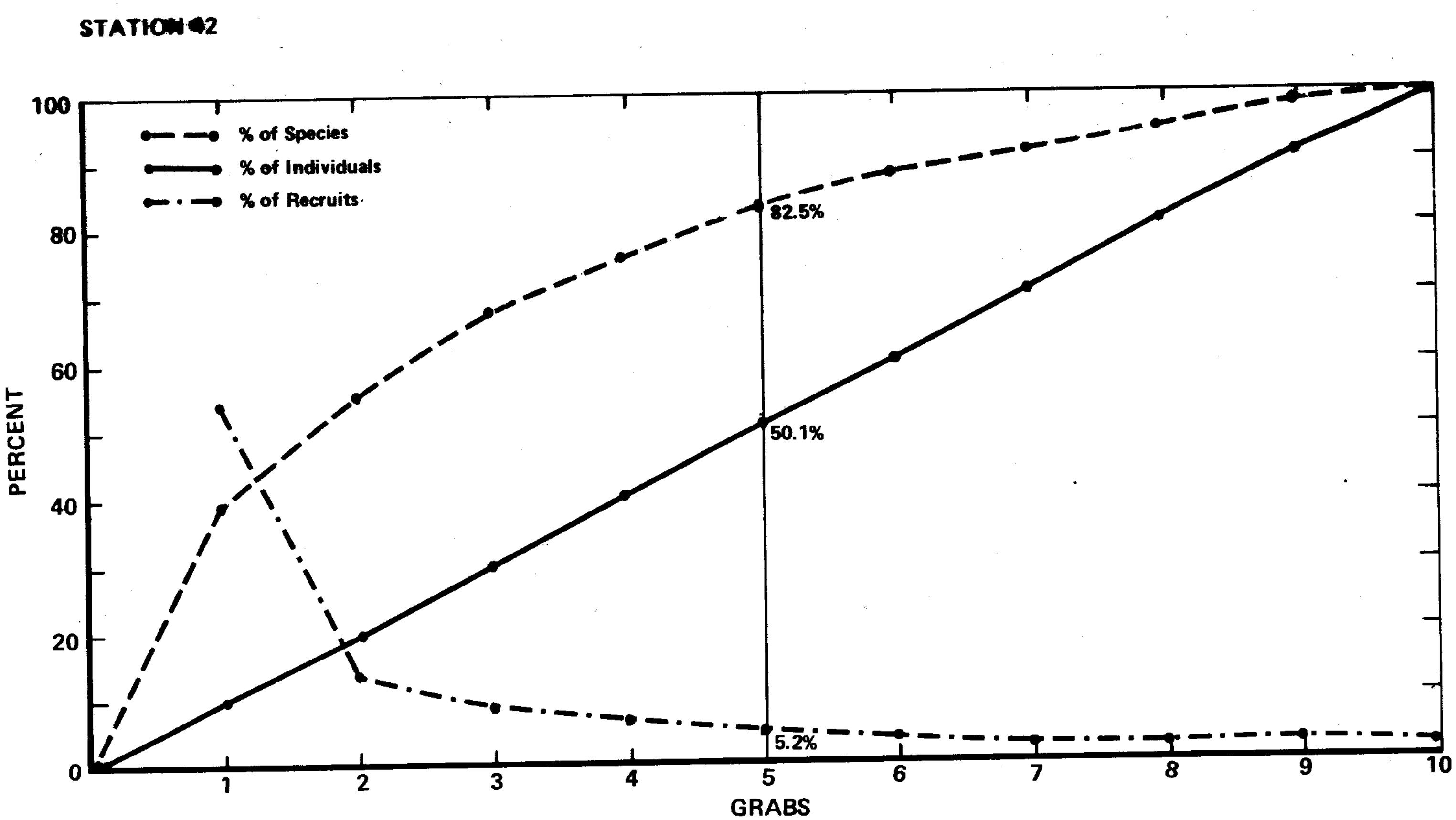

Figure 2. Plots of cumulative percentage of individuals and species, and percent of recruits added at each subsequent grab for station 42. The total number of individuals and total of species collected in 10 grabs equals 100 percent.

RESULTS

Numerical Analysis; Untransformed Abundance Data

A normal cluster analysis of untransformed abundance data produced seven station groups at the 29% similarity level; one station, station 39, did not join any group (Figs. 3 and 4). Two major station groups were formed in the shelf area. One of these groups labeled inshore group 1 (IG1) consisted of five stations in the transect south of Resurrection Bay, five stations south of Cordova and station 32 south of Icy Bay (Fig. 4). Inshore group 2 (IG2) consisted of four stations east of Kayak Island. A third large group, the Shelf Break Group (SBG), was composed of stations near the 200 m contour and on the shelf south of Yakutat Bay. Other smaller station groups included stations 43 and 58 (Group 4, G4), stations 53 and 54 in Hinchinbrook entrance (Group 5, G5), stations 7, 28 and 59 (Group 6, G6) and stations 56 and 57 on Tarr Bank (Group 7, G7).

Species groups formed by an inverse cluster analysis of untransformed abundance data at the 31% similarity level are listed in Table 5. An examination of the original two way coincidence table (224 species x 32 stations) and the reduced two way tables (Tables 2, 3, and 4) was useful in determining the distribution of species among the station groups and identifying the species which distinguish certain station groups from each other. Many species groups were composed of species linked together by their presence in a single station within a station group. These species were only occasionally found at other stations. While these species groups are useful in examining differences that occur within station groups, they add little to our understanding of the differences between station groups. In the interest of simplicity these species groups were eliminated from our discussion of the differences between station groups. Thirty-one species groups were eliminated by this criteria. An additional nine species groups were composed of species linked together by their presence in two or more stations that were not in the same station group. The species in these nine groups (2, 7, 10, 24, 42, 46, 48, 55 and 56) were present in very low abundance (Table 2) and they were also eliminated. The remaining 19 species groups are included in Figure 5. The fidelity and constancy of these species groups were arbitrarily divided into 5 classes: very high (VH), 95-100%; high (H), 66-94%; medium (M), 33-65%; low (L), 16-32%; very low (VL), 0-15% (Fig. 5). A summary of the distribution of the 19 major species groups (Fig. 5; Table 5) follows:

Species group 5: H - fidelity (Tables 3 and 5), VH - constancy (Tables 4 and 5) and average cell density of 17.0 (Table 2) in station group 7.

Species group 6: M - fidelity, H - constancy and average cell density of 4.5 in station group 7.

Species group 9: H - fidelity, H - constancy and average cell density of 4.4 in shelf break group.

Species group 16: The single species in this group, Maldane glebifex, was very abundant ($118/m^2$) in station 39.

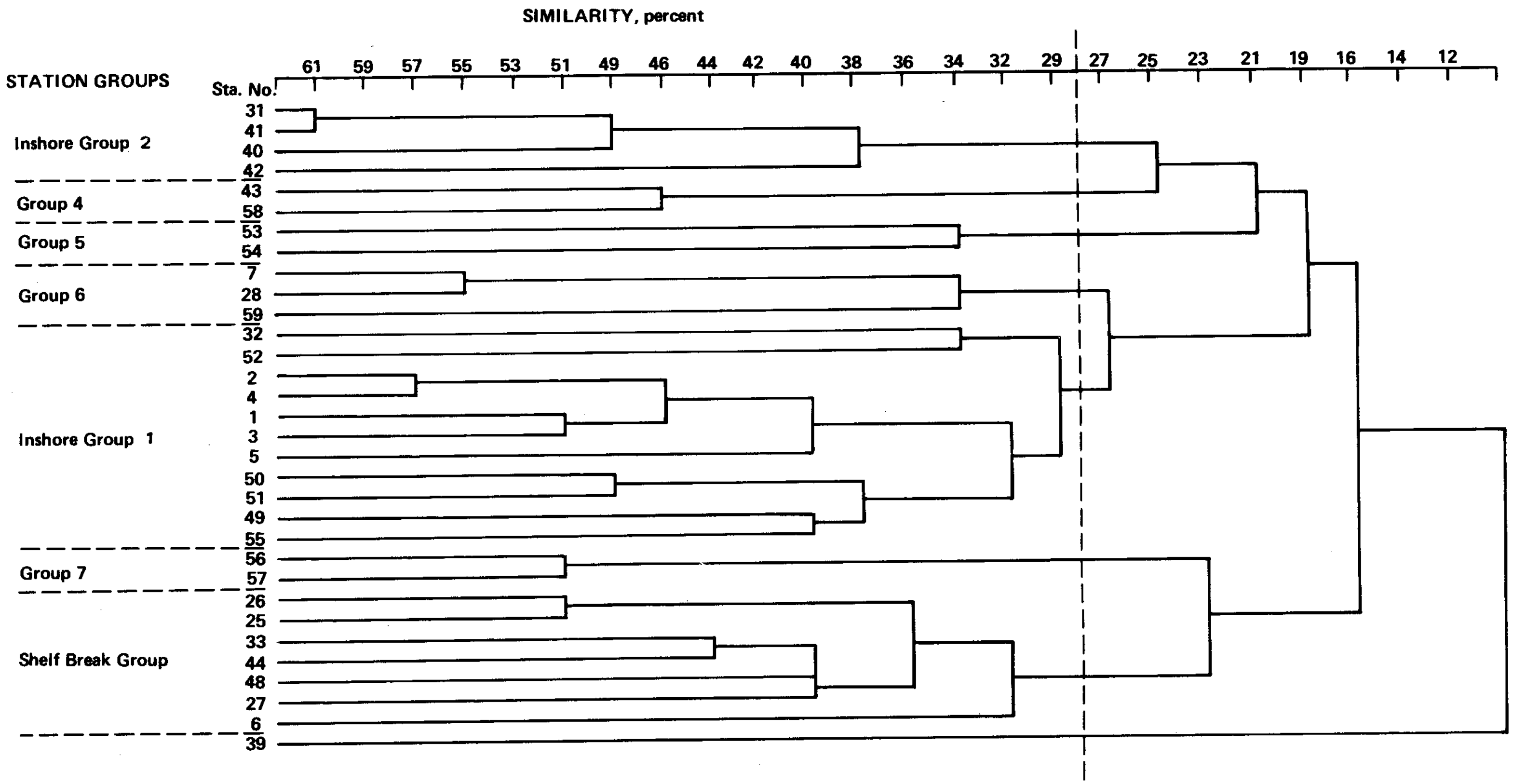

Figure 3. Dendrogram produced by cluster analysis using number of individuals/m^2 data.

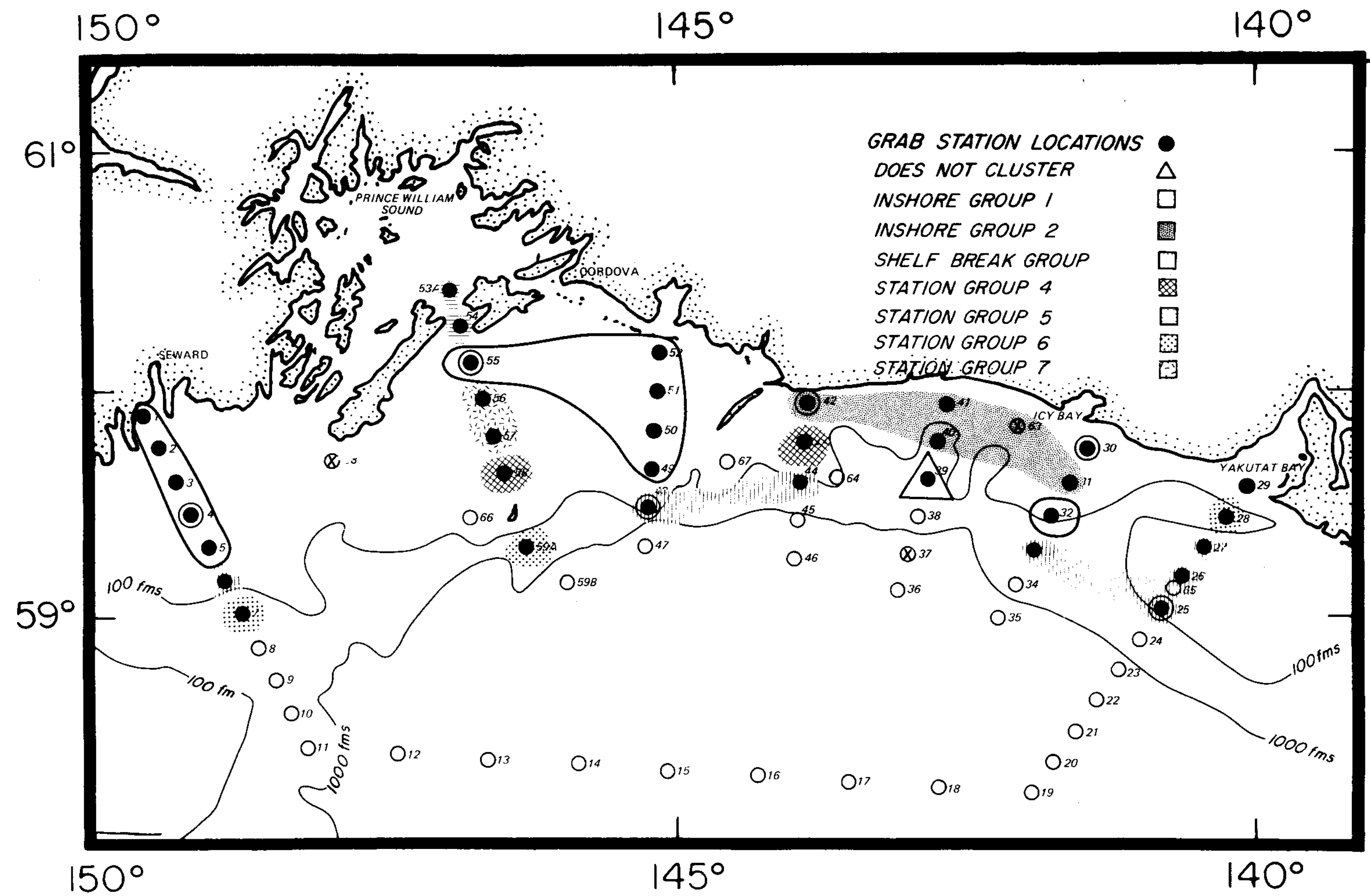

Figure 4. Station groups formed by cluster analysis using number of individuals/m^2 data.

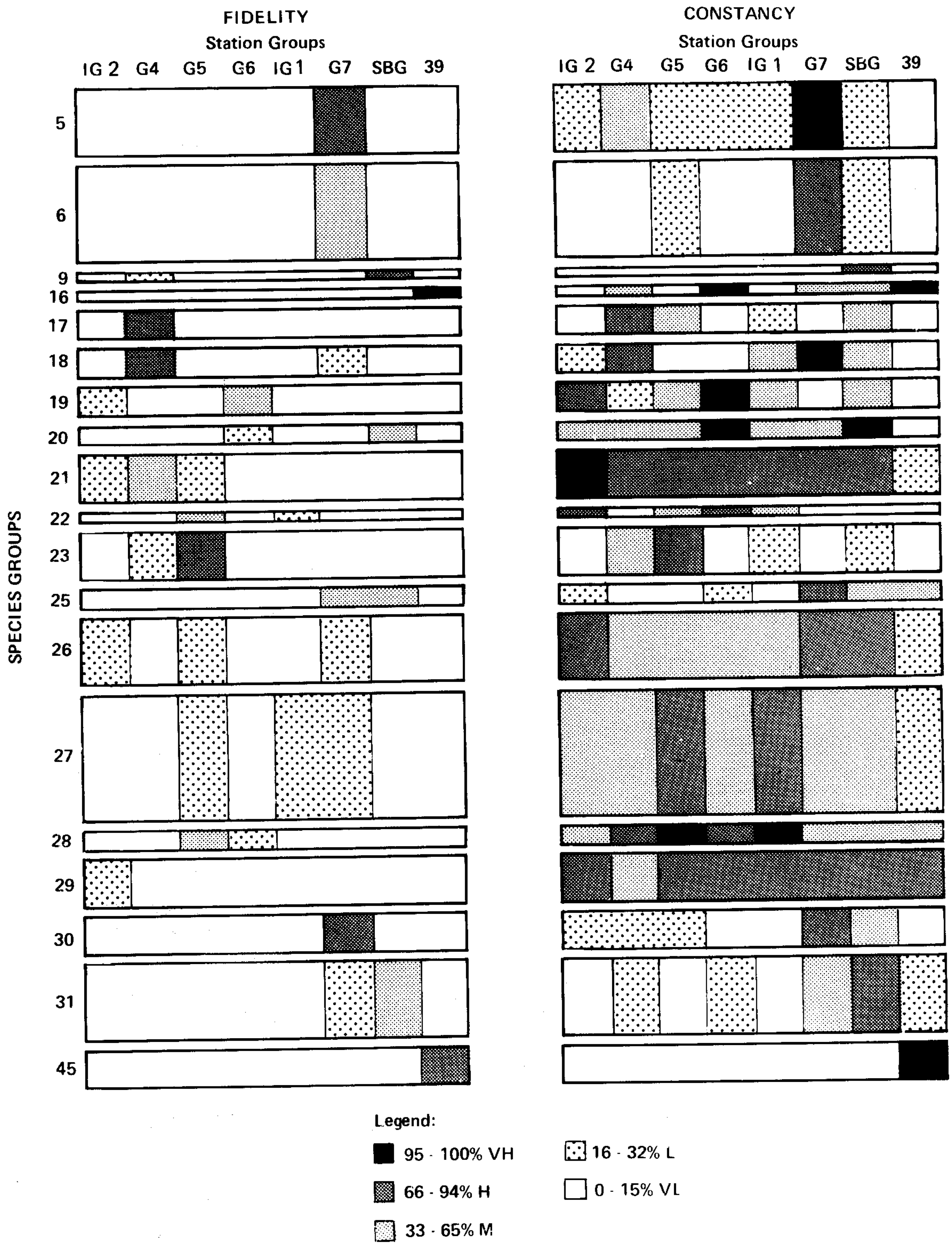

Figure 5. Fidelity and constancy of species groups formed by inverse cluster analysis using number of individuals/m^2 data.

TABLE 5. Species groups formed by inverse cluster analysis of abundance data. Identification numbers for cross reference with Table 1 are included in brackets.

Group	Species
1	*Eteone longa* (114), *Byblis* sp. (174), *Eunoe depressa* (2), *Nepthys caeca* (24), *Ampharete* sp. (85), *Paraphoxus simplex* (207), *Paraonis gracilis* (50), *Priapulis caudatus* (209), *Natica clausa* (139), *Clinocardium ciliatum* (124), *Paraphoxus robustus* (201), *Terebratulina transversa* (214), *Lumbrineris similabris* (42)
2	*Diamphiodia craterodmeta* (217)
3	*Haploscoloplos elongatus* (46), *Yoldia amygdalea* (110)
4	*Astarte* sp. (116), *Lepeta caeca* (135), *Gattyana treadwelli* (4), *Maera loveni* (178), *Maera danae* (177)
5	*Drilonereis falcata minor* (45), *Ampelisca macrocephala* (172), *Diastylis bidentata* (163), *Metopa alderi* (204), *Asychis similis* (68), *Terebratulina unguicula* (211), *Laques californianus* (213)
6	*Praxillella praetermissa* (77), *Haplopps tubicula* (176), *Chone sp.* (97), *Golfingia vulgaris* (207), *Nereis zonata* (21), *Maldane sp.* (69), *Amphissa columbiana* (44), *Monoculades diamesus* (194), *Exogone verugera* (17), *Anonyx nugax* (186)
7	*Nepthys ciliata* (23), *Spiochaetopterus costarum* (57), *Rhodine bitorguata* (78)
8	*Onuphis* sp. (33), *Pista* sp. (93), *Lepidonotus squamatus* (6), *Onuphis parva* (37), *Pseudopotamilla reniformis* (102), *Typosyllis armillaris* (15), *Serpula vermicularis* (104), *Propreamussium alaskense* (114), *Lepidepecreum comatum* (190), *Anonyx* sp. (184), *Ophiopholus aculeata* (219)
9	*Delectopecten randolphi* (115)
10	*Eunice valens* (38), *Campylaspis umbensis* (167), *Monoculodes sp.* (193)
11	*Lysippe labiata* (90), *Chitinopoma groenlandica* (103), *Maldanella robusta* (72), *Nicomache personata* (74), *Eudorella sp.* (158)
12	*Amage anops* (34), *Trophonopsis lasius* (43), *Pherusa plumosa* (62), *Pherusa papillata* (61), *Scalibregma inflatum* (63), *Campylaspis sp.* (166), *Polinices sp.* (140)

TABLE 5. Continued

Group	Species
13	*Typosyllis alternata* (14), *Onuphis conchylega* (34), *Eunice kobiensis* (39)
14	*Cucumaria calcigera* (224)
15	*Spiophanes kroyeri* (53), *Magelona japonica* (55), *Maldane sarsi* (70)
16	*Maldane glebifex* (71)
17	*Cyclocardia ventricosa* (119), *Tachyrynchus reticulatus* (138), *Cadulus* sp. (154)
18	*Crenella decussata* (112), *Cyclocardia crebricostata* (120), *Astarte polaris* (118)
19	*Dacrydium vitreum* (113), *Cadulus tolmei* (156), *Yoldia secunda* (111)
20	*Odontogena borealis* (123), *Golfingia margaritacea* (206)
21	*Nucula tenuis* (107), *Axinopsida sericata* (121), *Myriochele heeri* (80), *Psephidia lordi* (125), *Ophiura sarsi* (221)
22	*Yoldia* sp. (109)
23	*Capitella capitata* (67), *Eudorellopsis integra* (161), *Dentalium* sp. (152), *Urothoe denticulata* (181), *Spiophanes cirrata* (54)
24	*Melinna cristata* (91), *Nicippe tumida* (196), *Sthenelais fusca* (9)
25	*Chone gracilis* (98), *Euchone analis* (100)
26	*Tharyx* sp. (58), *Ampharete arctica* (86), *Praxillella gracilis* (76), *Pista cristata* (94), *Glycera cupitata* (28), *Byblis gaimardi* (175), *Heterophoxus oculatus* (199)
27	*Ctenodiscus crispatus* (215), *Molpadia intermedia* (223), *Ninoe gemmea* (44), *Nepthys punctata* (26), *Eudorella emarginata* (158), *Goniada annulata* (31), *Onuphis iridescens* (36), *Nepthys* sp. (22), *Chaetoderma robustum* (105), *Dentalium dalli* (153), *Leucon* sp. (157), *Diastylis* sp. (162), *Cadulus stearnsi* (155)

TABLE 5. Continued

Group	Species
28	*Lumbrineris zonata* (43), *Sternaspis scutata* (66)
29	*Nuculana pernula* (108), *Thyasira flexuosa* (122), *Lumbrineris* sp. (40), *Terebellides stroemi* (96), *Unioplus macraspis* (218)
30	*Exogone* sp. (16), *Idanthyrsus armatus* (81), *Peisidice aspera* (7), *Metopa* sp. (203)
31	*Gnathia* sp. (170), *Clavipora occidentalis* (210), *Typosyllis* sp. (13), *Ischnochiton albus* (106), *Aricidea suecica* (48), *Phascolion strombi* (208), *Notoproctus pacificus* (75), *Owenia fusiformis* (79), *Harpiniopsis sanpedroensis* (198)
32	*Calathura branchiata* (168)
33	*Laonice cirrata* (51), *Ampelisca birulai* (173)
34	*Terebratulina crossei* (212)
35	*Cardiomya oldroydi* (134), *Ophiopenia disacantha* (220), *Cardiomya pectinata* (132)
36	*Pandora bilirata* (130)
37	*Nereis procera* (20), *Diastylis paraspinulosa* (164), *Suavodrillia* sp. (145), *Nereis pelagica* (19)
38	*Macoma moesta alaskana* (127), *Pandora filosa* (129), *Turbonilla* sp. (149), *Retusa obtusa* (150), *Odostomia* sp. (148)
39	*Polinices nanus* (141), *Rocinela belliceps* (169)
40	*Suavodrillia willeti* (146)
41	*Nereis* sp. (18), *Melinna elizabetha* (92), *Onuphis geophiliformis* (35), *Oenopota* sp. (147)
42	*Chone infundibuliformis* (99), *Polinices pallidus* (142)
43	*Astarte montagui* (117), *Eudorella pacifica* (160), *Nicomache lumbricalis* (73), *Melita dentata* (180)
44	*Spiophanes bombyx* (52), *Cardiomya planetica* (133), *Hiatella arctica* (128), *Aglaophamus rubella anops* (27), *Hippomedon* sp. (187), *Arcetoebea spinelytris* (1)

TABLE 5. Continued

Group	Species
45	*Brada villosa* (60), *Melita* sp. (179), *Amphicteis macronata* (89), *Ampelisca* (171)
46	*Pholoe minuta* (8), *Artacama coniferi* (95)
47	*Macoma calcarea* (126), *Protomedeia* sp. (183), *Orchomene* sp. (191), *Harpinia kobjakovae* (197), *Cylichna alba* (151), *Cistenides brevicoma* (83), *Photis* cf. *P. reinhardi* (182)
48	*Aricidea jeffreysi* (49), *Hippomedon kurilicus* (188), *Harmothoe imbricata* (5), *Diastylis* cf. *D. tetradon* (165)
49	*Anaitides maculata* (10), *Chaetozone setosa* (59), *Ophiodromus pugettensis* (12), *Amphictene auricoma* (82)
50	*Brisaster townsendi* (216), *Stegophiura* (222), *Chionoecetes* sp. (205)
51	*Lyonsia norvegica* (131), *Bathymedon* sp. (192)
52	*Glycinde picta* (29), *Lumbineris bicirrata* (41)
53	*Glycinde armigera* (30), *Aricidea* (47), *Gattyana brunnea* (3), *Lipidepecreum kasatka* (189), *Megalomma splendida* (101), *Anonyx ochoticus* (185)
54	*Ampharete acutifrons* (87), *Solariella varicosa* (137)
55	*Solariella obscura* (136)
56	*Nepthys cornuta* (25), *Spiochaetopterus* (56)
57	*Travisia pupa* (65), *Amphicteis* sp. (88), *Goniada maculata* (32)
58	*Ammotrypane aulogaster* (64)
59	*Paraphoxus* sp. (200)
60	*Westwoodilla coecula* (195)

Species group 17: All species abundant in station 58 of group 4. <u>Cyclocardia</u> <u>ventricosa</u> also found in station 43 of group 4. Species are present in H constancy in station group 4 and H constancy in group 5 and the shelf break group.

Species group 18: Very abundant (av. cell density=94.3) in station group 4 and abundant (av. cell density=38.7) in station group 7. Species are present in VH constancy in group 7, H constancy in group 4 and M constancy in inshore group 1 and shelf break group.

Species group 19: Most abundant in group 6 (av. cell density=51.1) also abundant (av. cell density=15.3) in inshore group 2. Species are present in VH constancy in group 6, H constancy in inshore group 2 and M constancy in group 5, inshore group 1 and shelf break group.

Species group 20: Very abundant in shelf break group (av. cell density=77.5) and abundant in station group 6 (av. cell density=38.4). VH constancy in shelf break group and group 6, $\geq$ 50 constancy (Table 4) in all station groups except station 39.

Species group 21: Very abundant in station group 4 (av. cell density=135.2), inshore group 2 (av. cell density=118.4) and group 5 (av. cell density=74.8). H to VH constancy in all groups except station 39.

Species group 22: Most abundant in station group 5. M to H constancy in groups 5 and 6, and inshore groups 1 and 2.

Species group 23: Most abundant in station group 5. H constancy in group 5, M constancy in group 4.

Species group 25: Most abundant in shelf break group and group 7. Very low abundance elsewhere. H constancy in group 7, patchy distribution in shelf break group.

Species group 26: Most abundant in shelf break group and groups 7 and 4. Ubiquitous, M to H constancy in all groups except station 39.

Species group 27: Most abundant in groups 5 and 7. Ubiquitous, M to H constancy in all groups except station 39.

Species group 28. Most abundant in station groups 5 (av. cell density=54.0), 6 (av. cell density=29.7) and inshore group 1 (av. cell density=23.6). Ubiquitous, $\geq$ 50% constancy in all station groups. 100% constancy in group 5 and inshore group 1.

Species group 29: Most abundant in inshore group 1 (av. cell density= 16.2) but abundance only slightly lower in all other groups. Ubiquitous, 60% or greater constancy in all groups.

Species group 30: Most abundant in group 7 (av. cell density=42.2), present in lower abundance in shelf break group (av. cell density=7.9). Very low abundance in all other stations. H constancy in group 7, M constancy in shelf break group L and VL constancy in all other groups.

Species group 31: Most abundant in shelf break group (av. cell density= 13.0), present in lower abundance in group 6 (av. cell density=4.6). H constancy in shelf break group, M constancy in group 7. L or VL constancy and low abundance in all other groups.

Species group 45: H fidelity and VH constancy in station 39.

The species groups which characterize and differentiate the station groups formed by cluster analysis of untransformed abundance data are as follows:

Inshore group 1: Species groups 20, 21, 22, 27, 28
Very similar to Inshore group 2 in terms of species composition, but the abundance of species in species group 21 is much greater in inshore group 2 (Table 2). Species groups 22 and 27 have a L fidelity and M to H constancy in this group. Species groups 20, 21 and 28 have a very low fidelity but a M to VH constancy in inshore group 1.

Inshore group 2: Species groups 19, 21, 26, 29
Species groups 19, 21, 26 and 29 were present in L fidelity but H to VH constancy in inshore group 2.

Station group 4: Species groups 17, 18, 21
Species groups 17 and 18 have a H fidelity and H constancy in this group. Species group 21 has a M fidelity and H constancy in group 4.

Station group 5: Species groups 21, 22, 23 and 28
Species group 23 has a H fidelity and H constancy in group 5. Species groups 22 and 28 have M fidelity and a M and VH constancy respectively in station group 5. Species group 21 has a L fidelity but H constancy in this group.

Station group 6: Species groups 19, 20, 28
Species group 19 has M fidelity and VH constancy in group 6. Species groups 20 and 28 have L fidelity but H to VH constancy in group 6.

Station group 7: Species groups 5, 6, 18, 20, 21, 25, 26, 28, 30
Species groups 5, 6, 25 and 30 have M to H fidelity and H to VH constancy in station group 7. Species groups 18 and 26 have a low fidelity but a high to very high constancy in this group. Species groups 20, 21 and 28 have a very low fidelity but M to H constancy in station group 7.

Shelf break group: Species groups 9, 20, 21, 25, 31
Species group 9 has a H fidelity and H constancy in this group. Species groups 20, 25 and 31 have a M fidelity and an M to VH constancy in the shelf break group. Species group 21 has a VL fidelity but a H constancy in this group.

Station 39: Species groups 16, 29 and 45
Station 39 was distinguished from other stations by the paucity of its fauna, the abundance of *Maldane glebifex* (Species group 16) and presence of species in group 45. Species group 29 had a VL fidelity but a high constancy in station 39.

A principal coordinate analysis using untransformed abundance data and the Czekanowski coefficient (Fig. 6) revealed groupings similar to those produced by cluster analysis (Figs. 3 and 4). The shelf break group and station groups 5 and 7 produced fairly tight and distinct groups on plots of the first and second (Fig. 6a), first and third (Fig. 6b) and second and third coordinate axes (Fig. 6c). Stations 58 and 43 (group 4) produced a tight and distinct grouping on plots of the first and second axes but showed considerable separation on all other plots. The greater abundance of the bivalves, *Crenella decussata*, *Cyclocardia crebricostata* and *Psephidia lordi* and the brittle star *Ophiura sarsi* in station 58 as compared to station 43 accounts for much of the separation between these stations. Inshore group 1 and inshore group 2 produced loose groupings on all three plots. Figure 6 indicates that there are closer similarities between inshore groups 1 and 2 and station group 6 than there are between any other groups (Fig. 6).

Loadings of stations on the first three coordinate axes of a principal coordinate analysis of untransformed abundance data using the Canberra "metric" similarity coefficient are shown in Figure 7. In this case stations in inshore group 1, with the exception of station 5, formed a relatively tight group on all axes. Station 5 exhibited considerable separation from most other stations in inshore group 1, and was in fairly close proximity to several of the shelf break stations. Stations 31 and 40 of inshore group 2 were interspersed among the stations in inshore group 1. Station 41 was distinct from inshore group 1 stations on the third coordinate axis while station 42 (inshore group 2) showed considerable separation from group 1 stations on all three axes. The separation of station 42 from other stations in inshore groups 1 and 2 was caused by species in species groups 38, 41 and 42 that were present in station 42 in low abundance ($\leq$ 11 ind/m^2); these species were absent from the other stations (Table 2) in inshore groups 1 and 2. Station groups 4, 5 and 6 were all contiguous with inshore group 1. Stations 58 and 43 (Group 4) formed a tight group on all plots. The Canberra "metric" coefficient

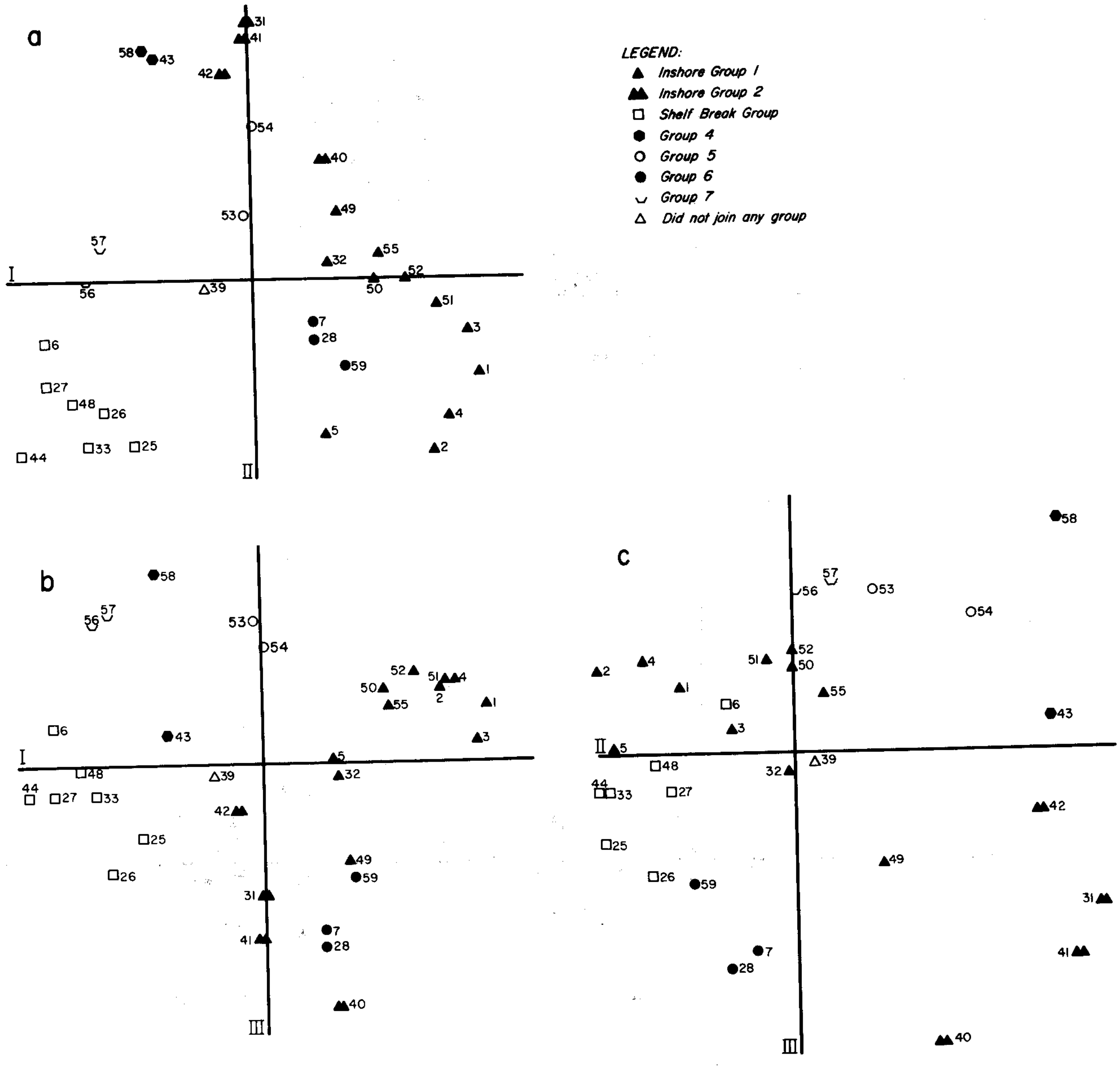

Figure 6. Plots of loadings on the first three coordinate axes extracted by principal coordinate analysis using number of individuals/m^2 and the Czekanowski similarity coefficient.
a. represents loadings on the first and second; b. the second and third; and, c. the first and third coordinate axes.

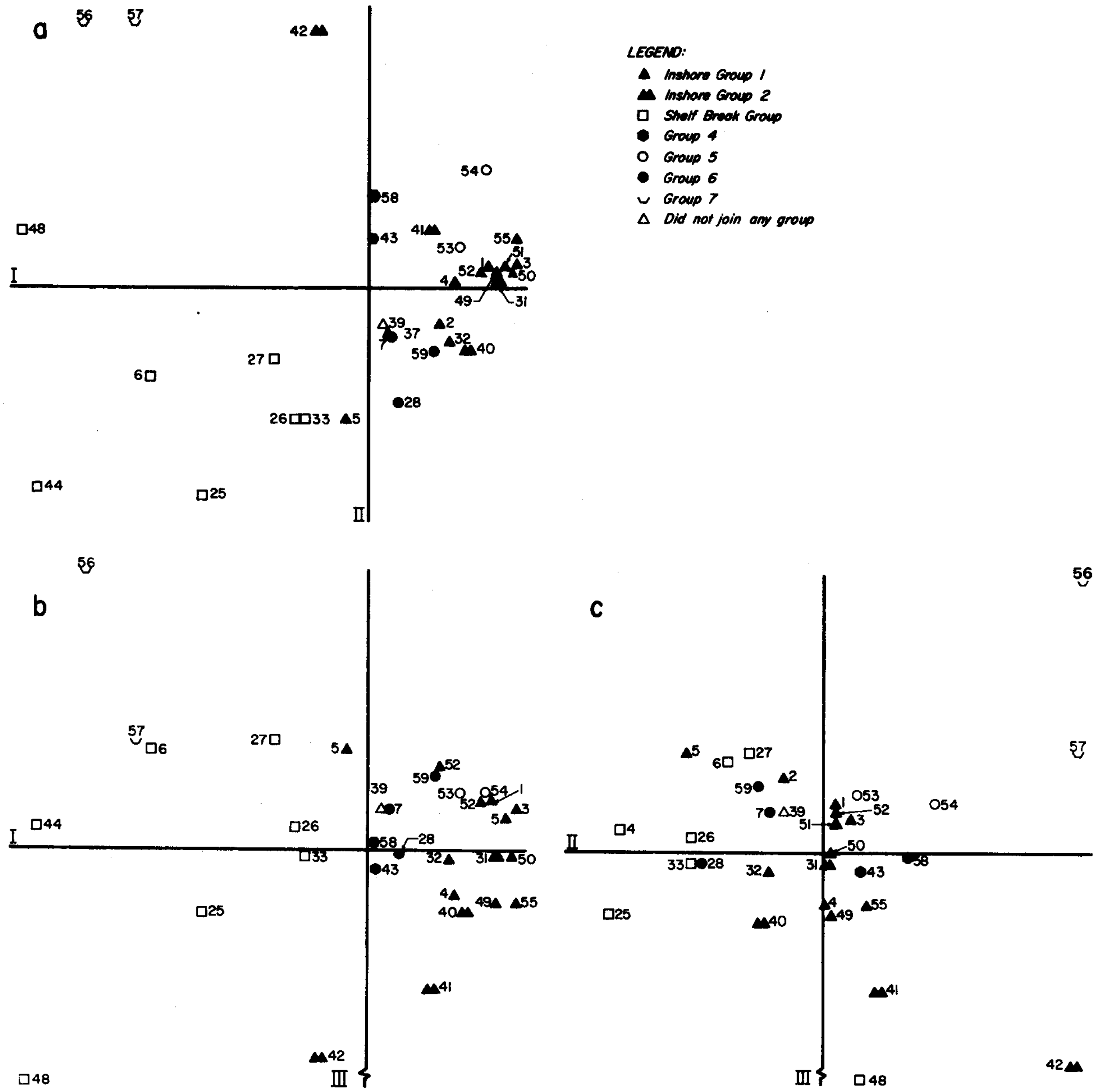

Figure 7. Plots of loadings on the first three coordinate axes extracted by principal coordinate analysis using number of individuals/m^2 data and the Canberra "metric" similarity coefficient.

reduced the effect of the differences in the abundance of Crenella decussata, Cyclocardia crebricostata, Psephidia lordi and Ophiura sarsi between these two stations. Stations 56 and 57 (group 7) were still quite distinct in relation to the other stations but they showed considerable separation between themselves on the third coordinate axis. This separation was probably caused by species in species group 1 which were predominantly found in station 56, and species groups 5 and 6 which were predominantly found in station 57. The shelf break group stations form a rather diffuse group and station 48 showed considerable separation from the other stations in this group on the second and third coordinate axes.

Numerical Analysis; Transformed Abundance Data

A cluster analysis of natural logarithm transformed abundance data delineated five station groups at the 37% similarity level; stations 39 and 42 did not join any of the groups formed (Figs. 8 and 9). Inshore groups 1 and 2 and station group 6, formed in the analysis of untransformed abundance data (Figs. 3 and 4), merged to form a single large inshore group while groups 4, 5 and 7 and the shelf break group remained unchanged (Figs. 8 and 9). Inshore group 1 and 2, and station group 6 were distinguished from each other predominantly on the basis of differences in the abundance of dominant species by cluster analysis of untransformed data (Table 2). They were fused when the influence of the dominant species was reduced by applying a natural log transformation. The presence, in station 42, of species from species groups 15, 38, 41 and 42, which are rare in all other stations, distinguished station 42 from the other stations in the inshore group.

Principal coordinate analysis using the Czekanowski coefficient and natural logarithm transformed abundance data (Fig. 10) generally confirmed the results of the cluster analysis (Fig. 8). Stations 53 and 54 (Fig. 10) were always contiguous with stations from the inshore group while all other station groups exhibited a greater separation from the inshore group. Loadings of the stations in the inshore group on the third axis showed considerable spread.

Principal coordinate analysis using natural logarithm transformed data and the Canberra "metric" coefficient (Fig. 11) greatly reduced the effect of differences in abundance on the analysis and therefore increased the influence of rare species. Nevertheless, the groupings apparent in this analysis were similar to those formed by the other treatments of transformed data. Again station 5 showed some separation from the other stations in the inshore group as did station 48 from the other shelf break stations. Station 5 was unique among the stations in the inshore station group in having representation among species groups 20 and 31 which are typically characteristic of the shelf break stations. The fauna in species group 5 appeared to be transitional between that of the inshore group(s) and the shelf break group. Station 48 differed from other stations in the shelf break group by the presence of species from species groups 24, 33, 41, 42 and 43. However, all of these species were present in extremely low abundance ($\leq$ 4 ind/m^2) and were collected in only one or two of five grab samples.

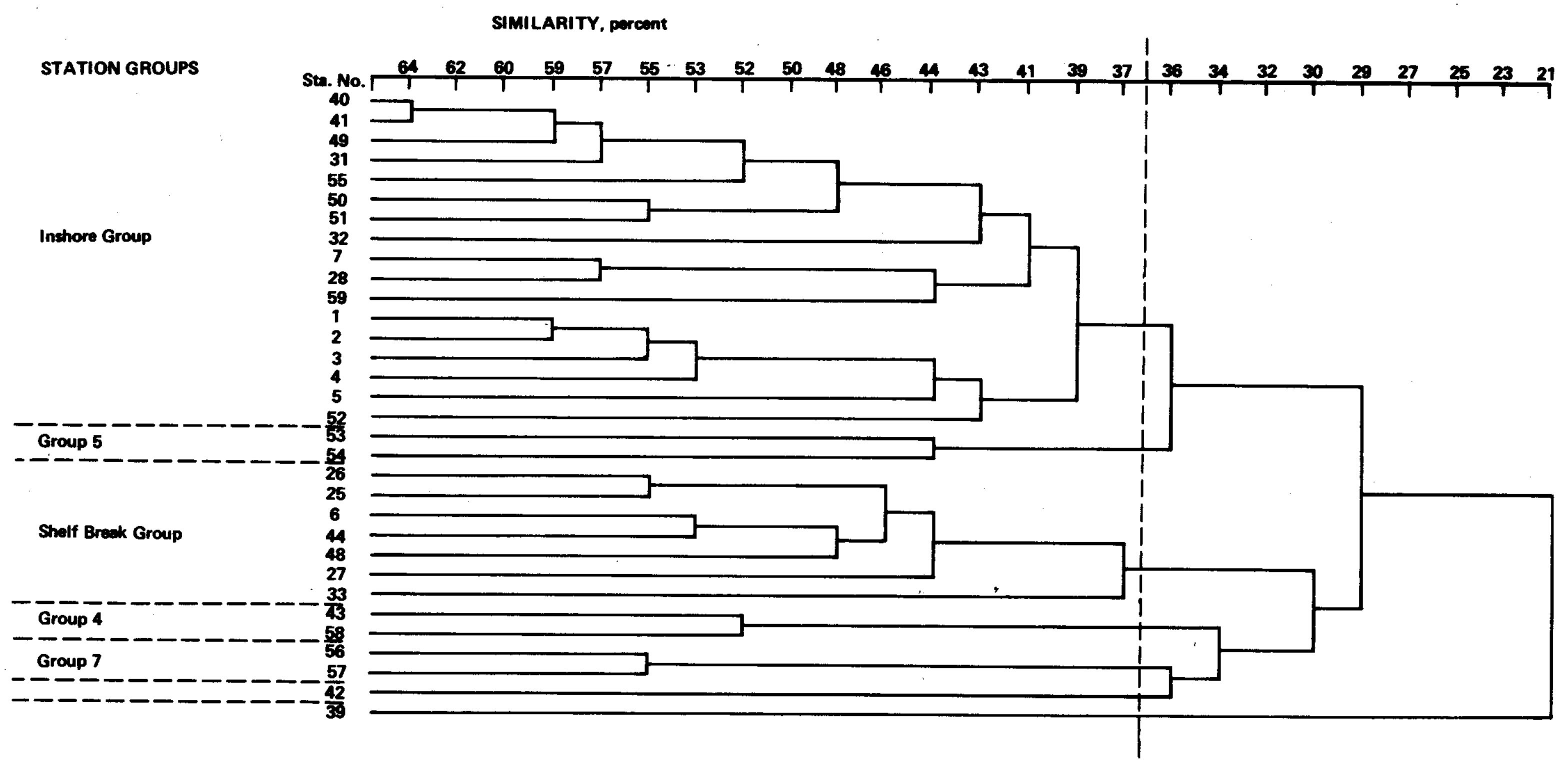

Figure 8. Dendrogram produced by cluster analysis using natural logarithm transformed number of individuals/m^2 data.

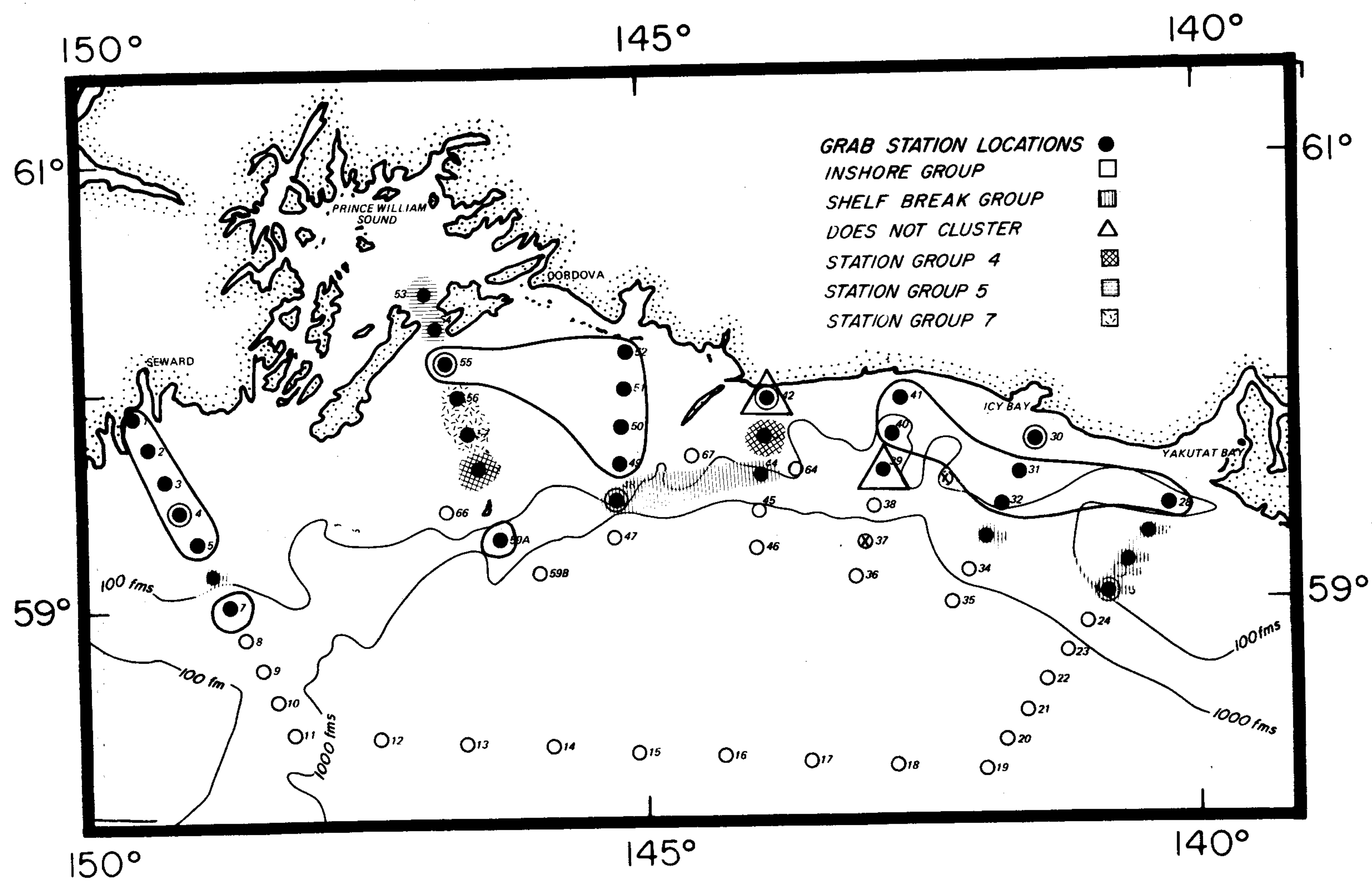

Figure 9. Station groups formed by cluster analysis using natural logarithm transformed number of individuals/m^2 data.

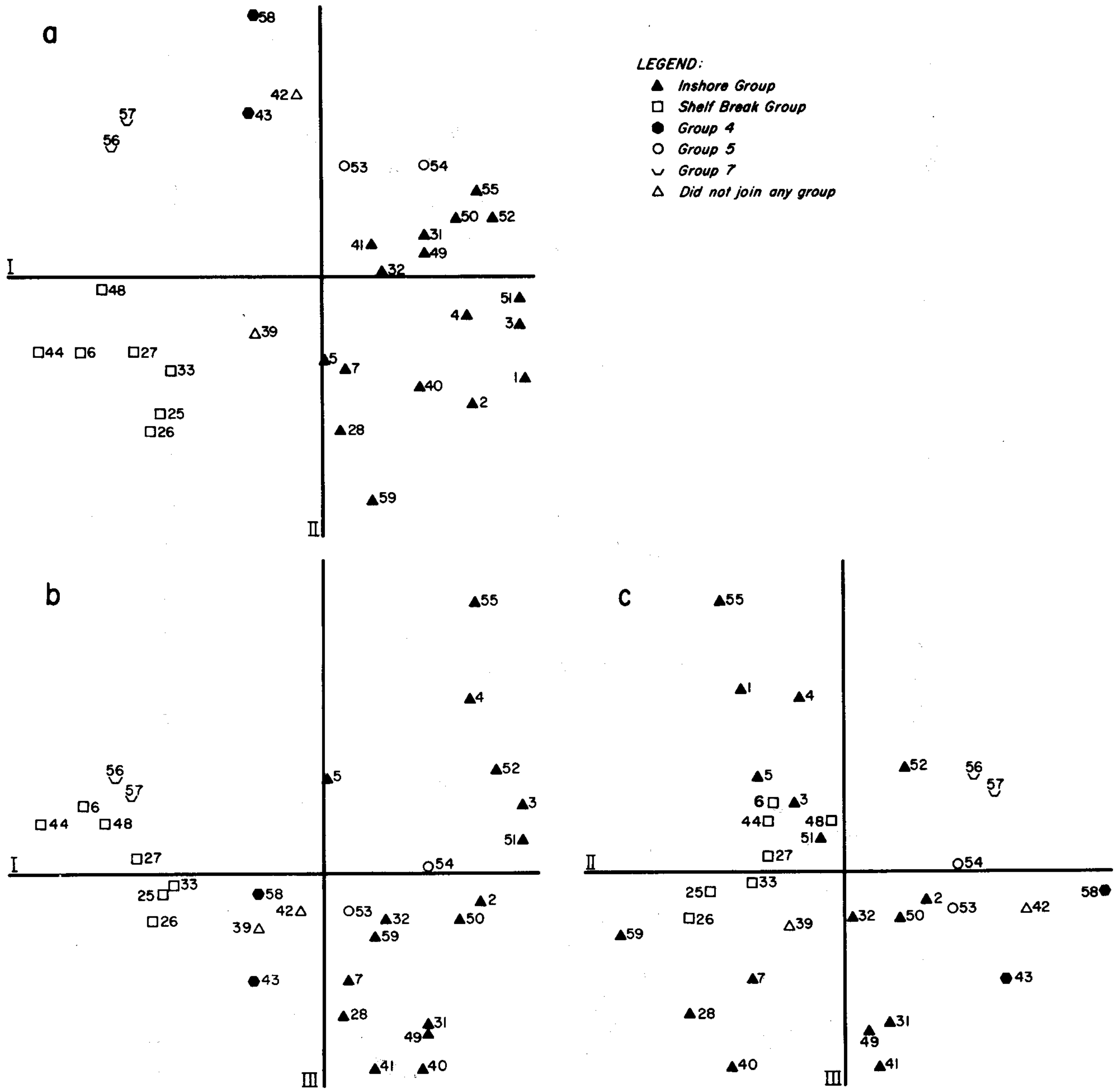

Figure 10. Plots of loadings on the first three coordinate axes extracted by principal coordinate analysis using natural logarithm transformed number/ m^2 and the Czekanowski similarity coefficient.

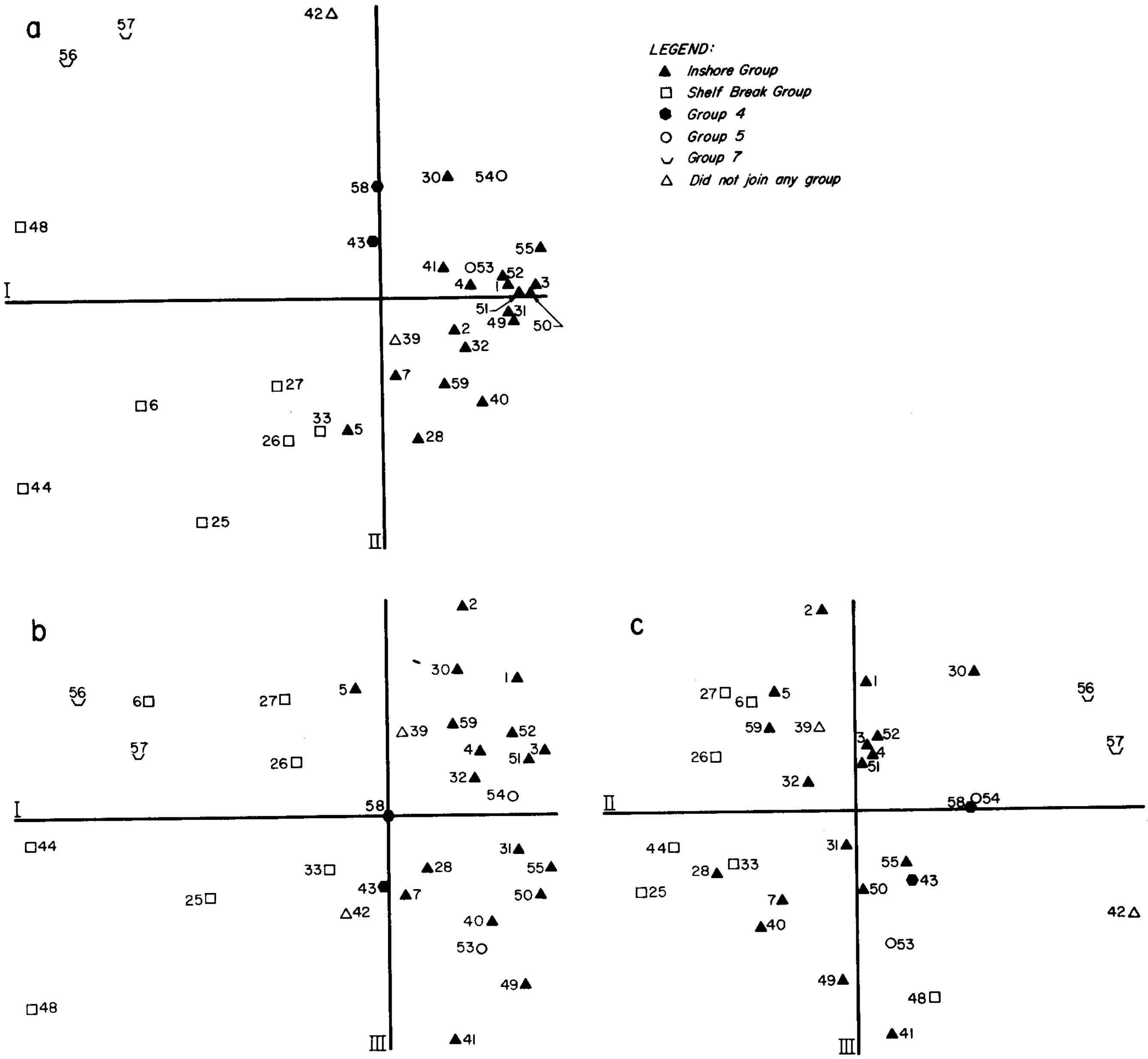

Figure 11. Plots of loadings on the first three coordinate axes extracted by principal coordinate analysis using natural logarithm transformed number of individuals/m^2 data and the Canberra "metric" similarity coefficient.

When the Canberra "metric" coefficient was used with both transformed and untransformed data in principal coordinate analyses, stations in the shelf break group were expanded in space and stations in the inshore group were contracted as compared to results obtained with the Czekanowski coefficient (Figs. 6, 7, 10 and 11). This would seem to indicate that the stations in the shelf break group had relatively high similarities in terms of abundant species and lower similarities among the rarer species, whereas in the inshore groups the opposite is true. An examination of the faunal composition of these stations supports this view (unpub. data from OCSEAP submitted to the National Oceanographic Data Center).

Numerical Analysis; Binary Data

A cluster analysis based on presence-absence data using the Sørenson similarity coefficient was performed to examine the relationship of station 30 to all other stations. The fauna at station 30 was quite different from other stations, and it was the last station to be fused in the cluster analysis (Fig. 12). The combined presence of the bivalves Yoldia scissurata, Yoldia amygdaiea and Lyonsia norvegica, the polychaetes Nepthys ciliata and Haploscoloplos elongatus and the brittle star Diamphiodea craterodmeta distinguished this station from the other stations in the NEGOA area.

Numerical Analysis Comparing Station Groups

A cluster analysis was also performed using station groups as entities and species as attributes in order to examine the relationship between the station groups (Fig. 13). The Czekanowski coefficient was used with untransformed abundance data. Inshore groups 1 and 2 and station group 6 were the first groups to be linked by this analysis (Fig. 13). Then, at the 31% similarity level, station group 4 was linked with station group 5 and the shelf break group was linked with group 7 (Fig. 13). Stations 30 and 39 had the very low similarities with the other station groups (Fig. 13).

Sediment Analysis

Data on sediment type is presented in Table 6 and Figure 14 (sediment size data from A. S. Naidu in Burrell 1976). In order to present sediment data in the ternary diagram (Fig. 14), sand and gravel fractions were summed. Station 57 and stations in station group 5, and the shelf break group are closely associated in the ternary diagram (Fig. 14), but these groups can be distinguished from each other on the basis of the proportion of gravel present (Table 6).

Data collected by Feely and Cline (1977) on the distribution of suspended matter 5 m above the bottom is presented in Figure 15. The high suspended particulate concentrations over the shelf area from west of Yakutat Bay to Resurrection Bay are derived principally from runoff from the Malaspina and Bering Glaciers and the Copper River (Feely and Cline, 1977). Lower concentrations of suspended matter were found near the 200 m contour and the shelf south of Yakutat Bay (shelf break stations, Fig. 4), on Tarr Bank (stations 56, 57; Fig. 4), and in Hinchinbrook Entrance.

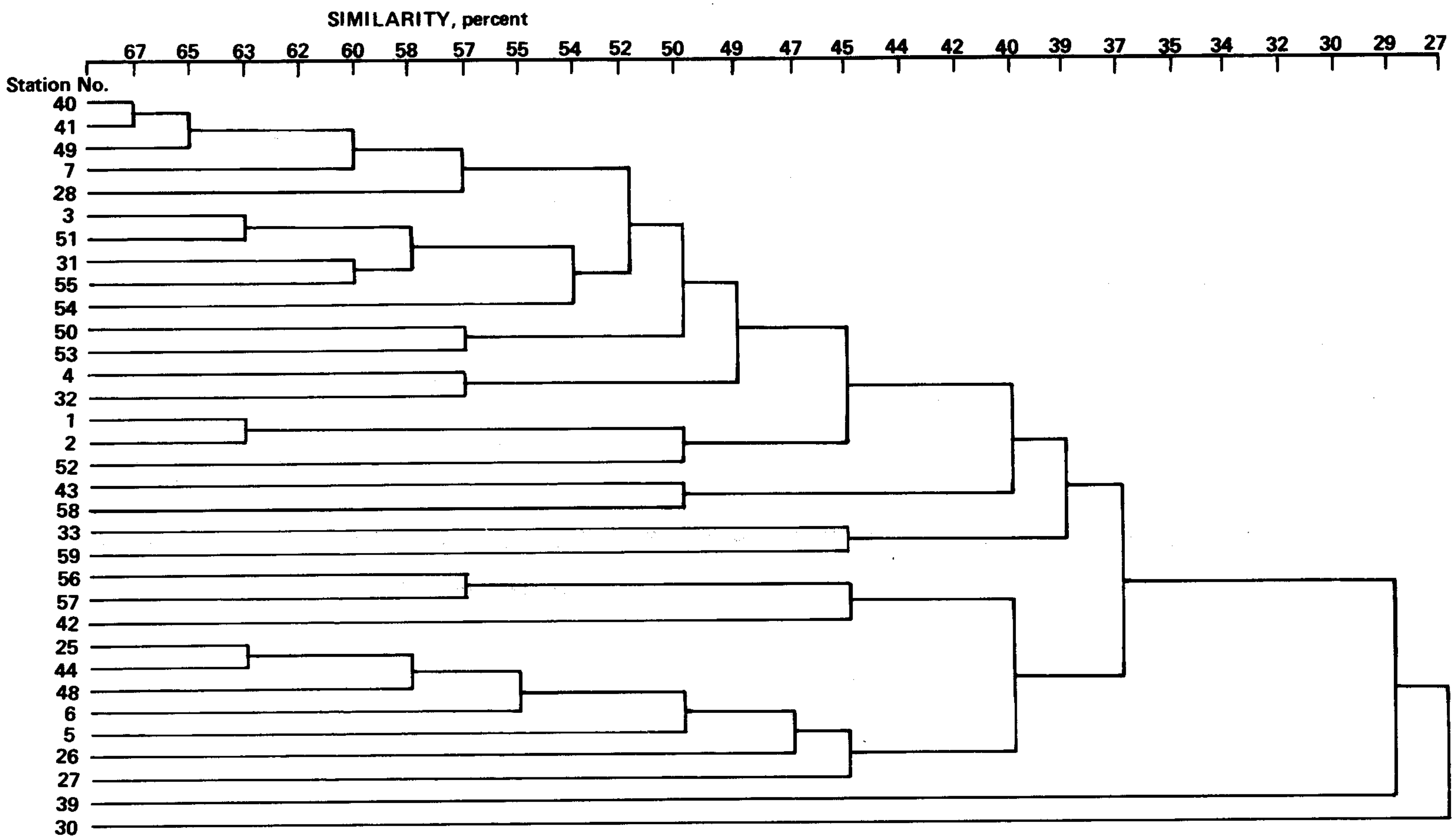

Figure 12. Dendrogram produced by cluster analysis using presence-absence data.

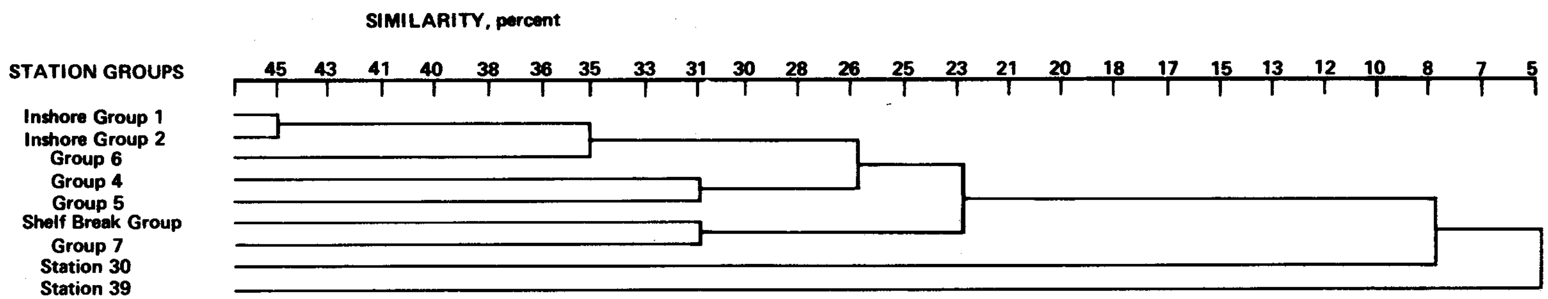

Figure 13. Dendrogram of cluster analysis of station groups using number of individuals/m^2 data.

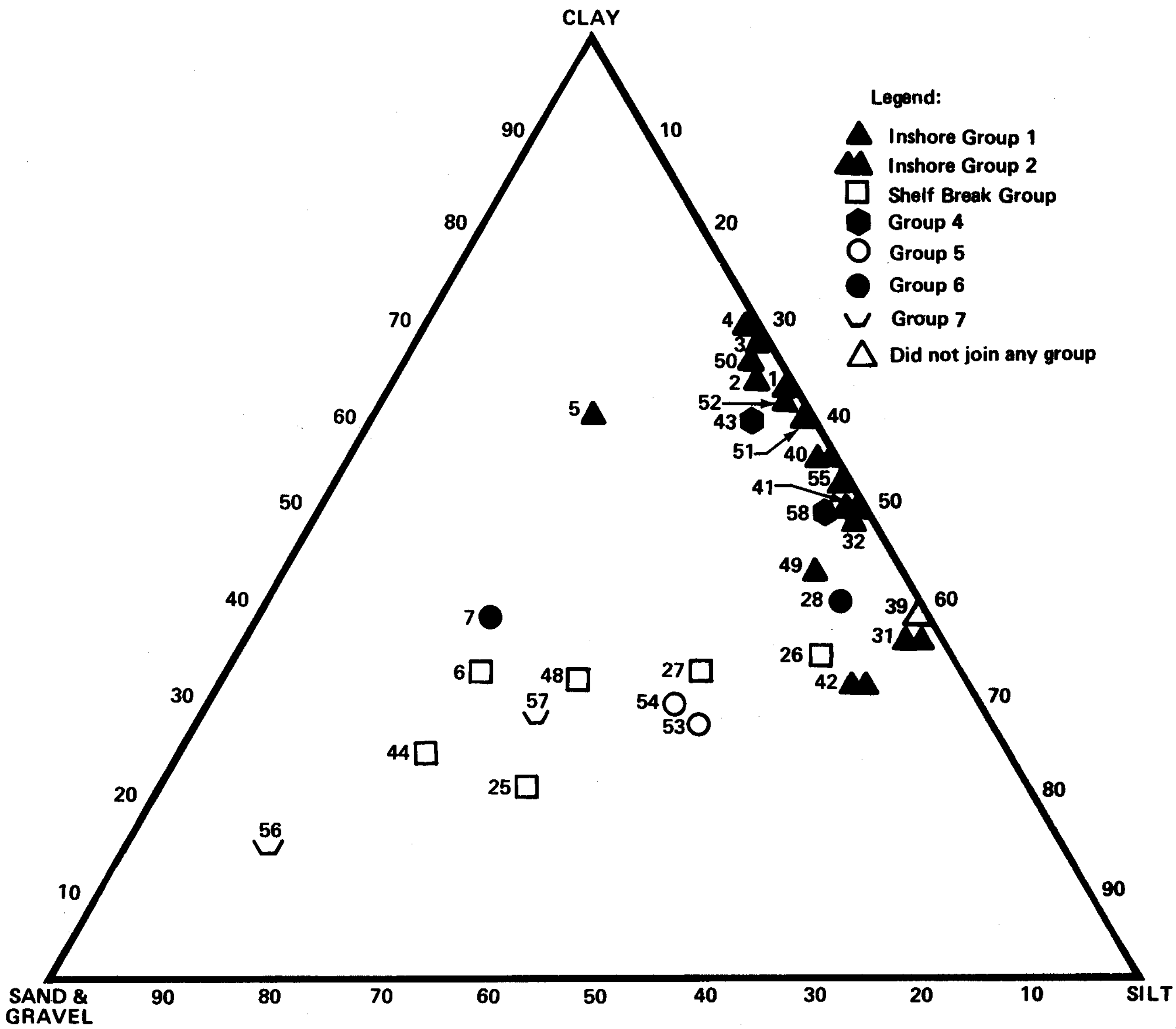

Figure 14. Ternary diagram of gravel-sand, silt and clay contents. Stations are symbolized following the groupings formed by cluster analysis of number of individuals/m^2 data. Inshore group 1, inshore group 2 (with the exception of station 42) and station group 6 were fused to form a single large group (Inshore group) by cluster analysis of transformed number of individuals/m^2 data.

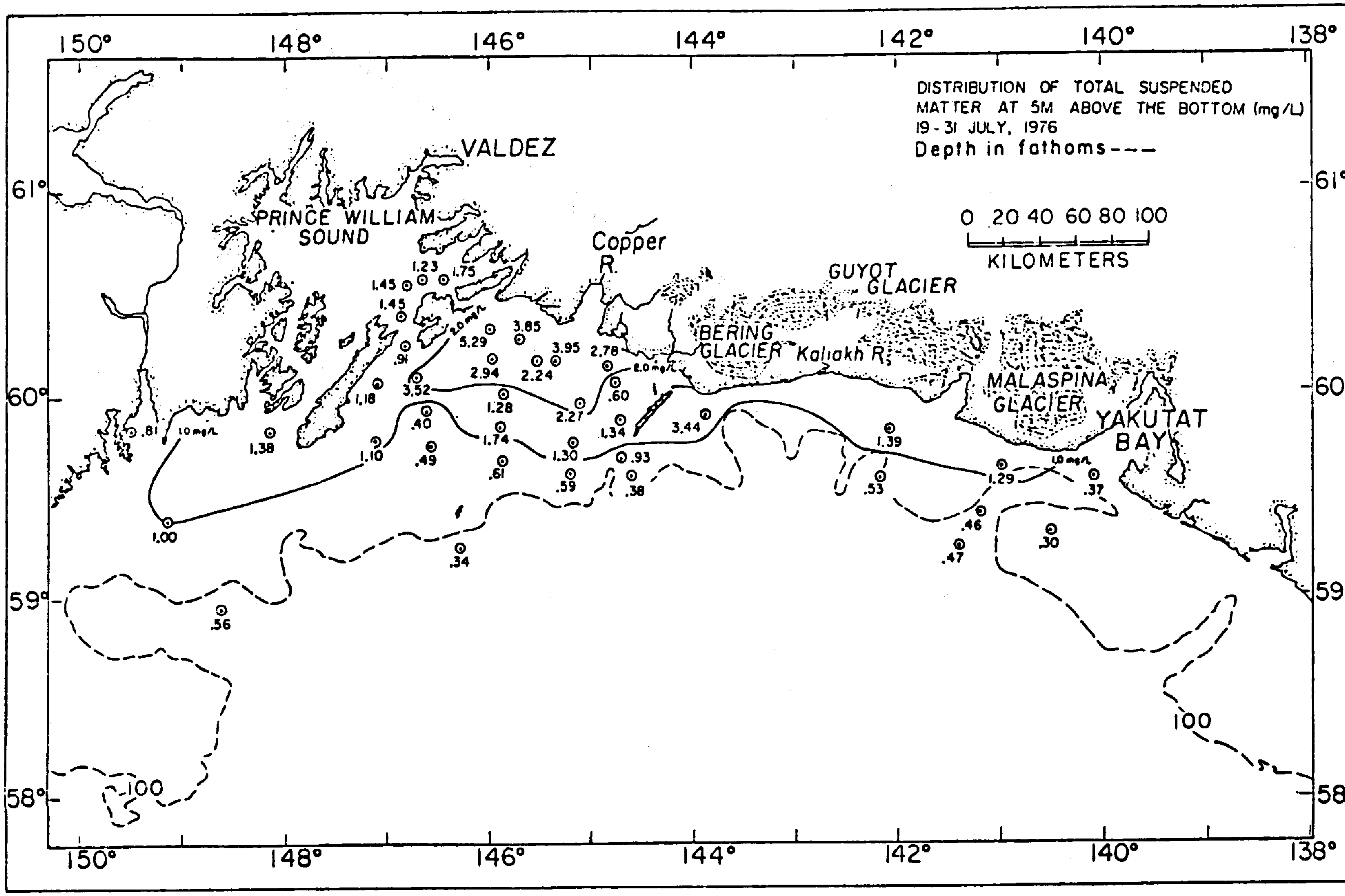

Figure 15. Distribution of total suspended matter at 5 m above the bottom in the northeastern Gulf of Alaska, 19-31 July 1976. (Figure from Feely and Cline 1977).

TABLE 6. Sediment size distribution by station group.

Station Number	Depth	% Gravel	% Sand	% Silt	% Clay
Inshore Group 1					
32	179	0	0.42	51.09	48.49
52	53	0	0.44	37.83	51.72
2	219	0	3.35	33.85	62.80
4	200	0	0.42	30.70	68.87
1	263	0	1.08	37.10	61.82
3	220	0	0.40	31.92	67.68
5	174	3.12	16.84	20.25	59.80
50	164	0	2.50	33.30	64.20
51	135	0	0.27	39.54	60.19
49	186	0	7.71	49.53	42.75
55	117	0	1.26	48.22	50.52
Inshore Group 2					
31	117	0	1.68	62.70	35.62
41	119	0	0.31	49.37	50.12
40	195	0	0.23	44.53	55.24
42	93	0	10.58	58.88	30.54
Group 4					
43	117	0	4.39	35.85	59.76
58	97	0	3.41	47.00	49.59
Group 5					
53	279	0	28.07	46.02	25.91
54	204	0	27.94	43.47	28.49
Group 6					
7	220	0	36.11	21.59	42.29
28	239	0.27	6.87	52.66	40.20
59	334	-	-	-	-
Group 7					
56	64	24.39	42.49	18.05	15.07
57	67	26.59	14.20	29.39	26.83
Shelf Break Group					
26	148	4.32	8.47	53.64	33.57
35	179	1.18	44.96	33.42	20.44
33	219	-	-	-	-
44	181	3.01	50.64	22.95	23.40
48	117	19.95	15.54	33.51	31.00
27	129	13.17	10.49	43.56	32.88
6	151	6.27	37.69	23.42	32.62
Station 30	43	-	-	-	-
Station 39	549	0	0.10	61.15	38.75

Abundance, Biomass and Diversity

Abundance, biomass and diversity data arranged according to station groups, are presented in Table 7. The abundance of infaunal organisms was much higher in inshore group 2 than in inshore group 1 as a result of the increased abundance of members of species group 21 in inshore group 2 (Table 2). The high abundance of species in species group 21 at stations in inshore group 2 is also reflected in an increased Simpson diversity and decreased Brillouin evenness in inshore group 2 relative to inshore group 1 (Table 7). Diversity (measured by both the Shannon and Brillouin indices) was highest in stations 56 and 57 (group 7) and the shelf break stations. Dominance (Simpson diversity and Brillouin evenness) was relatively low in these stations. The abundance of the fauna was highest in station group 7. The fauna at the shelf break stations had an intermediate abundance but the lowest biomass relative to all other station groups. Stations in station groups 4 and 5 had a relatively high abundance of infaunal organisms. The high Simpson diversity and low Brillouin evenness values for station groups 4 and 5 indicated that there was a relatively high dominance in these stations. *Psephidia lordi* and *Ophiura sarsi* were co-dominants in station group 4 while *Ophiura sarsi* was dominant in station group 5.

Trophic Structure

The trophic structure of station groups formed by cluster analysis of untransformed abundance data is shown in Table 8. Deposit feeders dominate the fauna in inshore groups 1 and 2, station groups 5 and 6 and station 39. The ratio of deposit feeders to suspension feeders decreased slightly in the shelf break group while the fauna in station groups 4 and 7 and station 30 was dominated by suspension feeders. The distribution of the motility classes within the station groups is also presented in Table 8. Sessile organisms represented less than 30% of the fauna (by numbers) in all station groups except group 7, the shelf break group and station 39 where about 50% of the fauna were sessile.

Summary of the Results

1. Inshore groups 1 and 2 and station group 6 delineated by cluster analysis of untransformed data were fused by cluster analysis using natural logarithm transformed abundance data. Although there were similarities between the fauna of inshore groups 1 and 2 (Table 2), these groups were separated by cluster analysis of untransformed data primarily on the basis of differences in the abundance of species in species group 21 (Table 2). Station group 6 was separated from inshore groups 1 and 2 primarily by the increased abundance of species groups 19 and 20 in station group 6 (Table 2). Deposit feeders dominate the fauna of these three station groups (Table 8). Stations in inshore groups 1 and 2 are located in areas with a high suspended load above the bottom (Fig. 15). The sediment at these stations was composed primarily of silts and clays (Fig. 14, Table 6). Stations in station group 6 are located in areas with a lower suspended load above the bottom (Fig. 15). Sediment data are available for only two (Stations 7 and 28) of the three stations in group 6. The sediment size distribution in these two stations, differed markedly from each other (Table 6, Fig. 14). A visual examination of the grab samples

Table 7. Abundance, biomass and diversity of benthic sampling stations. Stations are arranged according to the station groups formed by cluster analysis of untransformed abundance data.

Station #	Abundance ($\#/m^2$)	Biomass (gm/m^2)	No. of Species	Simpson Diversity	Shannon Diversity	Brillouin Diversity	Brillouin Evenness
Inshore Group 1							
32	412	135.1	49	0.07	3.26	1.33	0.83
52	194	39.8	34	0.06	3.05	1.21	0.86
2	232	282.9	39	0.07	3.18	1.26	0.87
4	262	118.2	69	0.04	3.61	1.42	0.85
1	330	354.2	41	0.08	3.08	1.25	0.83
3	460	409.0	51	0.04	3.43	1.41	0.87
5	416	114.3	75	0.04	3.77	1.51	0.87
50	416	180.5	51	0.04	3.45	1.41	0.88
51	294	198.5	39	0.05	3.25	1.31	0.88
49	650	173.8	58	0.05	3.40	1.41	0.84
55	463	225.9	68	0.08	3.25	1.32	0.77
	$\bar{X}$ 375	202.9	52	0.05	3.34	1.35	0.85
Inshore Group 2							
31	984	194.6	47	0.13	2.62	1.10	0.68
41	1442	139.2	69	0.14	2.71	1.14	0.63
40	812	98.9	51	0.08	3.00	1.26	0.76
42	912	73.6	84	0.07	3.29	1.37	0.74
	$\bar{X}$ 1038	126.5	63	0.42	2.91	1.22	0.70
Group 4							
43	1112	112.6	68	0.09	3.12	1.31	0.73
58	1654	143.7	55	0.16	2.38	1.36	0.59
	$\bar{X}$ 1383	256.3	62	0.12	2.75	1.34	0.66
Group 5							
53	1436	212.1	84	0.06	3.50	1.46	0.78
54	1056	370.2	59	0.19	2.53	1.06	0.62
	$\bar{X}$ 1246	291.1	72	0.12	3.02	1.26	0.70

TABLE 7. Continued

Station #	Abundance (#/m²)	Biomass (gm/m²)	No. of Species	Simpson Diversity	Shannon Diversity	Brillouin Diversity	Brillouin Evenness
Group 6							
7	740	102.6	73	0.08	3.19	1.31	0.74
28	544	67.4	62	0.09	3.17	1.30	0.76
59	302	38.2	43	0.08	3.08	1.24	0.81
	$\bar{X}$ 528	69.4	59	0.08	3.15	1.28	0.77
Group 7							
56	1590	194.3	132	0.08	3.74	1.56	0.76
57	1270	178.7	102	0.06	3.69	1.54	0.80
	$\bar{X}$ 1430	186.5	117	0.07	3.72	1.55	0.78
Shelf Break Group							
26	518	23.8	55	0.04	3.51	1.45	0.87
25	498	24.5	87	0.04	3.75	1.52	0.84
33	630	53.4	79	0.06	3.50	1.43	0.80
44	980	51.3	124	0.02	4.20	1.73	0.87
48	755	32.1	125	0.03	4.05	1.66	0.84
27	600	26.4	68	0.05	3.48	1.43	0.82
6	1448	43.1	99	0.10	3.34	1.40	0.72
	$\bar{X}$ 775	36.4	91	0.05	3.69	1.52	0.82
Sta. 30	905	41.0	51	0.26	2.19	0.92	0.55
Sta. 39	340	27.4	40	0.15	2.70	1.09	0.73

TABLE 8. Distribution of motility and feeding classes in station groups. SE=sessile, DM=discreetly motile, M=motile, DF=deposit feeder, SF=suspension feeder, P=predator, S=scavenger (Table 1). The data is arranged according to station groups formed by cluster analysis of untransformed abundance data.

	Motility (%)			Feeding Class (%)				
Station group	SE	DM	M	DF	SF	P	S	Other
Inshore group 1	29	30	41	70	28	1	1	0
Inshore group 2	22	14	64	63	24	9	3	1
Station group 4	5	58	37	27	60	12	<1	1
Station group 5	10	13	77	70	8	19	3	0
Station group 6	12	29	59	87	6	5	2	0
Station group 7	51	13	36	26	53	9	12	0
Shelf break group	53	17	30	55	32	6	6	1
Station 30	2	54	44	18	54	7	22	2
Station 39	52	4	44	72	4	14	8	1

taken at the third station in group 6, station 59, indicated that the sediment was predominantly silts and clays.

2. Station 5 was placed in the inshore group by cluster analyses using both untransformed and transformed data. However, principal coordinate analyses (Figs. 7, 10 and 11) indicated that it also had some affinities to the shelf break group stations. Station 5 appears to be transitional between the inshore group and the shelf break stations in terms of both its fauna and sediments (Fig. 14).

3. Station 42 was linked with stations in inshore group 1 in a cluster analysis of untransformed data by the abundance of species in species group 21 in all the stations in that group. However, the presence of species from species groups 15, 38, 41 and 42 separated station 42 from the other stations in the inshore group and when transformed data was used station 42 did not join any cluster group. The sediment at station 42 was predominantly silts and clays mixed with a small amount (10%) of sand (Fig. 14).

4. Station group 4 was dominated by species in species groups 21, 18 and 17 (Table 2). This group was distinguished from inshore group 1 and 2 and station group 6 by species groups 17 and 18 and 29 (Table 2). The sediment at the stations in this group was predominantly silt and clay. The fauna was dominated by suspension feeders.

5. Station group 5 showed some affinities to inshore groups 1 and 2 and station group 6 (Figs. 7, 10 and 11; Table 2). However, species groups 23 and 28 distinguished this group from inshore groups 1 and 2 and station group 6. Both of these stations are located in Hinchinbrook Entrance and the sediment at these stations consists of sand intermixed with silts and clays (Fig. 14). The fauna was dominated by deposit feeders (Table 8).

6. Station group 7 was a rather distinct group with some similarities to the shelf break group stations (Tables 2 and 5). These stations are located on Tarr Bank and the sediment contained appreciable amounts of sand and gravel (Table 6). The fauna at these stations was dominated by suspension feeders (Table 8).

7. Shelf break group was dominated by species in species groups 20 and 31. The sediment at these stations was composed of sand and gravel mixed with silts and clay (Table 6). The fauna in this group was predominantly composed of deposit feeders (Table 8). The biomass of the fauna in the shelf break stations was very low (Table 7).

8. Station 30 did not join any station groups formed by a cluster analysis using presence-absence data. The four most numerous species were <u>Axinopsida serricata</u>, <u>Ampelisca macrocephala</u>, <u>Nepthys ciliata</u>, and <u>Lumbrineris zonata</u>. The fauna at station 30 was dominated by suspension feeders (Table 8).

9. Station 39 did not join any of the station groups formed by a cluster analysis of both untransformed and transformed abundance data. The fauna at this station was dominated by the polychaete <u>Maldane glebifex</u>

(species group 10) and the polychaete Maldane sarsi, and members of species groups 29 and 45 were common. The sediment at this station was silt and clay with a trace of sand (Table 6) and the fauna was dominated by deposit feeders (Table 8).

DISCUSSION

Numerical Analysis

Both cluster and principal coordinate analyses require subjective decisions that will influence the nature of the results. These decisions are (1) should the data be standardized or transformed; (2) selection of a similarity coefficient; and (3) selection of a clustering strategy or method of ordination. A subjective judgement delimiting the groups formed must also be made either by examining a dendrogram (classification) or loadings of points on coordinate or component axes (ordination). Rather than select a single strategy we decided to use several strategies, and select those groupings which seemed to make the most sense in terms of environmental parameters.

We utilized cluster analysis as the primary technique for delineating station and species groups. Similarity matrices for cluster analysis routines were calculated using the Czekanowski coefficient with untransformed and natural logarithm transformed data. We selected the Czekanowski coefficient rather than the Canberra "metric" coefficient for cluster analysis routines because the Czekanowski coefficient tends to emphasize the effects of dominant species. Raphael and Stephenson (1972) found that the Czekanowski coefficient with its emphasis on dominant species produced station groups that were more closely related to abiotic attributes. Clifford and Stephenson (1975) state "The implications of this appear to be that a reasonable stress [emphasis] on dominant species is preferable to stress on the infrequently occurring ones if indications of the importance of abiotic factors are required. [Thus], Contrary to expectation the best indicator species at least in the above studies [Raphael and Stephenson, 1972] of the marine benthos were not the uncommon ones". Dicks (1976) found in his studies of the benthos in the North Sea that rare species could not be sampled well enough, even with 10 grabs per site, to be reliable indicator species. Furthermore, we have found that the use of the Canberra "metric" coefficient, especially when used with transformed data, can result in spurious distinctions caused by rare species which are inadequately sampled (Feder et al., 1977).

Boesch (1973) used a double standardization to eliminate the effects of differences in abundance between individuals. He argued that two species which might have "similar habitat requirements, yet one is always much more abundant than the other," would appear to be dissimilar in an analysis unless abundances are standardized. We agree that some form of standardization or transformation should be utilized. However, differences in abundance may also imply that differences in the suitability of the habitat for the species in question may, in fact, exist. In the absence of a thorough knowledge of the habitat requirements of the species utilized for the analysis we feel that both untransformed and transformed or standardized data should be examined.

We have found that the group-average sorting strategy gives useful results and we have used it exclusively here. Boesch (1973) and Stephenson et al. (1972) used both group average and "flexible" sorting strategies (Lance and Williams, 1966). Boesch (1973) found the flexible strategy yielded "the more instructive classification" while Stephenson et al. (1972) using a variety of criteria found both strategies to have merit. In future studies we plan to compare the results obtained by both of these methods.

Principal coordinate analysis was used as an aid in interpreting the results of the cluster analysis routines. The use of both the Czekanowski and Canberra "metric" coefficients with transformed and untransformed data in principal coordinate analyses enabled us to compare the relative similarity of stations as delineated by analyses ranging from one which placed a strong emphasis on the numerically dominant species (Czekanowski coefficient, untransformed data) to one placing an almost equal emphasis on all species regardless of their abundance (Canberra "metric" coefficient, transformed data).

Cluster analysis of untransformed data formed groups (Figs. 3 and 4) which had the closest correlation to abundance and diversity (Table 7). There were large differences in the abundance and diversity of the fauna in inshore groups 1 and 2 formed by cluster analysis of untransformed data (Table 7). However, when transformed data was used, the influence of dominant species was reduced, and inshore groups 1 and 2, with the exception of Station 42, were fused into a single group (Figs. 8 and 9). The diversity of station 42 was higher than that of the other stations in inshore group 2 (cluster analysis, untransformed data; Table 7). In this single case, the analysis of transformed data separated station 42 from the inshore group where it appears to have been misplaced by the analysis of untransformed data in terms of its diversity.

Station groups formed by cluster analysis of transformed data (Figs. 8 and 9) had the best correlation with the grouping of stations according to sediment type (Fig. 14; Table 6). Except for stations 5 and 7, stations in the single large inshore group, formed by cluster analysis of transformed data (Figs. 8 and 9), contained fine sediments. Station 42 had a higher percentage of sand than the stations (except stations 5 and 7) in the inshore group and, it did not join any cluster groups when transformed data was used. Station 5 contained considerably more gravel than the other stations in the inshore group (Fig. 14; Table 6). This station was classified as a member of the inshore group(s) by cluster analysis of both untransformed and transformed data. However, principal coordinate analysis indicated that this station had similarities to both the inshore and the shelf break group stations (Figs. 7 and 11). The sediment size distribution in station 7 differed markedly from that of other stations in the inshore group (Fig. 14; Table 7). However, there is no evidence from either cluster analysis (Figs. 3 and 8) or principal coordinate analysis (Figs. 6, 7, 10 and 11) that its fauna differed greatly from the inshore group or group 6 stations.

Principal coordinate analysis was useful for (1) identifying misclassification resulting from cluster analysis such as the inclusion of station 5 in one of the inshore groups (Figs. 3, 4, 8 and 9) and (2) examining similarities between station groups. An examination of the results of the principal coordinate analyses, indicates that station groups 4 and 5 were more similar to the inshore group stations than they were to either station group 7 or the shelf break group (Figs. 6, 7, 10 and 11). The results of a cluster analysis comparing station groups (Fig. 13) also indicated that station groups 4 and 5 have closer affinities to the inshore group stations than to stations in the shelf break group and group 7.

Factors Influencing Faunal Distributions

The major discontinuities in the spatial distribution and diversity of the fauna in the northeastern Gulf of Alaska were closely related to sediment characteristics (Fig. 14; Table 6). The exclusion of suspension feeders from silt-clay sediments has been noted by many investigators (Davis, 1925; Jones, 1950; Sanders 1956, 1958; Thorson, 1957; McNulty *et al*., 1962). Rhoads and Young (1970) hypothesized that the activities of deposit feeders excludes suspension feeders by creating an easily-resuspended unstable sediment-water interface which tends to clog the gills of suspension feeders, bury or inhibit settling of their larvae and prevent attachment of epifauna. Sediment instability may also act to exclude suspension feeders by requiring an excessive energy expenditure to maintain contact with the overlying water (Myers, 1977). Throughout much of the NEGOA shelf high sedimentation rates result in poorly consolidated fine deposits (Molnia and Carlson, 1977) which, according to Rhoads and Young (1970) should tend to exclude suspension feeding organisms. This exclusion, in fact, appears to occur in NEGOA. Stations in inshore group 1 and 2 are located in areas where the suspended load was high (Fig. 15) and the sediments were fine (Fig. 14); the fauna at these stations was dominated by deposit feeders (Table 8). The fauna at stations 53 and 54 (group 5) was also dominated by deposit feeders (Table 8); the sediment at these stations was composed predominantly of silts and clays mixed with 27 to 28% sand. The shelf break stations and stations 56 and 57 (station group 7) contained increasingly greater amounts of sand and gravel mixed with silts and clays (Table 6), and the suspended load at these stations was relatively low (Fig. 15). The relative abundance of suspension feeders was slightly greater in the shelf break stations than in stations of inshore groups 1 and 2, and suspension feeders were the dominant trophic group in stations 56 and 58 (Table 8). However, the trophic structure of stations 43 and 58 (station group 4) appeared to be at variance with the hypothesis of Rhoads and Young (1970). The fauna of these stations consisted primarily of suspension feeders (Table 8) even though the sediments were fine. We have no quantitative data on the water content or shear strength of the surficial sediments and a visual examination of grab samples provided no indication that the substrate at these stations, was firmer than it was in the inshore group stations. The suspension feeding bivalves *Psephidia lordi*, *Crenella decussata*, *Cyclocardia crebricostata* and *Astarte polaris* were numerical dominants at stations 43 and 58. If, as Figure 15 appears to indicate, the sedimentation rates are relatively low in stations 43 and 58, burial and gill clogging may be less of a problem for suspension feeders in these stations. In addition, the small size and relatively low bulk density of *Psephidia lordi* and *Crenella decussata* may allow them to maintain themselves near the sediment surface in soft muds (Thayer, 1975). Specimens of *Astarte polaris* and *Cyclocardia crebricostata* taken at these stations were also small in size (<1.5 cm). Young and Rhoads (1971) noted that suspension feeding species which had successfully colonized unstable substrates in Cape Cod Bay had developed adaptations to alleviate fouling of feeding structures and maintain a stable position relative to the substrate. Further study is required to determine the existance and nature of mechanisms that might enable P. lordi, C. decussata, C. crebricostata and A. polaris to adapt successfully to conditions caused by an unstable substrate.

Discontinuities in the distribution of sessile species were also noted (Table 8). The percent abundance of sessile organisms was low in all station groups except the shelf break group, group 7 and station 39 (Table 8). Stations in the shelf break group and group 7 are located in areas with relatively low sedimentation rates (Fig. 15; Molnia and Carlson, 1977) and coarse sediments (Fig. 14; Table 6). Station 39 is the only station which had high concentrations of sessile organisms and contained fine sediments. However, this station was located in an area where the sedimentation rate would be expected to be low (Fig. 15). Jumars and Fauchald (1977) postulated that sessile species would tend to be excluded from areas with disturbed sediments or high sedimentation rates due to the effects of burial and "alteration of local sediment characteristics, probably giving an advantage to those individuals who can move to locally optimum conditions". Jumars and Fauchald (1977) further hypothesized that the relative abundance of sessile individuals would decrease as the flux of organic material to the substrate decreased. They reasoned that in areas with a limited food supply "the foraging radius required for adequate nutrition exceeds the reach of most sessile individuals". Since much of the sediment deposited in the northeastern Gulf of Alaska is of glacial origin it might be expected that these sediments would be relatively low in organic carbon. In Port Valdez, Alaska there are minima in organic carbon concentrations in sediments adjacent to the mouths of streams draining directly from glaciers (Sharma and Burbank, 1973). The exclusion of sessile organisms from areas in the Gulf of Alaska with a high suspended load above the bottom may be due in part to low concentrations of organic material in sediments which are primarily glacial in origin. Finally, it is obvious that the lack of a suitable substrate for attachment would exclude many sessile organisms from areas with fine unconsolidated sediments.

SUMMARY

The numerical analysis routines utilized in this study were successful in identifying station groups which correspond to differences in the size distributions of the sediment and the trophic structure of the fauna. However, the question of how the properties of these different sediment types control the distribution of organisms remains largely unanswered. Measurement of biologically meaningful sediment parameters (Rhoads and Young, 1970; Johnson, 1974; Levinton, 1977; DeWilde, 1977; Rhoads, 1977) and studies of morphological and behavioral adaptations in response to sediment characteristics are required before we can hope to answer this question.

Cluster analysis of untransformed data indicated that there were differences in faunal distributions between inshore groups 1 and 2 even though these stations were very similar in terms of trophic structure and sediment size distributions. Feder *et al*. (1973, 1977) also found discontinuities in faunal distributions over the extremely uniform sediments (Sharma and Burbank, 1973) of the deep basin in Port Valdez, Alaska. We still know very little of the factors which affect the distribution of soft bottom benthic species (Levinton, 1977). However, there is a growing body of evidence that most deposit feeding organisms probably depend on bacteria as a primary source of food (Zhukova, 1963; Newell, 1965; Brinkhurst and Chua, 1969; Fenchel, 1970; Hargrave, 1970; Kofoed, 1975a, 1975b). As a first step in understanding distributions of soft bottom species, fluxes of organic carbon to the sediment, turnover of organic matter in the substrate, and bacterial biomass should be measured.

ACKNOWLEDGEMENTS

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APPENDIX III

DATA SUMMARY FOR R/V *DISCOVERER* CRUISE DS001

APPENDIX III, TABLE I

LIST OF THE STATIONS PROCESSED FROM CRUISE DS001 R/V *DISCOVERER*, MARCH 1976

GULF OF ALASKA BENTHIC GRAB DATA -- MARCH 1976 03/14/78 PAGE 1

STATION-SAMPLE LISTING

		TOT CNT	TOT WWGT	CNT/SQM	WWGT/SQM	GRABS
CRUISE 001	STATION 001	102.	78.793	204.	157.586	0001 0004 0002 0005 0003
CRUISE 001	STATION 002	87.	17.117	174.	34.234	0002 0005 0003 0004 0001
CRUISE 001	STATION 003	143.	109.403	286.	218.806	0005 0004 0003 0002 0001
CRUISE 001	STATION 004	93.	99.651	186.	199.302	0002 0001 0005 0004 0003
CRUISE 001	STATION 005	59.	54.467	118.	108.934	0001 0005 0004 0003 0002
CRUISE 001	STATION 006	246.	24.438	492.	48.877	0001 0002 0004 0005 0003
CRUISE 001	STATION 007	86.	16.591	215.	41.477	0003 0002 0001 0004
CRUISE 001	STATION 025	137.	14.907	274.	29.813	0005 0004 0002 0003 0001
CRUISE 001	STATION 026	185.	32.924	370.	65.849	0005 0003 0002 0001 0004
CRUISE 001	STATION 027	65.	32.171	130.	64.343	0002 0001 0005 0003 0004
CRUISE 001	STATION 028	461.	25.275	922.	50.550	0001 0003 0002 0004 0005
CRUISE 001	STATION 029	29.	207.863	290.	2078.630	0001
CRUISE 001	STATION 030	285.	9.123	570.	18.246	0004 0005 0001 0003 0002
CRUISE 001	STATION 031	264.	84.778	528.	169.556	0004 0003 0005 0001 0002
CRUISE 001	STATION 032	140.	24.003	280.	48.006	0001 0005 0004 0002 0003
CRUISE 001	STATION 033	130.	32.599	260.	65.199	0004 0003 0005 0001 0002
CRUISE 001	STATION 039	96.	4.758	320.	15.860	0001 0003 0002
CRUISE 001	STATION 040	191.	19.421	382.	38.843	0003 0004 0005 0002 0001
CRUISE 001	STATION 041	292.	28.374	584.	56.748	0003 0002 0004 0001 0005
CRUISE 001	STATION 042	148.	40.391	296.	80.782	0003 0002 0005 0001 0004
CRUISE 001	STATION 043	335.	20.422	670.	40.844	0001 0005 0002 0004 0003
CRUISE 001	STATION 044	186.	23.707	372.	47.413	0002 0001 0004 0005 0003
CRUISE 001	STATION 048	149.	21.316	298.	42.632	0002 0005 0004 0003 0001
CRUISE 001	STATION 049	145.	30.475	290.	60.950	0005 0001 0004 0002 0003
CRUISE 001	STATION 050	116.	176.085	232.	352.170	0002 0001 0003 0004 0005
CRUISE 001	STATION 051	127.	36.615	254.	73.230	0004 0002 0003 0001 0005
CRUISE 001	STATION 052	181.	78.157	362.	156.314	0003 0002 0001 0005 0004
CRUISE 001	STATION 053	519.	220.114	1038.	440.229	0002 0005 0004 0003 0001
CRUISE 001	STATION 054	448.	123.170	896.	246.340	0001 0005 0002 0004 0003
CRUISE 001	STATION 055	145.	69.206	290.	138.412	0001 0004 0005 0003 0002
CRUISE 001	STATION 056	460.	319.085	920.	638.170	0001 0004 0003 0002 0005
CRUISE 001	STATION 057	462.	244.926	462.	244.926	0004 0007 0006 0008 0010 0009 0002 0005 0003 0001
CRUISE 001	STATION 058	177.	11.791	590.	39.304	0001 0003 0002
CRUISE 001	STATION 059	25.	13.928	125.	69.640	0002 0001
CRUISE 001	STATION 060	99.	5.142	198.	10.284	0001 0003 0002 0005 0004
CRUISE 001	STATION 061	108.	100.407	540.	502.037	0003 0001
CRUISE 001	STATION 062	147.	14.924	294.	29.848	0003 0001 0004 0005 0002
CRUISE 001	STATION 063	290.	22.964	580.	45.929	0002 0005 0001 0003 0004
CRUISE 001	STATION 068	121.	3.686	242.	7.372	0005 0002 0001 0004 0003
CRUISE 001	STATION 069	258.	27.670	645.	69.175	0003 0001 0002 0004
CRUISE 001	STATION 070	80.	15.804	800.	158.040	0001

TOTAL NUMBER OF STATIONS = 41.

APPENDIX III, TABLE II

LIST OF SPECIES IDENTIFIED FROM SAMPLES COLLECTED DURING CRUISE DS001 R/V *DISCOVERER*, MARCH 1976

GULF CF ALASKA BENTFIC GRAB CATA -- MARCF 1976 C3/14/78 PAGE 2

LIST CF ALL TAXCNCMIC GRCLFS FCLND

CRITERIA 1- TAXCN CCCLRS IN 5C PCT CR MCRE CF STATICNS
CRITERIA 2- AT LEAST 10 PCT CF INDIVIDLALS AT SCME STATICN
CRITERIA 3- AT LEAST 10 PCT CF WET BICMASS AT SCME STATICN
CRITERIA 4- ABUNCANT WRT NO. INCIVICLALS AT SCME STATICN
CRITERIA 5- ABUNCANT WRT TOTAL BICMASS AT SCME STATICN

TAXCN CCDE	TAXCN NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA CCC
3200000C0C00	FCRIFERA						4
32000000C0FC	FCRIFERA FRAGMENTS			X	X	X	11
3203150C0CFC	SPCNGICAE FRAGMENTS						1
33010C0C0C0C	FYCRCZCA						1
3301000C0CFC	FYCRCZCA FRAGMENTS			X	X		9
33030C0C0CCC	ANTHCZCA			X		X	2
3303470C0CCC	PENNATLLACEA VIRGLLARIICAE		X		X		9
33034801010C	PTILCSARCUS GLRNEYI			X		X	2
33035C0C0C00	ZCANTFINIARIA			X	X	X	3
3303500C0CFC	ZCANTFINARIA FRAGMENTS						1
330353020C0C	PEACHIA SP.				X		1
4000000C0C0C	RFYNCCCCELA						4
4C0C000C0CFC	RFYNCCCCELA FRAGMENTS			X	X	X	2C
400302000CCC	AMPFIPCRIDAE						1
48C1000C0000	FCLYCFAETA				X		8
4801000C00FC	FCLYCFAETA FRAGMENTS	X			X		39
480101000CCC	PCLYNCIDAE				X		4
480101000CFC	PCLYNCIDAE FRAGMENTS						3
48010102C1CC	ANTINCELLA MACRCLEPICA						1
48010105020C	ELNCE CEPRESSA						1
48010106030C	GATTYANA CIRRCSA						1
48010106050C	GATTYANA IPFICNELLCICES						1
48010106060C	GATTYANA TREACWELLI						1
48010108000C	FARMCTHCE SP.						2
48010108060C	FARMCTHCE IMBRICATA						2
48010108110C	FARMCTHCE LLNLLATA						1
48010109010C	FERMADICN TRLNCATA						1
48010111030C	LEPIDCNCTLS SCLAMATLS						1
48010115000C	FCLYNCE SP.						1
48010115C50C	FCLYNOE TARCSCVI						1
48010116010C	FCLYELNCA TLTA						1
4801020C0C0C	PCLYNCCCNTIDAE						C
48010201010C	PEISIDICE ASPERA		X		X		1C
480105000CCC	SIGALICNIDAE						C
48010501010C	PFLCE MINLTA						4
48010503010C	STFENELAUS FLSCA						1
48011000000C	ELPRCSINIDAE						C
48C11001030C	ELPFRCSINE FETERCBRANCFIA						1
4801120C0C0C	PFYLLCCCCIDAE						1
48011201000C	ANAITIDES						1
48011201040C	ANAITIDES MLCCSA						1
48011202000C	ETECNE SP.						1
48011202050C	ETECNE LCNGA						4
48011208010C	GENETYLLIS CASTANEA						1
4801210C0C0C	PILARIGICAE						C
48012102010C	SIGAMBRA TENTACLLATA						1
4801220C0C0C	SYLLICAE						3
48012201020C	ALTCLYTLS MAGNLS				X		3

GULF OF ALASKA BENTHIC GRAB DATA -- MARCH 1976

LIST OF ALL TAXONOMIC GROUPS FOUND

CRITERIA 1- TAXON OCCURS IN 50 PCT OR MORE OF STATIONS
CRITERIA 2- AT LEAST 10 PCT OF INDIVIDUALS AT SOME STATION
CRITERIA 3- AT LEAST 10 PCT OF WET BIOMASS AT SOME STATION
CRITERIA 4- ABUNDANT WRT NO. INDIVIDUALS AT SOME STATION
CRITERIA 5- ABUNDANT WRT TOTAL BIOMASS AT SOME STATION

TAXON CODE	TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
480122030400	SYLLIS SPONGIPHILA						2
480122050000	TYPOSYLLIS SP.				X		7
480122050100	TYPOSYLLIS ALTERNATA				X		5
480122050200	TYPOSYLLIS ARMILLARIS						2
4801220502F0	TYPOSYLLIS ARMILLARIS FRAGS						1
480122051300	TYPOSYLLIS REGULATA						1
480122060200	EUSYLLIS BLOMSTRANDI						3
480122060300	EUSYLLIS JAPONICA						1
480122070400	EXOGONE MOLESTA						1
480122120100	HAPLOSYLLIS SPONGICOLA						1
480123000000	NEREIDAE						0
480123020100	CHEILONEREIS CYCLURUS						2
480123040000	NEREIS SP.		X		X		8
480123040300	NEREIS PELAGICA						2
480123040600	NEREIS ZONATA				X		14
480124000000	NEPHTYIDAE						2
4801240000F0	NEPHTYIDAE FRAGMENTS						7
480124010000	NEPHTHYS SP.						19
4801240100F0	NEPHTHYS SP. FRAGS						2
480124010200	NEPHTYS CILIATA						1
480124010300	NEPHTYS CAECA						1
480124010500	NEPHTYS PUNCTATA	X		X		X	22
480124010900	NEPHTYS LONGOSETOSA						2
480124020200	AGLAOPHAMUS RUBELLA ANOPS						6
480126000000	GLYCERIDAE						5
4801260000F0	GLYCERIDAE FRAGMENTS						1
480126010000	GLYCERA SP.						1
480126010100	GLYCERA CAPITATA				X		15
480127000000	GONIADIDAE						0
480127010100	GLYCINDE PICTA						3
480127020100	GONIADA ANNULATA				X		19
480128000000	ONUPHIDAE						0
4801280100F0	ONUPHIS SP. FRAGS						1
480128010100	ONUPHIS CONCHYLEGA						5
480128010200	ONUPHIS GEOPHILIFORMIS						3
480128010300	ONUPHIS IRIDESCENS	X			X		27
4801280103F0	ONUPHIS CONCHYLEGA FRAGS						1
480128010500	ONUPHIS PARVA				X		1
480128020600	ONUPHIS STIGMATIS						1
480129000000	EUNICIDAE						0
480129010200	EUNICE VALENS				X		3
480129010400	EUNICE KOBIENSIS						3
480130000000	LUMBRINERIDAE						0
480130010000	LUMBRINERIS SP.	X	X	X	X	X	40
4801300100F0	LUMBRINERIS SP. FRAGS						4
480130010100	LUMBRINERIS BICIRRATA						1
480130010400	LUMBRINERIS LATREILLI						1
480130010500	LUMBRINERIS SIMILABRIS						1

LIST OF ALL TAXCNCMIC GRCUPS FCUND

CRITERIA 1- TAXCN CCCURS IN 5C PCT OR MCRE CF STATICNS
CRITERIA 2- AT LEAST 10 PCT CF INDIVIDUALS AT SCME STATICN
CRITERIA 3- AT LEAST 1C PCT CF WET BICMASS AT SCME STATICN
CRITERIA 4- ABUNDANT WRT NO. INDIVIDUALS AT SCME STATICN
CRITERIA 5- ABUNDANT WRT TOTAL BICMASS AT SCME STATICN

TAXCN CCDE	TAXCN NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA CCC
48013001060C	LUMBRINERIS ZCNATA				X		8
48013002010C	NINCE SIMPLA						1
48013002020C	NINCE GEMMEA						14
48013002C2FC	NINCE GEMMEA FRAGS						1
48013200C0CC	ARABELLIDAE						C
48013201000C	DRILCNEREIS SP.						3
480132010CFC	DRILCNEREIS SP. FRAGS						1
48013201C1CC	DRILCNEREIS FILUM						2
48013201C40C	DRILCNEREIS FALCATA MINCR						6
48013202000C	ARABELLA SP.						1
480139000CCC	DCRVILLEIDAE						2
48013901020C	HAPLCSCCLCPLCS ELCNGATUS						6
48014000C00C	PARACNIDAE						C
4801400200CC	ARICIDEA SP.						4
48014002010C	ARICIDEA SUECICA				X		4
48014003010C	PARACNIS GRACILIS						4
4801410C0CCC	APISTCBRANCHIDAE						1
48014101000C	APISTCBRANCHUS SP.						2
4801420C0CCC	SPICNIDAE						3
4801420C0FC	SPICNIDAE FRAGMENTS						1
48014202C10C	LACNICE CIRRATA				X		7
48014204020C	PCLYDORA SCCIALIS						1
48C14205010C	PRICNOSPIC MALMGRENI						1
48C14207010C	SPIC FILICCRNIS				X		1
48014210030C	SPICPHANES CIRRATA						7
48014301000C	MAGELCNA SP.						1
48014301010C	MAGELCNA JAPCNICA						2
48014301020C	MAGELCNA PACIFICA						3
480143010 2FC	MAGELCNA PACIFICA FRAGS						1
4801480C000C	CHAETCPTERIDAE						1
48014803020C	SPICCHAETCPTERUS CCSTARUM						3
4801480302FC	SPICCHAETCPTERUS CCSTARUM FRAGS						2
48014903C0C	THARYX SP.		X		X		11
48014904010C	CHAETCZCNE SETCSA						2
480152000C0C	FLABELLIGERIDAE						1
48015201020C	BRADA VILLCSA						2
48015201030C	BRADA INHABILIS						1
48015203010C	PHERUSA PAPILLATA						1
48015203020C	PHERUSA PLUMCSA						1
4801550 1010C	SCALIBREGMA INFLATUM						5
48015600 0C0C	CPHELIIDAE						C
4801560100FC	AMMCTRYPANE SP. FRAGS						C
48015601010C	AMMCTRYPANE ALLCGASTER						1
480156010 1FC	AMMCTRYPANE ALLCGASTER FRAGS						1
48015604C0C	TRAVISIA SP.						1
48015604030C	TRAVISIA PUPA					X	3
48015701010C	STERNASPIS SCUTATA	X	X	X	X		22
4801570101FC	STERNASPIS SCUTATA FRAGS						1

GULF OF ALASKA BENTHIC GRAB DATA -- MARCH 1976

LIST OF ALL TAXONOMIC GROUPS FOUND

CRITERIA 1- TAXON OCCURS IN 50 PCT OR MORE OF STATIONS
CRITERIA 2- AT LEAST 10 PCT OF INDIVIDUALS AT SOME STATION
CRITERIA 3- AT LEAST 10 PCT OF WET BIOMASS AT SOME STATION
CRITERIA 4- ABUNDANT WRT NO. INDIVIDUALS AT SOME STATION
CRITERIA 5- ABUNDANT WRT TOTAL BIOMASS AT SOME STATION

TAXON CODE	TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
48015800000C	CAPITELLIDAE						1
48015801010C	CAPITELLA CAPITATA						8
48015802010C	HETEROMASTUS FILIFORMIS						7
48016100000C	MALDANIDAE				X		8
4801610000FC	MALDANIDAE FRAGMENTS						19
48016101000C	ASYCHIS S.						1
48016101020C	ASYCHIS SIMILIS				X		8
48016103010C	MALDANE SARSI						5
48016103020C	MALDANE GLEBIFEX		X		X		10
48016105000C	NICOMACHE SP.						1
48016105010C	NICOMACHE LUMBRICALIS						2
48016105020C	NICOMACHE PERSONATA						1
48016106000C	NOTOPROCTUS SP.						2
48016106010C	NOTOPROCTUS PACIFICA				X		9
48016108020C	AXIOTHELLA RUBROCINCTA						2
48016109010C	PRAXILLELLA GRACILIS	X		X	X		28
48016109030C	PRAXILLELLA AFFINIS						5
48016110000C	RHODINE SP.						1
4801611000FC	RHODINE SP. FRAGS						1
48016110010C	RHODINE BITORQUATA						3
4801620000FC	OWENIIDAE FRAGMENTS				X		4
48016201020C	OWENIA FUSIFORMIS						3
4801620102FC	OWENIA FUSIFORMIS FRAGS				X		5
48016202010C	MYRIOCHELE HEERI		X		X		12
4801620201FC	MYRIOCHELE HEERI FRAGS	X		X	X		29
48016300000C	SABELLARIIDAE						0
48016301020C	IDANTHYRSUS ARMATUS				X		4
48016400000C	PECTINARIIDAE						0
48016401010C	AMPHICTENE AURICOMA				X		4
48016402010C	CISTENIDES BREVICOMA						1
48016500000C	AMPHARETIDAE						3
4801650000FC	AMPHARETIDAE FRAGMENTS						2
48016501000C	ANAGE SP.						1
48016501010C	ANAGE ANOPS						1
48016502000C	AMPHARETE SP.						9
48016502010C	AMPHARETE ARCTICA						7
48016502080C	AMPHARETE ACUTIFRONS						2
48016505010C	MELINNA CRISTATA				X		13
48016505030C	MELINNA ELIZABETHA						4
48016510010C	ASABELLIDES SIBIRICA						1
48016600000C	TEREBELLIDAE						8
4801660000FC	TEREBELLIDAE FRAGMENTS						2
48016607000C	PISTA SP.						2
48016607010C	PISTA CRISTATA		X		X		16
48016607030C	PISTA ELONGATA						1
48016607050C	PISTA MACULATA						1
48016607060C	PISTA PACIFICA						1
48016612010C	ARTACAMA CONIFERI						4

LIST OF ALL TAXONOMIC GROUPS FOUND

CRITERIA 1- TAXON OCCURS IN 50 PCT OR MORE OF STATIONS
CRITERIA 2- AT LEAST 10 PCT OF INDIVIDUALS AT SOME STATION
CRITERIA 3- AT LEAST 10 PCT OF WET BIOMASS AT SOME STATION
CRITERIA 4- ABUNDANT WRT NO. INDIVIDUALS AT SOME STATION
CRITERIA 5- ABUNDANT WRT TOTAL BIOMASS AT SOME STATION

TAXON CODE	TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
480167000000	TRICHOBRANCHIDAE						1
4801670000FC	TRICHOBRANCHIDAE FRAGMENTS						1
4801670100FC	TEREBELLIDES SP. FRAGS						0
480167010100	TEREBELLIDES STROEMII						15
4801670101FC	TEREBELLIDES STROEMII FRAGS						1
480167020100	TRICHOBRANCHUS GLACIALIS						2
480168000000	SABELLIDAE				X		7
4801680000FC	SABELLIDAE FRAGMENTS						2
480168010000	CHONE SP.						2
480168010100	CHONE GRACILIS						2
480168010200	CHONE INFUNDIBULIFORMIS						1
480168010400	CHONE DUNERI						1
480168020100	EUCHONE ANALIS						4
480168040100	MEGALOMMA SPLENDIDA						1
480168070300	PSEUDOPOTAMILLA RENIFORMIS				X		3
480170000000	SERPULIDAE						0
480170010200	CHITINOPOMA GROENLANDICA				X		1
480170020100	CRUCIGERA IRREGULARIS						4
480170050000	SPIRORBIS SP.				X		1
480174000000	APHRODITIDAE						0
480174010300	APHRODITA PARVA						2
480176000000	DISCOMIDAE						0
480176010200	DISCOMA MULTISETOSUM						1
490000000000	MOLLUSCA						1
4900000000FC	MOLLUSCA FRAGMENTS						1
490103010100	CHAETODERMA ROBUSTA	X					21
490302030200	ISCHNOCHITON ALBUS		X		X		6
490400000000	PELECYPODA	X			X		25
4904000000FC	PELECYPODA FRAGMENTS						8
490402020100	NUCULA TENUIS	X	X		X		36
490403020000	NUCULANA SP.						1
490403020100	NUCULANA PERNULA	X	X	X	X	X	27
490403020600	NUCULANA CONCEPTIONIS						1
490403050000	YOLDIA SP.	X	X		X		22
490403050100	YOLDIA AMYGDALEA						6
490403050400	YOLDIA SCISSURATA			X			1
490403050800	YOLDIA SECUNDA			X	X	X	2
490403051200	YOLDIA MARTYRIA						1
490407010100	MYTILUS EDULIS						1
490407020100	CRENELLA DECUSSATA		X		X		10
490407030100	MEGACRENELLA COLUMBIANA						2
490407030300	MEGACRENELLA DECUSSATA						1
490407050000	DACRYDIUM SP.				X		5
490407050100	DACRYDIUM PACIFICUM						1
490407050200	DACRYDIUM VITREUM				X		7
490408000000	PECTINIDAE						1
490408050200	PROPEAMUSSIUM ALASKENSE						2
490408060100	DELECTOPECTEN RANDOLPHI						3

GULF OF ALASKA BENTHIC GRAB DATA -- MARCH 1976

LIST OF ALL TAXONOMIC GROUPS FOUND

CRITERIA 1- TAXON OCCURS IN 50 PCT OR MORE OF STATIONS
CRITERIA 2- AT LEAST 10 PCT OF INDIVIDUALS AT SOME STATION
CRITERIA 3- AT LEAST 10 PCT OF WET BIOMASS AT SOME STATION
CRITERIA 4- ABUNDANT WRT NO. INDIVIDUALS AT SOME STATION
CRITERIA 5- ABUNDANT WRT TOTAL BIOMASS AT SOME STATION

TAXON CODE	TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
490409010100	LIMA SABAURICULLATA						1
490409010300	LIMA HYPERBOREA						3
490411010000	ASTARTE SP.				X		5
490411010100	ASTARTE BOREALIS				X		1
490411010200	ASTARTE ALASKENSIS			X		X	2
490411010400	ASTARTE POLARIS			X	X	X	8
490411010800	ASTARTE ESQUIMAULTI			X	X		3
490412010000	CYCLOCARDIA SP.						3
490412010100	CYCLOCARDIA VENTRICOSA				X		13
490412010200	CYCLOCARDIA CREBRICOSTATA				X		5
490415020100	AXINOPSIDA SERRICATA		X		X		15
490415020300	AXINOPSIDA VIRIDIS				X		1
490415030100	THYASIRA FLEXUOSA	X	X		X		25
490418010000	MYSELLA SP.						2
490418020100	ODONTOGENA BOREALIS	X	X		X		22
490420010000	CLINOCARDIUM SP.						2
490420010100	CLINOCARDIUM CILIATUM						2
490421050100	PSEPHIDIA LORDI	X	X		X		21
490421060100	HUMILARIA KENNERLEYI						1
490423010100	SPISULA POLYNYMA						2
490424010000	MACOMA SP.						1
490424010100	MACOMA CALCAREA			X			3
490424010300	MACOMA BROTA						6
490424011300	MACOMA CARLOTTENSIS						1
490427010200	SILIQUA ALTA						1
490429020100	HIATELLA ARCTICA						4
490432010300	PANDORA BILIRATA						1
490434010200	PERIPLOMA ARCTICA						1
490435020000	THRACIA SP.						1
490435020200	THRACIA MYOPSIS						2
490437010000	CARDIOMYA SP.						2
490437010100	CARDIOMYA PECTINATA						6
490437010200	CARDIOMYA PLANETICA						3
490437010300	CARDIOMYA OLDROYDI						1
490438010100	LYONSIELLA OSBAKOVI						1
490500000000	GASTROPODA				X		13
4905000000F0	GASTROPODA FRAGMENTS						4
490503020500	PUNCTURELLA COOPERI						2
490506040000	SOLARIELLA SP.						1
490506040200	SOLARIELLA OBSCURA						5
490506040400	SOLARIELLA LEWISII						1
490523010100	CALYPTRAEA FASTIGATA						1
490525020100	NATICA CLAUSA						4
490525040100	POLINICES NANUS						1
490525040200	POLINICES PALLIDA						4
490530041600	TROPHONOPSIS LASIUS						1
490533000000	NEPTUNIDAE						1
490534010100	AMPHISSA COLUMBIANA						2

LIST OF ALL TAXCNCMIC GRCLPS FCLND

CRITERIA 1- TAXCN CCCLRS IN 5C PCT CR MCRE CF STATICNS
CRITERIA 2- AT LEAST 10 PCT CF INCIVIDLALS AT SCME STATICN
CRITERIA 3- AT LEAST 10 PCT CF WET BIOMASS AT SCME STATICN
CRITERIA 4- ABUNCANT WRT NO. INDIVICLALS AT SCME STATICN
CRITERIA 5- ABUNCANT WRT TOTAL BICMASS AT SCME STATICN

TAXCN CCDE	TAXCN NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA CCC
49053402040C	MITRELLA GCLLCI						
49054001010C	ACMETE CCUTHCUYI				X	X	3
49054101010C	SCAVCDRILLIA KENNICCTTII						1
49054104000C	CENCPCTA SP.						1
49054109000C	ANTIPLANES						1
49054110020C	LEUCCSYRINX CIRCINATA						1
49054201000C	CCCSTOMIA SP.						1
49054201250C	CCCSTOMIA CF. C.CYRIA						3
49054502010C	VCLVLVELLA CYLINCRICA						1
49054902030C	CYLICHNA ALBA						1
49054902050C	CYLICHNA ATTANCSA						1
49055700000C	DCRIDICAE						1
49060000000C	SCAPHCPCDA						2
49060101000C	DENTALIUM SP.						4
49060101010C	DENTALIUM DALLI						4
49060201000C	CADULUS SP.						5
49060201020C	CADULUS STEARNSI				X		4
49060201030C	CADULUS TCLMEI						6
52000000000C	PYCNCGCNIDA				X		6
52005000000C	PYCNCGCNIDAE						C
53000000000C	CRUSTACEA						1
53070000000C	PCDCCCPA						C
53180000000C	THCRACICA		X		X		17
531801020000	SCALPELLUM SP.						C
53180201040C	BALANUS CRENATUS			X	X	X	1
53180201100C	BALANUS NUBILIS						2
53180201110C	BALANUS RCSTRATUS		X	X	X	X	2
532800000FC	CUMACEA FRAGMENTS				X		1
53280401000C	LEUCCN SP.						15
53280401010C	LEUCCN NASICA				X		5
53280402000C	EUCCRELLA SP.						2
53280402010C	EUCCRELLA ENARGINATA						1
53280402020C	EUCCRELLA PACIFICA				X		16
532804030000	EUCCRELLOPSIS SP.						1
53280403010C	EUCCRELLOPSIS INTEGRA						1
53280403040C	EUCCRELLOPSIS CEFCRMIS				X		3
53280501000C	CIASTYLIS SP.						1
53280501030C	CIASTYLIS BICENTATA				X		9
53280701000C	CAMPYLASPIS SP						1
53280800000C	NANNASTACIDAE						1
53290100000C	TANAICAE						1
53300000000C	ISCPCCA						2
53300100000C	ARCTURIDAE						3
533002020900	SYNICOTEA PETTIECNEAE						3
53301101000C	GNATHIA		X		X		1
53301101010C	GNATHIA ELCNGATA				X		4
53301200000C	ANTHURIDAE						1
53310000000C	AMPHIPCDA						2
							7

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GULF OF ALASKA BENTHIC GRAB DATA -- MARCH 1976 03/14/78 PAGE 9

LIST OF ALL TAXONOMIC GROUPS FOUND

CRITERIA 1- TAXON OCCURS IN 50 PCT OR MORE OF STATIONS
CRITERIA 2- AT LEAST 10 PCT OF INDIVIDUALS AT SOME STATION
CRITERIA 3- AT LEAST 10 PCT OF WET BIOMASS AT SOME STATION
CRITERIA 4- ABUNDANT WRT NO. INDIVIDUALS AT SOME STATION
CRITERIA 5- ABUNDANT WRT TOTAL BIOMASS AT SOME STATION

TAXON CODE	TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
5331000000F0	AMPHIPODA FRAGMENTS				X		19
533102010000	AMPELISCIDA SP.						3
5331020100F0	AMPELISCIDA SP. FRAGS						2
533102010100	AMPELISCA MACROCEPHALA						11
533102010200	AMPELISCIDAE BIRULAI				X		9
533102010300	AMPELISCIDA DERJUGINI						1
533102010500	AMPELISCIDA ESCHRICHTI						1
533102020000	BYBLIS SP.						5
533102020200	BYBLIS GAIMARDI						10
533102030100	HAPLOOPS TUBICOLA				X		6
533115010000	CERAPUS SP.						0
533115030000	ERICTHONIUS SP.						1
533115030100	ERICTHONIUS HUNTERI						1
533115050000	NEOHELA						1
533115050100	NEOHELA MONSTROSA						2
533121000000	GAMMARIDAE						2
533121100300	MELITA FORMOSA						1
533122040200	UROTHOE DENTICULATA						9
533126030000	PROTOMEDEIA SP.						2
533126050000	PODOCEROPSIS SP.				X		1
533126050300	PODOCEROPSIS LINDAHLI						1
533134000000	LYSIANASSIDAE						2
533134030000	ANONYX SP.				X		8
5331340300F0	ANONYX SP. FRAGS						1
533134030200	ANONYX NUGAX						3
533134031300	ANONYX MAGNUS						1
533134140000	HIPPOMEDON						4
533134210400	LEPIDEPECREUM COMATUM						2
533134280100	OPISA ESCHRICHTI						1
533134290500	ORCHOMENE NUGAX						1
533134400100	SOCARNES BIDENTICULATUS						1
533135000000	MELPHIDIPPIDAE				X		1
533137050400	BATHYMEDON NANSENI						1
533137090000	MONOCULODES						1
533137090500	MONOCULODES DIAMESUS						1
533140020100	NICIPPE TUMIDA						4
533142000000	PHOXOCEPHALIDAE						1
5331420000F0	PHOXOCEPHALIDAE FRAGMENTS						1
533142010000	HARPINIA SP.						3
533142010200	HARPINIA KOBJAKOVAE				X		2
533142011300	HARPINIA TARASOVI						1
533142020100	HARPINIOPSIS SANPEDROENSIS				X		9
533142030100	HETEROPHOXUS OCULATUS						18
533142080000	PHOXOCEPHALUS						1
533142080100	PHOXOCEPHALUS HOMILIS						5
533143000000	PLEUSTIDAE		X		X		1
533148020000	METOPA SP.				X		11
5331480200F0	PARAPHOXUS SP. FRAGS						1

LIST OF ALL TAXCNCMIC GRCUFS FCUND

CRITERIA 1- TAXCN CCCURS IN 5C PCT OR MCRE CF STATICNS
CRITERIA 2- AT LEAST 10 PCT CF INDIVIDUALS AT SCME STATICN
CRITERIA 3- AT LEAST 10 PCT CF WET BIOMASS AT SCME STATICN
CRITERIA 4- ABUNCANT WRT NO. INDIVIDUALS AT SCME STATICN
CRITERIA 5- ABUNCANT WRT TOTAL BICMASS AT SCME STATICN

TAXCN CCDE	TAXCN NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA CCC
53314802080C	PARAPHCXUS LEPTCCARPA						1
53314802110C	PARAPHOXUS RCBUSTA				X		5
53315003010C	SYRRHCE CRENULATA				X		1
5331501C0C0C	CERAPHUS SP.						1
53319800C0C0	CAPRELLIDAE				X		5
5333000C0C00	CECAPCDA						3
53330000CCFC	CECAPCDA FRAGMENTS						1
53331102030C	PAGURUS ALEUTICUS						1
533317030200	CHICNOECETES BAIRDI			X		X	2
53331801060C	CANCER CREGCNENSIS				X		1
53332103000C	PINNIXA SP.						1
53332103C40C	PINNIXA SCHMITTI						5
590000000C0C	SIPUNCULIDA				X		1C
590000C0C0FC	SIPUNCULIDA FRAGMENTS						1
59010101000C	GCLFINGIA SP.						1
59010101010C	GCLFINGIA MARGARITACEA			X	X	X	13
59010101020C	GCLFINGIA VULGARIS				X		12
59010102010C	PHASCCLION STRCMBI				X		6
60010C0C0C0C	ECHIURIDA						1
6001000C0CFC	ECHIURIDA FRAGMENTS						1
6100000C0C0C	PRIAPULIDA						3
610101020200	PRIAPULUS CAUDATUS						1
6600000CCC00	ECTCPRCCTA						3
6600000C0CFC	ECTCPRCCTA FRAGMENTS				X		9
660108010CFC	MICRCPCRINA SP. FRAGS						2
660108010IFC	MICRCPORINA BCREALIS FRAGS						1
6603060I0ICC	CLAVIPORA CCCIDENTALIS						4
67000000000C	BRACHICPCDA						2
67020000010C	BRACHICPCD A			X			1
67020000020C	BRACHICPCD B						1
67020101010C	HEMITHIRIS PSITTACEA						2
67020301010C	TEREBRATULINA UNGUICULA				X		5
67020301030C	TEREBRATULINA CRCSSEI						2
67020503010C	LAQUEUS CALIFCRNIANUS			X	X	X	7
67020504010C	TEREBRATALIA TRANSVERSA			X	X	X	2
6800000C0CFC	ECHINCDERMATA FRAGMENTS						1
6801000C0CCC	ASTERCIDEA						3
68010601010C	CTENODISCUS CRISPATUS	X	X	X	X	X	22
68010801050C	HENRICIA LEVIUSCULA				X		2
680112090CFC	LETHASTERIAS SP. FRAGS			X		X	1
68C2000C0C0C	ECHINCIDEA						1
68020301010C	BRISASTER TCWNSENDI			X		X	7
6802040C0CCC	STRCNGYLCCENTRCTIDAE						1
68020402000C	STRCNGYLOCENTRCTUS SP.			X		X	1
68020402010C	STRCNGYLOCENTRCTUS DRCEBACHIENS						1
68C204020300	STRCNGYLCCENTRCTUS PALLIDUS			X		X	1
68030000000C	CPHIURCIDEA				X		12
6803000C00FC	CPHIURCIDEA FRAGMENTS	X		X	X	X	24

GULF CF ALASKA EENTFIC GRAB CATA -- MARCF 1976

LIST OF ALL TAXCNCMIC GRCUPS FCUND

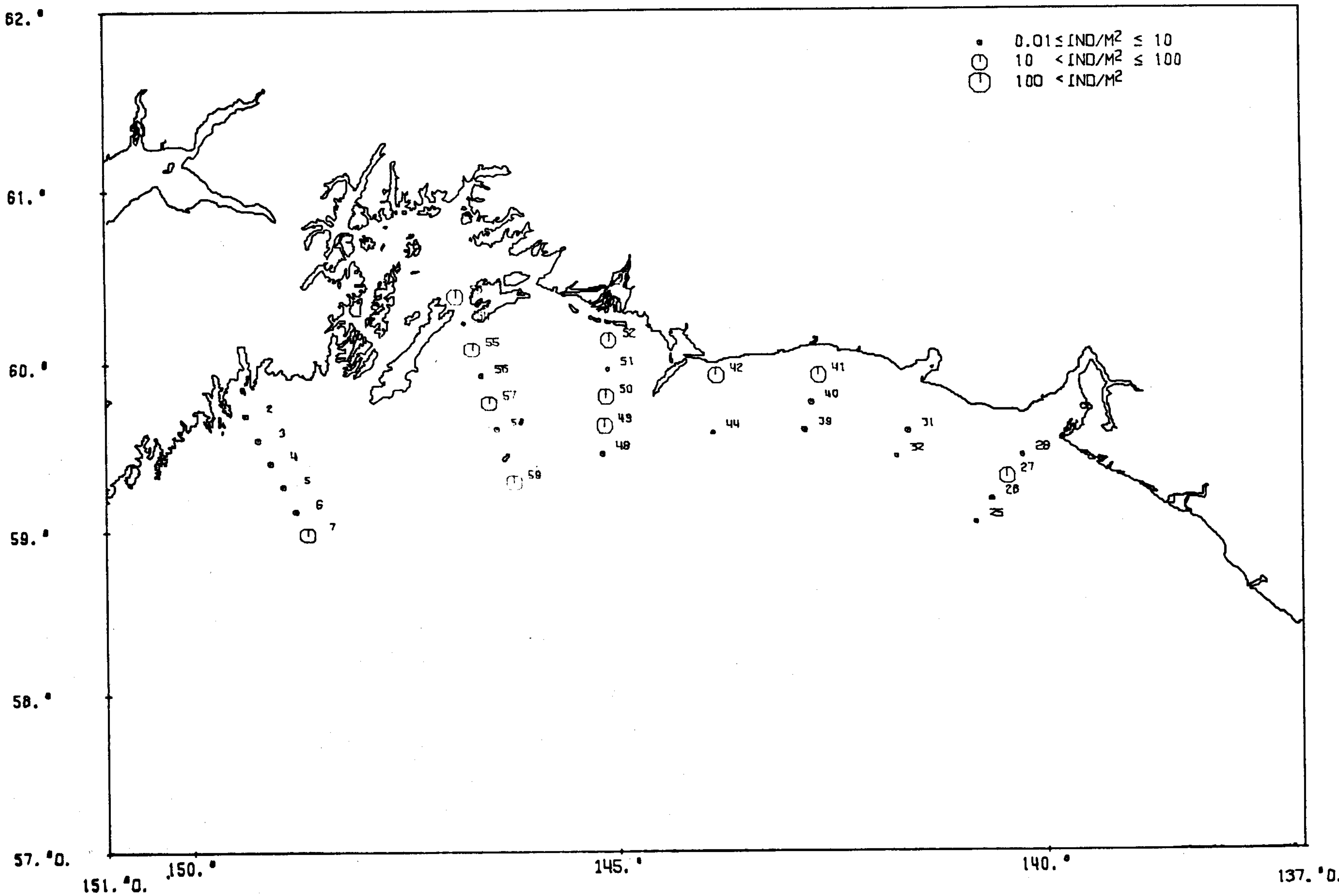
CRITERIA 1- TAXCN CCCURS IN 50 PCT CR MCRE CF STATICNS
CRITERIA 2- AT LEAST 1C PCT CF INCIVIDUALS AT SCME STATICN
CRITERIA 3- AT LEAST 10 PCT CF WET BICMASS AT SCME STATICN
CRITERIA 4- ABUNDANT WRT NO. INDIVIDUALS AT SCME STATICN
CRITERIA 5- ABUNDANT WRT TOTAL BICMASS AT SCME STATICN

TAXCN CCDE	TAXCN NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA CCC
680302030C0C	CIAMPHICDA SP.						1
680302030100	CIAMPHICDIA CRATERCDMETA		X		X	X	6
680302030300	CIAMPHICDEA PERIERCTA						2
680302040100	MCNAMPHIURA SUNCEVALLI						1
680302080000	UNICPLUS SP.						2
680302080100	UNICPLUS MACRASPIS		X	X	X	X	12
680305010600	CPHICCANTHA CATALEIMMCIDA			X			1
680306010100	CPHICPHCLIS ACULEATA			X	X	X	8
6803090C0C00	CPHIURIDAE						1
6803090C00FC	CPHIURIDAE FRAGMENTS						1
680309050100	CPHICPENIA CISACANTHA						8
680309050200	CPHICPENIA TETRACANTHA						1
680309061100	CPHIURA SARSI	X	X	X	X	X	26
6803090611FC	CPHIURA SARSI FRAGS						1
6804000C0000	HCLCTHURCIDEA					X	4
680405010100	MCLPADIA INTERMEDIA			X	X	X	12
680410010C00	CUCUMARIA SP						1
680410010100	CUCUMARIA CALCIGERA						1
68C412020000	PSCLUS SP.						1
680412020CFC	PSCLUS SP. FRAGS						C
680412020500	PSCLUS PHANTAPUS						2
6805000C0C00	CRINCIDEA						1
68050000C0FC	CRINCIDEA FRAGMENTS						1
7200000C0C00	URCCHCRDATA				X		4
720000000CFC	URCCHCRDATA FRAGMENTS				X	X	2
720205010C00	CHELYSOMA SP.						1
79000000C0C0	TELECSTEI						1
79150413C300	GYMNCCANTHUS PISTILLIGER						1
791505040100	ASTEROTHECA ALASCANA						1
791611140100	LUMPENELLA LCNGIRCSTRIS						C
999999999900	UNIDENTIFIBLE		X	X	X	X	16

TOTAL NUMBER CF TAXCNS = 438

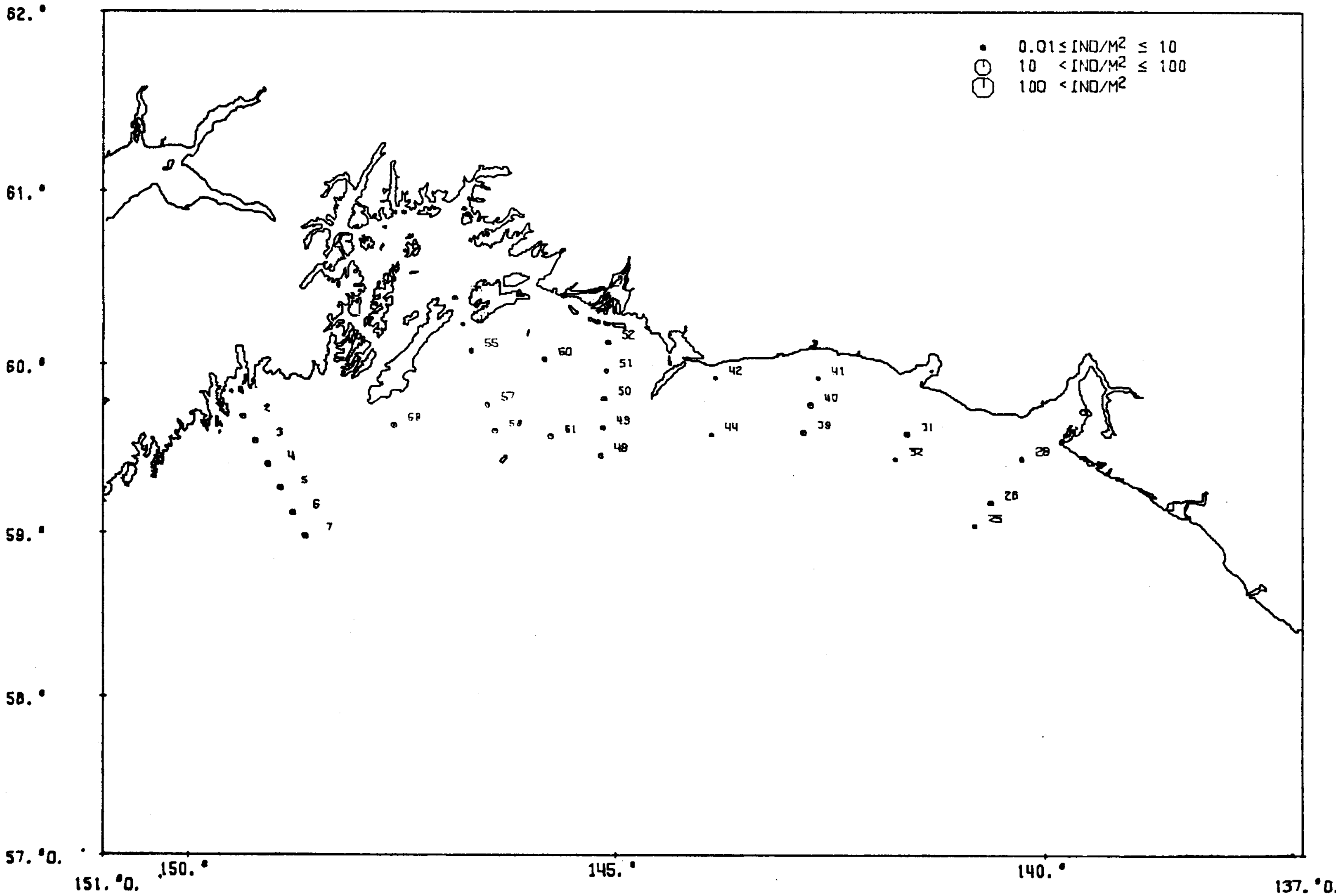
APPENDIX IV

DISTRIBUTION MAPS OF THE DOMINANT SPECIES IN THE NORTHEASTERN GULF OF ALASKA (NEGOA)



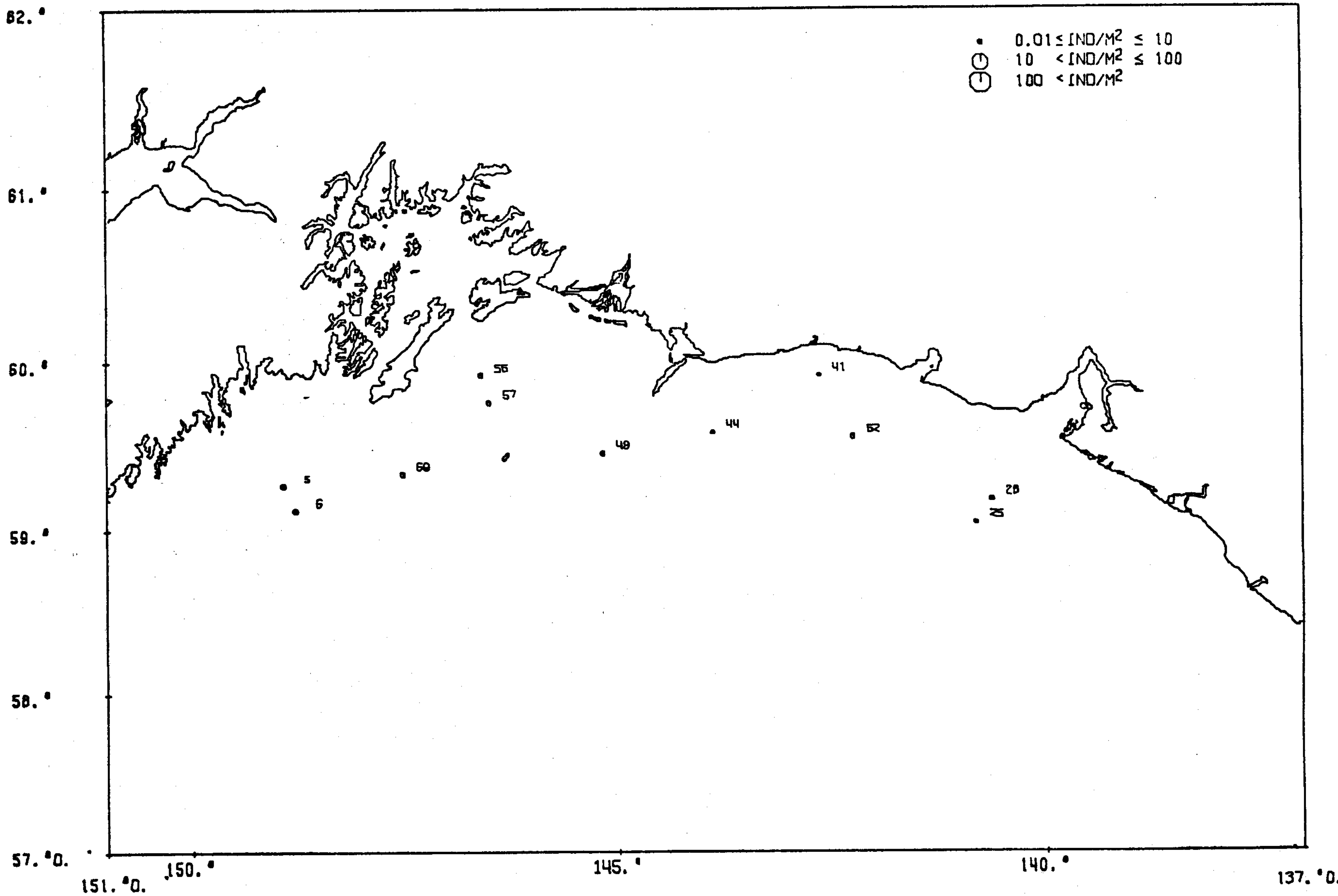
GULF OF ALASKA

LUMBRINERIS SIMILABRIS



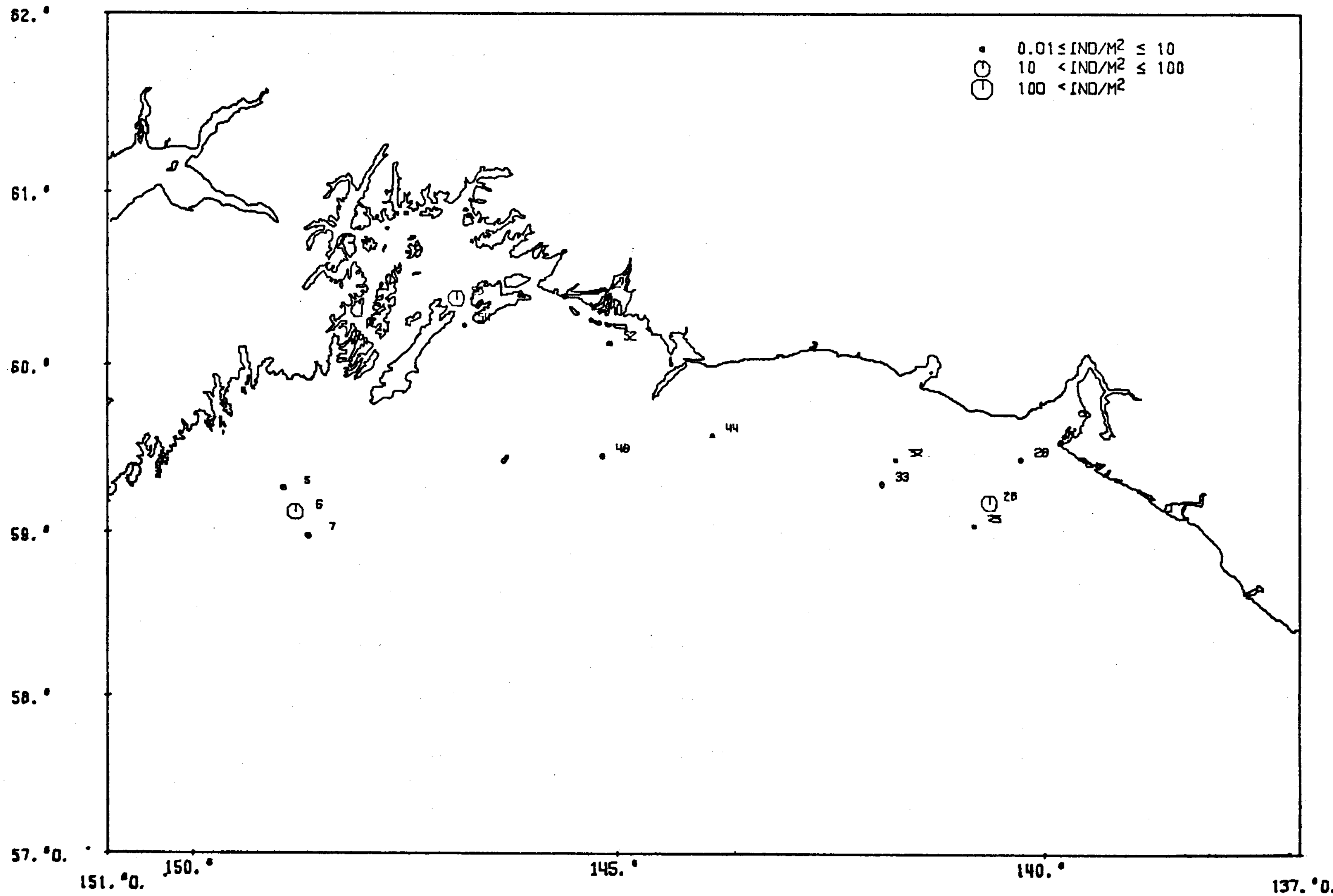
GULF OF ALASKA

NEPHTYS PUNCTATA



GULF ØF ALASKA

EUCHONE ANALIS



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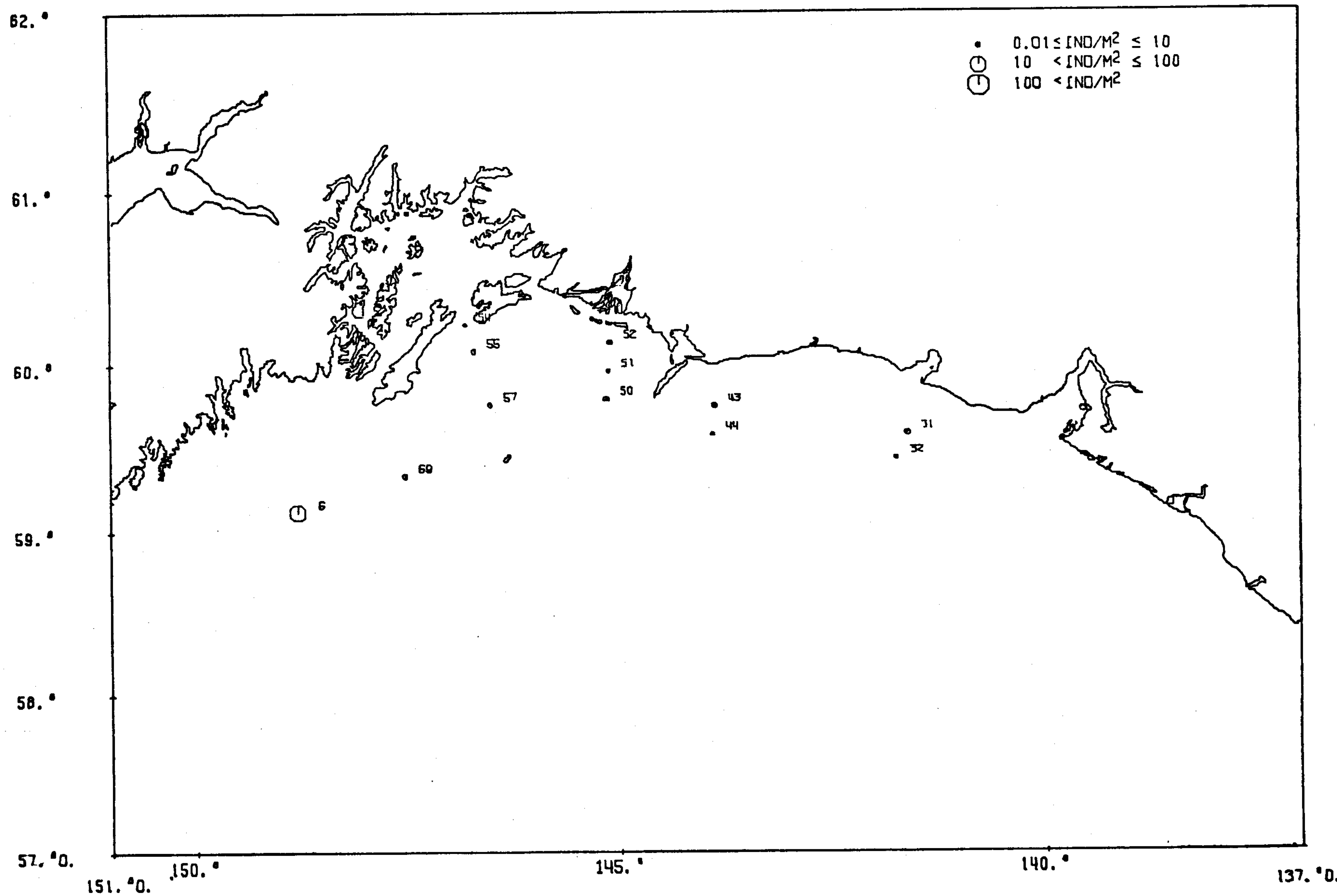

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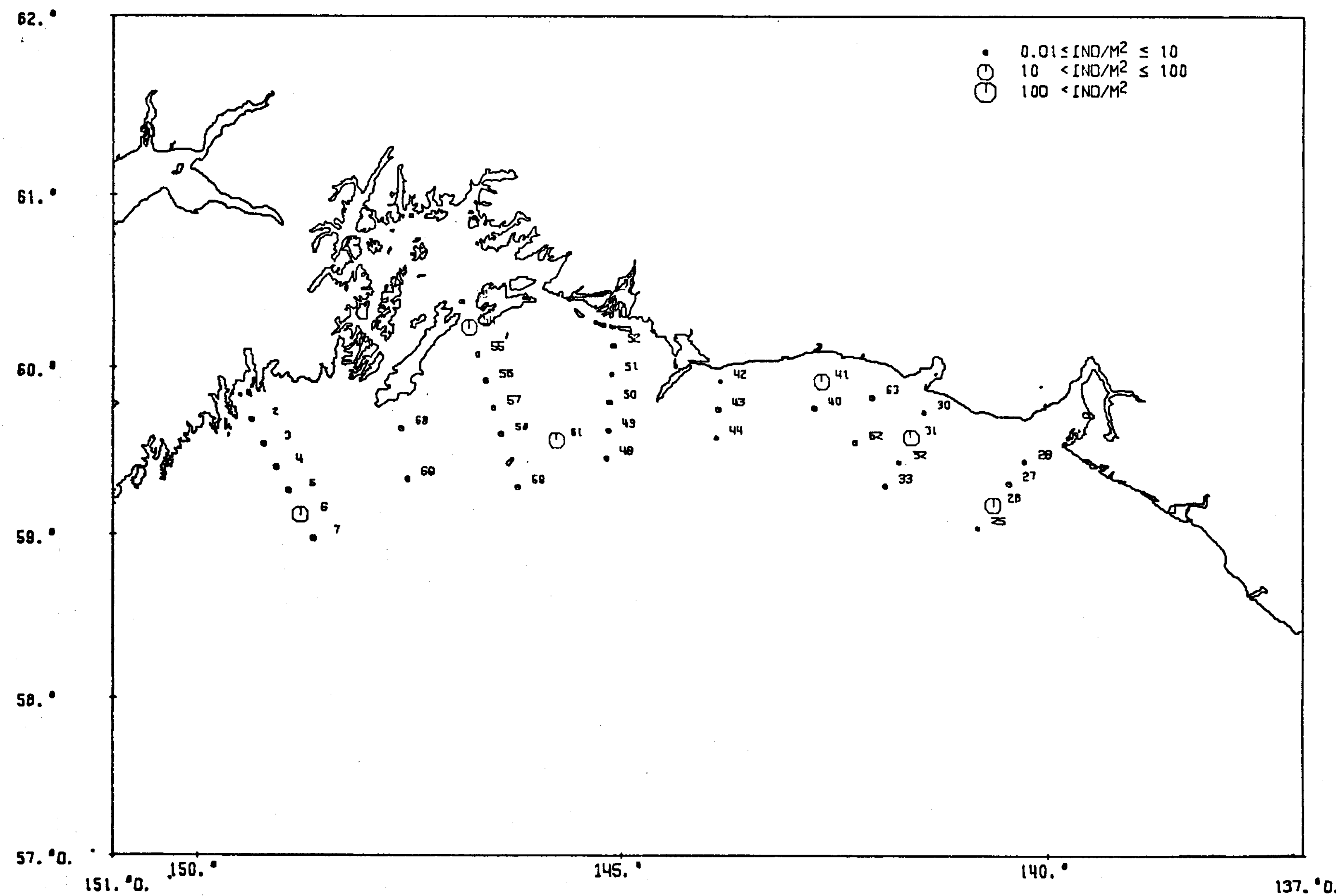

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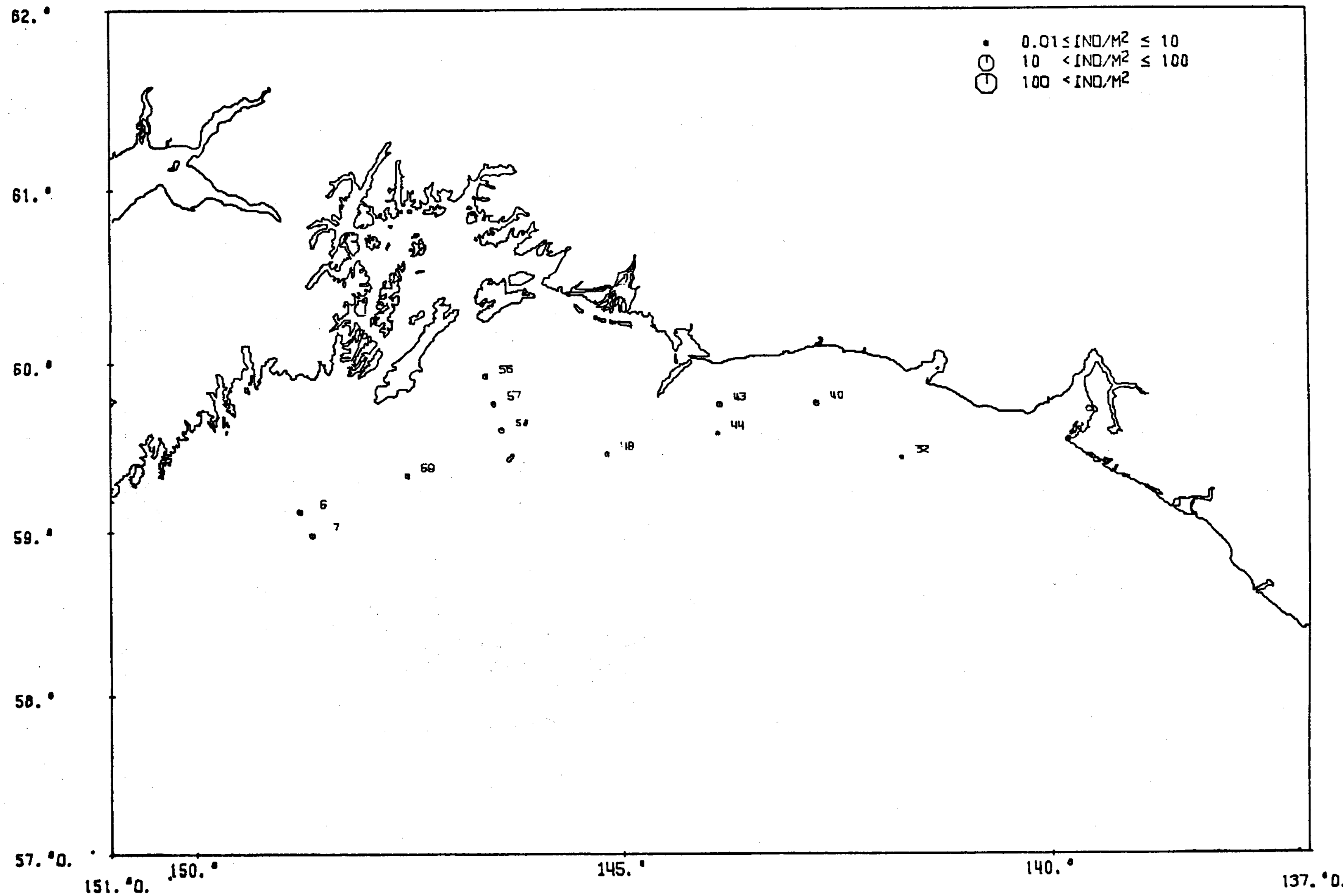

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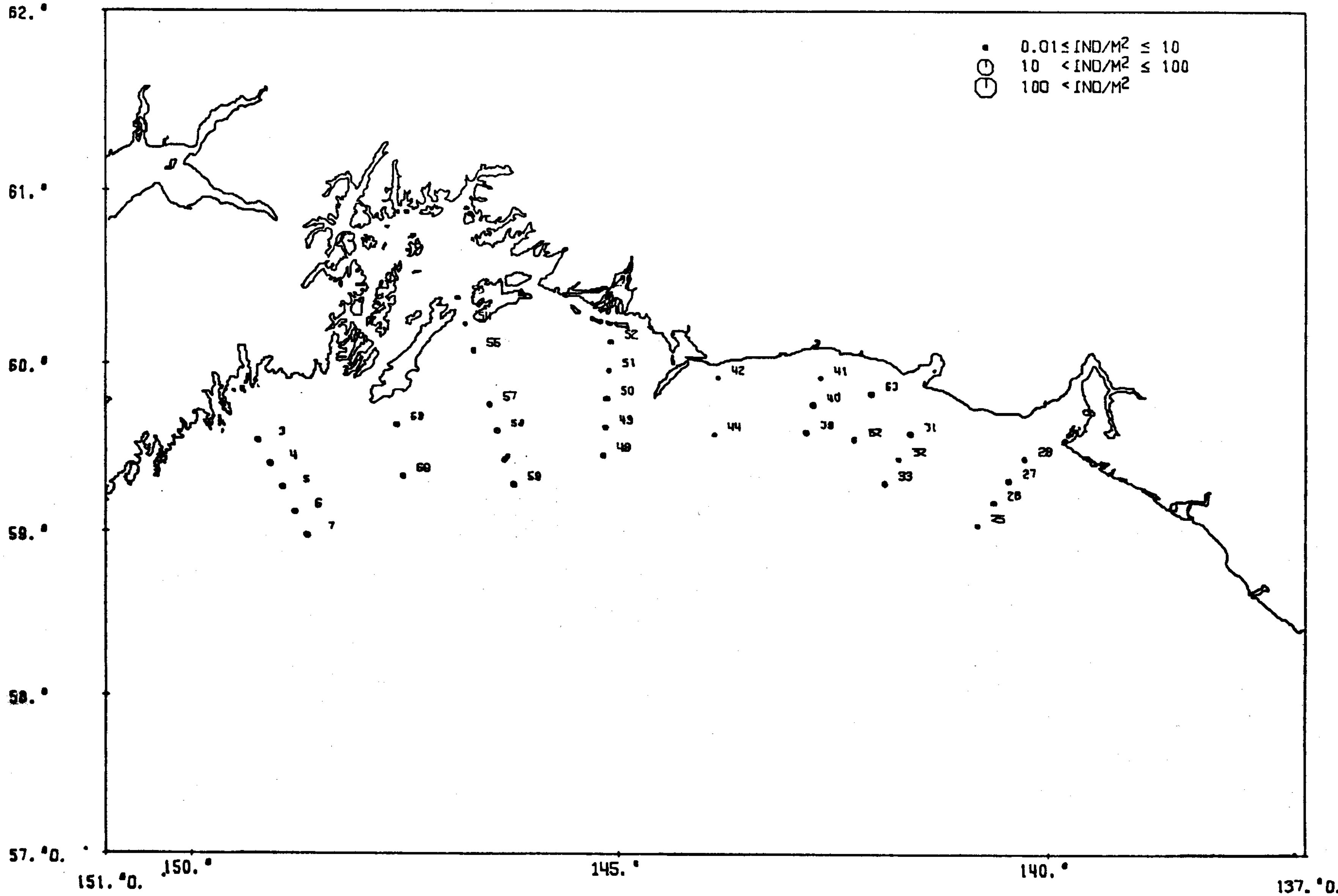

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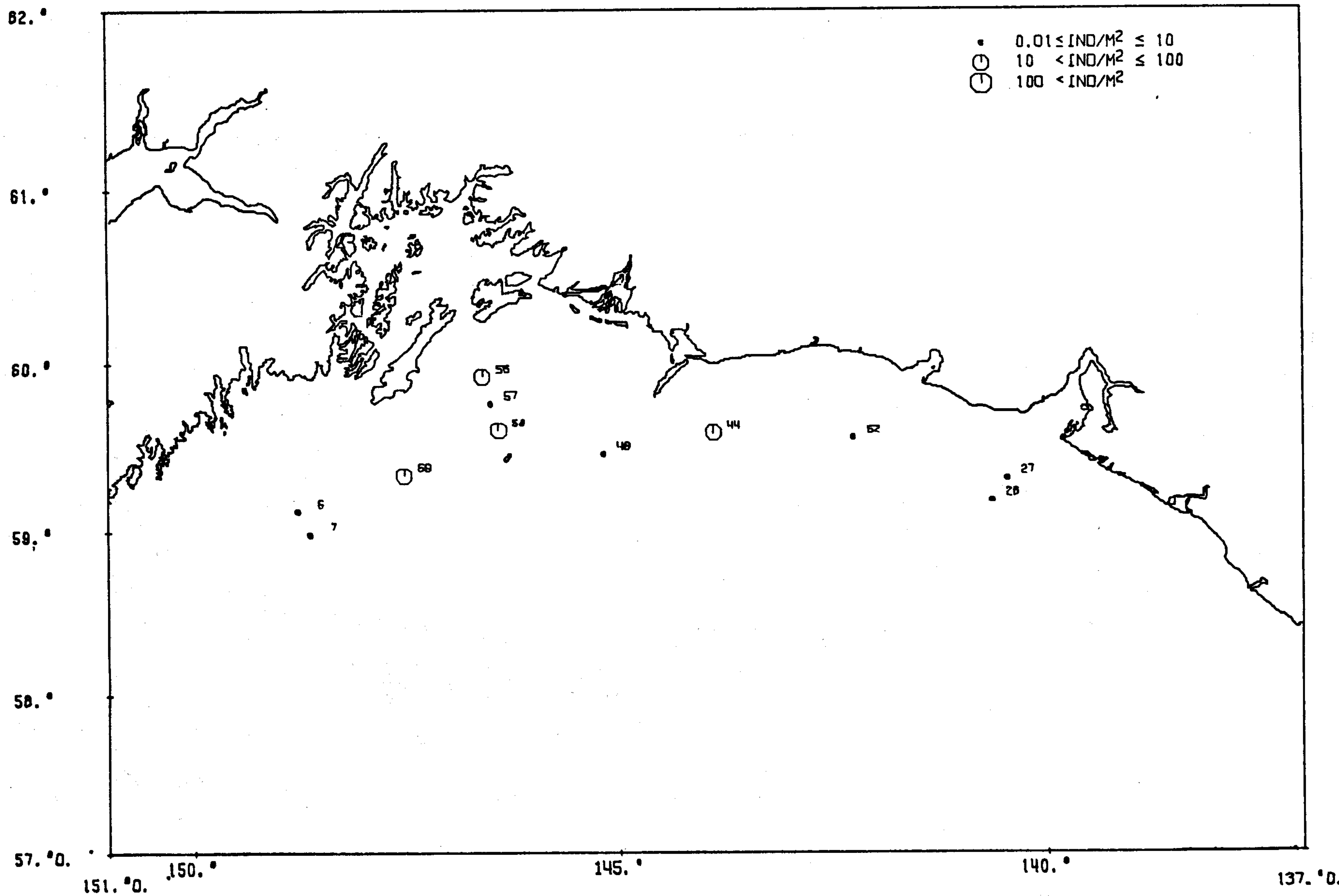

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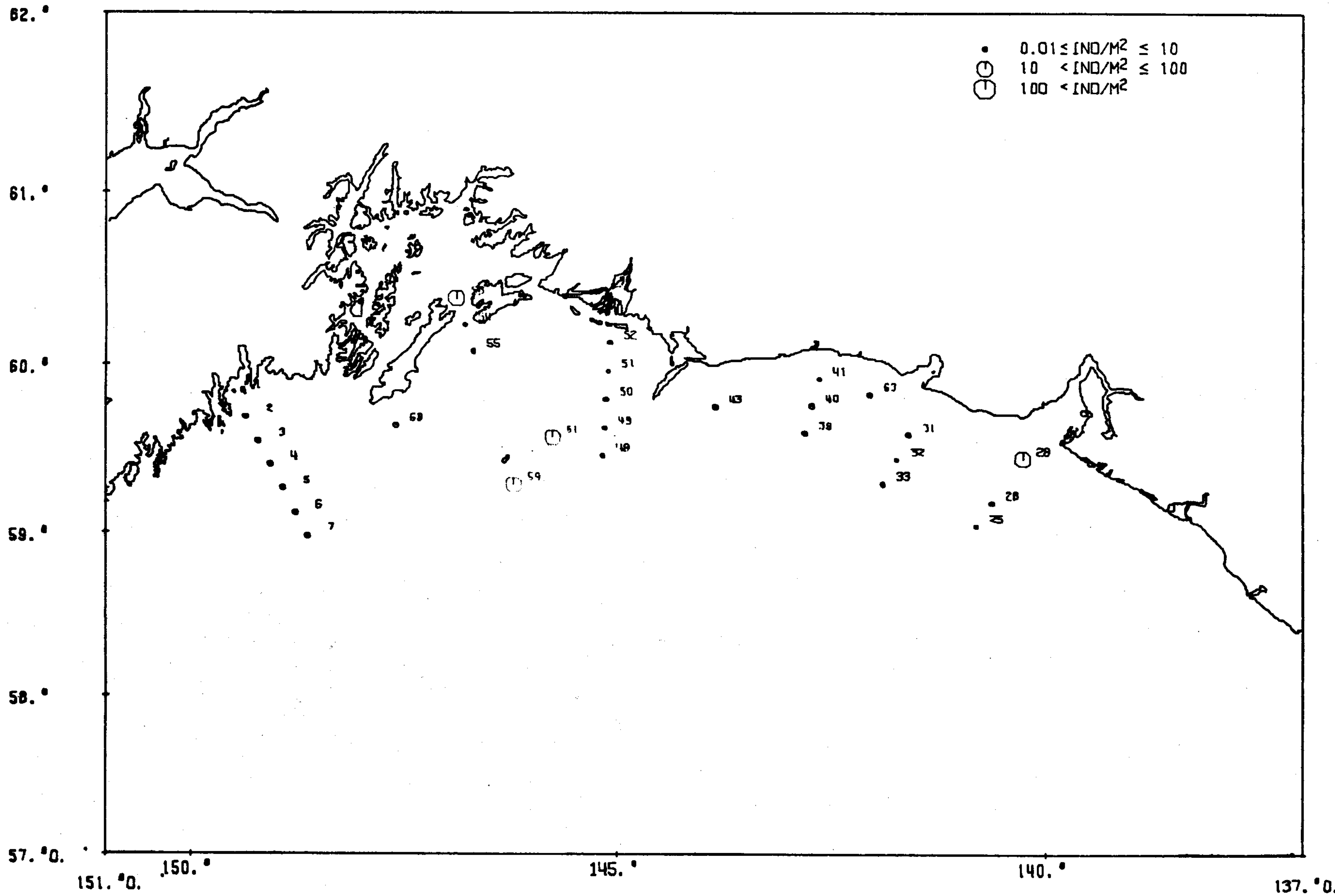

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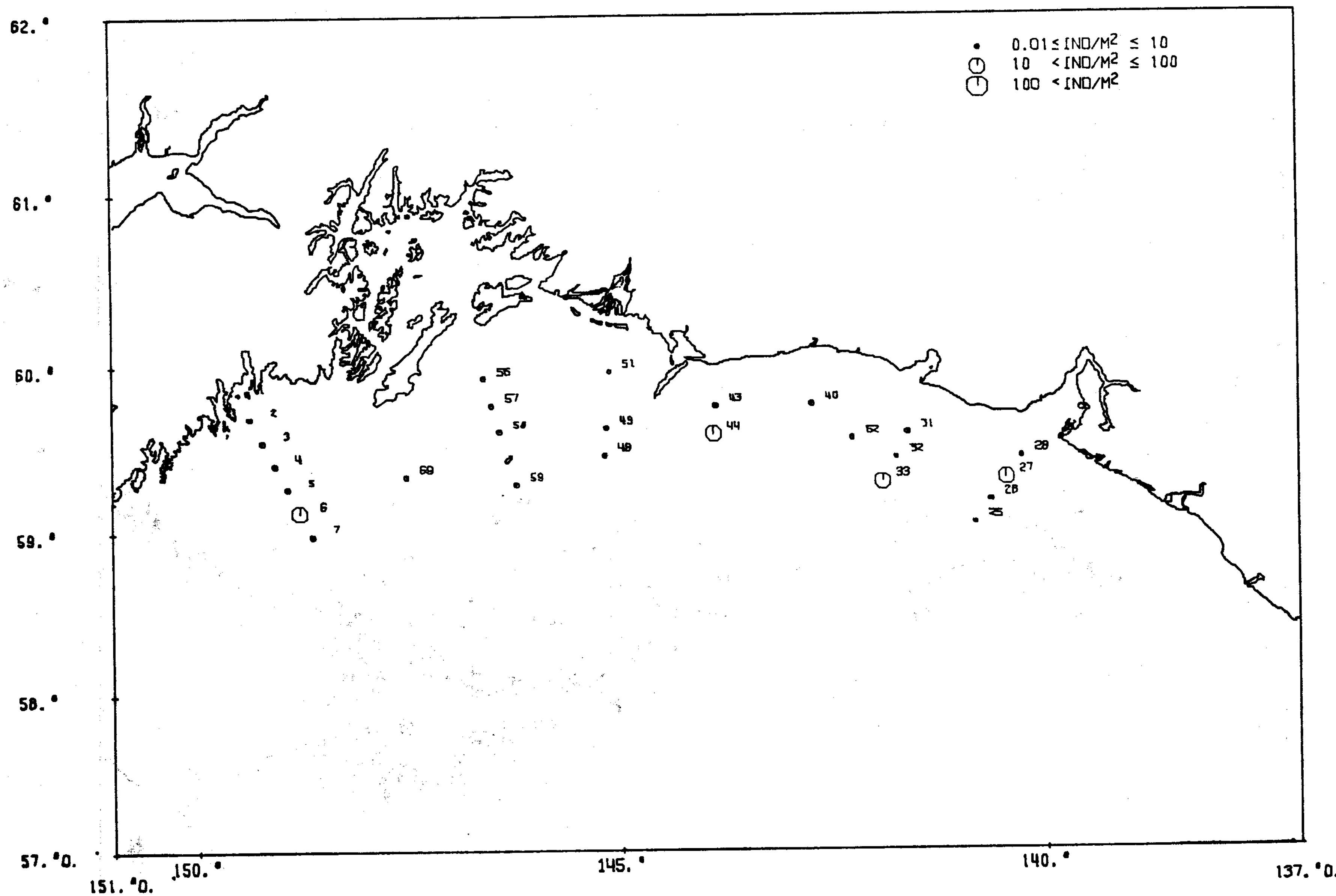

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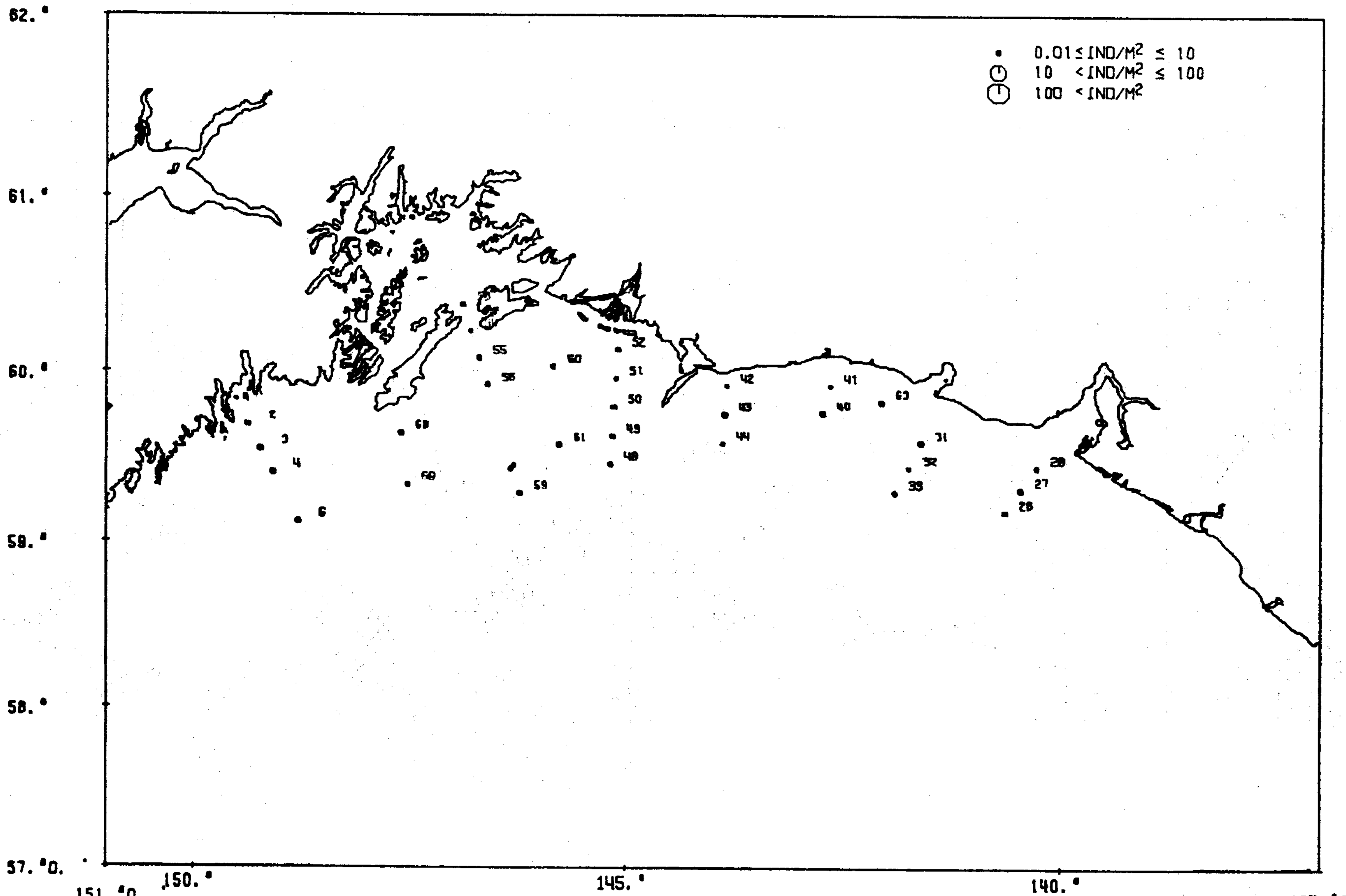

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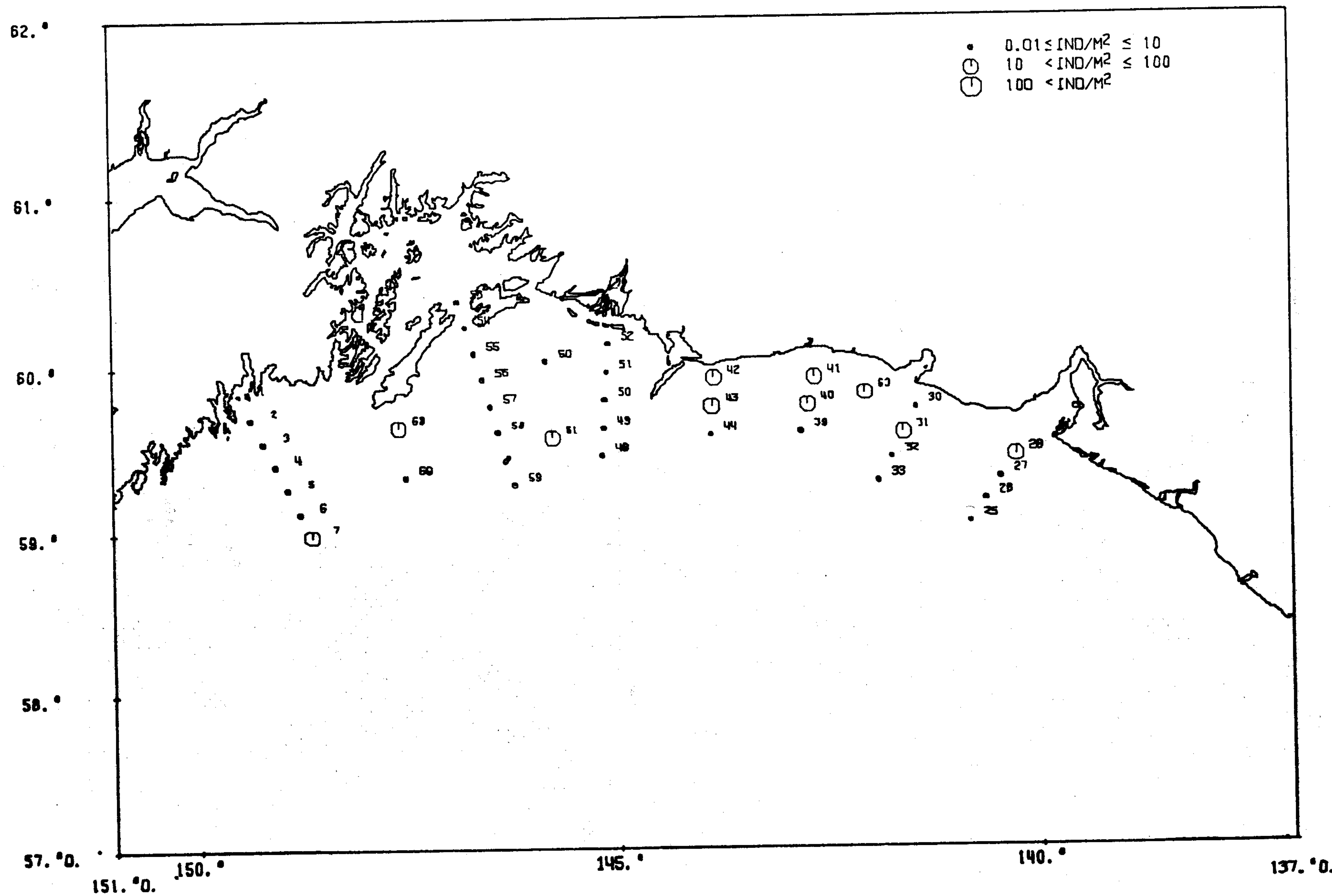

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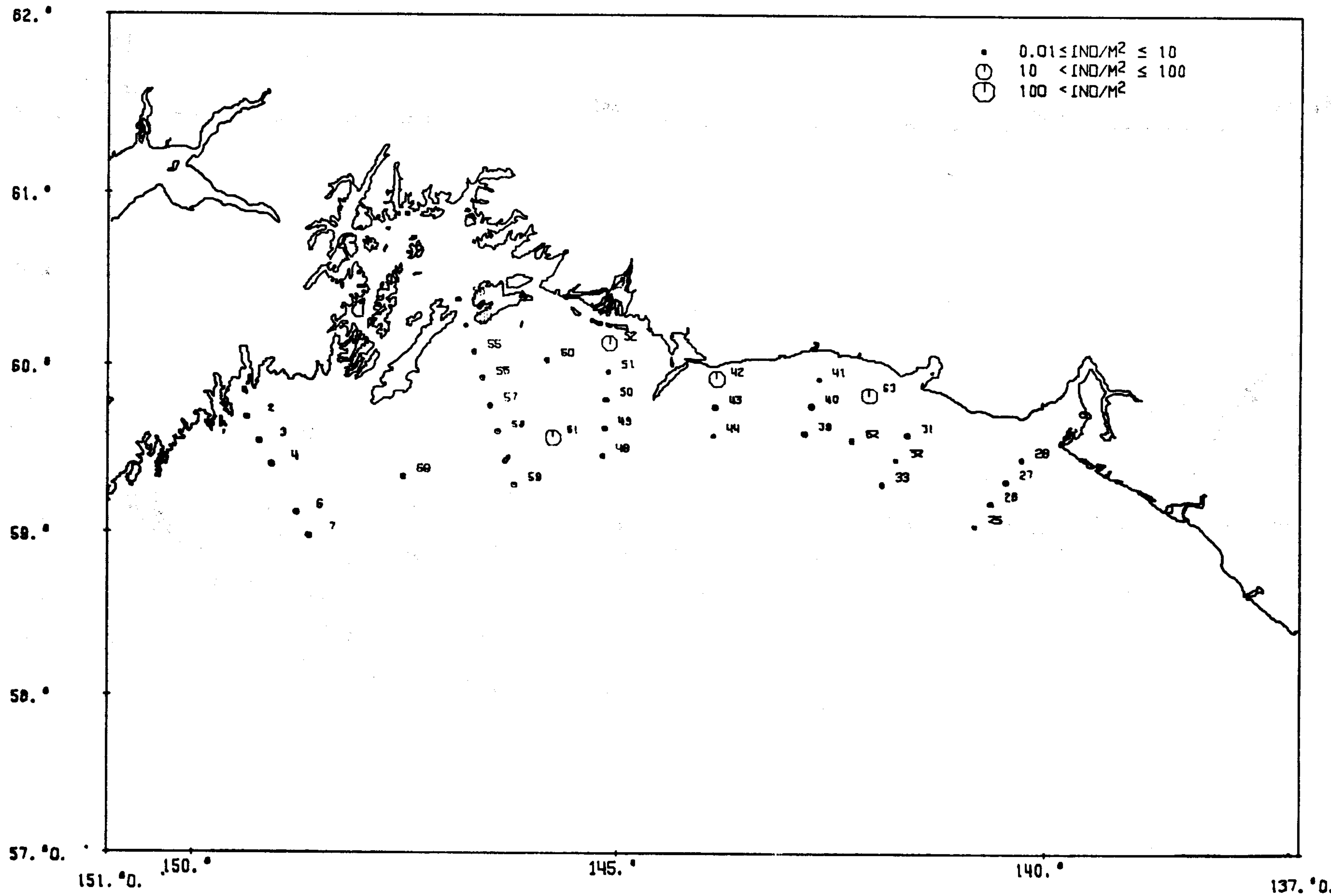

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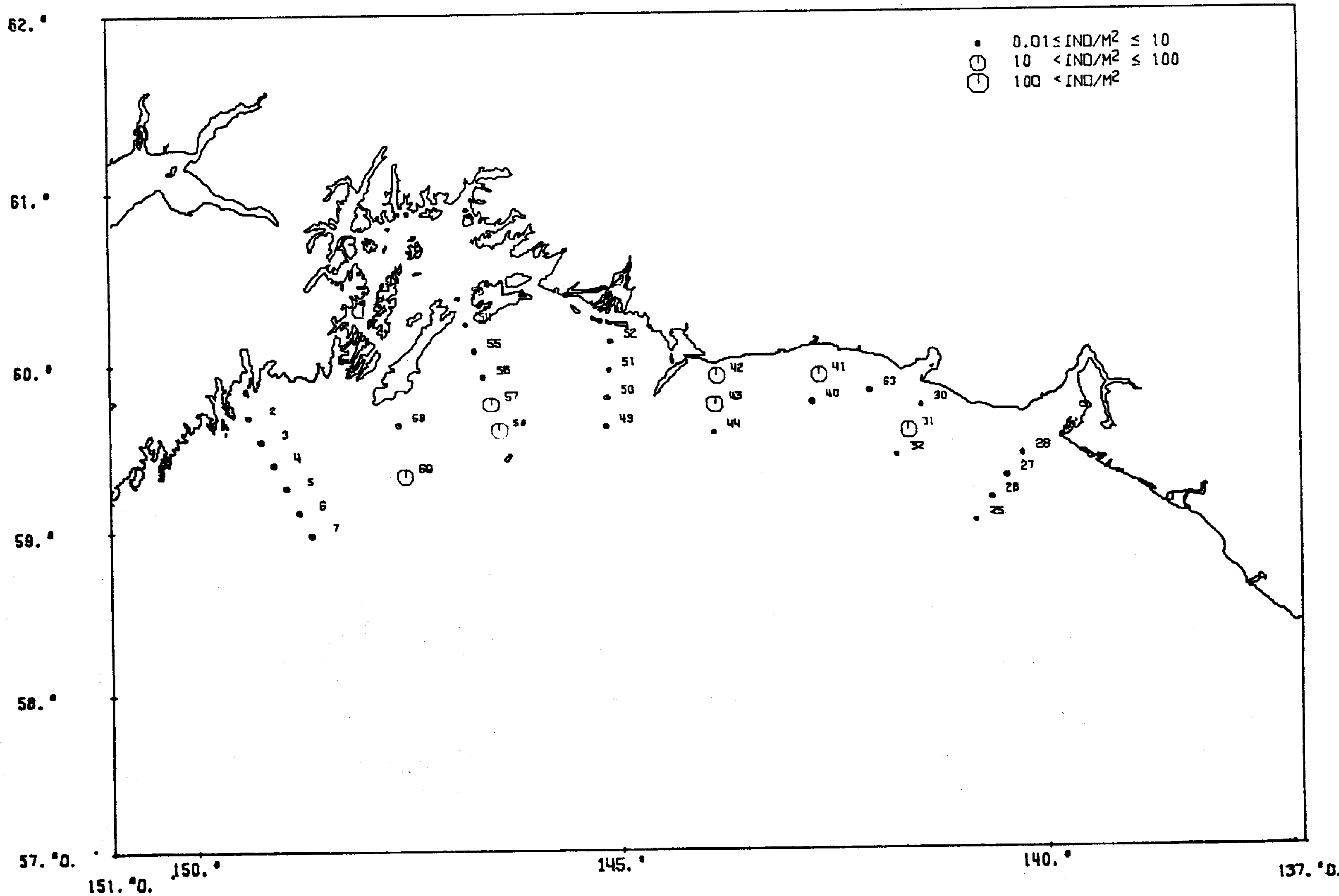

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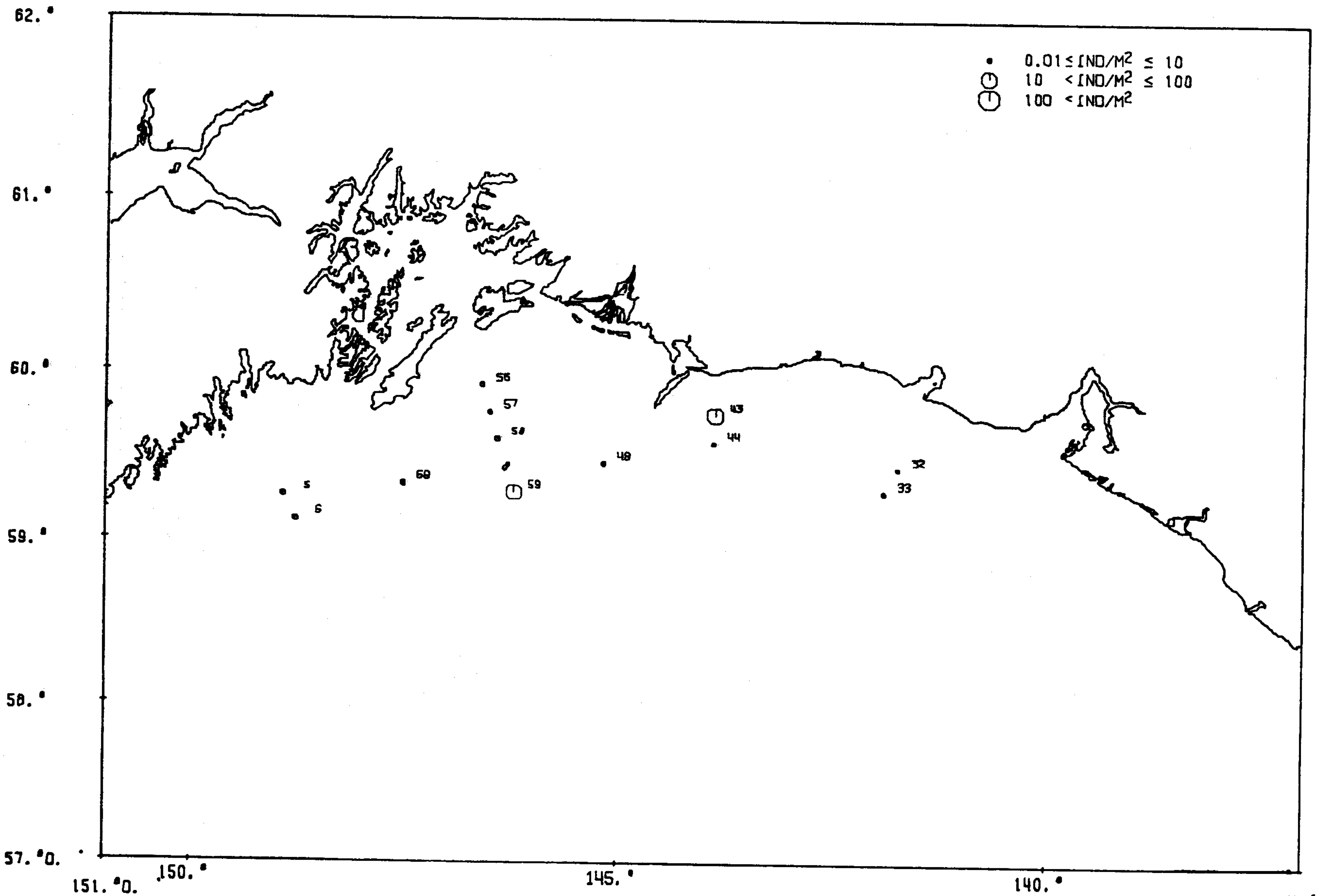

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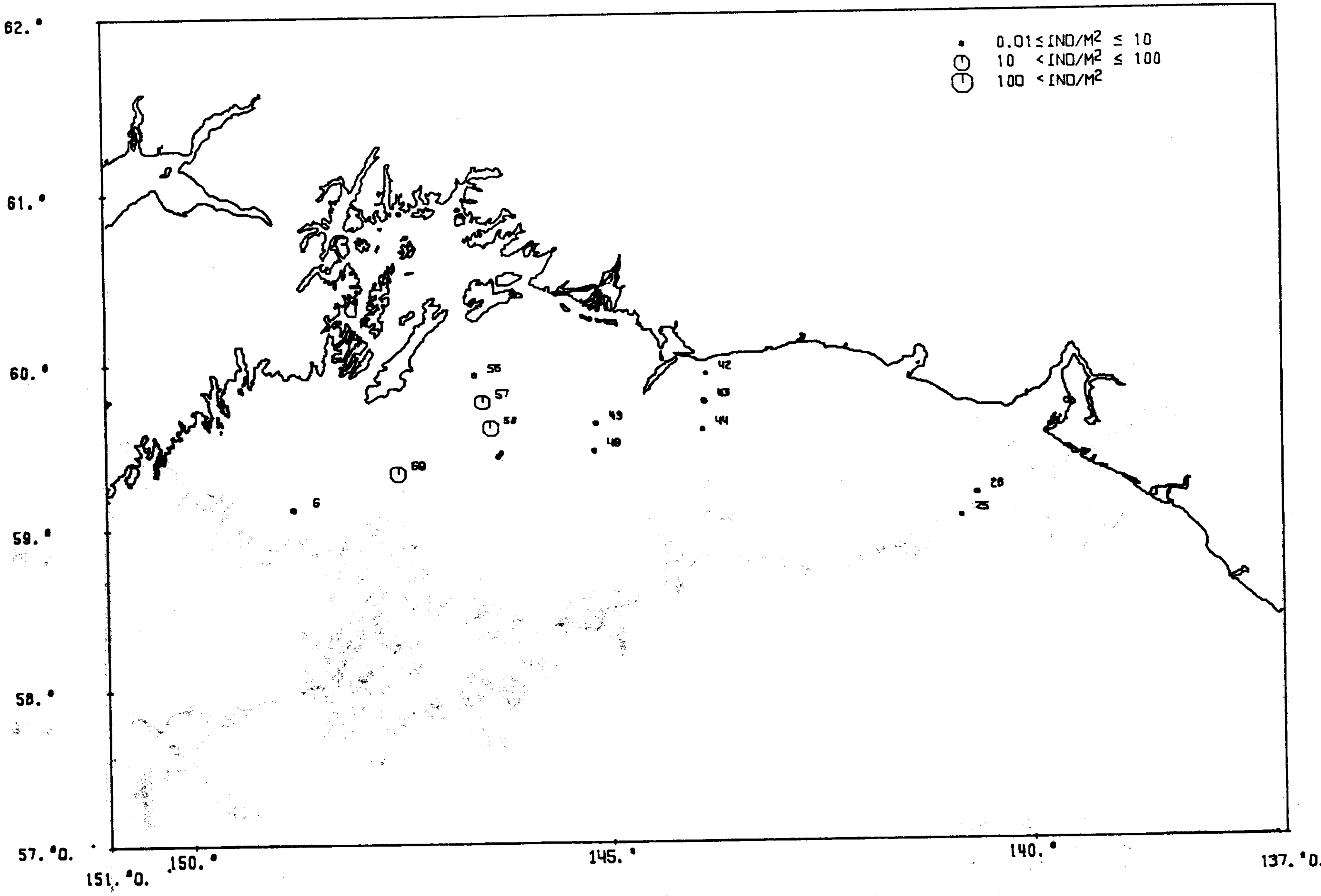

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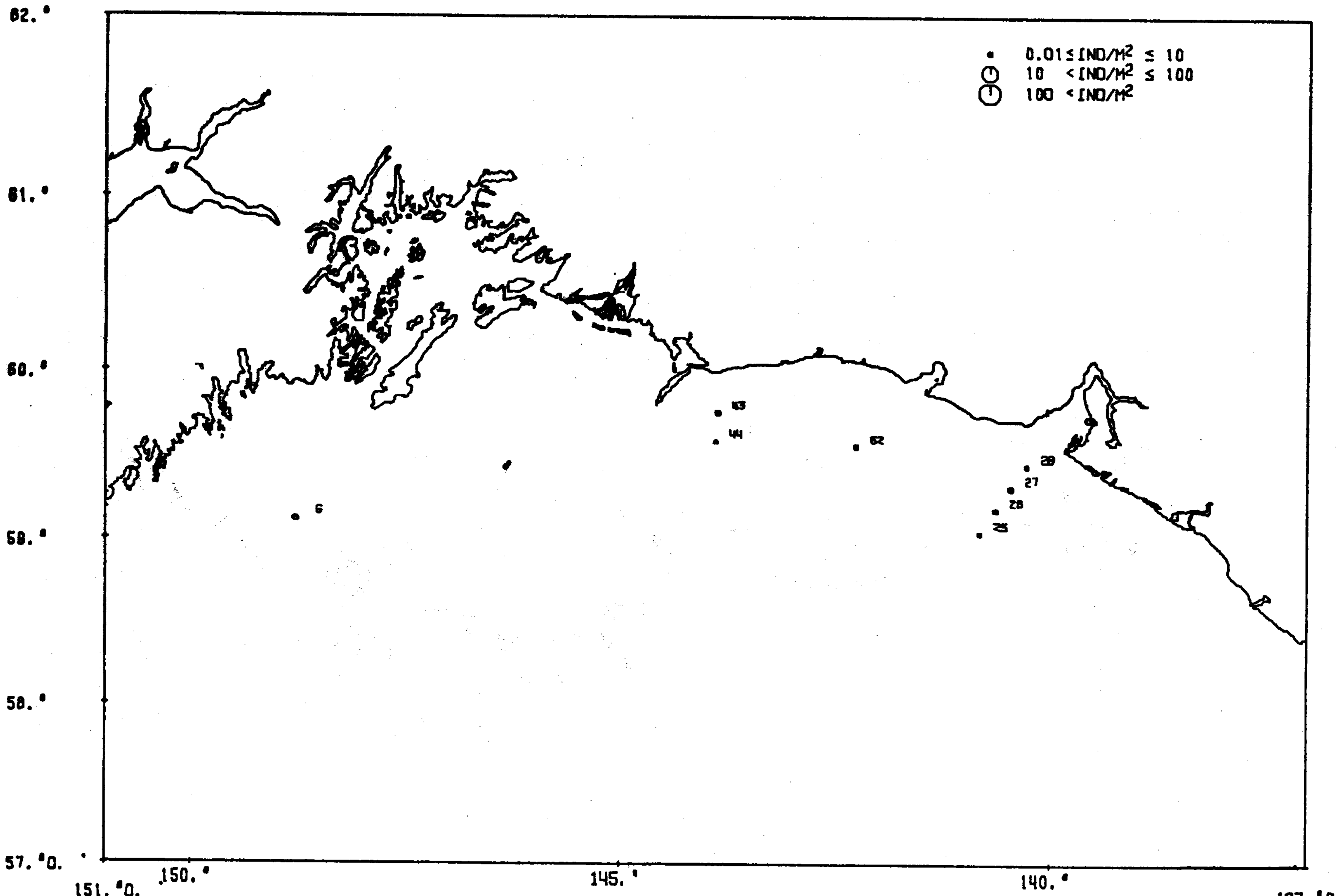

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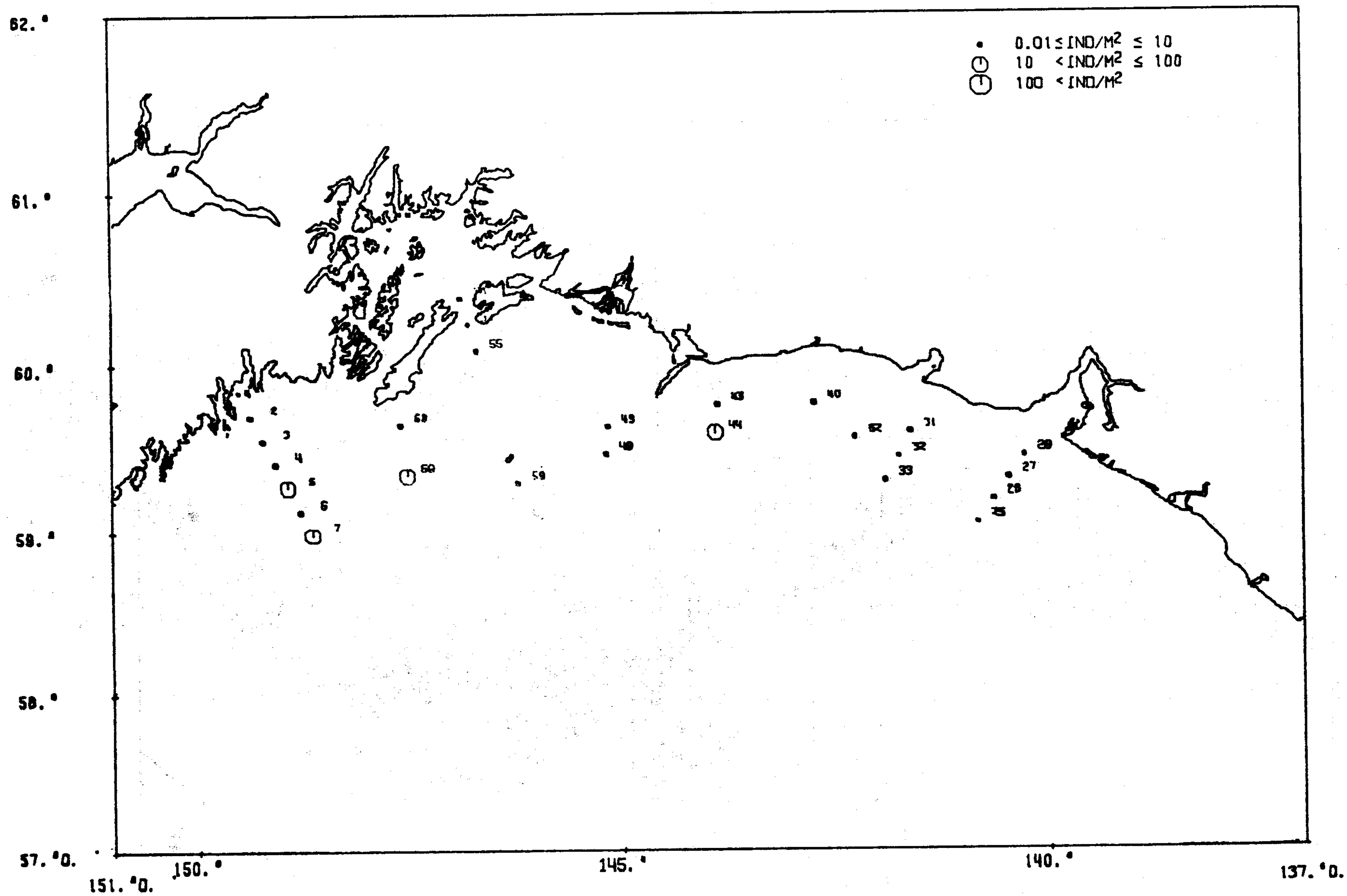

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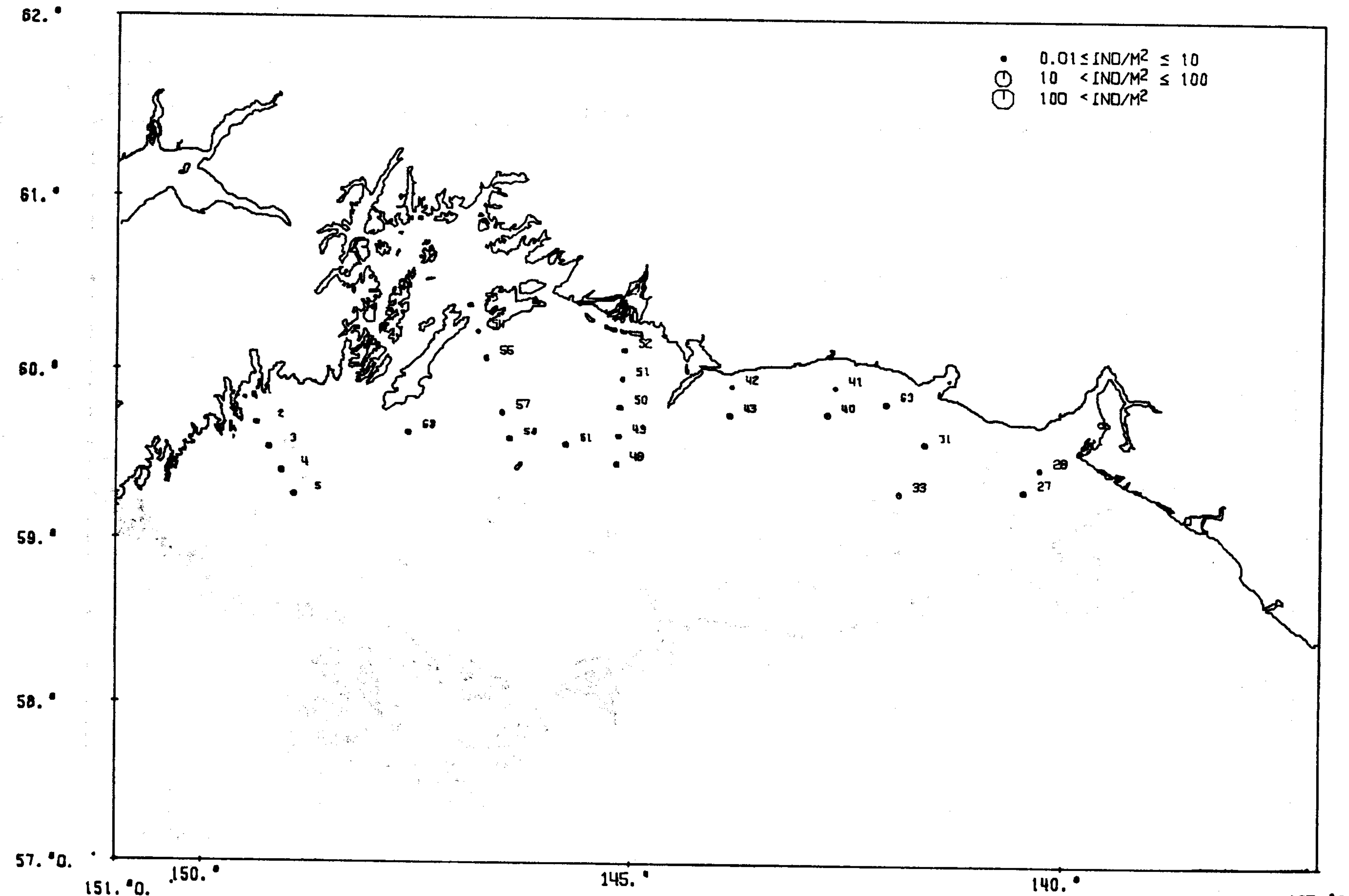

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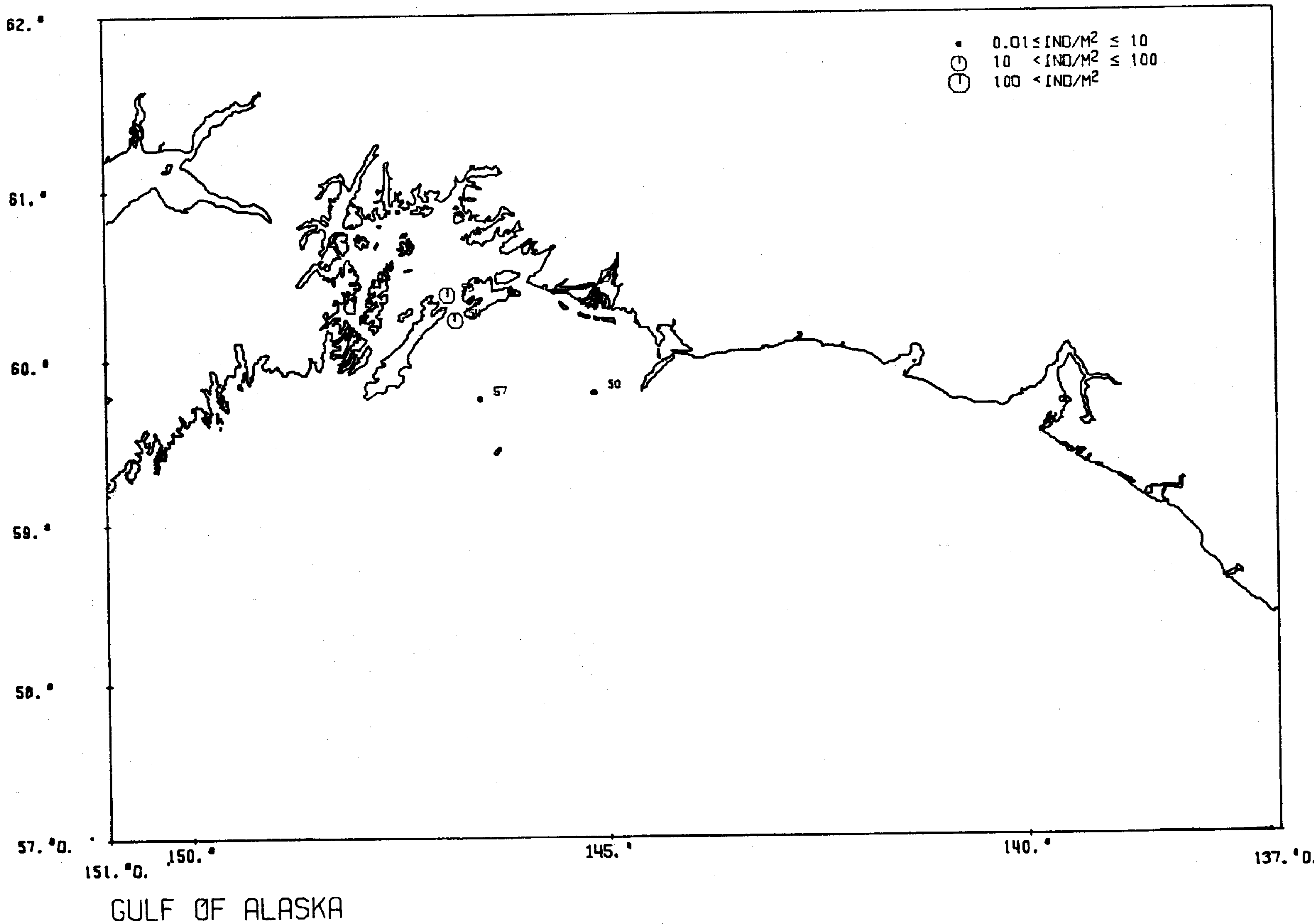

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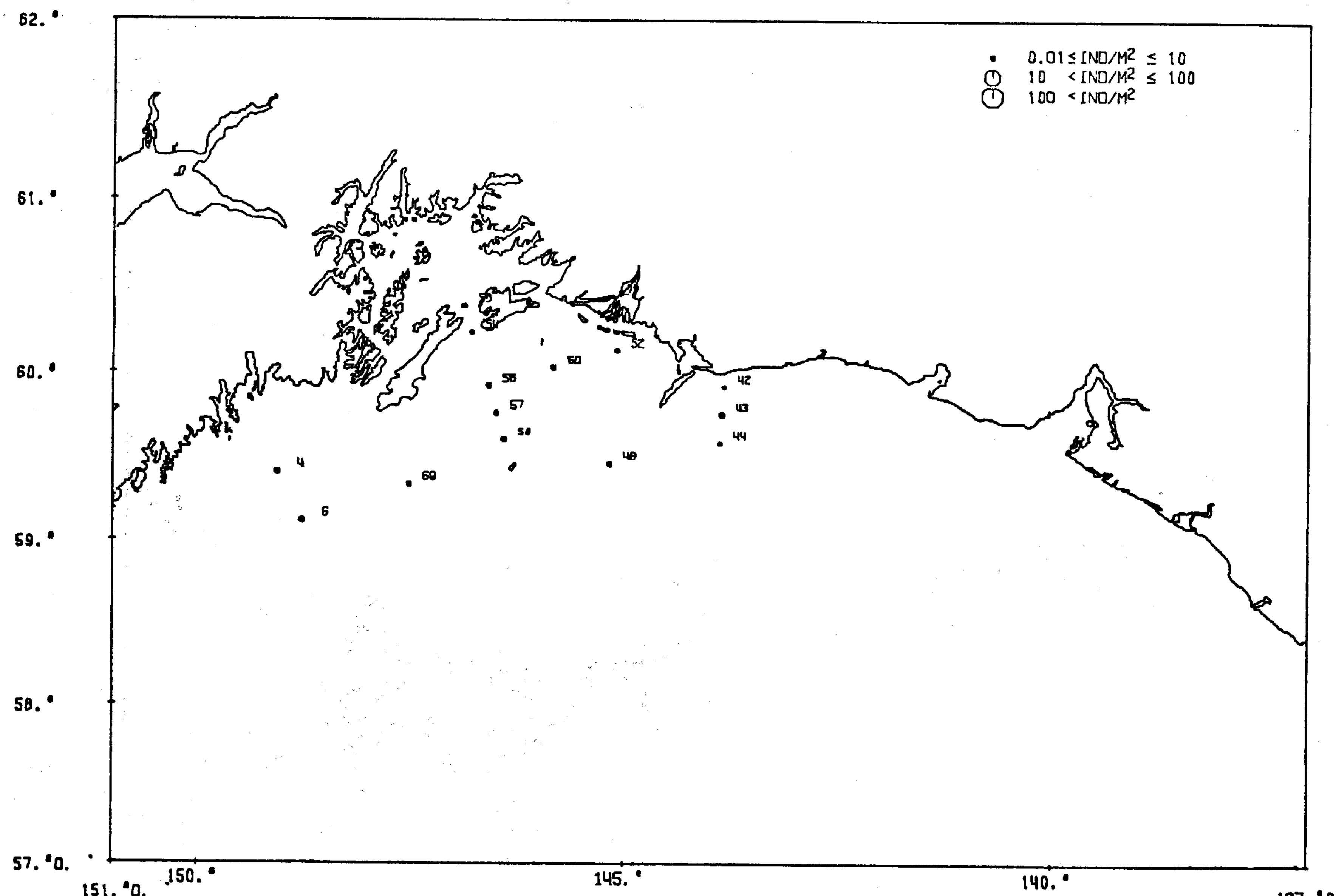
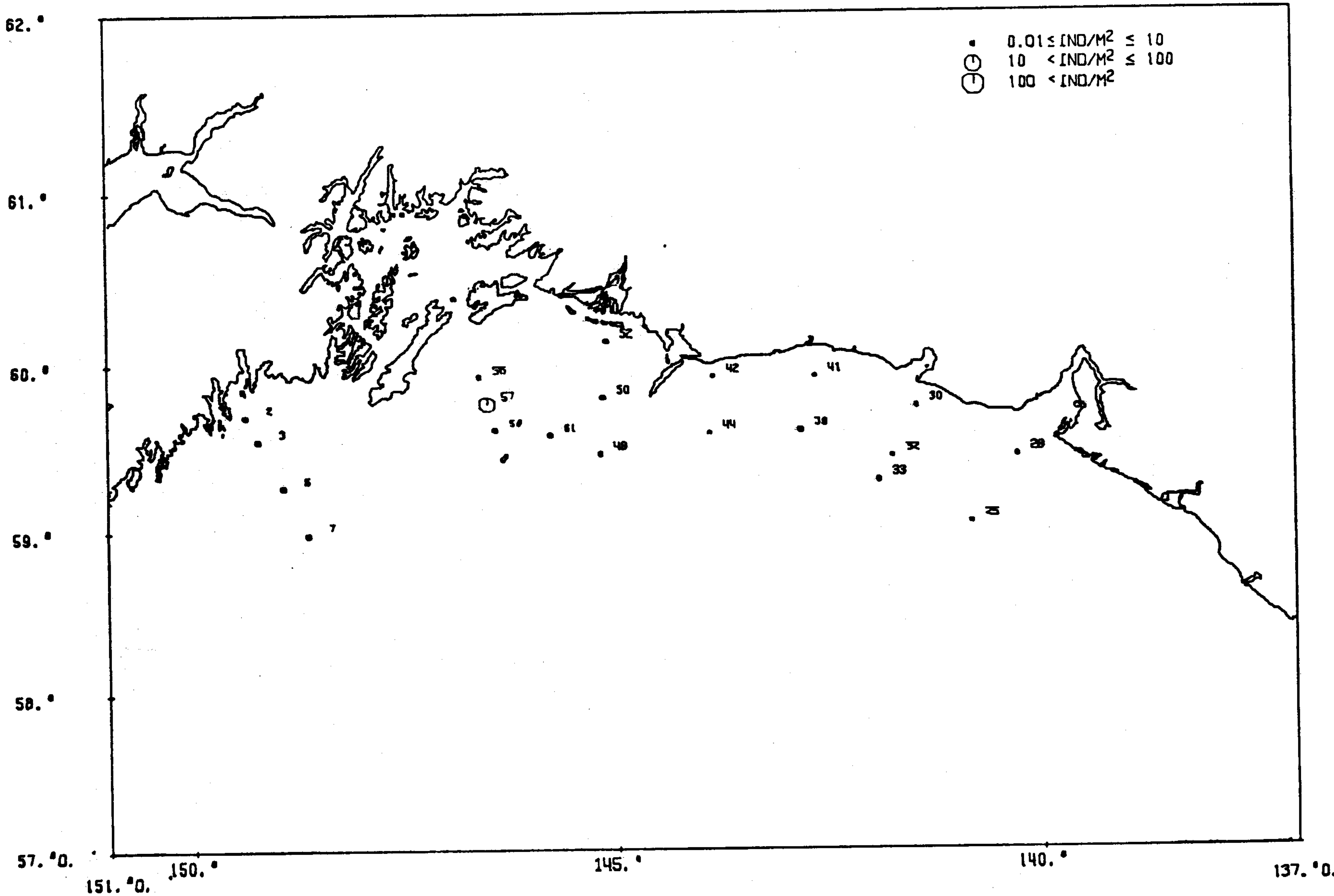


GULF OF ALASKA

BYBLIS GAIMARDI



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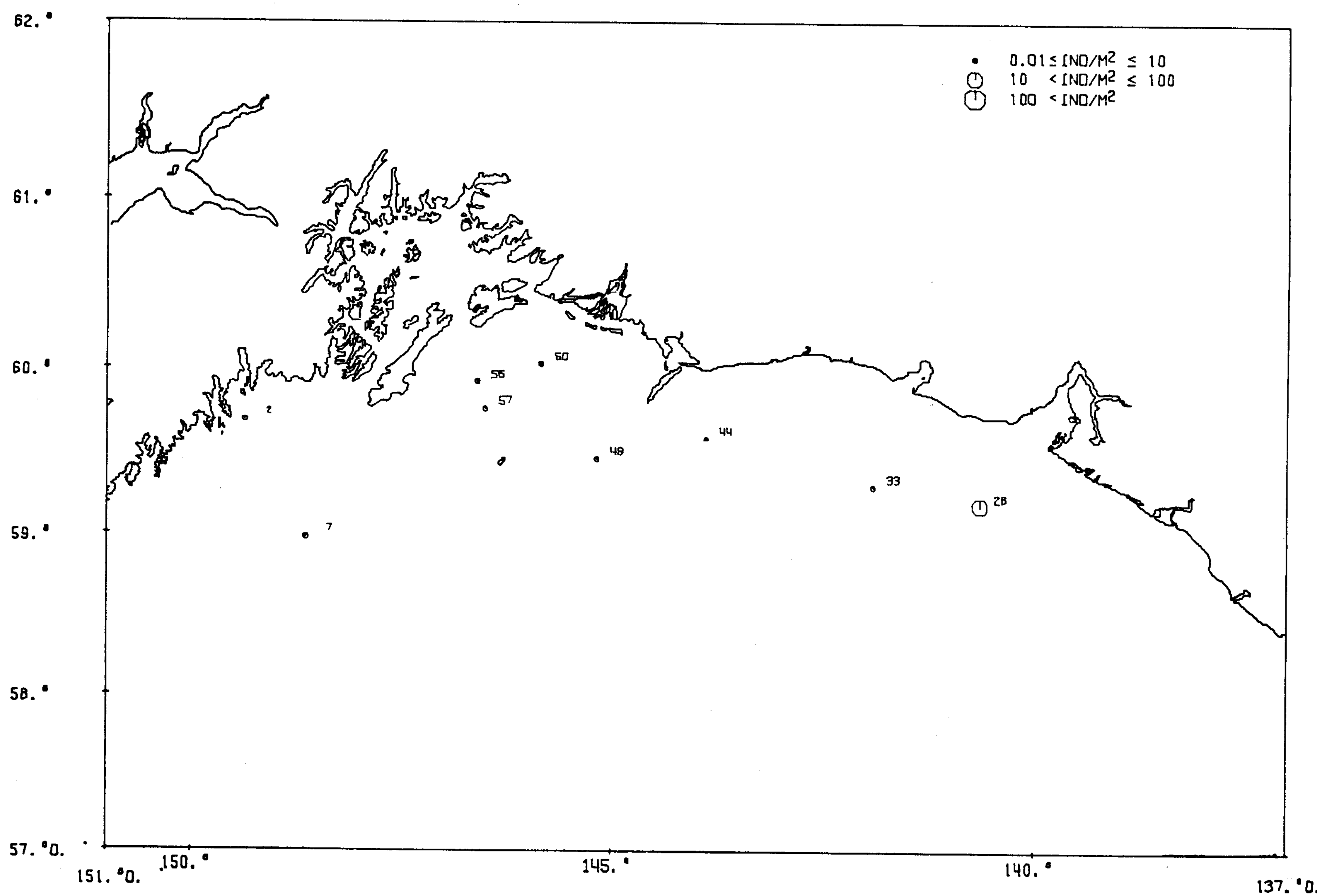

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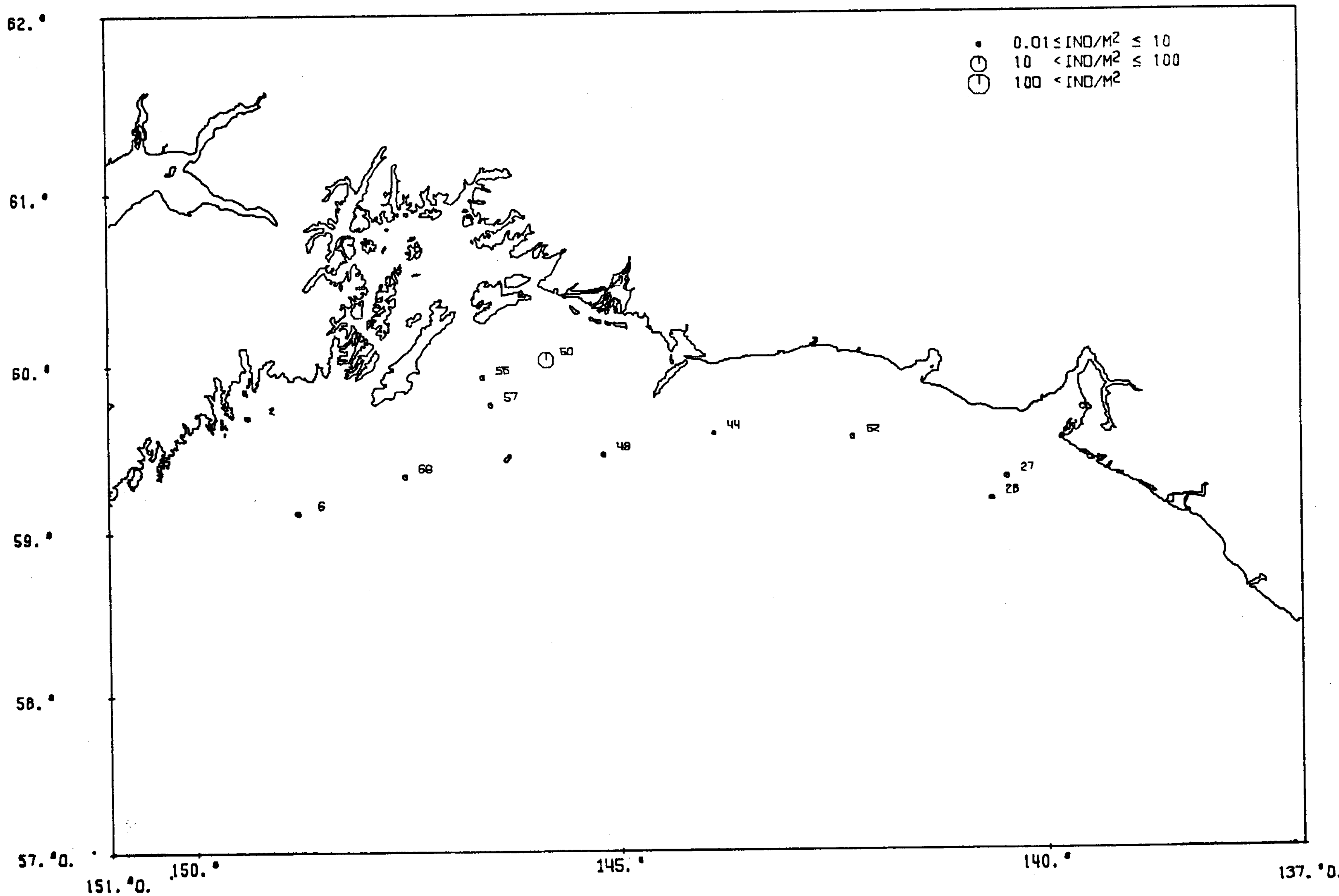
TEREBRATULINA UNGUICULA



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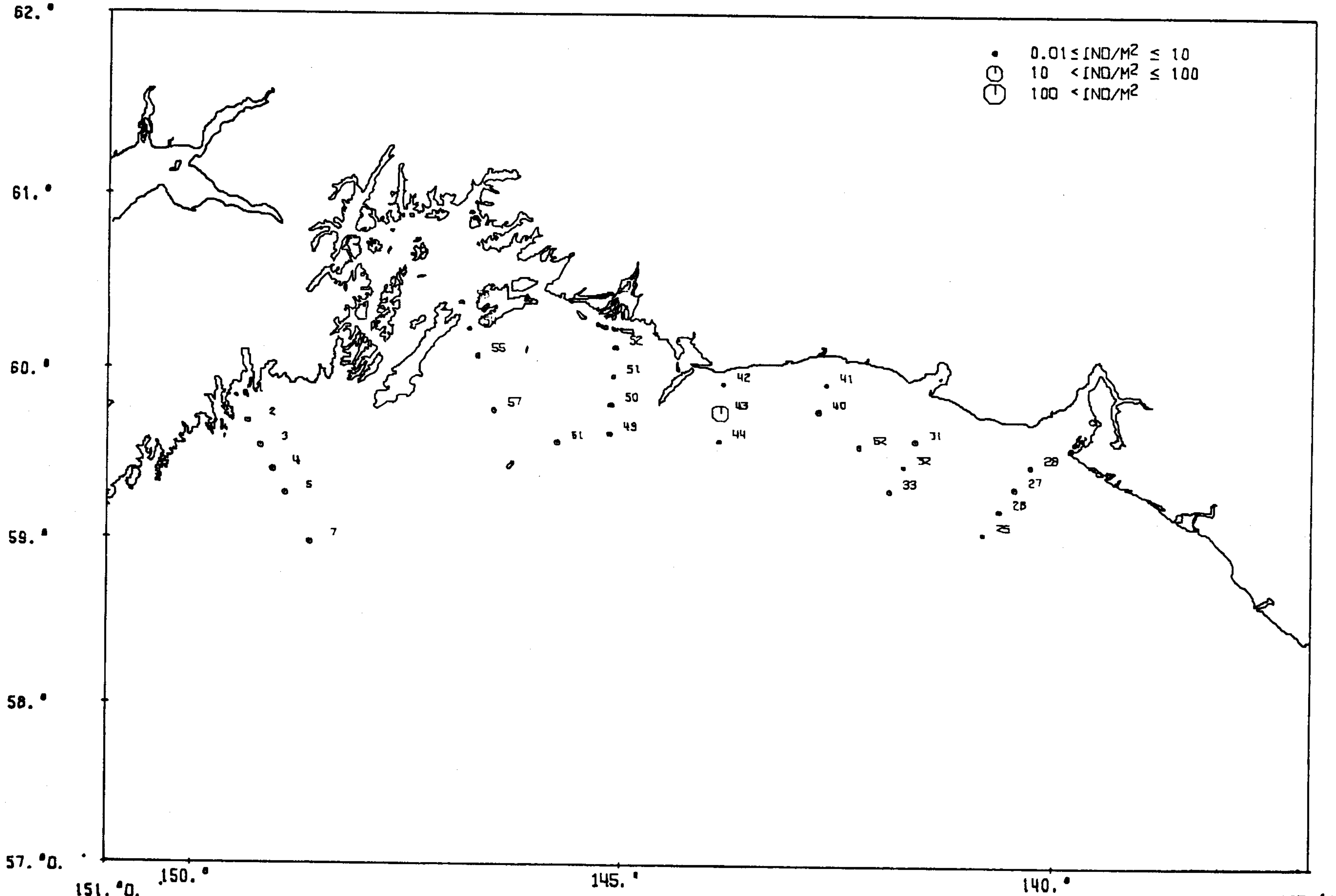
LAQUEUS CALIFORNIANUS



GULF OF ALASKA

CTENODISCUS CRISPATUS

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FINAL REPORT

BIBLIOGRAPHY OF NORTHERN MARINE WATERS
(microfiche only)

Research Unit 5

Dr. H. M. Feder
Institute of Marine Science
University of Alaska
Fairbanks, Alaska

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FINAL REPORT

Contract No. R7120802
Research Unit #175

BASELINE STUDIES OF FISH AND SHELLFISH RESOURCES OF NORTON SOUND AND THE SOUTHEASTERN CHUKCHI SEA

Principal Investigator:

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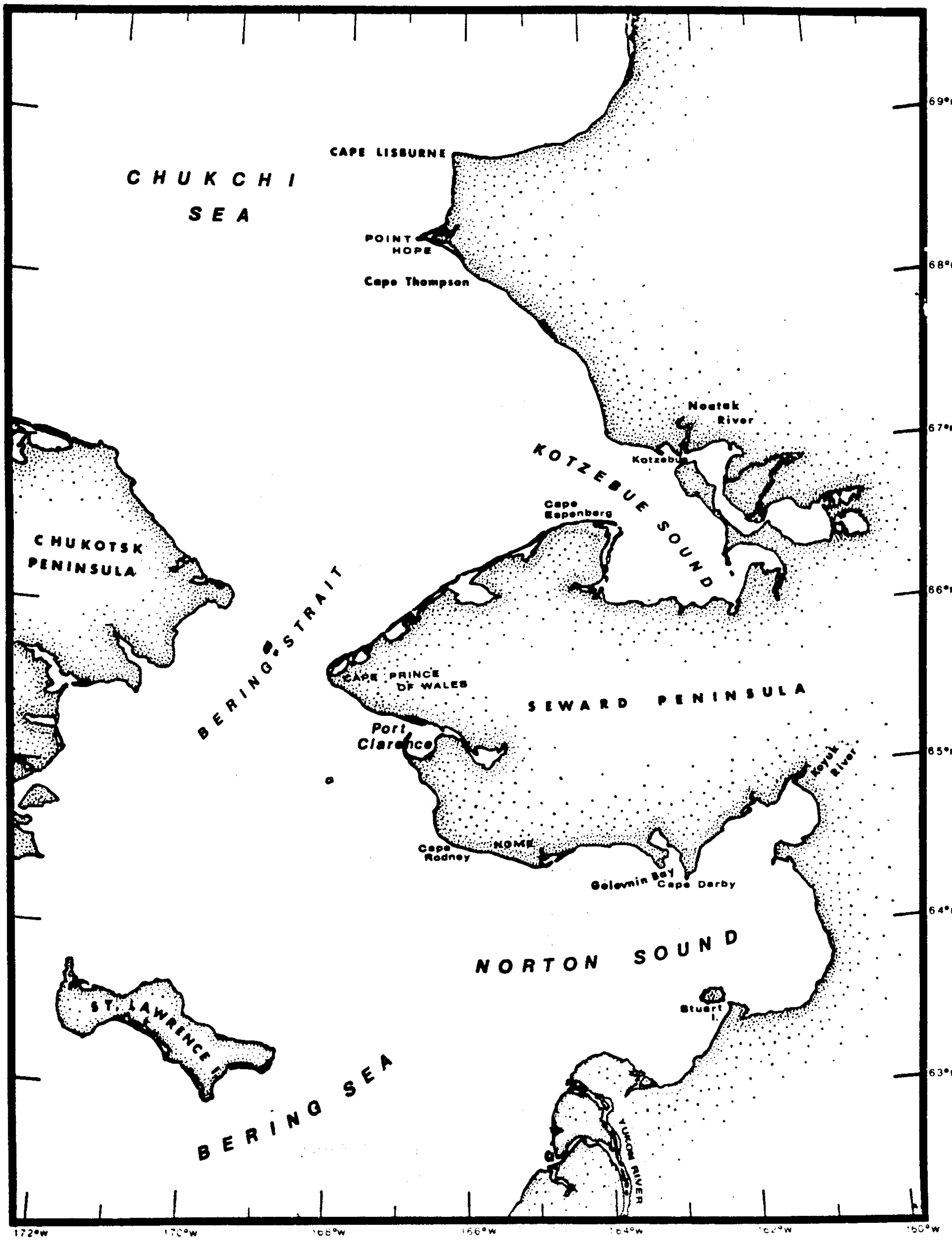
October 21, 1977



CAPE LISBURNE
CHUKCHI SEA
POINT HOPE
Cape Thompson
Noatak River
Kotzebue
KOTZEBUE SOUND
Cape Espenberg
CHUKOTSK PENINSULA
BERING STRAIT
CAPE PRINCE OF WALES
SEWARD PENINSULA
Port Clarence
Koyuk River
Cape Rodney
NOME
Golovnin Bay
Cape Derby
NORTON SOUND
Stuart I.
ST. LAWRENCE I.
BERING SEA
YUKON RIVER
69°N
68°N
67°N
66°N
65°N
64°N
63°N
172°W
170°W
168°W
166°W
164°W
162°W
160°W

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SIGNIFICANT ACCOMPISHMENTS AND CONCLUSIONS

This report contains findings from an intensive six-week survey (September-October, 1976) of fish and shellfish fauna in Norton Sound, the southeastern Chukchi Sea, and adjacent waters and a brief review of other pertinent information on the survey region from other data sources.

Norton Sound, the northern Bering Sea, Kotzebue Sound, and the southeastern Chukchi Sea represent a northern portion of the Alaska continental shelf, and this report has provided the most comprehensive study of these regions in terms of areal coverage and biological data collected. Of the 242 separate demersal trawling sites planned for sampling, 192 were successfully surveyed. In addition to the systematic demersal trawl survey, 33 gillnet sets and 8 pelagic trawl tows were performed to provide some knowledge of the areal distribution of those fish stocks located near the sea surface in the survey region. Overall, 277 trawl and gillnet catches were obtained during the survey and these contained a total of nearly 30 metric tons of fish and invertebrates. Size composition or other biological information was obtained from over 46,000 specimens of fish, crabs, and snails. Over 200 fish and invertebrate species were encountered.

Results of the survey defined the distributions and centers of abundance of several fish, crab, and snail species within the survey region and period. In addition, standing stock estimates and species composition of demersal fauna by geographic subdivisions of the survey region were determined. Analyses of species associations showed recurrent groupings of certain species and their regional distributions. Estimates of biological characteristics, including size and age composition, length-weight relationships, and growth characteristics, were provided for dominant fish species and for several species of crabs and snails.

The 1976 baseline survey provided considerable information on the distribution and abundance of fish and shellfish in the study area. Overall, the relative abundance was very low for nearly all organisms intensively studied. A total biomass for all demersal fauna in the survey region was estimated at only 338,000 mt and those groups studied in detail (shellfish of potential economic importance and fish) comprised only 25% of this amount. In contrast, recent biomass estimates for similar faunal groups in the highly productive eastern Bering Sea are 60 times greater than that determined in our survey area.

Most species studied were found in highest relative abundance in shallow, warm-water regions and greatest density occurred in Norton Sound. Highest abundance in Norton Sound was especially apparent for the young age groups of many fish species.

Biological information gathered during the survey suggests possible stock segregation of several species within the survey region. For many fish species, growth rate and length-weight relationships determined from samples obtained in areas north of Bering Strait differed from those gathered to the south. Growth of most fish appeared greatest in areas studied south of Bering Strait. Size composition and growth information also indicated that individuals present in our survey region were smaller and grew to lesser maximum sizes than members of the same species in regions south of our study area.

Although this report may substantially add to our knowledge of certain marine resources in northern areas of the Alaska continental shelf, this study also indicates a need for considerably more information in order to more adequately understand the dynamic nature of living marine resources of this region. Other information should be obtained if we are to make the proper decisions as to how man may manipulate or utilize these resources and to understand to what extent environmental alterations such as exploration for energy sources may affect this region.

III

INTRODUCTION

BACKGROUND

During September-October 1976, the Northwest and Alaska Fisheries Center (NWAFC), National Marine Fisheries Service (NMFS) conducted an offshore baseline survey of fishes and economically important invertebrates inhabiting continental shelf waters of Norton Sound, the southeastern Chukchi Sea, and adjacent regions. This survey was funded by the Bureau of Land Management and provided resource information both for BLM's evaluation of the influence on the environment by proposed oil and gas development in the region and for the NMFS Marine Monitoring, Assessment, and Prediction (MARMAP) program.

The study area, a relatively important region for subsistence fisheries and for certain commercial fishing operations, includes extensive areas where substantial petroleum reserves may exist (Figure III-1). Knowledge of the living marine resources within such areas is essential if careful evaluation is to be made of benefits derived from petroleum development vis-a-vis potential detrimental effects to the environment.

The Bureau of Land Management has the responsibility for conducting the offshore leasing. By law, BLM must provide an environmental impact statement (EIS) assessing the environmental risks involved in developing potential offshore oil reserves in Alaskan waters. BLM therefore arranged with the National Oceanic and Atmospheric Administration (NOAA) to provide the necessary physical, chemical, and biological data for the regions considered in this report. In Alaskan waters, NOAA's Environmental Research Laboratories (ERL) manage the environmental studies through its Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office. OCSEAP has contracted with various federal agencies, such as NMFS, the State of Alaska, and several universities to conduct the necessary research.

This report represents results from the 1976 baseline survey and from the analyses of pertinent historical fisheries research information and commercial fisheries data. It is a contemporary evaluation of fish and shellfish resources of the marine environment from Norton Sound northward through the Bering Strait and into the southeastern Chukchi Sea. The report provides considerable information to aid the BLM in an environmental assessment of the survey region and supplies the NMFS MARMAP program with a broad multispecies data base of resource and environmental measurements.

Figure III-1.--Study area for the 1976 BLM/OCS baseline survey of Norton Sound and the southeastern Chukchi Sea and approximate areas of the Alaskan continental shelf under consideration for leasing.

OBJECTIVES OF THE REPORT

The objectives of the report are:

(1) to describe the composition, distribution, and apparent abundance of demersal fish, shellfish, and certain pelagic fish resources of the marine environment from Norton Sound north into the Chukchi Sea;

(2) establish, for the more abundant and possibly economically important species, population characteristics that could change through environmental stresses (e.g., stock size, age and size composition, growth rate, and length-weight relationships); and,

(3) compare information from the 1976 baseline survey period with historical information.

ORGANIZATION OF FINDINGS

This report is organized in a manner similar to earlier NMFS baseline studies (NWAFC, 1976) and initially acquaints the reader with a physical description of the survey area (section IV) and then a description of the fauna (section V). These are followed by sections pertaining to historical information (section VI), an assemblage of data on fishery resource utilization (section VII), and results of the 1976 survey (section VIII). In the final section(IX) a synthesis and interpretation of the results of the baseline study are presented.

TERMINOLOGY

Terms frequently used in this report and those for which definitions may be difficult to find in standard fishery and statistical texts are defined here.

Species Names

The nomenclature used for fishes may be found in Quast and Hall (1972) and the American Fisheries Society (1970). With the exception of some crabs and molluscs, only scientific names are used for invertebrates. The common names given for crab are those developed in commercial fisheries, with one exception. The fishing industry prefers the name "snow crabs" for members of the genus Chionoecetes, but "Tanner crab," the standard name used in scientific reports, is retained here.

Fisheries-Related Terms[1/]

Age group.--Within a population, those fish or invertebrates of the same age. Age is the number of years of life completed.

Age structures.--For fish, these are otoliths (ear bones) and/or scales on which annual rings are laid down.

Carapace.--The dorsal convex portion of a crab's exoskeleton.

Catch per unit effort (CPUE), or "catch rate".--The catch in numbers or weight taken per standard length of tow or area swept by the trawl.

Clutch size.--Proportion of the crab's egg chamber filled by the egg mass.

Cohort.--Those individuals of a population of the same age group, i.e., of the same year class.

Exploitable biomass.--That portion of a population of a susceptible size and geographical distribution available to a fishery.

Maximum sustained yield (MSY).--The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions.

Modeling.--The development of mathematical equations to describe population and/or ecosystem processes for heuristic and predictive purposes.

Mortality.--Often designated as "natural," "fishing," and "total" mortality; may be expressed either as an instantaneous exponential function or percentage decrease in population size per unit time.

Recruitment.--Addition of new fish or shellfish to the exploitable population by growth from smaller size groups.

Skip molt.--In reference to an individual which did not molt during the previous molting season.

Standing stock.--The total population of the species vulnerable to the fishing gear in a specific area. Standing stock may be described in terms of weight (biomass) or numbers of individuals (population).

Year class or brood year.--Year of birth of an age group.

1/ Some definitions are adapted from Richer, 1975.

Geographical Designations

Arctic boreal.—A zoogeographic term describing species occurring in the Bering Sea, Okhotsk Sea, and the Sea of Japan that have ranges extending into the Arctic Ocean. Low Arctic boreal species are those limited to waters south of the Chukchi Sea in this region.

Inner Kotzebue Sound.—Defined here as that portion of Kotzebue Sound south of a line from Cape Espenberg to Cape Blossom (near the village of Kotzebue).

Inner Norton Sound.—That area of Norton Sound east of a line from Cape Darby to Stuart Island.

Kotzebue Sound.—Defined here as that area of the Chukchi Sea east of 165°W long. and south of 67°37'N lat.

Northern Bering Sea.—That portion of the Bering Sea north of a line connecting Cape Navarin, St. Lawrence Island, and the mouth of the Yukon River; west of Norton Sound; and south of Bering Strait.

Norton Sound.—Defined here as that body of water east of a line from Cape Rodney to the mouth of the Yukon River.

IV

DESCRIPTION OF THE STUDY AREA

The area of investigation during the 1976 survey includes waters of the northern Bering Sea, Norton Sound, Kotzebue Sound and the southeastern Chukchi Sea between 63° and 68°40'N latitude and from the US-USSR Convention line of 1867 eastward to the Alaska mainland. This northern portion of the Alaskan continental shelf is unique in several respects, especially its uniform shallowness. Maximum depth throughout the entire 140,000 sq km region barely exceeds 50 meters. Bottom slopes are very slight except on approach to land masses such as in Bering Strait and north of St. Lawrence Island. Isobaths are generally parallel to the Alaska coastline and extend into the embayments of Norton and Kotzebue sounds (Figure IV-1).

Geological features of the coastline and sediments in the survey area are typical of other regions of the Pacific Ocean (Fleming and Heggarty, 1966). Bottom composition close inshore consists of small rocks and gravel and changes to mud and sand and eventually to grey mud and sand in deeper offshore areas (Alverson and Wilimovsky, 1966). Extensive amounts of silt occur off the mouths of various large rivers such as the Yukon River in Norton Sound and Noatak and Kobuk rivers in Kotzebue Sound.

The survey region is influenced by a variety of oceanographic and climatological factors. Current systems within Norton Sound, the northern Bering Sea, and Chukchi Sea are barotrophic, fairly uniform from surface to bottom, and flow in a northward direction generally paralleling depth contours (Fleming and Heggarty, 1966).

Three water masses are associated with the survey area: the Anadyr, Bering Shelf, and Alaskan coastal which are descriptive of their sources. The latter two mentioned exert the greatest influence on the survey region, while the Anadyr water mass is important only in Bering Strait. Coachman, _et al_. (1976) stated that current flow across the region is not uniform. Currents generally are slow but accelerate markedly when constricted by straits and along the southern coastlines of westward projecting land masses.

The Chukchi Sea is part of the Arctic Basin and, in oceanographic terms, considered part of the Atlantic Ocean, separated from the Pacific Ocean at Bering Strait. Current flow through Bering Strait, however, is northward providing a continuity of conditions between the northern Bering Sea and the Chukchi Sea (Fleming and Heggarty, 1966).

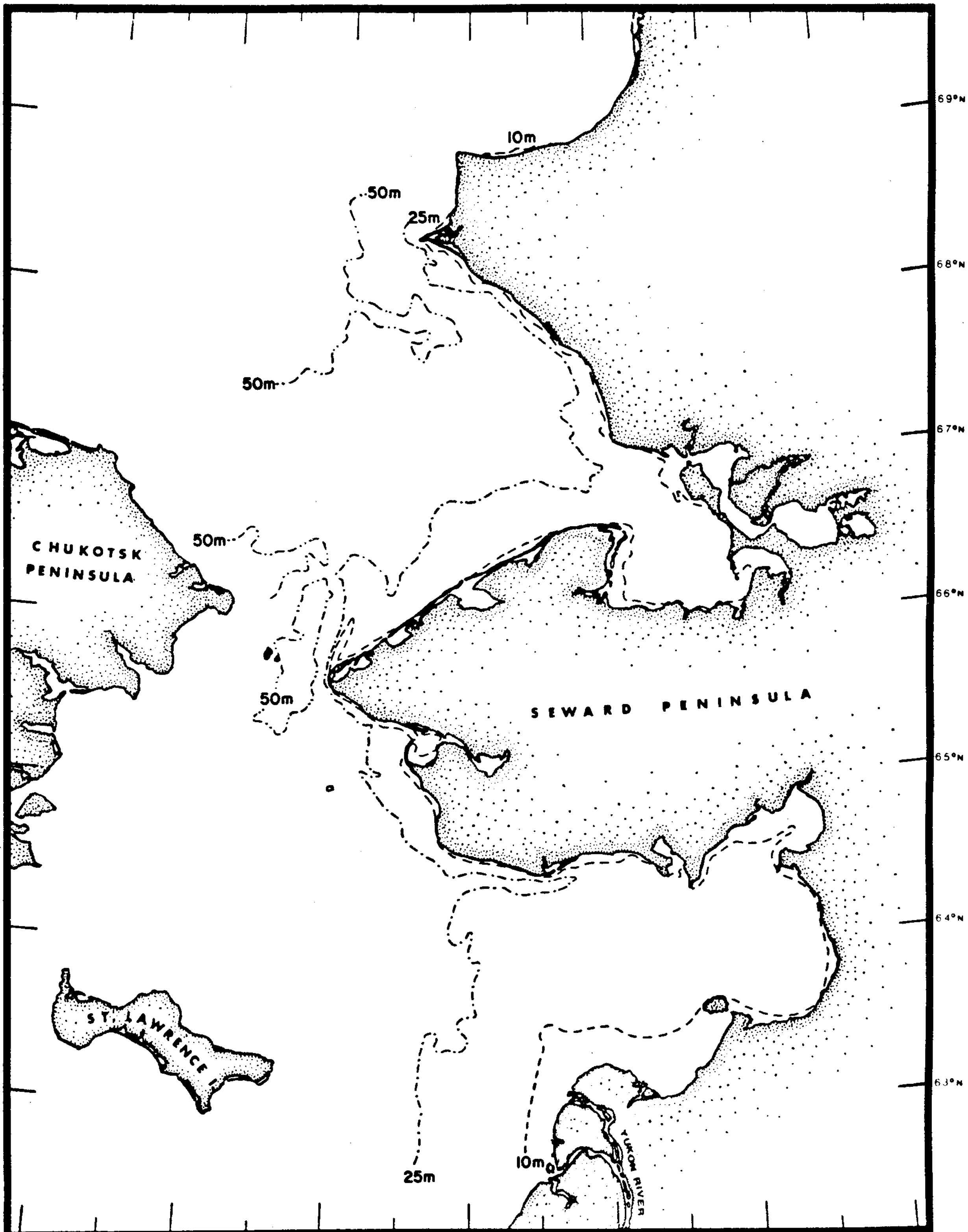


Figure IV-1.--Bathymetry of Norton Sound, the northern Bering Sea and southeastern Chukchi Sea.

Since the survey region is associated with arctic land masses, winters are extremely harsh. Ice covers the study area for over seven months, starting as early as mid-September in Kotzebue Sound with spring breakup occurring during late June-July (Alverson and Wilimovsky, 1966). Winter water temperatures near the sea bottom approach freezing throughout the region and vast ice flows cause extensive scouring of the littoral zone sea bed from the beach to depths of at least six meters (Sparks and Pereyra, 1966). In summer, water temperatures become relatively warm, especially adjacent to the Alaska mainland. This is due in part to the current system and overall shallowness of the study region. Waters at all depths nearshore reach 15°C (Fleming and Heggarty, 1966). Surface temperatures remain relatively warm throughout the survey area, but bottom temperatures drop from 15°C nearshore to 0-2°C at the western extremes of the survey area north of St. Lawrence Island and also in the northwesternmost portion of the study area in the Chukchi Sea (Figure IV-2). Shallow water areas which contain relatively cold bottom temperatures include inner Kotzebue Sound and the eastern extreme of Norton Sound.

River systems have a substantial effect on the study region. Significant quantities of fresh water are introduced into Norton Sound by the Yukon River during May-August. Small but locally significant quantities also flow into Kotzebue Sound from the Kobuk and Noatak rivers. The resulting fresh water substantially dilutes the sea water, and salinity is often less than 31°/oo adjacent to the Alaska coastline in the study region. Fleming and Heggarty (1966) noted that the influence of river systems (and currents) on waters of Norton and Kotzebue sounds creates more or less isolated environments in these embayments.

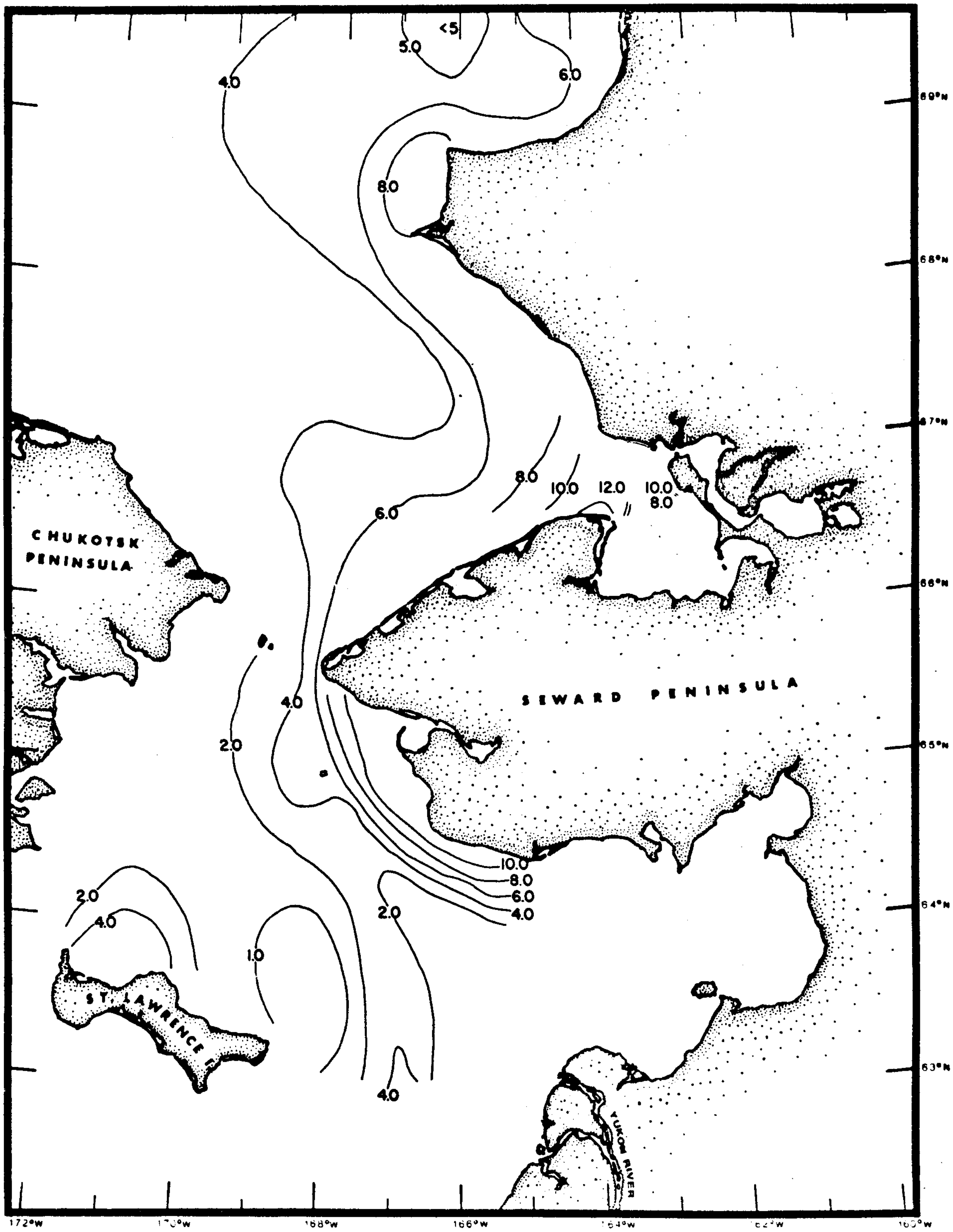


Figure IV-2.--Bottom temperature isotherms for Norton Sound, the northern Bering Sea and southeastern Chukchi Sea (from Fleming and Heggarty, 1966).

V

DESCRIPTION OF THE FAUNA

FISH FAUNA

Norton Sound and the southeastern Chukchi Sea support about 87 fish species belonging to 15 families (Table V-1). Of these, 78 species are considered marine forms and seven families comprise over 85% of the total fish fauna (Table V-2). Similar to the Bering Sea fish fauna, Norton Sound and the Chukchi Sea have a higher proportion of cottids and liparids than other oceans.

Schmidt (1950) reported only 66 species occurring in the northern Bering Sea. Increased diversity in the study area can probably be attributed to two reasons: inclusion of more arctic forms and extension of species ranges since Schmidt's study.

Benthic species comprise the majority of fish taxa (74% of total) in the study area. Since the entire region is relatively shallow (see Section IV), deep benthic fauna are absent. The remainder of the fish taxa can be considered pelagic, including a substantial number of anadromous and euryhaline forms. Most of the pelagic species are of commercial importance including such genera as *Clupea*, *Osmerus*, *Oncorhynchus*, and *Salvelinus*.

The fish fauna of Norton Sound, the southeastern Chukchi Sea, and adjacent waters are characterized by three distinct groups: (1) those coldwater groups indigenous to Arctic marine waters including such taxa as Arctic cod, longhead dab, Arctic flounder, and a number of cottoid and blennioid species; (2) a subarctic boreal group whose distribution is centered south of the study area in the Bering Sea or regions of the eastern and western Pacific which includes saffron cod, yellowfin sole, Alaska plaice, starry flounder, Pacific herring, and others; and (3) an anadromous fresh-water group with several forms such as char, whitefish, and smelt whose marine distribution occurs only in the estuarine and other near-shore environments.

Since the survey region is closely associated with arctic waters, 23 species have ranges which extend to the Atlantic Ocean. Fourteen species do not occur south of the northern Bering Sea or Gulf of Anadyr, and an additional 27 taxa do not occur south of the Alaska Peninsula-Aleutian Archipelago. According to Quast and Hall (1972), only 46 species can be considered "endemic" Pacific marine forms.

Table V-1. -- Families of fishes and approximate number of genera and species reported from Norton Sound, the southeastern Chukchi Sea and adjacent waters (after Quast and Hall, 1972).

Family	No. Genera	No. Species
Petromyzontidae	1 1/	1
Clupeidae	1	1
Salmonidae	4	14 2/
Osmeridae	3	3
Gadidae	4	4
Zoarcidae	3	10
Gasterosteidae	1	1
Hexagrammidae	1 3/	1
Cottidae	11	20 4/
Agonidae	5	6
Cyclopteridae (= Liparidae)	2	6
Anarhichadedae	1	1
Stichaeidae	7	7
Ammodytidae	1	1
Pleuronectidae	9 5-6/	11
TOTALS:	54	87

1/ Not mentioned as occurring in study region, but range extends both north and south of Norton Sound and the southeastern Chukchi Sea.

2/ Includes several freshwater forms which may enter saltwater.

3/ Whitespotted greenling, Hexagrammus stelleri, was not reported north of the Bering Sea by Quast and Hall (1972), however, several specimens were obtained as far north as the southeastern Chukchi Sea during the 1976 BLM/OCS survey.

4/ Yellow Irish lord, Hemilepidotus jordani, and the tadpole sculpin, Pyschrolutes paradoxus, were not reported from study region by Quast and Hall (1972), however, specimens were obtained during 1976 BLM/OCS survey.

5/ Pacific halibut, Hippoglossus stenolepis, not reported in study region by Quast and Hall (1972), however, one specimen was obtained in Bering Strait during the 1976 BLM/OCS survey.

6/ Rock sole, Lepidopsetta bilineata, not reported in study region by Quast and Hall (1972), however, Ellson et al, (1949) indicated two individuals captured 40 miles NE of St. Lawrence Is. and Andriyashev (1954) reported rock sole present between St. Lawrence Island and the Gulf of Anadyr.

Table V-2.--Proportion of seven predominant families to total species composition of Norton Sound-southeastern Chukchi Sea fish fauna.

Family	Percentage of total fish species
Cottidae	23
Salmonidae	16
Pleuronectidae	13
Zoarcidae	11
Stichaeidae	8
Agonidae	7
Cyclopteridae	7
Total of seven dominant families:	85

Species groups of importance in the survey area because of their relative abundance and/or diversity are: cods, flatfishes, sculpins, salmonids, eelpouts, pricklebacks, poachers, snailfish, smelts and herring.

Four species of cods (family Gadidae) are reported by Quast and Hall (1972) to occur in waters of the study area: the Arctic cod (*Boreogadus saida*), the saffron cod (*Eleginus gracilis*), the Pacific cod (*Gadus morhua macrocephalus*), and walleye or Alaska pollock (*Theragra chalcogramma*). The range of Pacific cod, however, extends northward only to the southern boundary of the survey area near St. Lawrence Island. The more northern cod forms, Arctic cod and saffron cod, are the dominant gadids in Norton Sound, the southeastern Chukchi Sea, and adjacent waters.

Flatfish (family Pleuronectidae) are represented in the study region by 10 species and 8 genera (Quast and Hall, 1972). These include arrowtooth flounder (*Atheresthes stomias*), flathead sole (*Hippoglossoides ellasadon*), Bering flounder (*H. robustus*), Pacific halibut (*Hippoglossus stenolepis*), yellowfin sole (*Limanda aspera*), longhead dab (*L. probscidea*), Arctic flounder (*Liopsetta glacialis*), starry flounder (*Platichthys stellatus*), Alaska plaice (*Pleuronectes quadrituberculatus*),and Greenland turbot (*Reinhardtius hippoglossoides*). Dominant pleuronectid species in the survey region include subarctic boreal forms such as starry flounder, Alaska plaice, and yellowfin sole.

The most diverse family in the study area in terms of species is the sculpins (family Cottidae). Quast and Hall (1972) list 20 species and 12 genera for this region. These include hamecon (*Artediellus scaber*), Arctic hookear sculpin (*A. uncinatus*), antlered sculpin (*Enophrys diceraus*), Leister sculpin (*E. lucasi*), *Gymnocanthus pistilliger*, Arctic staghorn sculpin (G. tricuspis), yellow Irish lord (Hemilepidotus jordani), Hemilepidotus zapus, spatulate sculpin (Icelus spatula), Megalocottus laticeps, belligerent sculpin (M. platycephalus), plain sculpin (Myoxocephalus joak), fourhorn sculpin (M. quadricornis), M. platycephalus, Arctic sculpin (M. scorpoides), shorthorn sculpin (M. scorpius groenlandicus), eyeshade sculpin (Nautichthys pribilovius), and tadpole sculpin (Psychrolutes paradoxus). Dominant sculpins in the survey area include the arctic boreal forms, plain sculpin and shorthorn sculpin, and an arctic form, the Arctic staghorn sculpin.

Other families with several representatives in the survey region include the salmon (family Salmonidae) with 14 species and 4 genera; the eelpouts (family Zoarcidae) with 10 species and 3 genera; the pricklebacks (family Stichaeidae) with 7 species and 7 genera; the poachers (family Agonidae) with 6 species and 5 genera; and the snailfish (family Cyclopteridae) with 6 species and 2 genera. The families Osmeridae and Clupeidae are represented only by 3 and 1 species, respectively, but the toothed or rainbow smelt (Osmerus mordax dentex, O. eperlanus) and Pacific herring (Clupea harengus pallasi) are numerous and commonly occur in the Norton Sound-southeastern Chukchi Sea region.

INVERTEBRATE FAUNA

Extensive studies by Sparks and Pereyra (1966) have provided substantial information for most invertebrate fauna in the southeastern Chukchi Sea, but very little data is available concerning invertebrates in Norton Sound. Prevailing currents in these areas are northerly and originate in the Bering Sea (see Section IV). Sparks and Pereyra (1966) stated that this results in great similarity between invertebrate fauna found in the southeastern Chukchi Sea and that present in the Bering Sea. Although little is known specifically about invertebrate stocks in Norton Sound, this portion of the study region lies between the Bering and Chukchi Seas, and therefore it seems reasonable to expect considerable similarity between Norton Sound and Chukchi Sea invertebrate fauna.

Invertebrates form the most diverse and abundant group in the benthic community of the study region. According to Abbott (1966) and Sparks and Pereyra (1966), 14 invertebrate phyla are present in the study area. When combined, these phyla represent 91 families, 145 genera, and over 220 species (Table V-3). Most organisms encountered are Pacific boreal, and the absence of many higher arctic forms probably results from the northward currents which impede southerly migrations by all but highly mobile forms.

Table V-3.--Invertebrate phyla and approximate number of classes, families, genera, and species reported present in the southeastern Chukchi Sea (after Sparks and Pereyra, 1966: and Abbott, 1966).

Phylum	Common names for phylum representatives	Numbers of various taxonomic levels present by phylum			
		Classes	Families	Genera	Species
PORIFERA	Sponges	2	9	11	12
COELENTERATA (=CNIDARIA)	Coelenterates	3	7	11	11
CTENOPHORA	Combjellies	1/	1/	2	2
NEMERTIA	Ribbon worms	1/	1/	1/	1/
BRYZOA (=ECTOPROCTA)	Moss animals	1/	1/	3	3
BRACHIOPODA	Lambspells	1/	1/	1/	1/
SIPUNCULOIDEA (=SPICULANA)	Coelomate worms	1	1	1	1
PRIAPULOIDEA (=PRIAPULA)	"	1	1	1	1
ECHIUROIDEA (=ECHIURA)	"	1	1	1	1
MOLLUSCA	Clams, snails, squids, etc.	4	35	54	97
ANNELIDA	Segmented worms	1/	1/	5	5
ARTHROPODA	Barnacles, shrimp, and crab	8	14	27	44
ECHINODERMATA	Starfish and others	4	11	15	21
CHORDATA (=TUNICATA)	Ascidians	1	7	12	23
Totals:		30	91	145	223

1/ Not reported.

Mollusca, Arthropoda, Echinodermata, and Tunicata are the dominant faunal elements of the benthic invertebrate community of the study region. These four phyla constitute 83 percent of all species present. Other phyla with several representatives include Porifera and Coelentrata.

Molluscs represent the most diverse phylum present in the study region. Sparks and Pereyra (1966) list four classes present: the bivalves (class Pelecypoda), snails and whelks (class Gastropoda), octopuses (class Cephalopoda), and amphineurids (class Amphineura) with the former two classes predominating.

Bivalve molluscs are represented by 16 families in the study region. Some principal families include the cockles (family Cardiidae), the macoma clams (family Tellinidae), and the nut clams (family Nuclididae). These three families comprise eight species in the study region including abundant forms such as the Greenland cockle (Serripes groenlandicus), Iceland cockle (Clinocardium ciliatus), chalky macoma (Macoma calcarea), and the smooth nut clam (Nucula tenuis). Although not taken during offshore sampling, Sparks and Pereyra (1966) observed windrows of the bay mussel, Mytilus edulis, on Chukchi Sea beaches.

Gastropod molluscs are an extremely diverse element of the fauna. Sparks and Pereyra (1966) listed 18 families present with the superfamilies Neptuneidae and Buccinidae contributing most species. Predominant members of these families include the fat neptune (Neptunea ventricosa), N. heros, the fragile buccinum (Volutopsius fragilis), Bering's buccinum (Beringius beringii), the polar buccinum (Buccinum polare), the silky buccinum (B. scalariforme), and B. angulosum. The latter two species are indicated by Nagai (1974) as comprising a significant portion of eastern Bering Sea commercial snail harvests by Japan.

Two classes and 14 families of Arthropods are present in the survey region according to Sparks and Pereyra (1966). Decapod crustacea is by far the dominant class comprising three shrimp families (Crangonidae, Hippolytidae, and Pandalidae) and four families of crab (Paguridae, Lithodidae, Majidae, and Atelicylidae). Prominent representatives of these families include organisms such as crangonid shrimp (Sclerocrangon boreas and Argis lar), humpy shrimp (Pandalus gonurius), hermit crabs (Pagurus spp.), king crabs (Paralithodes spp.), Tanner crab (Chionoecetes opilio), spider crabs (Hyas spp.), and the helmet crab (Telemessus cheiragonus). Several of these crustaceans are of economic importance in other regions. King crab comprise a relatively important portion of sport and subsistence fisheries catches within the survey region.

Echinodermata is represented by relatively few species (21); however, in terms of weight caught in trawls, this phylum is by far the dominant element of the entire benthic community of the study area (Sparks and Pereyra, 1966). Four classes are present, Asteroidea (starfish), Ophiuroidea (basketstars and brittlestars), Echinoidea (sand dollars), and Holothuroidea (sea cucumbers), with the former two classes being most prevalent. Asteroidea is represented in the survey region by four families, the most diverse being Asteriidae. Common forms of this family include _Leptasterias_ spp., _Asteria amurensis_, and _Evasterias_ spp. Four families of ophiuroideans also are present and consist of two types: a single species of basketstar (_Gorgonocephalus caryi_) and several species of brittlestars (_Ophiura sarsii_, _O. maculata_, _Ophiopholis aculeata_, and others).

The other dominant invertebrate group within Norton Sound and the southeastern Chukchi Sea is Tunicata, the ascidians. Abbott (1966) listed 7 families present in the study area with the more common being Styelidae and Pyuridae. Dominant forms in these families include: _Styela coriacea_, _S. rustica macrenteron_, _Dendroda puchella_, the sea onion (_Boltenia ovifera_ and _B. echinata_), and the sea potato (_Tethym aurantium_).

A BRIEF SYNOPSIS OF RESEARCH IN NORTON SOUND AND THE SOUTHEASTERN CHUKCHI SEA

Although scientific activities have occurred within the survey region for nearly two centuries, most studies have been concerned with examining the hydrographic and geodetic aspects of these northern Alaska waters. Only in fairly recent times have surveys been directed specifically toward obtaining detailed information on fish and invertebrate resources. Early biological studies in the Chukchi Sea (summarized by Wilimovsky, 1966) primarily focused on the collection of indigenous fish and invertebrates and while these investigations greatly enhanced basic knowledge of arctic fauna, little quantitative information was obtained.

It seems likely that many investigators who passed northward through the Bering Strait also made observations in waters to the south, however, specific information is lacking regarding surveys of Norton Sound and the northern Bering Sea. The Soviet Union sponsored extensive trawl surveys of both the Chukchi and northern Bering Seas in 1932-33. Information from these surveys was used by Andriyashev (1937) to provide considerable knowledge on northern fishes. Exploratory fishing surveys of Norton Sound and areas north of St. Lawrence Island by the U.S. Fish and Wildlife Service in 1948-49 were reported by Ellson, Powell, and Hildebrand (1950), but only general comments were made regarding the distribution and abundance of fish and shellfish. Japan provided the most recent northern Bering Sea surveys (1968-1970); however, their area coverage only extended to just south of the 1976 BLM/OCS survey boundary.

The only extensive attempt to identify the magnitude and importance of marine resources in the survey region occurred as a result of studies funded by the Atomic Energy Commission in the Cape Thompson region of the southeastern Chukchi Sea in 1959-60. The investigations were performed as part of Project Chariot to establish environmental baselines for determining the effects of a nuclear explosion on the biota of the region. Data from several of these Cape Thompson studies provide much of the data base to which the 1976 BLM/OCS survey information could be compared. These investigations include studies of the oceanography (Fleming and Heggarty, 1966), benthic invertebrates (Sparks and Pereyra, 1966; and Abbott, 1966), and fishes (Alverson and Wilimovsky, 1966) of the region.

VII

A REVIEW OF COMMERCIAL AND SUBSISTENCE FISHERIES IN THE SURVEY REGION

Utilization of fishery resources in the Norton Sound-Chukchi Sea region is fairly limited and falls into two categories—commercial operations and subsistence fisheries. Commercial activities are limited solely to harvests of salmon and herring, and subsistence fisheries, though also relying heavily on these pelagic fish, additionally utilize limited amounts of groundfish and shellfish (Table VII-I). This section presents a brief synopsis of both commercial and subsistence activities, identifying major harvest areas and catch levels over the past several years.

Table VII-1.--A partial list of fish and shellfish harvested commercially and for subsistence in Norton Sound, the southeastern Chukchi Sea, and adjacent waters in 1976. (Source: State of Alaska Department of Fish and Game.)

Chum salmon
Pink salmon
King salmon
Coho (silver) salmon
Red (sockeye) salmon
Whitefish (*Coregonus* spp.)[1/]
Sheefish[1/]
Pacific herring
Toothed smelt[1/]
Arctic cod[1/]
Saffron cod[1/]
Greenling (*Hexagrammus* sp.)[1/]
Sculpins[1/]
Halibut[1/]
Flounder (family Pleuronectidae)[1/]
Mussels[1/]
Clams[1/]
King crab[1/]

1/ Taken for subsistence only.

Commercial Fisheries

Salmon.--Salmon gillnetting is the principal commercial fishery in the survey region. Five species are harvested in Norton Sound waters with the vast majority of catches being pink and chum salmon. The only substantial fishery north of Bering Strait is in Kotzebue Sound, and chum salmon have accounted for over 99% of yearly harvests in this area. Local residents comprise nearly the entire commercial fishing force within the survey region.

Annual commercial salmon harvests in the Norton Sound region have ranged from 74,000-316,000 fish for the period 1962-1976 (Table VII-2) and have averaged about 170,000. During that time, chum salmon have comprised nearly 65% of the total catch, followed by pink salmon with 29%. Coho and king salmon account for most of the remainder, with red salmon taken only in trace amounts in any year. During the 15-year period examined, largest harvests occurred during 1974 and 1975. The commercial catch for 1976 of 192,000 salmon was considerably below the two highest catch years but still substantially above the 15-year average and only slightly less than the average salmon harvest for the past five years (1972-1976).

Table VII-2.--Commercial catches of salmon by year and species in the Norton and Kotzebue sound regions, 1962-1976. (Source: State of Alaska Department of Fish and Game).

	Norton Sound						Kotzebue Sound		
Year	King	Red	Coho	Pink	Chum	Area total	Chum	Others[1/]	Area total
1962	7,286	18	9,156	33,187	182,784	232,431	129,948	127	130,075
1963	6,613	71	16,765	55,625	154,789	233,863	54,445	143	54,588
1964	2,018	126	98	13,567	148,862	164,671	76,499	5	76,504
1965	1,449	30	2,030	220	36,795	40,524	40,034	—	40,034
1966	1,553	14	5,755	12,778	80,245	100,345	30,764	1	30,765
1967	1,804	—	2,379	28,879	41,756	74,818	29,400	—	29,400
1968	1,045	—	6,885	71,179	45,390	124,499	30,384	—	30,384
1969	2,392	—	6,836	89,949	82,795	178,972	59,335	48	59,383
1970	1,853	—	4,423	64,908	107,034	178,218	159,664	—	159,664
1971	2,593	—	3,127	4,895	131,362	141,977	154,956	1	154,957
1972	2,885	—	450	45,143	101,235	149,713	169,664	3	169,667
1973	1,918	—	9,282	46,499	119,098	176,797	375,432	5	375,437
1974	2,951	—	2,092	148,519	162,267	315,829	634,479	48	634,527
1975	2,321	—	6,218	32,820	216,443	257,802	561,710	—	561,710
1976	2,206	11	6,709	87,889	96,102	192,917	159,796	—	159,796

1/ Mostly pink salmon, but also includes king and red salmon.

Commercial catches in Kotzebue Sound have ranged from 29,000 to over 634,000 fish during the past 15 years and have averaged nearly 180,000. Chum salmon is essentially the only species taken in this region; a few pink, king, and red salmon are taken occasionally. Highest annual harvests again occurred in 1974 and 1975 (Table VII-2). Approximately 160,000 salmon were harvested commercially in 1976. This catch was the lowest since 1971 and only slightly more than half the average taken over the past five years.

Herring.--Commercial fishing for herring occurs primarily in Norton Sound by local inhabitants and foreign gillnet fleets. Fishing is performed primarily with gillnets and occasionally by beach seines; herring roe is the main product of commercial operations. Most harvests occur after winter ice break-up in May-June, while herring are in spawning concentrations.

Specific areas of herring harvests by local inhabitants are not known; however, most operations in Norton Sound are thought to occur near Stuart Island and in Golovin Bay. Catch statistics for commercial fishing by local residents are extremely limited. The earliest record of commercial harvests was in 1964 when about 18 mt were taken (Table VII-3). Catches

Table VII-3.--Commercial harvest of Pacific herring by local inhabitants in Norton Sound. (Source: State of Alaska Department of Fish and Game).

Year	Catch in metric tons
1964	18.1
1965	—
1966	—
1967	—
1968	—
1969	—
1970	7.3
1971	17.7
1972	15.3
1973	32.3
1974	3.1
1975	1/
1976	7.7

1/ Not available.

since that time have been small and sporadic with largest catches of 15-32 mt occurring from 1971-1973. The commercial herring harvest for 1976 was less than 8 mt.

Herring harvests by Japanese gillnet fleets also have been highly variable since operations started on a limited scale in 1968. The initial fishing operations that year appeared to be exploratory, with a total catch of 125 mt. From 1969-1971, effort increased dramatically (Table VII-4), but catches peaked in 1969 at 1,270 mt and never approached that amount thereafter. In 1972 Japanese gillnet effort dropped to low levels and remained low until 1974 when it nearly equalled levels of 1969-71. The total annual harvest at that later time, however, was only half the maximum amount taken five years earlier. In 1975, the last year for which Japanese catch statistics are available, total herring harvest and effort levels were the lowest recorded for the fishery.

Table VII-4.--Commercial harvests of Pacific herring by Japan in Norton Sound and the northern Bering Sea, 1968-1975. (Source: Japan Fisheries Agency.)

Year	Catch (mt)	Effort (tans)
1968	125	2,750
1969	1,270	33,380
1970	54	32,290
1971	621	45,720
1972	11	9,610
1973	25	9,270
1974	720	30,050
1975	5	450

Throughout the years that Japan has conducted a Pacific herring fishery in the survey area, catches have been taken almost entirely from central Norton Sound, especially near Stuart Island (Figure VII-1). Harvests outside Norton Sound (west of 165°W. longitude) in the northern Bering Sea have been very small, less than 5% of any yearly catch.

The extent that the Japanese harvests have affected Pacific herring stocks in the survey region is unknown. However, annual gillnet effort during 1970, 1971, and 1974 nearly equalled or exceeded amounts fished during the peak catch year of 1969, but catches during these later years failed to approach the 1969 harvest.

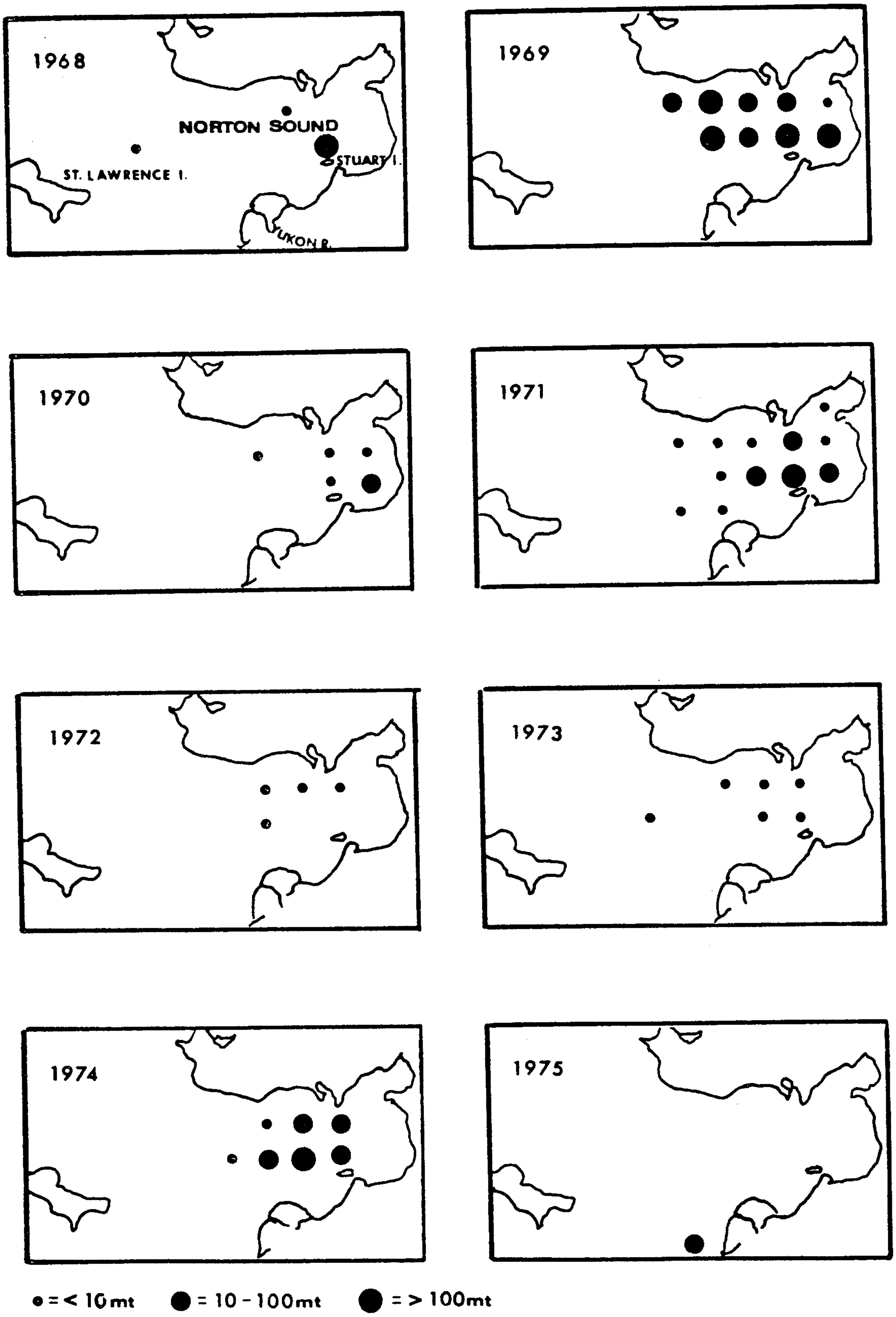


Figure VII-1.--Locations and relative catch magnitudes for Pacific herring caught by the Japanese gillnet fleet in Norton Sound and the northern Bering Sea, 1968-1975 (Source: Japan Fisheries Agency).

Subsistence Fisheries

Salmon.--Salmon taken in the subsistence fisheries are used both for human consumption and dog food. Subsistence catch data prior to the early 1960's is very limited but some early records indicate that over 2 million salmon were taken annually during the early 1900's (Alaska Department of Fish and Game, 1976). Declines in subsistence fishing started in the 1930's as airplanes replaced the sled dog as a mail carrier. This decline accelerated in recent years as welfare payments and employment opportunities increased (including commercial fishing) and snow vehicles came into use. Since considerable numbers of salmon (and other fish) were used to feed sled dogs, fewer fish were needed as canine populations declined. Thus, rather than reflecting fish abundance, the decline in subsistence fishing mainly reflects less fishing effort and less dependence on fish due to a changing way of life for inhabitants in the region.

Subsistence salmon harvests in Norton Sound have ranged from 22,800 to 55,000 fish (Table VII-5) and averaged about 35,000 during 1962-1976. For the same period, catches in Kotzebue Sound ranged between 16,000 and 70,000 fish (Table VII-5) with an overall average of about 29,000. As in the commercial fisheries, subsistence harvests in Norton Sound included catches of chum, pink, coho, and king salmon, while catches in Kotzebue Sound were almost entirely chum salmon.

Table VII-5.--Numbers of salmon by year and species taken for subsistence purposes in the Norton and Kotzebue sound regions, 1962-1976. (Source: State of Alaska Department of Fish and Game.)

	Norton Sound					Kotzebue Sound
Year	King	Coho	Pink	Chum	Area total	Area total 1/
1962	--	--	--	--	--	70,283
1963	5	118	16,607	17,635	34,365	31,069
1964	565	2,567	9,225	12,486	24,843	29,762
1965	574	4,812	19,131	30,772	55,289	30,500
1966	269	2,210	14,335	21,873	38,687	35,588
1967	817	1,222	17,516	22,724	42,279	40,108
1968	237	2,391	36,912	11,661	51,201	20,814
1969	436	2,191	18,562	15,615	36,804	29,812
1970	561	4,675	26,127	22,763	54,126	28,486
1971	1,026	4,097	10,863	21,815	37,801	23,959
1972	756	1,928	12,214	12,942	27,840	11,085
1973	392	520	14,770	7,185	22,867	18,942
1974	420	1,064	16,426	3,958	21,868	26,729
1975	186	192	15,078	6,449	21,905	27,605
1976	203	1,004	18,409	7,867	27,483	15,765

1/ Chum salmon only.

Herring.—The full extent of subsistence fishing for herring is unknown. In 1976, the only year for which data are available, the subsistence herring harvest in Norton Sound was estimated at about 14 mt, approximately twice the level of the commercial harvest. No figures are available for any other portion of the survey area. Apparently utilization of herring by local inhabitants decreases northward along the Alaska coast. Harvest levels north of the Yukon River are substantially lower than to the south. A primary reason for this difference is due to increased commercial fishing and greater availability of terrestrial big game animals in the more northern regions.

King crab.—A few red king crab are taken annually from Norton Sound by residents of Nome. Fishing occurs nearshore and during winter months with small crabpots or hand lines set through holes chopped in the ice. Annual amounts taken by this fishery are unknown; however, the State of Alaska has limited harvests to a maximum of 500 crab (either sex) per person.

VIII

RESULTS OF THE 1976 OCSEAP BASELINE SURVEY OF FISH AND SHELLFISH OF NORTON SOUND, THE NORTHERN BERING SEA, AND SOUTHEASTERN CHUKCHI SEA

METHODS

Survey Approach and Rationale

This 1976 OCSEAP survey was designed to estimate the spatial distribution, abundance, and population characteristics of fish and shellfish of potential economic importance in Norton Sound, the northern Bering Sea, and southeastern Chukchi Sea, which are areas under consideration for petroleum exploration and development. A study of demersal fauna was the primary thrust of the survey. Inasmuch as large segments of some fish stocks were thought to occur in mid-water and near the sea surface, limited off-bottom sampling was also incorporated into the survey design.

For sampling and analytical purposes, the survey area was subdivided into four major subareas. Demersal trawling stations were arranged in a systematic manner within each subarea (Figure VIII-1). At each station a one-half hour demersal trawl haul was performed. Subdivisions of the survey area and the density of demersal stations within each subarea were based on the location of potential oil lease sites, levels of impact from possible environmental alterations, and limited prior knowledge of the distribution patterns of principal fish and shellfish species in the study area. A description of each subarea with respective demersal sampling density follows:

Subarea 1, containing about 41,000 sq km, includes mostly offshore waters (from 25-65 m in depth) from Bering Strait to Point Hope, and nearshore areas along the north coast of the Seward Peninsula and north of Kotzebue Sound with depths greater than 9 m. This subarea is included in proposed oil lease regions and has been an occasional site of high-seas salmon fishing by foreign nationals. Sampling density was planned at one demersal station per 750 sq km.

Subarea 2, containing approximately 12,000 sq km, is another region of proposed oil exploration and an area for commercial and subsistence salmon fishing by residents of the Kotzebue area. This subarea includes all waters of Kotzebue Sound, deeper than 9 m., and waters outside Kotzebue Sound west to approximately 166°W longitude and north to approximately 67°30'N latitude. Sampling density was planned at about one demersal station per 375 sq km.

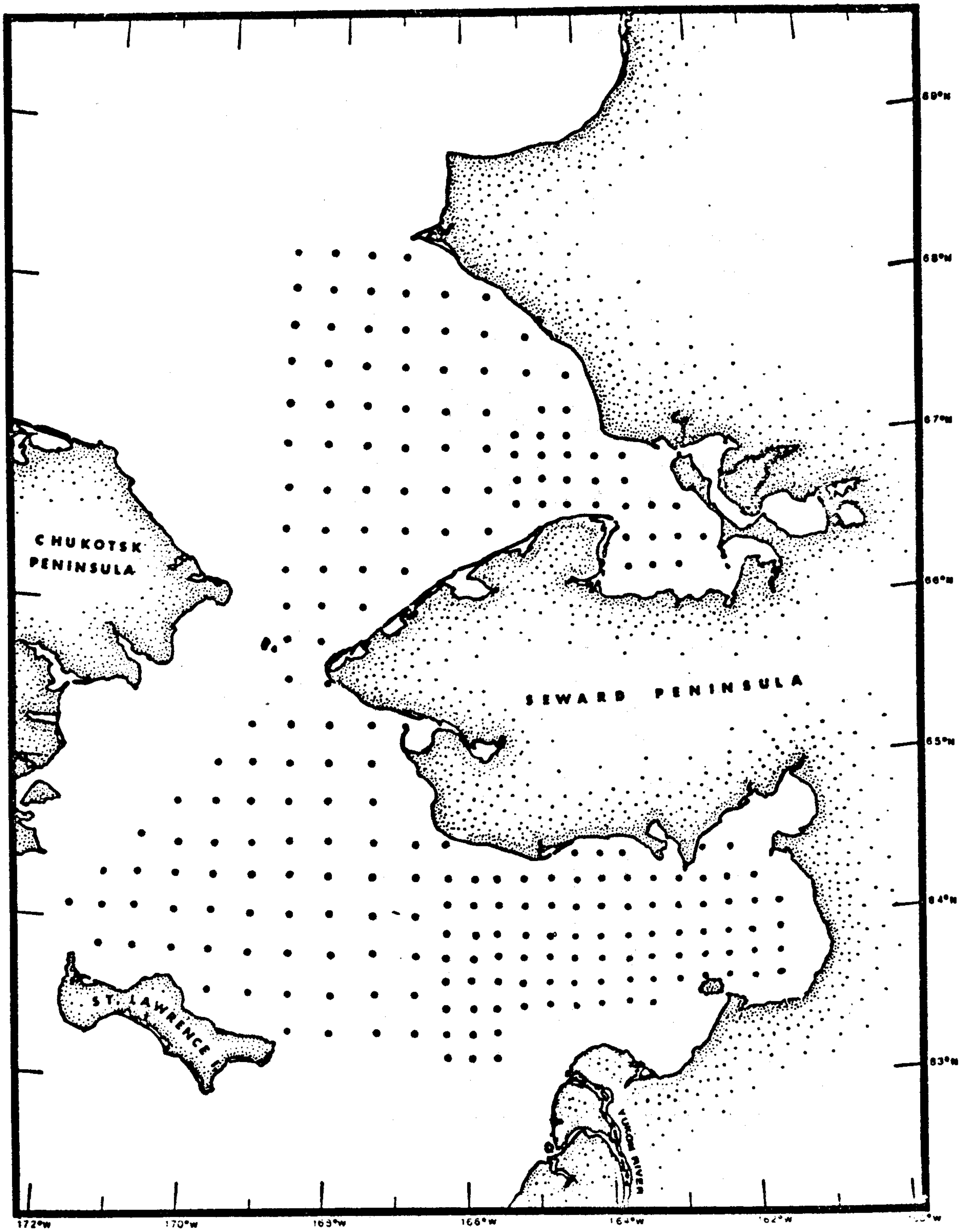


Figure VIII-1.--Planned sampling grid pattern for 1976 survey.

Subarea 3, containing nearly 47,000 sq km, is another region of possible oil exploration within the survey boundaries. This area includes waters of the northern Bering Sea, between depths of 9 and 65 m, from 165°W longitude west to the US-USSR Convention Line of 1867 and from St. Lawrence Island north to Bering Strait, including Port Clarence. Sampling density was the same as in subarea 1.

Subarea 4, containing over 31,000 sq km, includes most waters of Norton Sound east of 166°W longitude, ranging from 9 to 30 m in depth. This subarea is the occasional site of substantial herring fisheries by foreign nationals as well as the location of commercial salmon fishing and subsistence fisheries for residents of the coastal towns and villages of Nome, Unalakleet, St. Michael, Stebbins, and others. This region is also a possible area for petroleum exploration. Sampling density was the same as in subarea 2.

Preliminary examination of the 1976 survey information regarding species composition, size and age composition, and species catch rates indicated need for further division of the subareas for detailed analysis. Each subarea was divided into two sections forming a total of eight strata for the data analysis (Figure VIII-2). This subdivision was based on preliminary examination of data on all species combined rather than on individual species.

The above mentioned planning and sampling pattern pertains directly to demersal resource assessment, the primary portion of the survey. Mid-water trawling and surface gillnetting were incorporated into this demersal sampling system. Pelagic trawl tows were planned to occur on an opportunity basis, whenever off-bottom fish targets were encountered during transit between the demersal stations. The pelagic tows also were one-half hour in duration. The setting of gillnets occurred each evening and fishing time for this gear usually ranged between 8-10 hours. The location of each gillnet set was determined by selecting a site in close proximity to a series of demersal stations which could be occupied while the gillnets were fishing.

Because of the extensive amount of planned sampling and the relatively short time period in which the survey could be completed, it was necessary to deviate from the usual daytime-only trawling protocol as during earlier BLM baseline demersal trawl surveys. Trawling operations for this survey were conducted on an around-the-clock schedule. Since 24-hour operations were used, a portion of the alloted survey time was set aside to determine whether species composition and catch rates differed significantly between day and nighttime trawling. When differences were identified, fishing power factors were determined so that all catch information could be pooled into a standardized data base. Details regarding the design, analyses, and results of the day-night comparative fishing trials are given in Appendix D.

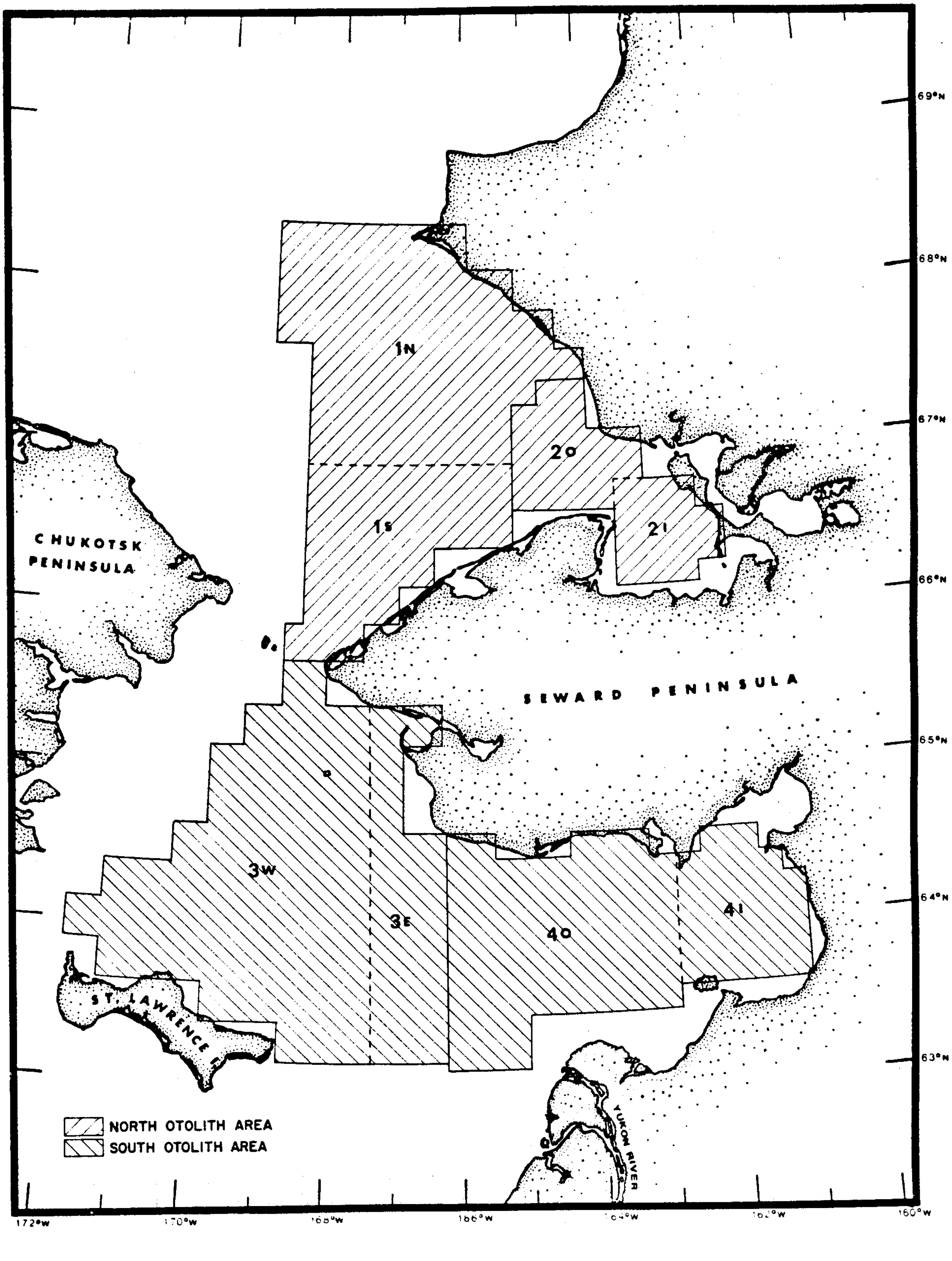


Figure VIII-2.--Otolith sampling areas and strata used for biomass analysis (1976 BLM/OCS survey).

Vessel and Fishing Gear

The NOAA research ship *Miller Freeman* was the only vessel used during the 1976 OCSEAP survey of Norton Sound, the southeastern Chukchi Sea, and adjacent waters. The *Miller Freeman* is a 1500 gross ton, 2200 horsepower stern trawler with an overall length of 65.5 m and equipped with a variable pitch propeller.

Fishing gear for the survey included the modified eastern demersal trawl used during earlier baseline surveys (NWAFC, 1976), the BCF Universal trawl for pelagic trawling, and a series of gillnet shackles connected together to form a 640 m long floating gillnet.

Each shackle of gillnet was 91 m (300 ft) x 5.5 m (18 ft) and contained a different mesh size of monofilament nylon. Seven mesh sizes (seven shackles) were planned to be fished at each gillnet station. These mesh sizes included: 21 mm (0.83") (stretched mesh measure), 35 mm (1.38"), 42 mm (1.65"), 63.5 mm (2.50"), 82.5 mm (3.25"), 114.3 mm (4.50"), and 133.4 mm (5.25"). The gillnet was fished with a radio buoy, marker pole, and floats attached to one end. Only a marker buoy and floats were attached to the other end of the gillnet set.

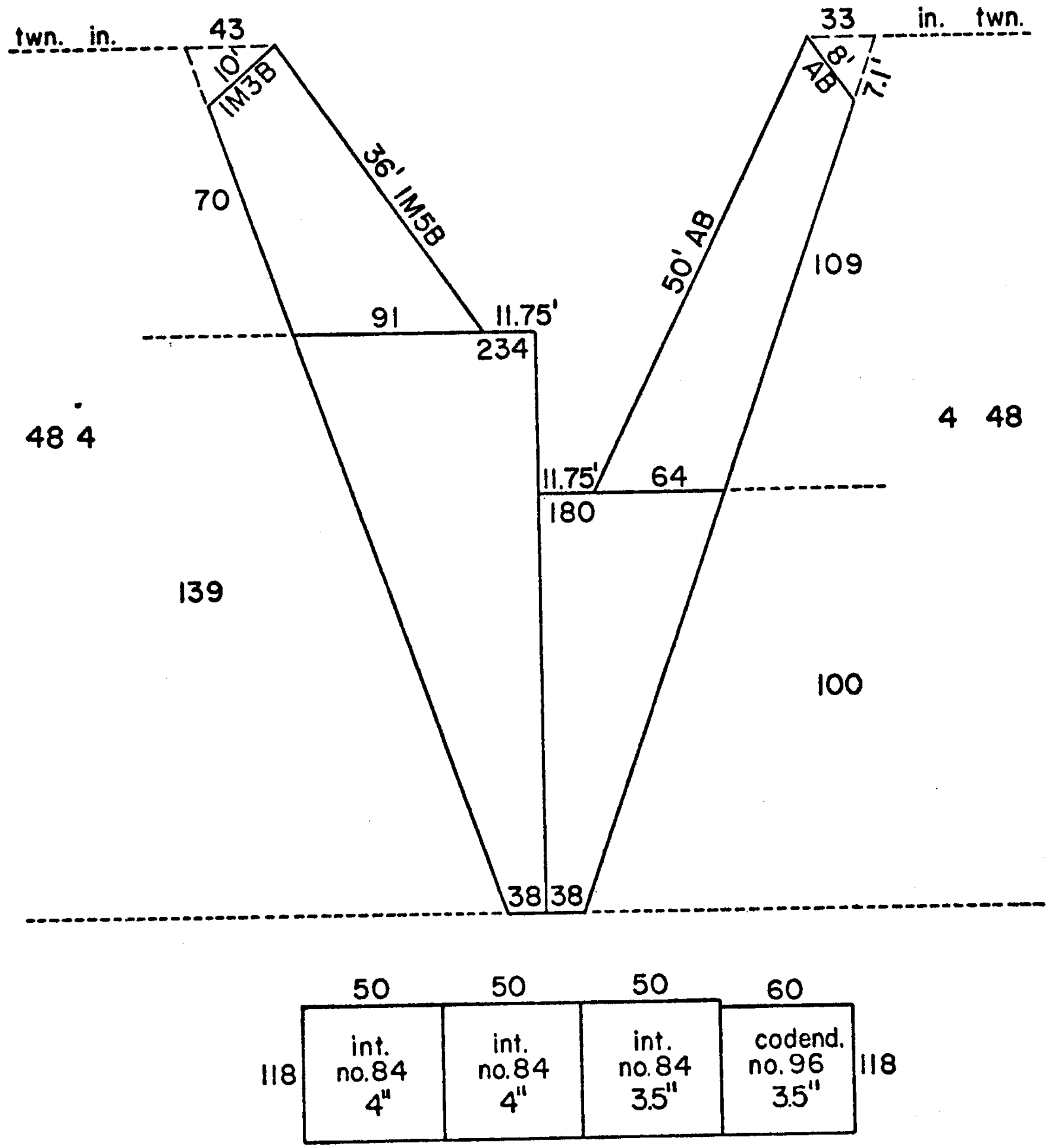
Both demersal and pelagic trawls were fished with 2.1 m x 3.0 m steel V-design trawl doors and their codends were lined with 31.8 mm (1.25") mesh web for retention of small fish. A set of four 45.7 m (150 ft) dandylines were fished with the demersal trawl, two connected to each wing. Six 54.9 m (180 ft) dandylines were used with the pelagic trawl, 3 connected to each wing. Descriptions of the trawls are given in Figures VIII-3 and VIII-4.

Sampling Procedures

Prior to the actual demersal fishing operations, some stations were first surveyed by echosounder to establish the condition of the bottom. At inshore stations where highly uneven or muddy and thus untrawlable bottom might be encountered, a two-mile echosounder transect was run over the station to determine both its trawlability and a course which would provide a uniform depth throughout the length of the tow. If the echosounder trace indicated rough bottom, the vessel proceeded to the next station rather than spending additional time searching for a trawlable area. If the echosounder trace indicated muddy bottom, a test set of 5-10 minutes was attempted. If extensive mudding of the trawl resulted from the test set, the station was abandoned.

Station positioning was by Loran C with radar fixes used at nearshore locations. Positioning accuracy of the tows in relation to planned station positions proved to be relatively good except in the northwest portion of the survey area where land masses were quite distant for radar fixes and only limited Loran fixes could be obtained.

MODIFIED EASTERN TRAWL NET



Netting: Dacron polyester body and wings, nylon intermediate and codend.

Headrope: 83 ft., 1/2-in. 6x19 galv. wire rope wrapped with 5/16-in. polypropylene rope.

Footrope: 112 ft., 5/8 in. dia. 6x19 galv. wire rope wrapped with 5/16-in. polypropylene rope.

Breastlines: 1/2-in. dia. braided nylon, 18 ft. long.

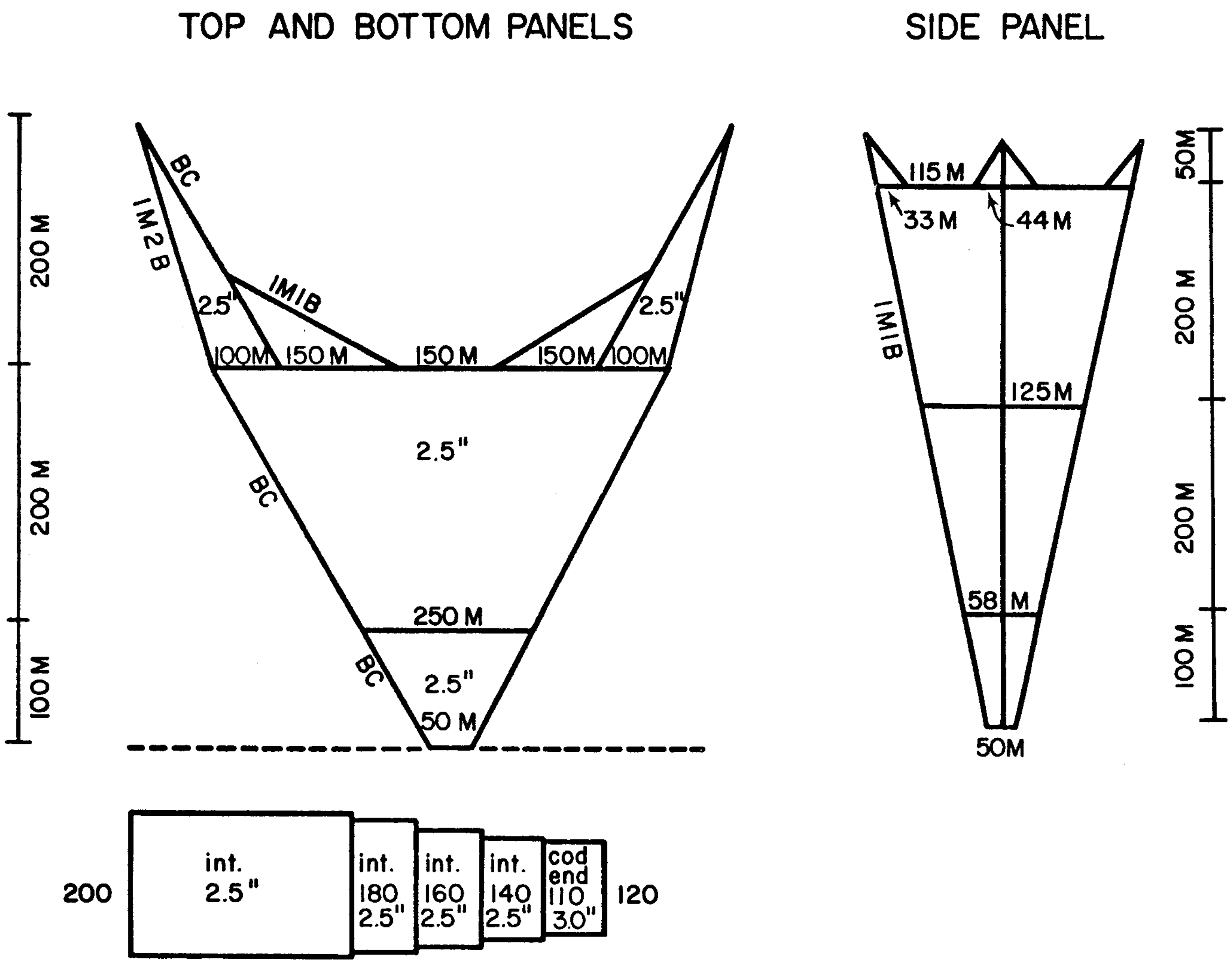
Riblines: 1/2-in. dia. braided nylon, extending length of first intermediate (webbing hung-in).

Flotation: 31-8 in. and 3-10 in. aluminum floats.

Dandylines: Single - 11 fath., 3/4-in. dia., double - 25 fath., one 3/4-in., one 5/9-in.

Otterboards: 7-10ft. Vee.

Figure VIII-3.--Diagram and description of the demersal trawl used during the 1976 BLM/OCS survey.



Netting: nylon

Headrope: 121 ft., 5/8 in. dia. braided nylon

Footrope: 121 ft., 5/8 in. dia. braided nylon

Breastlines and riblines: 5/8 in. dia. braided nylon

Floatation: 65-8 in. aluminum floats

Dandylines: 6-180 ft.

Otterboards: 7-10 ft. Vee.

Figure VIII-4.--Diagram and description of the pelagic trawl used during the 1976 BLM/OCS survey.

The direction of the trawl tows varied depending on prevailing wind and sea conditions. Tows generally were made into the wind. For demersal trawl hauls, the trawl was set prior to reaching the station so that the actual station position was reached about midway through the trawl tow. Towing speed for the Miller Freeman averaged about 6.5 km/hr (3.5 n mi/hr).

Demersal tow duration was 30 minutes. Timing of the tow was started after the vessel was slowed to allow the trawl to settle to the bottom and as the trawl winch brake was set. The average bottom distance trawled was 1.65 km (range: 0.7-3.2 km).

Pelagic tow duration also was 30 minutes. Timing for the mid-water sets was started when the proper amount of trawl warp had been payed out, the winch brake was set, and the proper trawl towing depth was attained. Proper trawling depth varied, depending on where fish targets occurred in the water column. The desired fishing depth was attained by adjusting towing speed and was monitored by means of a transducer attached to the trawl headrope. Because a variety of off-bottom depths were fished and since maintenance of trawl position in the water column required changing trawling speed in relation to currents, distance towed varied among the pelagic trawl tows. Average pelagic trawling speed for the Miller Freeman was about 8.3 km/hr (4.5 n mi/hr).

Gillnets were fished for 8-10 hours and starting time for the set occurred when the first end of the gillnet shackles was released down the stern ramp. The gillnets usually were allowed to drift during the set with the arrangement of the various mesh sizes such that a minimum of looping or drifting together of the corklines occurred. When the gillnets were set in shallow or nearshore locations, the ends were anchored to prevent the set from drifting into shallow unnavigable waters.

The gillnets were retrieved by having the vessel back down to the gear with the bow thruster. The net was then brought up the stern ramp and wrapped onto one of the trawl net reels. After the entire gillnet was aboard, it was removed from the reel and placed in a bin for storage until the next set.

Expendable bathythermograph (XBT) casts were made at the completion of each gillnet set, and pelagic and demersal trawl hauls.

Catch and Biological Sampling

Initial Handling of Trawl Catches

The method of processing trawl catches depended on catch size. If the catch did not exceed the 1,150 kg capacity of the sorting table, it was dumped directly onto the table and completely processed. For larger catches, only a subsample of the catch was processed. The subsampling method used was based on a system developed by Hughes (1976) and followed procedures established for earlier BLM surveys aboard the Miller Freeman (Kaimmer *et al.*, 1976). As with earlier surveys, prior to disposing of the unused portion of the catch overboard, all crabs were removed for separate counting and processing.

The size of catches in the survey area rarely exceeded 1000 kg. Of the 192 standard demersal tows completed, only three needed to be split before processing. All pelagic trawl catches were completely processed.

Initial Handling of Gillnet Catches

Catches from each mesh size were kept separate. As the gillnet sets were retrieved, catches from each shackle were removed and placed in tubs or baskets labeled for each mesh size as the net was wound on to the net reel.

Sorting and Weighing the Trawl Catch

After the catch was on the sorting table, it was sorted by species into wire bushel baskets and smaller plastic containers. For catches having a single dominant species, two to three baskets were filled simultaneously with that species and the baskets removed from the table in a set, weighed, and placed on deck as a group. While the dominant species was being sorted, other species were sorted into single baskets or other containers. The procedure of filling single or sets of baskets was repeated until the entire catch or subsample of the catch was sorted and weighed. Baskets were placed on deck in processing sequence in order to identify baskets of fish that came from the top, middle, and bottom of the trawl sample.

Baskets of fish were weighed to the nearest 0.5 kg on a 141 kg capacity platform scale or to the nearest 0.1 kg on a hand held spring scale when small catches occurred. Numbers of individuals by taxonomic group were determined by direct count or from subsample counts which were expanded to the total catch. Specimens that could not be identified to species were photographed, preserved, and labeled by genus or broader taxonomic group. Following the survey, unknown specimens were identified by taxonomic experts and the proper nomenclature transcribed onto the Trawl Catch Forms.

Sorting and Weighing the Gillnet Catch

After the entire gillnet catch was removed from the various shackles and placed in containers, each shackle catch was sorted by species into smaller containers. Weights and numbers caught were determined in a manner similar to that used in processing trawl catches.

Subsampling Demersal Catches for Biological Data on Fish

For the dominant species of fish encountered in demersal trawl hauls, catches were further processed for length composition, length-weight relationships, and samples of age structures (otoliths and scales). The species from which these data were collected and their order of priority for biological data were as follows:

1. Pacific herring
2. Saffron cod
3. Arctic cod
4. Yellowfin sole
5. Toothed smelt
6. Alaska plaice
7. Bering flounder
8. Starry flounder
9. Arctic flounder

A random sample for length frequency was taken from the catch of each species. Random samples consisted of from 200-300 saffron cod and 150-200 individuals of other fish species.

The procedure followed to obtain a random sample was as follows: as the baskets were taken from the sorting table and weighed, they were aligned on the deck in the order by which they were filled. When two or more baskets were filled simultaneously, they were kept together as parallel rows. To arrive at the desired number of fish for the sample, one row was picked at random to represent the catch. If there were still too many fish, the sample was further reduced by picking baskets from the front, middle, and end of the row. This procedure provided a subsample that would not be affected by any size stratification that might have existed on the sorting table. If an entire species catch resulted in numerous baskets of very small fish (400-1000 individuals/basket), the sample was obtained by taking random portions of the picked baskets from the front, middle, and end of the row. When catches of a species were equal to or less than the desired sample size, all individuals were measured.

Length-frequencies were recorded on plastic length-frequency strips. The fish were first sexed, then measured to the nearest centimeter from the tip of the snout to the middle of the caudal rays, except for Pacific herring which were measured from the tip of the snout to the posterior edge of the hypural plate. The sex of small juvenile fish was not always determined. Between stations or following the last station of the day, length-frequency data were transcribed from the plastic strips to standard length-frequency forms.

Samples for obtaining age structures and length-weight information were selected so as to obtain representative length classes of fish for each sex. At times, age structures or length-weight information were collected in conjunction with randomly collected length-frequency samples but at other times were selected independently. Independent samples for age and length-weight were obtained from specific geographical areas, referred to as "otolith areas". Two "otolith areas," north and south, were identified for the entire region (Figure VIII-2). The boundary between these areas, Bering Strait, was thought a possible point of separation between fish populations in the Norton Sound-northern Bering Sea region and in the southeastern Chukchi Sea. The otolith areas coincided with the demersal trawl sampling subdivision of the survey area, i.e., the north otolith region corresponded to subareas 1 and 2 combined and the south otolith region to subareas 3 and 4 combined.

Otoliths were the structures used for determining the age of all fish except salmon (Oncorhynchus spp.), for which scales were used. For each species up to 6 otoliths were obtained for each 1 cm size group by sex. This was done for each otolith area. Since few salmon were anticipated in catches, scale samples were obtained from every fish. The otoliths were stored in alcohol in glass vials. Scales were stored on gummed cards with acetate covers.

Length-weight data also were taken from 6 individual fish for each sex-centimeter group per otolith area. Individual fish were weighed to the nearest gram on a triple-beam balance.

Subsampling Trawl Catches for Biological Data on Crab

All king and Tanner crabs were removed from trawl catches regardless of catch size. If the number of crabs in the catch was less than 300, biological data were taken from all specimens. If the number exceeded 300 crabs, a subsampling procedure (Figure VIII-5) was used to provide a sample of about 300 crabs. The crabs were sorted by species and sex and then weighed and counted.

All crabs in the catch or samples of the catch were measured to the nearest millimeter using carapace width for Tanner crab and carapace length for king crab. Shell condition was also recorded for each individual.

Subsampling Trawl Catches for Biological Data on Snails

Many snail species are extremely difficult to identify in the field. For this reason, the operational plans called for the collection of random subsamples of snails at each station. No sorting or identification was to be done on the vessel. After all snails were removed from the catch, one to three cloth bags, depending on the size of the snail catch, were filled with a random assortment of snails and placed in a 55 gallon drum containing a 10% solution of formaldehyde. The maximum weight of a subsample collected at a station ranged up to about 7 kg. In addition to the collection of the random subsample, an actual count or estimate was made of total snail numbers in the entire catch and recorded on the Trawl Catch Form.

CRAB SAMPLING FLOW CHART

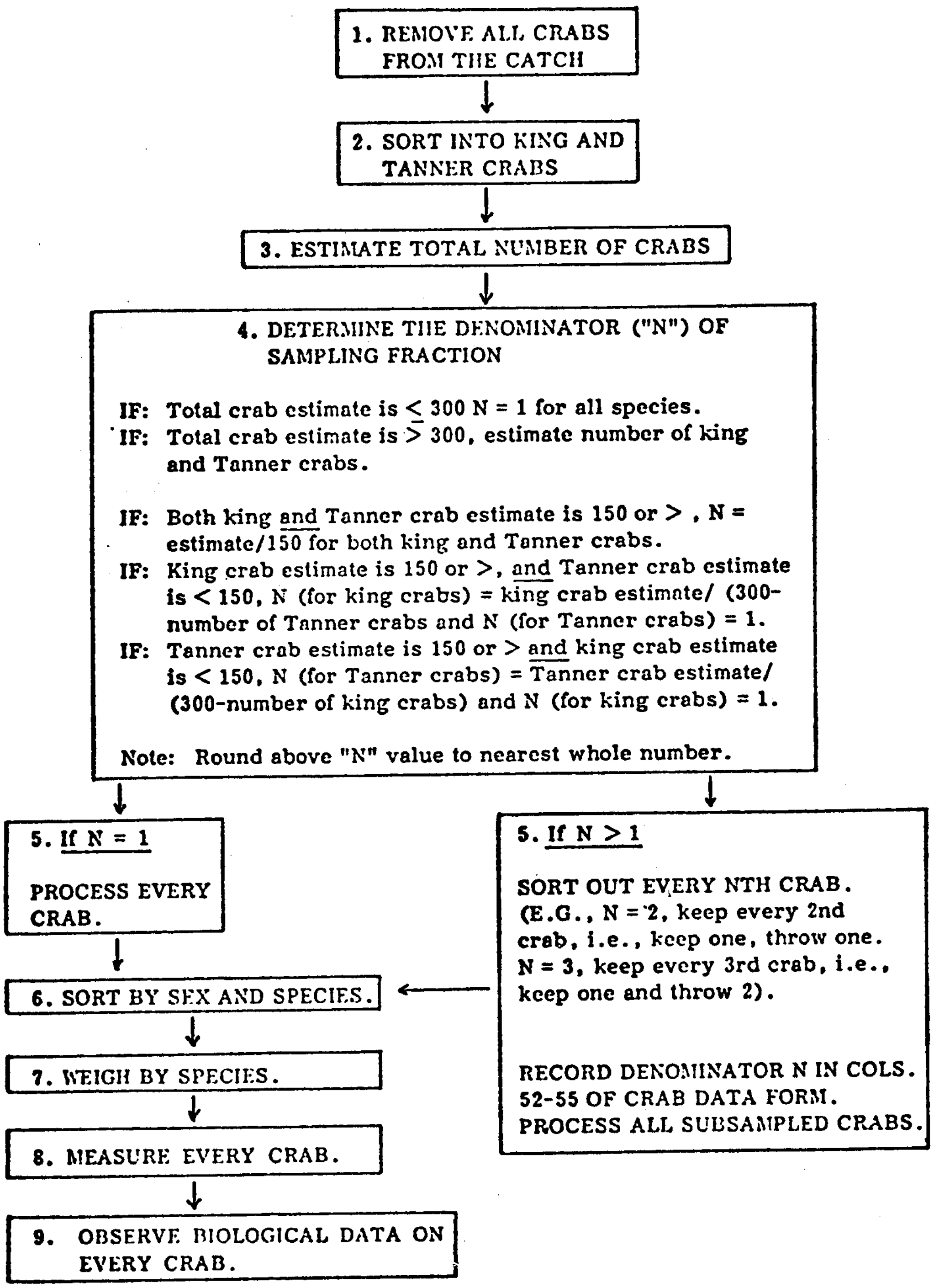


Figure VIII-5.--Sub-sampling procedure followed for processing species of crab during the 1976 Baseline Survey of Norton Sound and the south-eastern Chukchi Sea.

The drums of snails were returned to the NWAFC's Kodiak facility where the snails were identified, sexed, and measured. Total shell length was measured from the apex of the spire to the anterior end of the anterior canal.

Sampling Trawl Catches for Biological Data on Other Invertebrates

All other invertebrates encountered in the survey trawl catches were examined by personnel from a separate research unit from the University of Alaska, Institute of Marine Science (IMS). Information in this report which pertains to catch rates and biomass estimates for invertebrates other than king crab, Tanner crab, and snails were developed through data provided from IMS.

Age Determination of Fish

Annual marks on scales and otoliths were the basis for age determination. Otoliths were read by trained readers at NWAFC in Seattle. Techniques and accuracy of age determination by otoliths were similar to those described in the 1975 baseline study report for the eastern Bering Sea (NWAFC, 1976). Scales were examined by trained personnel of the State of Alaska Department of Fish and Game in Anchorage, Alaska, using established techniques for age identification.

Shell Age Determination of Crabs

The status of individual crabs with respect to molting was determined primarily from the appearance of the carapace and ventral surface of the crab. The following criteria were utilized in determining this status: (1) the size and density of attached marine organisms, (2) the color of the carapace and sternum, (3) the sharpness of spines, and (4) the presence of scratches on the sternum. Crabs were assigned to shell age categories as follows:

Shell age category	Designation	Description
0	molting	-
1	soft	Molted within the past two weeks, shell free of encrustation, no scratches on carapace, and spines sharp.
2	new	Molted within the past twelve months but not within the past two weeks, little encrustation, minor scratching, and blunting of spines.
3	old	Skipped one annual molting.

Data Management

A standard data management procedure was followed from data collection through analysis at NWAFC. Aboard ship, station information for fish was coded on three standard forms (Trawl Catch Form, Length-Frequency Form, and Specimen Data Form) for later keypunching on 80-column ADP cards (see Appendix B for examples of standard forms). The information recorded on the Trawl Catch Form included basic station data such as station number and position, date, depths of trawling, and catch by species. Catch data were initially recorded on an on-deck sampling form during the processing of the catch and later transcribed to the Trawl Catch Form. A similar sequence was followed for handling length data. This information was first recorded on a reuseable plastic strip and transferred later to the Length-Frequency Form. The Specimen Data Form was used for recording information on the weight of individual specimens and lengths of fish from which age structures (otoliths, scales) were removed and stored. Station information for crabs was coded on two standard forms (Crab Summary Form and Crab Data Form). Information coded on the Crab Summary Form was similar to station data recorded on the Trawl Catch Form. In addition, the numbers of crabs measured and caught were recorded by tow, species, and sex. The Crab Data Form was used to record carapace size, sex, shell condition, egg clutch, and sampling fraction, as well as station identification for each crab measured.

The information on the standard forms was checked for accuracy and completeness and submitted for keypunching. The ADP cards were then edited by computer programs to detect obvious discrepancies (detailed quality control procedures are given in Appendix A). Computer listings of the data in easily readable formats were made for visual checking against the data on the original standard forms. After verification and correction were completed, the data on the ADP cards were transferred to disk files. Numerous editing programs were then used for additional screening. All survey data were eventually placed on magnetic tape for transfer to Environmental Data Services through the OCSEAP office in Juneau, Alaska.

Analytical Procedures

Standardization of Catches

Catches were standardized to a trawling distance of 1 km. These standardized catches were calculated as follows:

$$CPUE_{ijk} = \frac{C_{ijk}}{D_{ij}.F_{tk}}$$

where $\underline{CPUE}_{ijk}$ refers to the catch per unit of effort (kg/km) for species $\underline{k}$ at the $\underline{j}$th station in the $\underline{i}$th subarea. $\underline{C}_{ijk}$ equals the catch (kg), $\underline{D}_{ij}$ equals the distance trawled (km) computed from beginning and ending Loran C readings at each station, and $\underline{F}_{tk}$ is the relative fishing power correction factor time of sampling (day or night) t in respect to species $\underline{k}$.

The relative fishing power correction factor was obtained through an analysis of results of comparative day-night fishing trials at several locations. The correction factors for nighttime catches were related to catches made during the day. These are given in Table VIII-1 for the principal species encountered in the survey area for which significant day-night catch differences were statistically established. Details of the methodology and analysis for estimating these correction factors are given in Appendix D.

Table VIII-1.--Fishing power coefficients calculated for principal fish species encountered during day-night trawling comparisons in Norton Sound and the southeastern Chukchi Sea during the 1976 baseline study.

	Species 1/				
Time	Starry flounder	Saffron cod < 15 cm	Saffron cod ≥ 15 cm	Toothed smelt	Pacific herring
Day	1.00	1.00	1.00	1.00	1.00
Night	1.69	1.52	1.50	2.08	1.45

1/ For other principal species, no differences in fishing power were established. For all other species, the fishing power correction factor was assumed equal to 1 for both day and night.

Catch Per Unit of Effort by Stratum and Total Survey Area

The mean CPUE by species and stratum was computed as follows:

$$\overline{CPUE}_{ik} = \frac{\sum_{j=1}^{n_i} CPUE_{ijk}}{n_i}$$

where n_i equals the number of successfully trawled stations in the $\underline{i}$th stratum. The variance of this estimate was:

$$VAR\ (\overline{CPUE}_{ik}) = \frac{\sum_j (CPUE_{ijk})^2 - n_i\ (\overline{CPUE}_{ik})^2}{n_i\ (n_i - 1)}$$

The overall mean CPUE for the entire survey area ($\overline{CPUE}_{Tk}$) was determined as a weighted sum of the mean CPUE values by stratum:

$$\overline{CPUE}_{Tk} = \frac{\sum_i (\overline{CPUE}_{ik} \cdot A_i)}{A_t}$$

where $\underline{A}_i$ equals the area of the $\underline{i}$th stratum and $\underline{A}_t$ equals the area of all stratum combined.

The variance of this estimate was determined as a weighted sum of the individual variances by strata:

$$VAR\ (\overline{CPUE}_{tk}) = \sum_i \left(\left(\frac{A_i}{A_t} \right)^2 \cdot VAR\ (\overline{CPUE}_{ik}) \right)$$

Standing Stock Estimates

Population weight—Biomass estimates by subarea followed the methods described by Alverson and Pereyra (1969):

$$\hat{B}_{ik} = \overline{CPUE}_{ik} / q_k$$

where $\hat{\underline{B}}_{ik}$ equals the estimated standing stock by weight of the $\underline{k}$th species in the $\underline{i}$th stratum, and $\underline{q}_k$ is a coefficient of catchability, $\underline{w}$ is the average effective trawl width:

$$q_k = C_k\ (\overline{w}/A_i)$$

and $\underline{C}_k$ is the coefficient of vulnerability of species $\underline{k}$ for those individuals of sufficient size to be retained by the trawl which are within the area "swept" during a standard tow. The coefficient of vulnerability consists of two components: (1) $\underline{C}_h$, the vulnerability of those individuals that actually come within the influence of the trawl, and (2) $\underline{C}_u$, the proportion of the total individuals in the volume of water above the seabed area swept by the trawl which would come within the trawl's influence. Species-specific coefficients of vulnerability are not known for the survey area, but have been assumed to be constant and equal to 1.0. The estimated area covered by the trawl when towed 1 kilometer ($\underline{a}$) is equal to 0.017 km^2. [1/] Therefore, the biomass of species $\underline{k}$ within stratum $\underline{i}$ can be estimated:

$$\hat{B}_{ik} = (Ai/\bar{w})\ \overline{CPUE}_{ik}$$

having a variance of:

$$VAR\ \hat{B}_{ik} = \left(\frac{a_i}{\bar{a}}\right)^2 \cdot (VAR\ \overline{CPUE}_{ik})$$

where $\underline{a}$ is the mean bottom area sampled in 1 km trawl distance (km^2).

Ninty-five percent confidence intervals of the estimated biomass are then computed:

$$\hat{B}_{ik} \pm t_{(.05)(n_e)} \sqrt{VAR\ \hat{B}_{ik}}$$

The biomass estimate for a given species or taxonomic group and its variance for the total survey area were obtained by summing the sub-area biomasses and variances, respectively:

$$\hat{B}_{Tk} = \sum_{i=1} \hat{B}_{ik}$$

$$VAR\ \hat{B}_{Tk} = \sum_{i=1} VAR\ (\hat{B}_{ik})$$

$$= \sum_{i=1}\left(\left(\frac{A_i}{a}\right)^2 \cdot VAR\ \overline{CPUE}_{ik}\right)$$

Effective degrees of freedom (n_e) for the calculation of confidence limits for biomass estimates for the total survey area were determined according to Cochran (1962):

$$n_e = \frac{\left(\sum_{i=1} f_i \cdot VAR\ CPUE_{ijk}\right)^2}{\sum_{i=1} \dfrac{f_i^{\,2} \cdot (VAR\ CPUE_{ijk})^2}{n_i - 1}}$$

where

$$f_i = \frac{N_i \quad (N_i - n_i)}{n_i}$$

1/ Based on an estimated 17-meter horizontal opening of the R/V *Miller Freeman* trawl while fishing.

and $\underline{N}_i$ equals equals the total number of sampling units in the $\underline{i}$th stratum (A_i/a) and $\underline{n}_i$ equals the number of stations in stratum $\underline{i}$.

Population numbers--Estimates of population numbers within strata and for the total survey area were determined in the same manner as population weight, simply substituting numbers for weight in all the calculations. Fishing power coefficients used to standardize catch rate by number between day and nighttime trawling were identical to those used for catch rate by weight.

Size Composition

Size composition by numbers in the population was estimated for those strata where sufficient length-frequency data were collected. Length-frequency data for individual stations were expanded by a weighting factor to give an estimate of the total standard catch in numbers by size and sex for a given species:

$$\hat{N}_{ijklm} = n_{ijklm} \cdot \hat{P}_{ijk} / \sum_{m=1}^{3} \sum_{l=1}^{L} n_{ijklm}$$

where $\underline{\hat{N}}_{ijklm}$ equals the estimated number of individuals of size category $\underline{l}$, sex $\underline{m}$, and species $\underline{k}$ at the $\underline{j}$th station of stratum $\underline{i}$ where length information was collected, and $\underline{L}$ is the total number of size categories. The independent variable $\underline{n}_{ijklm}$ is the number of fish, crab or snails in this category actually measured, and the weighting factor is the ratio of total number of individuals of species $\underline{k}$ per standard tow $(\underline{\hat{P}}_{ijk})$ to the number of individuals of species $\underline{k}$ measured in the length frequency sample. The number of fish, crab, or snails by size-sex category for individual strata $(\underline{\hat{P}}_{iklm})$ was obtained by summing the size-sex categories for those stations where this was available and expanding this sum to the total standing stock of fish, crab, or snails in each subarea:

$$\hat{P}_{iklm} = \frac{\sum_{j=1} N_{ijklm}}{\sum_{j=1} \sum_{k=1} \sum_{l=1} N_{ijklm}} \cdot \hat{P}_{ik}$$

When size composition estimates were available for all strata, overall estimates of the standing stock size composition of a species for the total survey area were obtained by summing the population numbers by size-sex category $(\underline{\hat{P}}_{iklm})$ for all strata. If size composition estimates were not available for all strata in which the species occurred, estimates of overall size composition for the total survey area were obtained by expanding the summed size composition data by a ratio of overall population estimate for the species $(\underline{\hat{P}}_k)$ to the summed population estimates of the strata for which size composition information was available.

Length and Weight

For most species of fish, the relationship between length and weight takes the form:

$$\text{weight} = a \cdot (\text{length})^b$$

A least-squares linear regression procedure was used to fit length-weight observations grouped by sex and otolith area to the logarithmic transformation of this equation:

$$\log(\text{weight}) = \log a + b \cdot \log(\text{length})$$

Estimates of the coefficients $\underline{a}$ and $\underline{b}$, and a coefficient of correlation $\underline{r}$ were determined. The correlation coefficient $\underline{r}$ was computed:

$$r = \sum_{i=1}^{n} (x \cdot y) \Big/ \sqrt{\sum_{i=1}^{n} (x^2 \cdot y^2)}$$

where $\underline{x}$ and $\underline{y}$ are the deviations of observed length and weight values from their respective means and $\underline{n}$ equals the number of observations. An analysis of covariance (ANCOVA) was used to evaluate the statistical basis for pooling data sets, the regression coefficients determined for each treatment (data grouped by sex or otolith area) being tested for significant differences. This sequence of analyses was performed on all possible groupings of the data by species, resulting in comparisons of differences between area by sex, between sexes by area, and between areas by combined sexes.

Age Composition and Growth

Age-length tables were constructed by species and sex for each otolith area having sufficient data. These tables show the number of actual observations in each size-age class and estimates of mean length-at-age. Comparisons of plots of mean lengths-at-age were used to combine age-length data from otolith areas for which the approximated growth curves were not markedly dissimilar. The rationale for combining age data was: (1) to increase the number of observations of length-at-age within age classes to give more precise estimates of mean length-at-age; and, (2) to reduce the total number of data sets for further analyses.

Age-length tables were constructed from the otolith area groupings and used as keys to represent the age-length relationships of the respective species in the grouped strata.

Age composition--From the above keys, expanded age-length tables were constructed for each species by sex and strata using the method of K. R. Allen (1966). This method applies the age-length relationship for a region to population estimates in numbers at length, resulting in tables of numbers at-age-and-length by stratum. To make this conversion, the proportion of ages within any length interval were calculated from the keys and then applied to the corresponding numbers in the length-frequency distribution for a stratum. The result is an age-length table in which actual observations have been expanded to estimates of total numbers of individuals in the population at age and length. Estimates of the age composition (numbers of fish in each age class) for the population were obtained by summing the values in the expanded age-length table over all lengths by age. (In applying size composition data to the age-length key, lengths outside the length range of the key were not assigned ages. This, along with the truncation of size composition data, resulted in minor discrepancies between population estimates (numbers) for some strata and the sum total of numbers of individuals-at-age in those strata.)

Growth--Mean lengths-at-age for the grouped otolith areas from expanded age-length tables were used to fit growth curves in the form:

$$l_t = L_\infty \ (1-e^{k(t-t_o)})$$

where $\underline{l}$ equals length in centimeters at time $\underline{t}$ (years), $\underline{L}_\infty$ is an asymptotic length (cm), $\underline{k}$ (year^{-1}) is a growth completion rate, and $\underline{t}_o$ (years) is the intercept of the curve with the x-axis. Three methods were used, differing only in the data used for fitting the curve. First, curves were fit to all mean lengths-at-age as calculated from the expanded age-length table by otolith area or combinations at otolith areas. In the second fit, mean lengths which might have been biased because the complete size range for an age was not fully recruited to the fishing nets were deleted as were mean lengths derived from a relatively small number of observations at-age in the age-length key. Age of "complete" recruitment was estimated using logarithmic catch curve analysis (Ricker, 1975, p. 34). The third fit was created by adding the origin (0,0) as a data point to the above selected data set. This was done in order to compensate for missing data points for young ages which were not fully recruited by the gear.

The parameters $\underline{k}$, $\underline{L}_\infty$ and $\underline{t}_o$ were estimated by the iterative method of Fabens (1965).

ASSUMPTIONS AND DATA LIMITATIONS

We have provided for the various fish and shellfish population estimates of stock abundance, composition, and distribution based on an extensive trawl survey conducted over a period of six weeks. In providing these estimates, we have made certain assumptions regarding the adequacy of bottom trawls for sampling demersal populations and the time-space distribution of populations. We have assumed that the trawl obtained samples that were representative of the density and composition of the animals in the sampled area, and that the trawl's performance (vertical and horizontal width of the mouth opening and the bottom-tending characteristics) remained constant from station to station. A corollary to these assumptions is that changes in the catch of a species for a given unit of effort (distance fished) is directly proportional to changes in density. The other assumptions regarding the time-space distribution of populations is that, during the period of the survey, populations were static, i.e., there were no shifts in abundance within the survey area as well as no movements of animals in and out of the survey area.

These assumptions need to be qualified. Although the trawl continues to be the most effective gear for sampling bottomfish and large epibenthic invertebrates, it has certain limitations. Trawls are selective. Sizes, and even species, of animals captured are influenced by the mesh size, particularly in the bag or codend. Even species within the size range, which theoretically should be captured, may differ in their ability to escape the influence of the trawl. Because trawling is necessarily restricted to relatively smooth bottom to avoid hanging up and damage to the net, animals over uneven and rocky bottoms are not adequately sampled. The selective features of trawls thus alter the composition, sizes, and quantities of species captured from that which occur in its path. The degree to which the "apparent" distribution and relative abundance differs from the actual is unknown. Thus, estimates of standing stock are representative only for those species which are vulnerable as well as accessible to the trawl. However, our estimates assume that for a given species and size, all animals are vulnerable and accessible ($\underline{c}$ = 1.0), since we do not know what the actual value of $\underline{c}$ is for any of the species. For crabs the coefficient $\underline{c}$ may be close to 1.0, but for semi-demersal fish like Arctic cod and herring or for burrowing animals like snails, $\underline{c}$ may be much less than 1.0.

We have no way to account for the space-time distribution of populations during the survey period (September-October) and have assumed a static situation. The survey period was selected because it was assumed that movements of fish and shellfish populations were relatively limited at that time and weather conditions for the survey area were optimal. It is conceivable, however, that moving aggregations of animals may have been sampled more than once during the survey and that, for several populations like Arctic cod and herring, there may have been movements in and out of the survey area. To significantly reduce the duration of the survey while maintaining the demersal sampling coverage would have required extensive increases in the number of vessels and personnel.

In considering these limitations to our survey approach we hope that our findings provide some average conditions of demersal resource abundance, distribution, and composition, and a very general view of the types of pelagic species which occur in this northern region of the Alaska continental shelf.

RESULTS OF THE DEMERSAL SURVEY

A total of 242 demersal stations was planned for the survey. Of these, 192 were successfully trawled (Figure VIII-6) and were used in estimating biomass (Table VIII-2). The remaining planned stations either had rough or muddy bottoms preventing successful station completions (23 stations) (Figure VIII-7); were identified as untrawlable from echosounding transects (19 stations); or, though within the survey boundaries, were not fished because they were west of the continental shelf median line (8 stations). 1/

Table VIII-2.--Number of stations successfully trawled and sampling density by total survey area and stratum, BLM/OCS survey, September-October, 1976.

Subarea	1 Southeastern Chukchi Sea		2 Kotzebue Sound		3 Northern Bering Sea		4 Norton Sound		Total
Stratum	1N	1S	2Ø	21	3W	3E	4Ø	41	
Stations planned for sampling	36	19	20	13	48	16	64	26	242
Stations successfully trawled	29	15	19	8	32	14	58	17	192
Area in km^2	28,321	12,667	7,193	5,076	36,458	10,249	22,300	8,895	131,159
Sampling density (km^2/station)	976.6	844.5	378.6	634.5	1139.3	732.1	384.5	523.2	683.1

Fish and invertebrate taxa collected during the survey are listed in Tables VIII-3 and VIII-4, respectively.

Along with station and catch information for all of the trawling stations, specimen data included: 31,609 length measurements, 2,105 readable age structures, and 2,020 length-weight measurements for fish; 10,445 carapace measurements for crabs; and 4,147 measurements of shell size for snails (Tables VIII-5 to 9).

Bottom temperature isotherms as determined during the survey are shown in Figure VIII-8.

1/ A boundary established by the 1958 International Convention of the Continental Shelf for dividing shelf areas adjacent to two territories, in this instance, between the U.S. and U.S.S.R. The boundary limits the area for harvest or collection of creatures of the continental shelf such as crabs and other bottom-dwelling organisms.

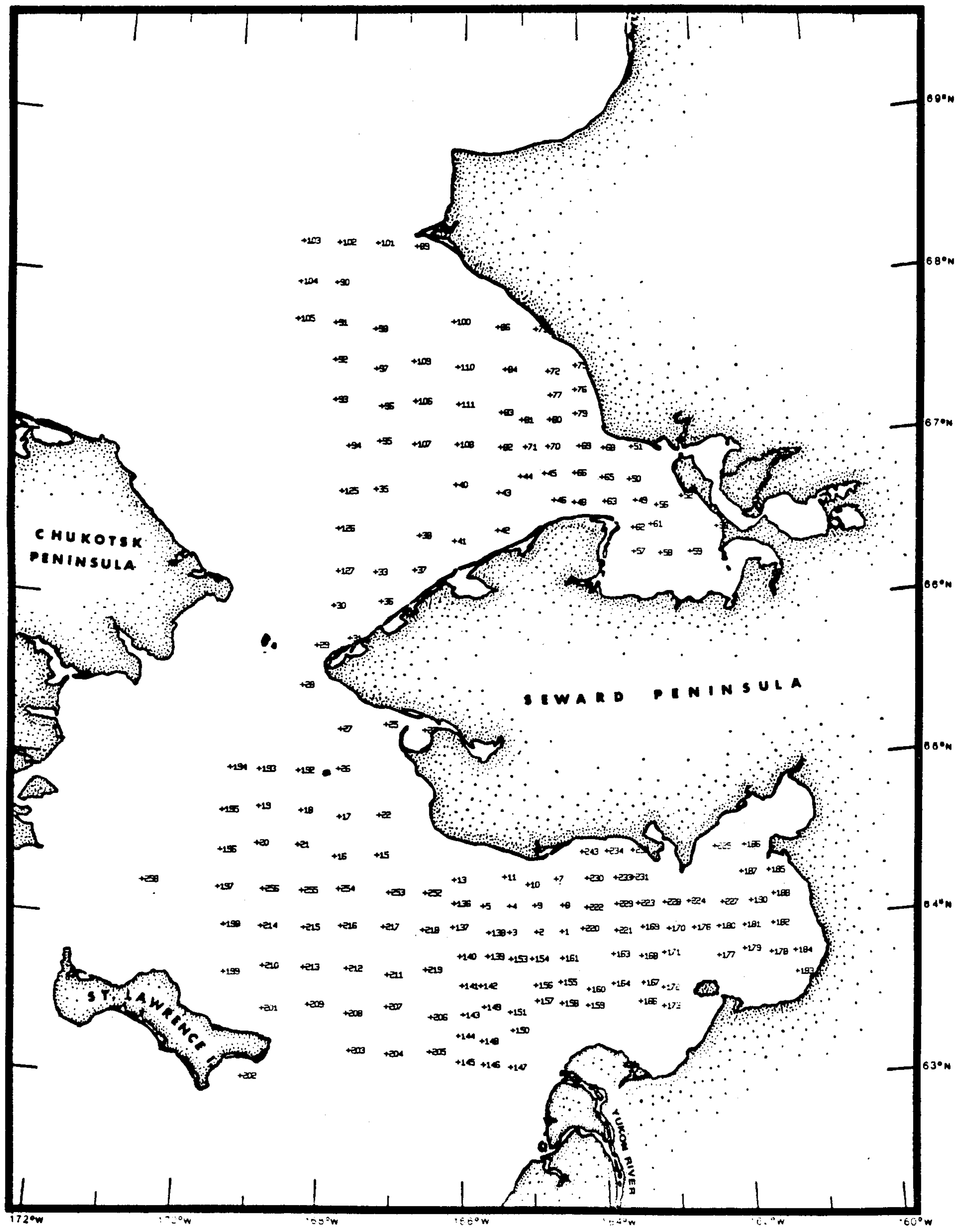


Figure VIII-6.--Demersal stations successfully sampled during the 1976 survey.

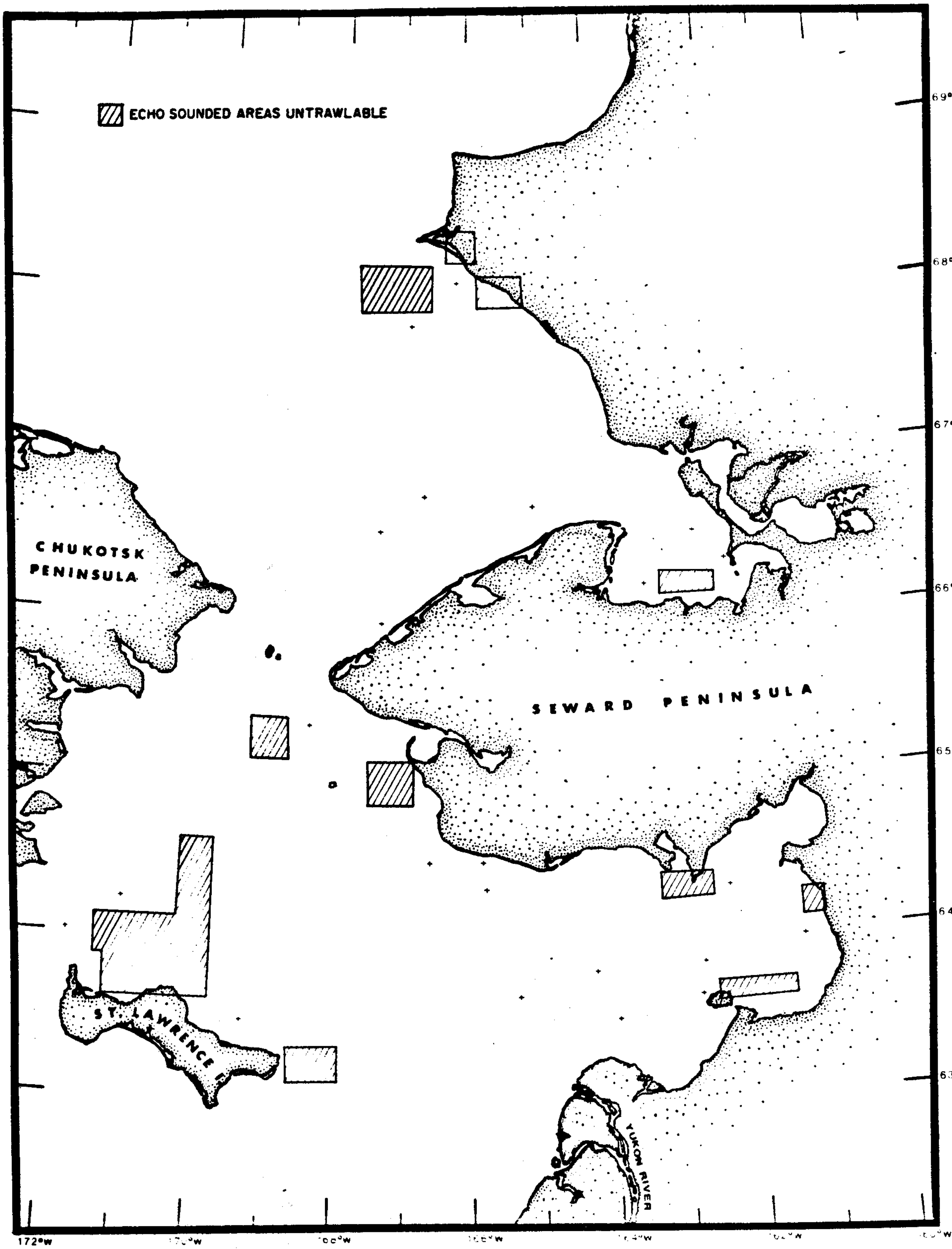


Figure VIII-7.--Untrawlable areas and unsuccessful trawl stations (indicated by '4") encountered during the 1976 BLM/OCS survey.

Table VIII-3.--List of fish species collected in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).[1/]

Species		Common Name
	CLUPEIDAE	
Clupea harengus pallasi		Pacific herring
	SALMONIDAE	
Oncorhynchus keta		Chum salmon
Oncorhynchus gorbuscha		Pink salmon
Oncorhynchus tshawytscha		King salmon
Coregonus laurettae		Bering cisco
Salvelinus alpinus		Arctic char
	OSMERIDAE	
Mallotus villosus		Capelin
Osmerus mordax dentex		Toothed or rainbow smelt
Hypomesus olidus		Pond smelt
	GADIDAE	
Boreogadus saida		Arctic cod
Eleginus gracilis		Saffron cod
Theragra chalcogramma		Pollock
Gadus macrocephalus		Pacific cod
	ZOARCIDAE	
Lycodes turneri		Polar eelpout
Lycodes palearis		Wattled eelpout
Gymnelis viridus		Fish doctor
	HEXAGRAMMIDAE	
Hexagrammos stelleri		Whitespotted greenling
	COTTIDAE	
Artediellus uncinatus		Arctic hookear sculpin
Enophrys diceras		Antlered sculpin
Gymnocanthus pistilliger[2/]		Threaded sculpin
Gymnocanthus tricuspis		Arctic staghorn sculpin
Hemilepidotus jordani		Yellow Irish Lord
Megalocottus platycephalus		Belligerent sculpin
Myoxocephalus jaok		Plain sculpin
Myoxocephalus scorpius groenlandicus[3/]		Shorthorn sculpin
Myoxocephalus quadricornis		Fourhorn sculpin
Nautichthys pribilovius		Eyeshade sculpin
Psychrolutes paradoxus		Tadpole sculpin
Triglops pingeli		Ribbed sculpin

Table VIII-3 (Cont'd)

AGONIDAE	
Aspidophoroides olriki	Arctic alligatorfish
Occella dodecaedron	Bering poacher
Pallasina barbata	Tubenose poacher
Agonus acipenserinus	Sturgeon poacher
CYCLOPTERIDAE	
Cyclopteridae sp.	Snailfish sp.
Eumicrotremus orbis	Pacific spiny lumpsucker
ANARHICHADIDAE	
Anarhichas orientalis	Bering wolffish
STICHAEIDAE	
Chirolophus polyactocephalus	Decorated warbonnet
Lumpenus fabricii	Slender eelblenny
Lumpenus mackayi 2/	
Stichaeus punctatus	Arctic shanny
Eumesagrammus praecisus	Fourline snakeblenny
AMMODYTIDAE	
Ammodytes hexapterus	Pacific sand lance
GASTEROSTEIDAE	
Pungitius pungitius	Ninespine stickleback
PLEURONECTIDAE	
Hippoglossoides robustus	Bering flounder
Hippoglossus stenolepis	Pacific halibut
Limanda aspera	Yellowfin sole
Limanda proboscidea	Longhead dab
Liopsetta glacialis	Arctic flounder
Platichthys stellatus	Starry flounder
Pleuronectes quadrituberculatus	Alaska plaice
Reinhardtius hippoglossoides	Greenland halibut

1/ Nomenclature from American Fisheries Society 1970, unless otherwise noted.

2/ Nomenclature from Wilimovsky (1958).

3/ Personal communication from N. J. Wilimovsky.

Table VIII-4.--List of invertebrates collected in Norton Sound, the southeastern Chukchi Sea and adjacent waters during the 1976 BLM/OCS survey.[1/]

Phylum PORIFERA	SPONGES
Class Incalcarea	
Family Mycalidae	
Myxilla incrustans	
Stelodoryx sp.[2/]	
Family Microcionidae	
Microciona lambei	
Phylum CNIDARIA (COELENTERATA)	COELENTERATES
Class Anthozoa	
Family Actinstolidae	
Stomphia coccinea	
Family Actiniidae	
Tealia crassicornis	
Family Alcyonacea Nephtheidae	
Eunephthya rubermis	
Phylum TENTACULATA (ECTOPROCTA)	MOSS ANIMALS
Class Bryozoa	
Family Heteroporidae	
Heteropora pelliculata	
Family Diastoporidae	
Mesenteripora meandrina	
Unidentified Bryozoans[2/]	
Phylum SIPUNCULIDA	COELOMATE WORMS
Phascolosoma maritaceum	
Phascolosoma	
Phylum PRIAPULIDA	COELOMATE WORMS
Priapulus caudatus	
Phylum ECHIUROIDEA (ECHIURA)	COELOMATE WORMS
Class Echiurida	
Family Echiuridae	
Echiurus echiurus	
Phylum MOLLUSCA	SNAILS, CLAMS, OCTOPUSES AND OTHERS
Class Gastropoda	
Family Trochidae	
Margarites giganteus[3/]	Large margarite snail
Solariella obscura[3/]	Obscure solarelle
Solariella varicosa[3/]	Varicose solarelle
Solariella sp.[2/] [3/]	Unidentified solarelle snail
Family Turritellidae	
Tachyrhynchus erosus major[3/]	Eroded turret-shell
Tachyrhynchus reticulatus[3/]	Reticulate turret-shell
Family Calyptraeidae	
Crepidula grandis[3/]	Grand slipper-shell
Family Trichotropidae	
Trichotropis bicarinata[3/]	Two-keeled hairy-shell
Trichotropis insignis[3/]	Gray hairy-shell
Trichotropis kroyeri[3/]	Kroyer's hairy-shell

Table VIII-4.--cont.

Family Naticidae	
Natica clausa[3]	Arctic natica
Natica russa[3]	
Natica sp.[2] [3]	Unidentified natica snail
Polinices pallidus[3]	Moon-shell snail
Family Lamellariidae	
Velutina plicatilis[3]	Oblique vetulina
Velutina undata[3]	Undate vetulina
Velutina velutina[3]	Smooth vetulina
Velutina sp.[2] [3]	Unidentified vetulina snail
Family Muricidae	
Boreotrophon clathratus[3]	Clathrate trophon
Family Buccinidae	
Buccinum angulossum[3]	
Buccinum glaciale[3]	Glacial buccinum
Buccinum fringillum[3]	
Buccinum polare[3]	Polar buccinum
Buccinum scalariforme[3]	Silky buccinum
Buccinum solenum[3]	
Buccinum tenellum[3]	
Family Neptuneidae	
Clinopegma sp.[3]	
Clinopegma magna[3]	
Beringius beringii[3]	Bering's buccinum
Beringius fragili	
Beringius stimpsoni[3]	Stimpson's buccinum
Colus hypolispus[3]	
Colus ombronius[3]	
Colus spitzbergensis[3]	Spitzbergen colus
Colus sp.[2] [3]	Unidentified colus welk
Liomesus ooides[3]	
Neptunea borealis[3]	
Neptunea heros[3]	
Neptunea lyrata[3]	Common northwest neptune
Neptunea ventricosa form *beringiana*[3]	Fat neptune
Plicifusus brunneus[3]	
Plicifusus kroeyeri[3]	
Plicifusus verkruzeni[3]	
Pyrulofusus deformis[3]	
Volutopsius castaneus[3]	
Volutopsius filosus[3]	
Volutopsius fragilis[3]	Fragile buccinum
Volutopsius stefanssoni[3]	Stefansson's buccinum
Family Cancellaridae	
Admete couthouyi[3]	Common northern admete
Family Turridae	
Oenopota harpa[3]	
Oenopota nazanensis[3]	
Oenopota sp.[2] [3]	Unidentified lora
Obesotoma simplex[3]	
Family Pyramidellidae	
Odostomia arctica[3]	Arctic odostome
Family Scaphandidae	
Cylichna sp.[2] [3]	Unidentified barrel bubble
Family Dendronotidae	
Dendronotus arborescens	Free frond colis
Family Mopallidae	Amicula chiton
Amicula sp.[2]	

Table VIII-4.--cont.

Class Polyplacophora	
Family Acanthochitonidae	
Cryptochiton stelleri	Giant Pacific chiton
Class Pelecypoda	
Family Nuculidae	
Nucula tenvis	Smooth nut clam
Family Glycymeridae	
Glycymeris subobsoleta	West coast bittersweet
Glycymeris sp.[2/]	Unidentified bittersweet
Family Mytilidae	
Mytilus edulus	Blue mussel
Modiolus modiolus	Northern horse mussel
Musculus discors	Discord musculus
Musculus nigra	Black musculus
Family Astartidae	
Astarte borealis	Boreal astarte
Family Pectinidae	
Chlamys sp.[2/]	Unidentified chlamys scallop
Chlamys islandica	Iceland scallop
Family Cardiidae	
Clinocardium ciliatum	Iceland cockle
Clinocardium nuttalli	Nuttall's cockle
Clinocardium californiensis	California cockle
Serripes groenlandicus	Greenland cockle
Family Carditidae	
Cyclocardia crebricostata	
Cyclocardia crassidens	
Cyclocardia sp.[2/]	Unidentified cardita cockle
Family Myidae	
Mya arenaria	Softshell clam
Mya japonica	Japanese softshell clam
Family Veneridae	
Liocyma fluctuosa	Fluctuating liocyma
Family Mactridae	
Spisula polynyma	Stimpson's surf clam
Family Tellinidae	
Macoma calcarea	Chalky macoma
Macoma sp.[2/]	Unidentified macoma clam
Macoma brota	Brota macoma
Family Hiatellidae	
Hietella arctica	Arctic saxicave
Hiatella sp.	Unidentified saxicave
Panomya arctica	Arctic rough mya
Family Nuculanidae	
Nuculana sp.[2/]	Unidentified nut clam
Nuculana fossa	Fossa nut clam
Yoldia sp.[2/]	Unidentified yoldia clam
Yoldia amygdalea	Almond yoldia
Class Cephalopoda	
Family Octopodidae	
Octopus sp.[2/]	Unidentified octopus
Phylum ANNELIDA	SEGMENTED WORMS
Class Polychaeta	
Family Pectinaridae	
Pectinaria sp.[2/]	

Table VIII-4.—cont.

Family Sternaspidae	
Sternaspis sp.[2]	
Family Nereidae	
Nereis sp.[2]	
Family Sabellidae	
Bispira polymorpha	
Family Flabelligeridae	
Brada sachalina	
Brada sp.[2]	
Phylum ARTHROPODA	BARNACLES, SHRIMP, AND CRAB
Class Crustacea (Decapoda)	
Family Pandalidae	
Pandalis goniurus	Humpy shrimp
Pandalis hypsinotus	Coonstripe shrimp
Family Hippolytidae	
Spirontocaris murdochi	
Spirontocaris arcuata	
Eualus sp.[2]	
Heptacarpis sp.[2]	
Lebbus sp.[2]	
Family Crangonidae	
Crangon dalli	
Argis lar	
Sclearograngon boreas	
Family Lithodidae	
Hapalogaster grebnitzbii	
Paralithodes camtschatica	Red king crab
Paralithodes platypus	Blue king crab
Family Majidae	
Chionoecetes opilio	Tanner crab
Hyas coarctatus alutaceus	Lyre crab
Hyas lyratus	Lyre crab
Family Paguridae	
Labidochiris splendescens	
Pagurus arcuatus	Hermit crab
Pagurus trigonochierus	Hermit crab
Pagurus rathbuni	Hermit crab
Pagurus ochotensis	Hermit crab
Pagurus capillatus	Hermit crab
Family Atelecyclidae	
Telemessus cheiragonus	Telemessus crab
Family Balanidae	
Balanus sp.[2]	Unidentified barnacle
Balanus cariosus	
Class Isopoda	
Family Idoteidae	
Synidothea bicuspida	
Synidothea nodulosa	
Saduria entomon	
Family Sphaeromatidae	
Tecticeps alascensis	
Class Amphipoda	
Family Stegocephalidae	
Stegocephalopsis ampulla	

Table VIII-4.--cont.

Family Lysianassidae	
Socarnes bidenticulatus	
Anonyx nygax	
Anonyx sp.[2]	
Family Podoceridae	
Dulicha spinosissima	
Family Eusiridae	
Rhachotropis aculeata	
Rhachotropis sp.[2]	
Eusirus cuspidatus	
Family Hyperiidae	
Parathemisto japonica	
Family Gammaridae	
Melita sp.[2]	
Melita dentata	
Phylum ECHINODERMATA	STARFISH, BASKETSTARS, SEA URCHINS AND OTHERS
Class Asteroidea	
Family Pterasteridae	
Pteraster obscura	
Family Solasteridae	
Crossaster papposus	
Solaster endeca	
Family Asteridae	
Evasterias troschelli	
Evasterias echinata	
Asterias amurensis	
Leptastedias sp.[2]	
Leptasterias polaris	
Lethasterias nanimensis	
Family Echinasteridae	
Henrica sp.[2]	
Class Ophiuroidea	
Family Ophiolepididae	
Stegophiura sp.[2]	
Ophiura sarsi	
Family Gorgonocephalidae	
Gorgonocephalus caryi	basketstar
Family Ophiactidae	
Ophiopholis aculeata	
Class Echinoidea	
Family Strongylocentrotidae	
Strongylocentrotus drobachiensis	
Strongylocentrotus sp.[2]	Unidentified sea urchin
Family Echinarachniidae	
Echinarachnius parma	Sand dollar
Class Holothuroidea	
Family Cucumariidae	
Cucumaria sp.[2]	
Cucumaria caleigera	
Family Stichopodidae	
Stichopus sp.[2]	
Parastichopus sp.[2]	
Family Chiridotidae	
Chirodota pellacida	
Family Psolidae	
Psolus japonicus	

Table VIII-4.--cont.

Family Myriotrochidae	
Myriotrochus rinkii	
Phylum CHORDATA (TUNICATA)	ASCIDIANS
Class Ascidiacea Phlebobranchia	
Family Pyuridae	
Boltenia ovifera	Sea onion
Boltenia echinata	
Halocynthia aurantium	Sea potato
Family Stylelidae	
Pelonaia corrugata	
Family Rhodosomatidae	
Chelysoma sp.[2]	
Chelysoma columbianum	
Styela macrenteron	

1/ Nomenclature primarily according to Pavlovskii (1955) and identification, unless otherwise noted, by University of Alaska, Institute of Marine Science staff.

2/ Unknown number of species.

3/ Identification by R. MacIntosh, NMFS, NWAFC, Kodiak Facility.

Table VIII-5. -- Number of length measurements by species, sex, and subarea in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Species	Subarea	Number of Fish Measured				Number of Observation Sets
		Male	Female	Unsexed	Total	
Yellowfin sole	1N	0	0	0	0	
	1S	24	44	0	68	7
	2I	55	79	0	134	6
	2Ø	13	15	0	28	4
	3W	2	4	0	6	3
	3E	69	170	0	239	7
	4Ø	1,184	1,275	0	2,459	52
	4I	231	246	0	477	12
	TOTAL	1,578	1,833	0	3,411	91
Starry flounder	1N	2	7	0	9	1
	1S	5	19	21	45	6
	2I	0	2	0	2	1
	2Ø	2	0	0	2	2
	3E	52	29	0	81	6
	4Ø	239	226	0	465	45
	4I	19	9	0	28	9
	TOTAL	319	292	21	632	70
Pacific herring	1N	50	74	0	124	5
	1S	95	96	0	191	9
	2I	3	5	0	8	2
	2Ø	337	349	0	686	17
	3W	25	20	0	45	4
	3E	122	109	0	231	9
	4Ø	180	131	96	407	26
	4I	2	0	0	2	1
	TOTAL	814	784	96	1,694	73
Arctic cod	1N	373	273	590	1,236	25
	1S	124	81	0	205	7
	2I	13	15	0	28	3
	2Ø	103	113	30	246	13
	3W	115	119	169	403	21
	3E	96	63	66	225	12
	4Ø	665	674	4	1,343	41
	4I	60	58	0	118	15
	TOTAL	1,549	1,396	859	3,084	137
Saffron cod Adult	1N	10	8	0	18	5
	1S	119	38	0	157	11
	2I	13	20	0	33	2
	2Ø	161	156	0	317	11
	3W	9	51	0	60	8
	3E	522	548	0	1,070	13
	4Ø	5,081	3,621	42	8,744	58
	4I	564	372	0	936	17
	TOTAL	6,479	4,814	42	11,335	125
Pollock	1N	9	5	0	14	2
	1S	35	16	0	51	3
	3W	31	18	36	85	7
	3E	7	37	21	48	6
	4Ø	12	8	89	109	11
	4I	0	0	0	0	0
	TOTAL	94	84	146	324	29

Table VIII-5. -- (cont'd)

Toothed smelt	1N	95	64	0	159	7
	1S	43	24	13	80	8
	2I	29	23	0	52	5
	2∅	311	183	20	514	18
	3W	30	35	0	65	5
	3E	464	280	177	921	12
	4∅	837	577	103	1,517	48
	4I	98	82	0	180	10
	TOTAL	1,907	1,268	313	3,488	113
Alaska plaice	1N	15	3	0	18	3
	1S	60	28	0	88	8
	2I	31	19	0	50	5
	2∅	57	28	0	85	10
	3W	10	18	0	28	6
	3E	88	68	0	156	7
	4∅	332	327	0	659	50
	4I	216	105	0	321	15
	TOTAL	809	596	0	1,405	104
Capelin	1N	0	0	121	121	3
	1S	0	0	46	46	3
	2∅	0	0	47	47	1
	3W	37	55	217	309	10
	3E	0	0	98	98	2
	4∅	0	1	0	1	1
	4I	9	16	0	25	3
	TOTAL	46	72	529	647	23
Longhead dab	1S	2	3	0	5	1
	2∅	9	16	0	25	3
	3E	18	43	0	61	4
	4∅	85	178	0	263	14
	4I	1	0	0	1	1
	TOTAL	115	240	0	355	23
Bering flounder	1N	34	68	0	102	19
	1S	1	4	0	5	3
	2∅	16	14	0	30	6
	TOTAL	51	86	0	137	28
Arctic flounder	1N	0	1	0	1	1
	1S	0	1	0	1	1
	2I	9	14	0	23	1
	2∅	4	2	0	6	1
	4∅	2	42	0	44	9
	4I	0	1	0	1	1
	TOTAL	15	61	0	76	14
Saffron cod Juvenile	1N	0	0	344	344	6
	1S	0	0	424	424	8
	2I	0	0	182	182	3
	2∅	0	0	304	304	7
	3W	0	0	85	85	4
	3E	0	0	372	372	10
	4∅	164	0	2,778	2,942	47
	4I	0	0	368	368	12
	TOTAL	164	0	4,857	5,021	97
TOTAL, ALL SPECIES		31,609				

Table VIII-6.--Number of readable age structures collected by species, sex, and otolith area in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Species	Sex	Otolith Area: North Southeastern Chukchi Sea and Kotzebue Sound	Otolith Area: South Norton Sound and Northern Bering Sea	Areas Combined
Arctic cod	Male	66	57	123
	Female	68	73	141
Alaska plaice	Male	52	93	145
	Female	33	118	151
Bering flounder	Male	13	2	15
	Female	40	2	42
Pacific herring	Male	85	66	151
	Female	65	58	123
Saffron cod	Male	130	136	266
	Female	135	160	295
Starry flounder	Male	--	61	61
	Female	--	24	24
Toothed smelt	Male	53	76	129
	Female	45	74	119
Yellowfin sole	Male	39	93	132
	Female	78	110	188

Table VIII-7.--Number of weight-at-length observations by species, sex, and otolith area in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Species	Sex	Otolith Area: North Southeastern Chukchi Sea and Kotzebue Sound	Otolith Area: South Norton Sound and Northern Bering Sea	Areas Combined
Arctic cod	Male	70	67	137
	Female	74	70	144
Alaska plaice	Male	48	93	141
	Female	33	121	154
Bering flounder	Male	17	1	18
	Female	38	1	39
Pacific herring	Male	38	24	62
	Female	38	42	80
Saffron cod	Male	122	128	250
	Female	141	152	293
Starry flounder	Male	1	77	78
	Female	6	31	37
Toothed smelt	Male	49	100	149
	Female	31	89	120
Yellowfin sole	Male	38	92	130
	Female	80	108	188

Table VIII-8.--Number of carapace measurements by species, sex, and subarea in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Species	Subarea	Number of crab measured			Number of observation sets
		Male	Female	Total	
Red king crab	2Ø	7	0	7	3
	3W	10	2	12	3
	4Ø	1,277	151	1,431	47
	4I	36	27	63	13
Total		1,330	180	1,513	66
Blue king crab	3W	100	77	177	19
	3E	2	1	3	2
Total		102	78	180	21
Tanner crab	1N	1,955	992	2,947	27
	1S	898	426	1,324	16
	2I	103	103	206	6
	2Ø	1,019	480	1,499	18
	3W	1,717	662	2,379	32
	3E	143	39	182	8
	4Ø	123	91	214	19
	4I	1	0	1	1
Total		5,959	2,793	8,752	127
TOTAL, ALL SPECIES	10,445				

Table VIII-9.--Numbers of shell measurements for snails by species, sex, and subareas in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Species	Subarea	Number of snails measured: Male	Female	Total	Number of observation sets
Neptunea borealis	1N	16	21	37	13
	1S	5	5	10	4
	2I	2	0	2	2
	3W	19	14	33	11
	3E	3	1	4	3
	4Ø	5	15	20	4
	4I	3	2	5	4
Total		53	58	111	41
Neptunea heros	1N	250	218	468	22
	1S	168	117	285	10
	2I	95	82	177	7
	2Ø	15	13	28	5
	3W	391	327	718	27
	3E	161	105	266	11
	4Ø	218	230	448	29
	4I	176	160	336	14
Total		1,474	1,252	2,726	125
Neptunea ventricosa	1N	44	80	124	16
	1S	28	36	64	7
	2I	7	14	21	7
	2Ø	7	9	16	5
	3W	105	134	239	24
	3E	64	107	171	11
	4Ø	27	44	71	24
	4I	18	23	41	12
Total		300	447	747	106
Beringius beringii	1N	15	17	32	14
	1S	9	11	20	7
	2I	6	16	22	5
	2Ø	15	9	24	10
	3W	20	30	50	13
	3E	17	16	33	3
	4Ø	62	84	146	24
	4I	22	17	39	11
Total		166	200	366	87
Volutopsius fragilis	1N	15	12	27	9
	1S	1	3	4	1
	2I	12	3	15	5
	3W	0	3	3	3
	3E	5	2	7	2
	4Ø	3	5	8	2
Total		36	28	64	22
Pyrulofusos deformis	1N	15	2	17	2
	2I	5	7	12	4
	2Ø	1	2	3	1
	3W	21	28	49	11
	3E	14	18	32	2
	4Ø	9	9	18	10
	4I	0	2	2	2
Total		65	68	133	32
TOTAL, ALL SPECIES	4,147				

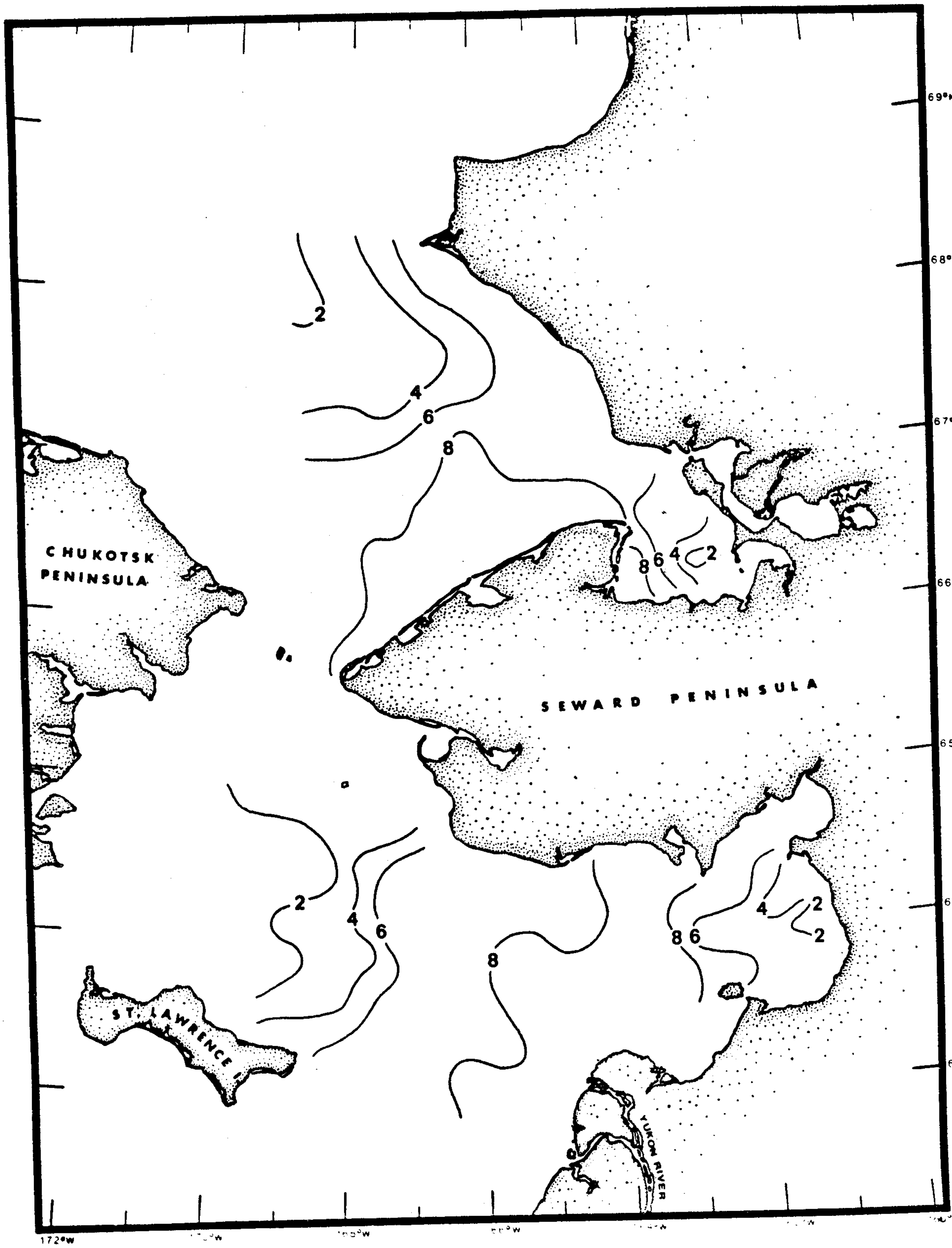


Figure VIII-8.--Bottom temperature isotherms in Norton Sound, the southeastern Chukchi Sea and adjacent waters for September-October as determined from 1976 Baseline survey.

Total Biomass

The total apparent biomass of all fish and invertebrates in the survey area was estimated at about 340 thousand mt (Table VIII-10). Of this, approximately 38% was located in regions north of Bering Strait (subareas 1 and 2) and 62% to the south (subareas 3 and 4).

In terms of relative abundance, the average catch rate for all taxa combined was highest in Norton Sound (subarea 4, 57.5 kg/km) (Table VIII-11 and Figures VIII-9 and 10). The other three regions, the southeastern Chukchi Sea (subarea 1), Kotzebue Sound (subarea 2), and northern Bering Sea (subarea 3), all had similar catch rates (39.3, 42.9, and 37.1 kg/km, respectively) with the lowest occurring in the latter region. Average catch rate for the entire survey area was approximately 43.2 kg/km trawled.

Relative Importance of Major Taxonomic Groups

For the entire survey area, fish fauna were estimated at over 47,000 mt but accounted for only 14% of the total biomass for the region surveyed. The proportion of biomass varied greatly by subarea, ranging from 42.6% in subarea 4 to 8.4% in subarea 2. Most of the fish biomass (over 77%) occurred south of Bering Strait (Table VIII-10).

By subarea, fish contributed from 7 to 19% of total catch rates. Their catch rate was highest in subarea 4 (10.9 kg/km), lower in subareas 2 and 3 (5.4 and 6.0 kg/km, respectively), and lowest in subarea 1 (2.7 kg/km) (Table VIII-11 and Figures VIII-11 and 12). Average total fish catch rate for the entire survey area was 6.1 kg/km trawled.

Overall, invertebrates accounted for 86% of the total demersal biomass; their biomass was estimated at about 290,000 mt. Nearly 60% of the invertebrate biomass was located in subareas 3 and 4 (Table VIII-10), south of Bering Strait; however, this proportion was almost identical to the proportion of area surveyed south of Bering Strait.

By subarea, invertebrate fauna contributed from 81 to 93% of the total catch rates. The average catch rate for total invertebrates was highest in subarea 4 (46.6 kg/km), decreased in subareas 1 and 2 (36.6 and 37.4 kg/km, respectively) and was lowest in subarea 3 (31.1 kg/km) Table VIII-9 and Figures VIII-13 and 14). Average total invertebrate catch rate for the entire survey area was 37.1 kg/km trawled.

Fish Groups

Fishes accounted for only a relatively small proportion of the overall demersal biomass determined for the 1976 survey region. Five fish families, Gadidae, Pleuronectidae, Cottidae, Clupeidae, and Osmeridae, provided over 95% of the estimated total fish biomass. Of these, the most

Table VIII-10. -- Apparent biomass by major taxonomic groups by subarea estimated from the BLM/OCS survey in Norton Sound and the southeastern Chukchi Sea, September-October, 1976.

Taxa	Biomass for 1/ total survey area (mt)	Proportion of total biomass 1/	Biomass by subarea				Proportion of taxa biomass by subarea			
			1	2	3	4	1	2	3	4
Gadidae	22,692	.067	1,447	1,027	7,674	12,544	.063	.045	.338	.553
Pleuronectidae	10,509	.031	2,783	399	1,999	5,328	.264	.038	.190	.507
Cottidae	6,699	.020	695	101	4,547	1,356	.104	.015	.679	.202
Clupeidae	2,878	.009	637	1,607	453	181	.221	.558	.157	.063
Osmeridae	2,463	.007	320	740	1,035	368	.130	.300	.420	.149
Zoarcidae	888	.003	250	65	387	186	.282	.073	.436	.209
Cyclopteridae	574	.002	333	7	224	10	.580	.012	.390	.017
Stichaeidae	222	.001	45	24	23	130	.203	.108	.104	.586
Agonidae	248	.001	83	8	79	78	.335	.032	.319	.315
Other fish	271	.001	8	2	211	50	.029	.007	.779	.186
Total fish	47,444	.140	6,601	3,980	16,632	20,231	.139	.084	.351	.426
Gastropod molluscs	19,341	.057	8,649	1,253	6,368	3,071	.447	.064	.329	.159
Pelecypod molluscs	632	.002	191	40	99	302	.302	.063	.157	.478
Shrimp	2,904	.009	1,171	175	936	622	.403	.060	.322	.214
<u>Chionoecetes</u> sp.	8,741	.026	3,879	3,597	1,210	55	.444	.412	.138	.006
<u>Paralithodes</u> sp.	5,192	.015	76	13	1,515	3,588	.014	.003	.292	.691
<u>Telemessus</u> sp.	2,769	.008	1,199	217	330	1,023	.433	.078	.119	.480
Total commercially important invertebrates	39,579	.117	15,165	5,295	10,458	8,661	.398	.134	.264	.219
Starfish	161,251	.478	38,842	17,252	34,264	70,893	.24	.107	.212	.440
Other echinoderms	27,010	.080	4,221	42	22,626	121	.156	.002	.838	.006
Other invertebrates 3/	62,395	.185	31,337	4,804	19,243	7,011	.502	.077	.308	.146
Total invertebrates	290,235	.859	89,565	27,393	86,591	86,686	.309	.094	.298	.299
TOTAL CATCH 4/	337,679		96,166	31,373	103,223	106,917	.285	.093	.306	.317

1/ Apparent estimated biomass susceptible to the trawl.
2/ Total biomass for all fish and invertebrate taxa.
3/ Primarily includes coelenterates, pagurid crabs and ascidians.
4/ Total catch of all fish and invertebrate taxa.

Table VIII-11. --Average catch per unit effort of major taxonomic groups by subarea estimated from the BLM/OCS survey in Norton Sound and the southeastern Chukchi Sea, September-October, 1976.

Taxa	CPUE for total survey area	Proportion of total CPUE 1/	CPUE by subarea				Proportion of total CPUE by subarea			
			1	2	3	4	1	2	3	4
Gadidae	2.90	.067	0.59	1.40	2.75	6.74	.015	033	.074	.117
Pleuronectidae	1.34	.031	1.14	0.55	0.72	2.86	.029	.013	.019	.050
Cottidae	0.86	.020	0.28	0.14	1.63	0.73	.007	.003	.044	.013
Clupeidae	0.37	.009	0.26	2.20	0.16	0.10	.007	.051	.004	.002
Osmeridae	0.31	.007	0.13	1.01	0.37	0.20	.003	.024	.010	.003
Zoarcidae	0.11	.003	0.10	0.09	0.14	0.10	.003	.002	.004	.002
Cyclopteridae	0.07	.002	0.14	0.01	0.08	0.01	.004	3/	.002	3/
Sticheidae	0.03	.001	0.01	0.03	0.01	0.07	3/	.001	3/	.001
Agonidae	0.03	.001	0.03	0.01	0.03	0.04	.001	3/	.001	.001
Other fish	0.04	.001	0.02	—	0.09	0.02	.001	3/	.002	3/
Total fish	6.06	.140	2.70	5.44	5.97	10.87	.069	.127	.161	.189
Gastropod molluscs	2.47	.057	3.54	1.71	2.29	1.65	.090	.040	.062	.029
Pelecypod molluscs	0.08	.002	0.08	0.06	0.04	0.16	.002	.001	.001	.003
Shrimp	0.37	.009	0.48	0.24	0.34	0.33	.012	.006	.009	.006
Chionoecetes sp.	1.12	.026	1.59	4.91	0.43	0.03	.040	.115	.012	.001
Paralithodes sp.	0.66	.015	0.03	0.02	0.54	1.93	.001	3/	.015	.034
Telemessus sp.	0.35	.008	0.49	0.30	0.12	0.55	.012	.007	.003	.010
Total commercially important invertebrates	5.05	.117	6.20	7.24	3.75	4.65	.158	.169	.101	.081
Starfish	20.61	.478	15.89	23.57	12.30	38.10	.404	.550	.332	.663
Other echinoderms	3.45	.080	1.73	0.06	8.12	0.06	.044	.001	.219	.001
Other invertebrates 2/	7.99	.185	12.81	6.56	6.90	3.78	.326	.153	.186	.066
Total invertebrates	37.10	.860	36.63	37.43	31.08	46.58	.931	.873	.839	.811
TOTAL CATCH 4/	43.16		39.33	42.87	37.05	57.46				

1/ Catch per unit effort (kg/km) for all fish and invertebrate taxa combined.
2/ Primarily includes coelenterates, pagurid crabs and ascidians.
3/ Proportion less than .0005.
4/ Total catch for all fish and invertebrate taxa.

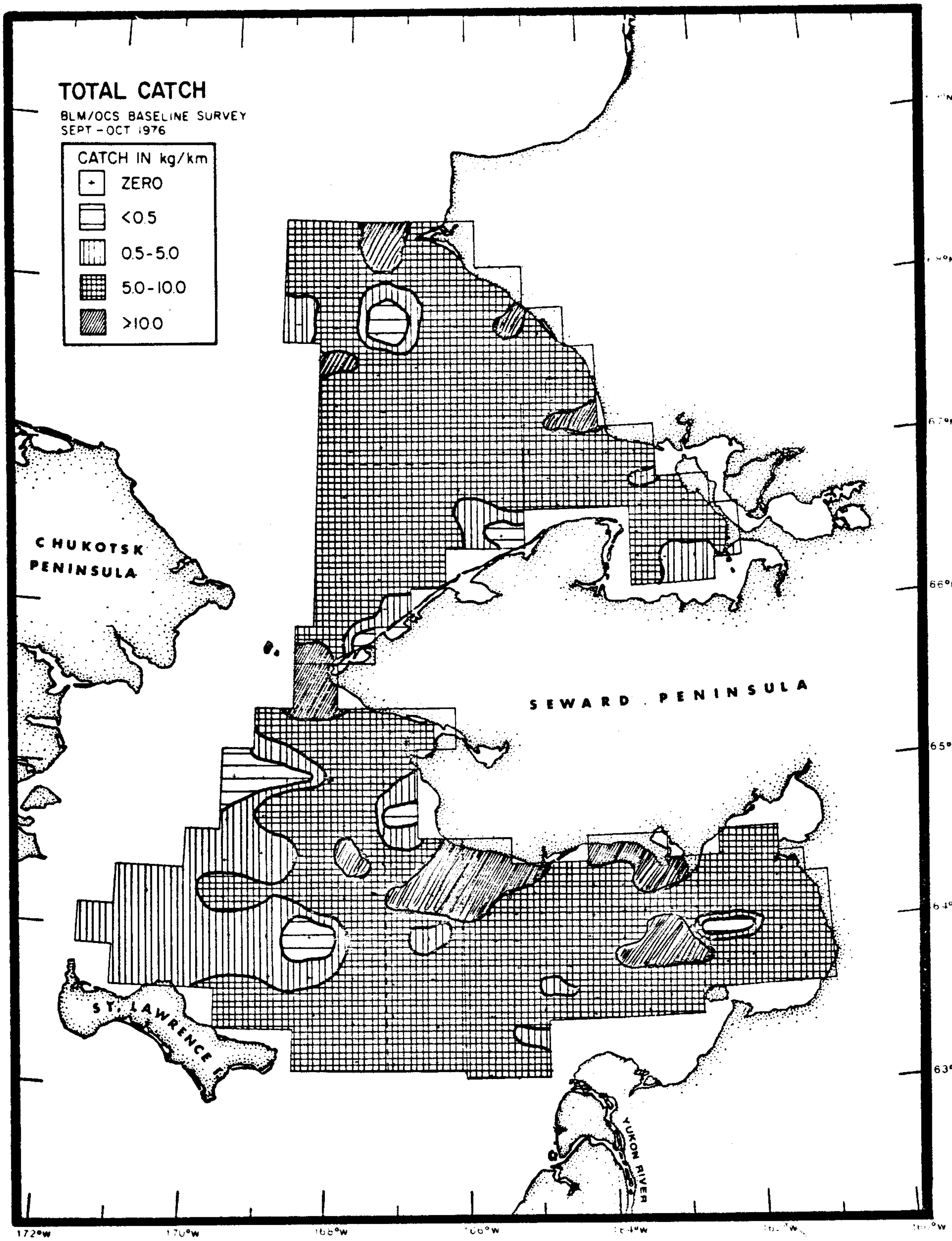


Figure VIII-9.--Distribution and relative abundance by weight of total fish and invertebrates in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

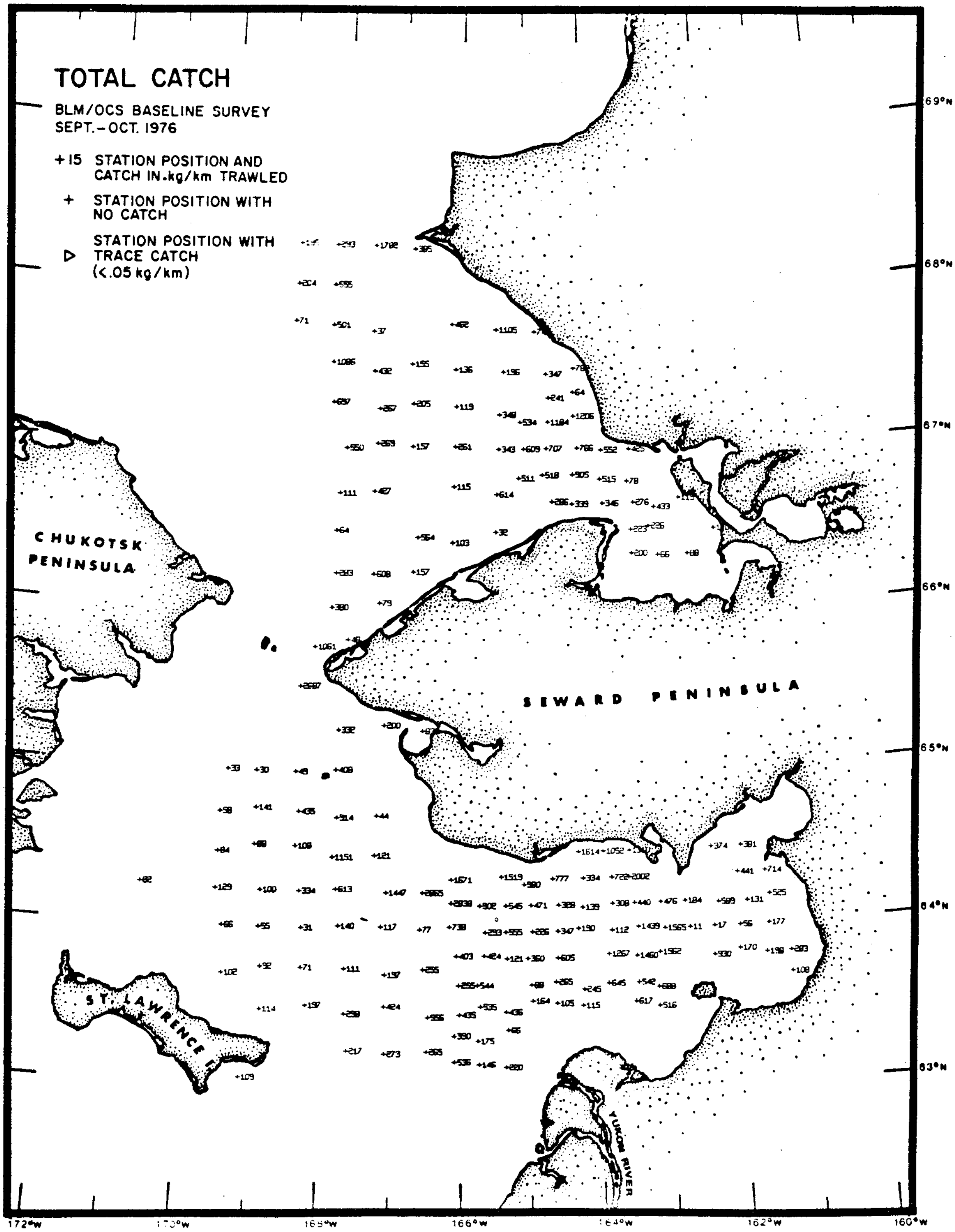


Figure VIII-10.--Distribution of catch rates by weight by total fish and invertebrates in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

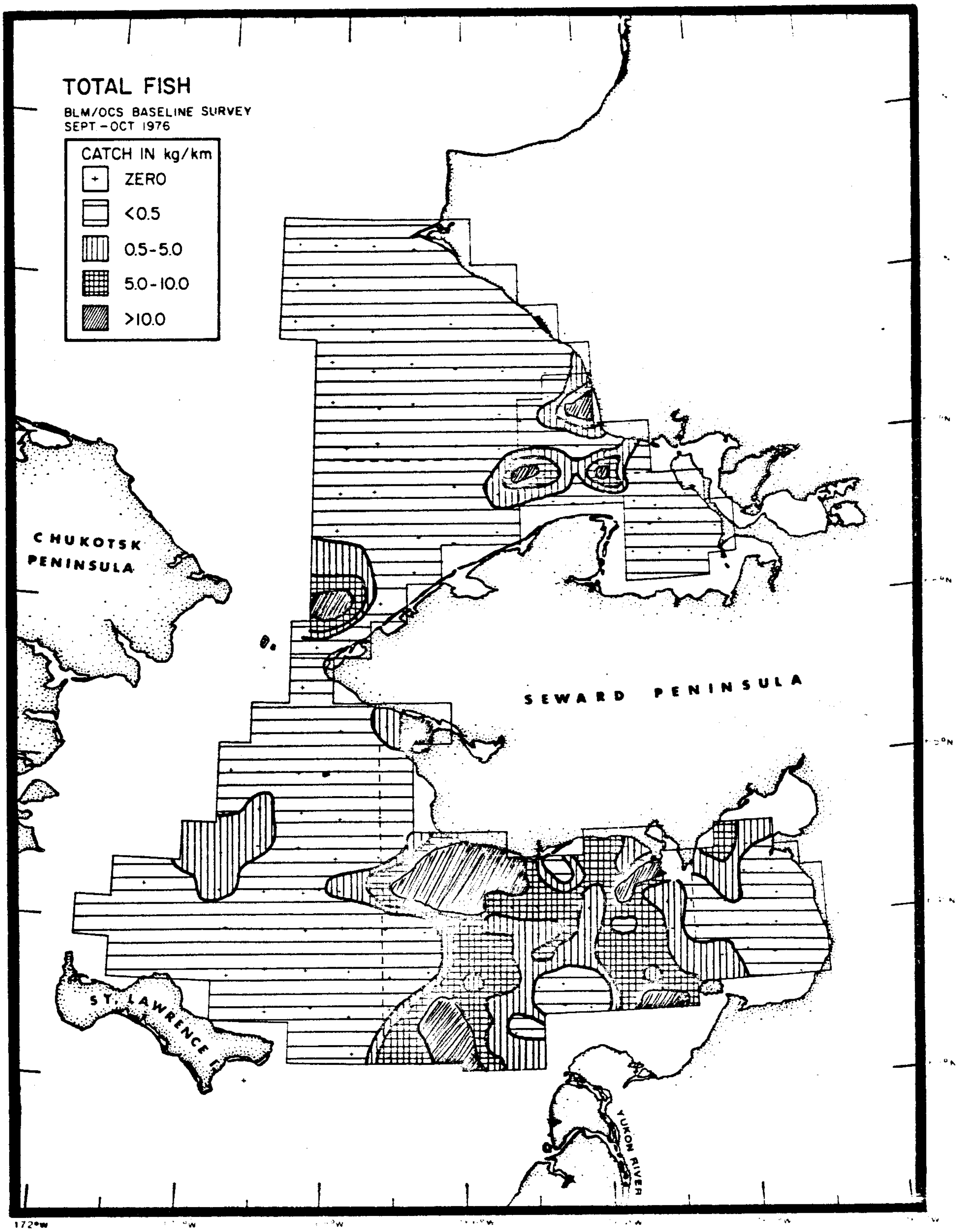


Figure VIII-11.--Distribution and relative abundance by weight of total fish in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

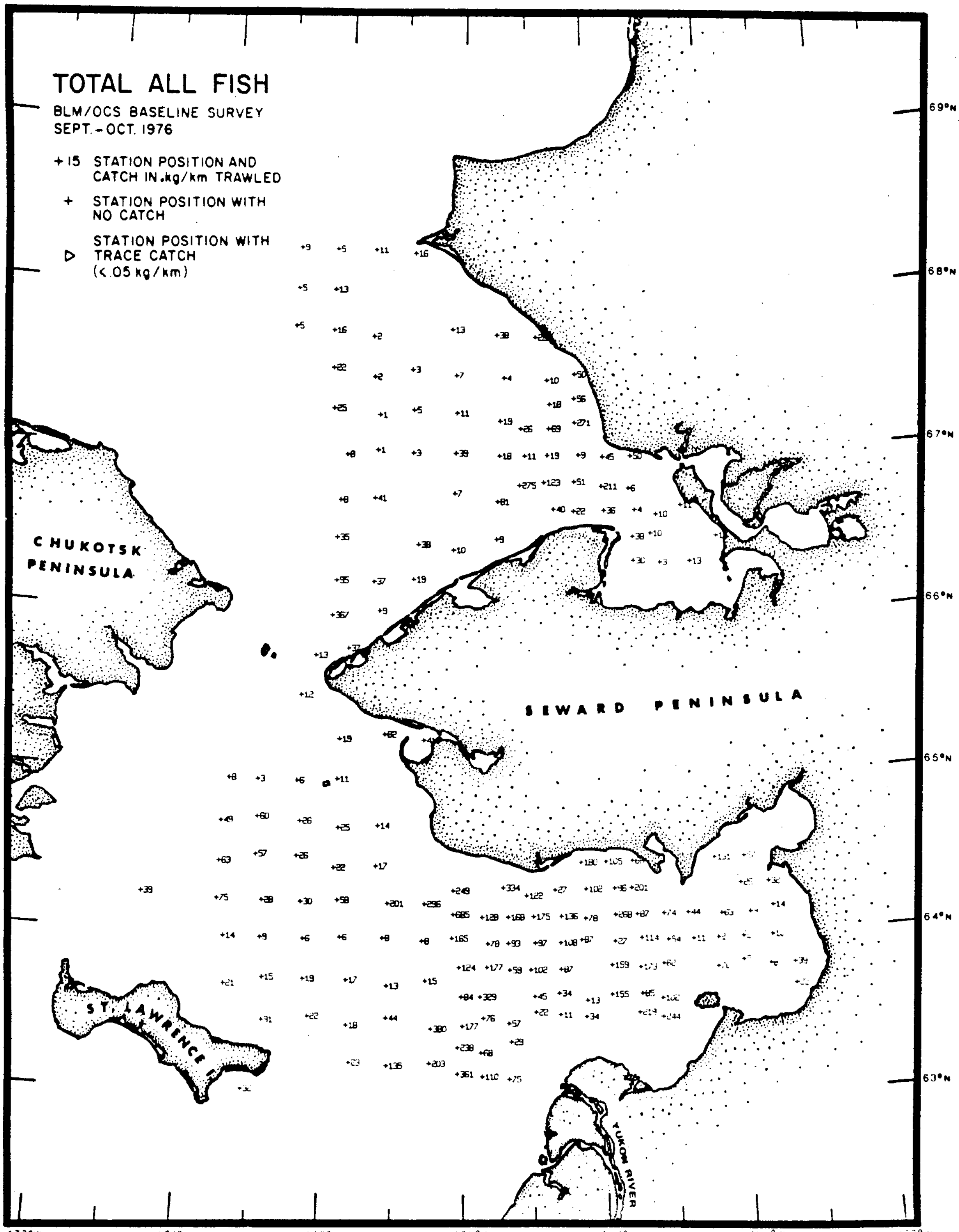


Figure VIII-12.--Distribution of catch rates by weight of total fish in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

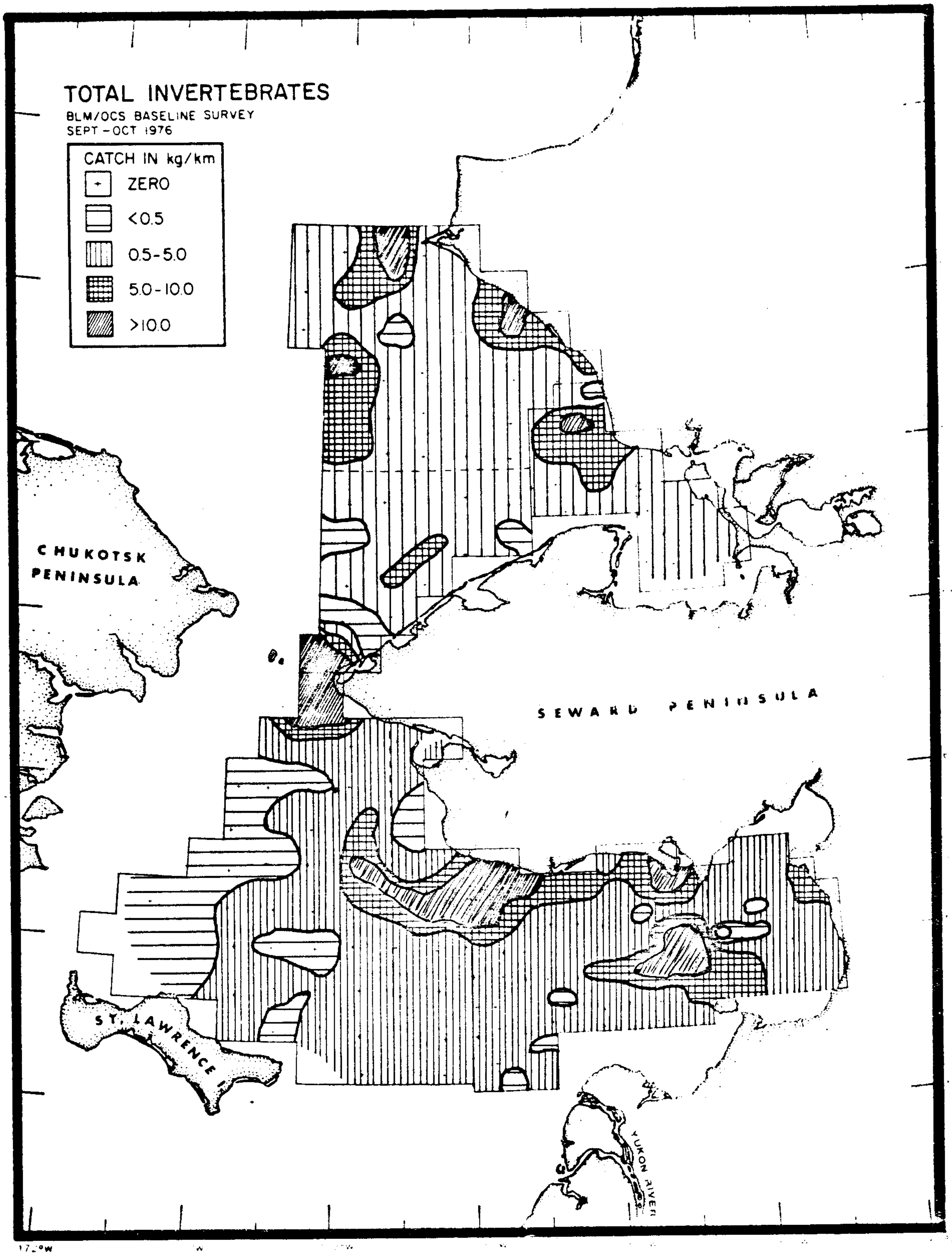


Figure VIII-13.--Distribution and relative abundance by weight of total invertebrates in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

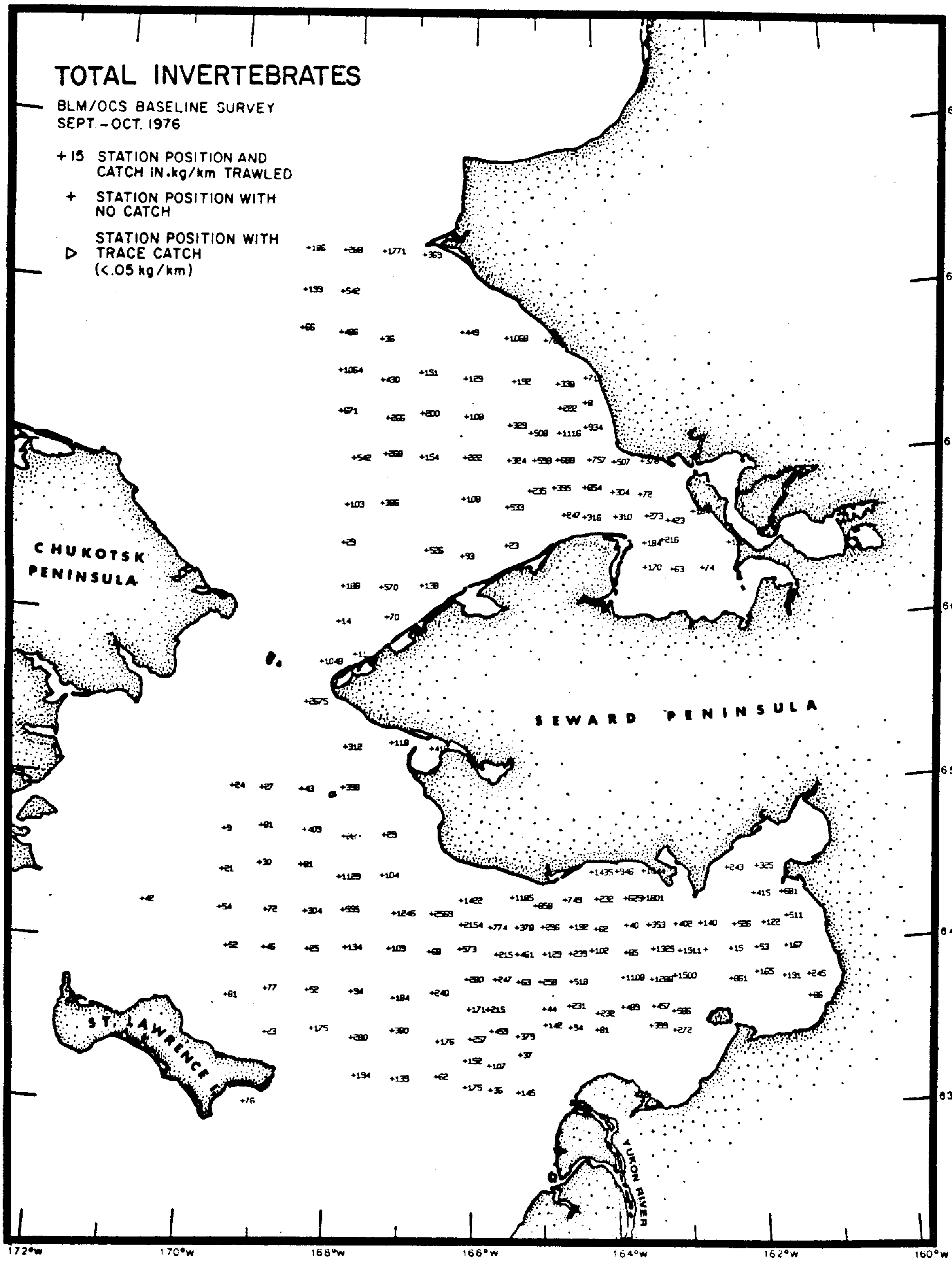


Figure VIII-14.--Distribution of catch rates by weight of total invertebrates in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

abundant families were Gadidae and Pleuronectidae, accounting for 70% of the fish biomass with this proportion varying from 36% in subarea 2 to 89% in subarea 4. Families Cottidae, Clupeidae, and Osmeridae, combined, contributed an additional 25% to total fish biomass. Of these three families, cottids were most abundant in the offshore subarea 3 while clupeids and osmerids were found in greatest concentration in the northern inshore subarea 2. Three other families, Zoarcidae, Stichaeidae, and Agonidae comprised most of the remaining 5% of the total fish biomass. Greatest abundance of these families occurred in the offshore subareas 1 and 3.

Gadidae (saffron cod and Arctic cod)

Gadids were represented by four species (Table VIII-3), with an estimated total apparent biomass of nearly 23,000 mt (Table VIII-10). This family was the most abundant component of the fish community, its members occurring in all subareas and accounting for nearly 48% of the total fish biomass (7% of the total demersal biomass). Two gadids, saffron cod and Arctic cod, comprised 99% of the catch of this family; walleye pollock and Pacific cod were found only in trace amounts. Maximum contribution of the Gadidae to total catch rates occurred in subarea 4 (6.7 kg/km), where they accounted for 62% of the catch rate for all fish (12% of the total demersal fauna catch rate) (Figures VIII-15 and 16).

Pleuronectidae (flatfishes)

The pleuronectids were represented by 8 species and 7 genera, with an apparent total biomass estimated at 11,000 mt. This family ranked second only to the gadids in relative overall abundance, comprising 22% of the total fish biomass for the survey region (Table VIII-10). Three species, starry flounder, Alaska plaice, and yellowfin sole, accounted for nearly 88% of the pleuronectid biomass. Flatfish distribution and abundance varied considerably by subarea (Figures VIII-17 and 18), with the highest average catch rate occurring in subarea 4 (2.9 kg/km), decreasing in subareas 1 and 3 (1.1 and 0.7 kg/km, respectively) and lowest in subarea 2 (0.5 kg/km). Pleuronectidae was the most abundant fish family in subarea 1.

Cottidae (sculpins)

Sculpins were represented by 13 species and 10 genera, with an apparent biomass estimated at nearly 7,000 mt. This family accounted for over 14% of the total fish biomass (2% of total biomass) in the survey area and were distributed over the entire survey region (Figures VIII-19 and 20). Highest catch rates occurred in the offshore subarea 3 (1.6 kg/km), where 68% of the total cottid biomass was found. The average catch rate for cottids over the entire survey region was 0.9 kg/km trawled and three species, the shorthorn sculpin, plain sculpin, and Arctic staghorn sculpin, comprised 86% of this catch rate.

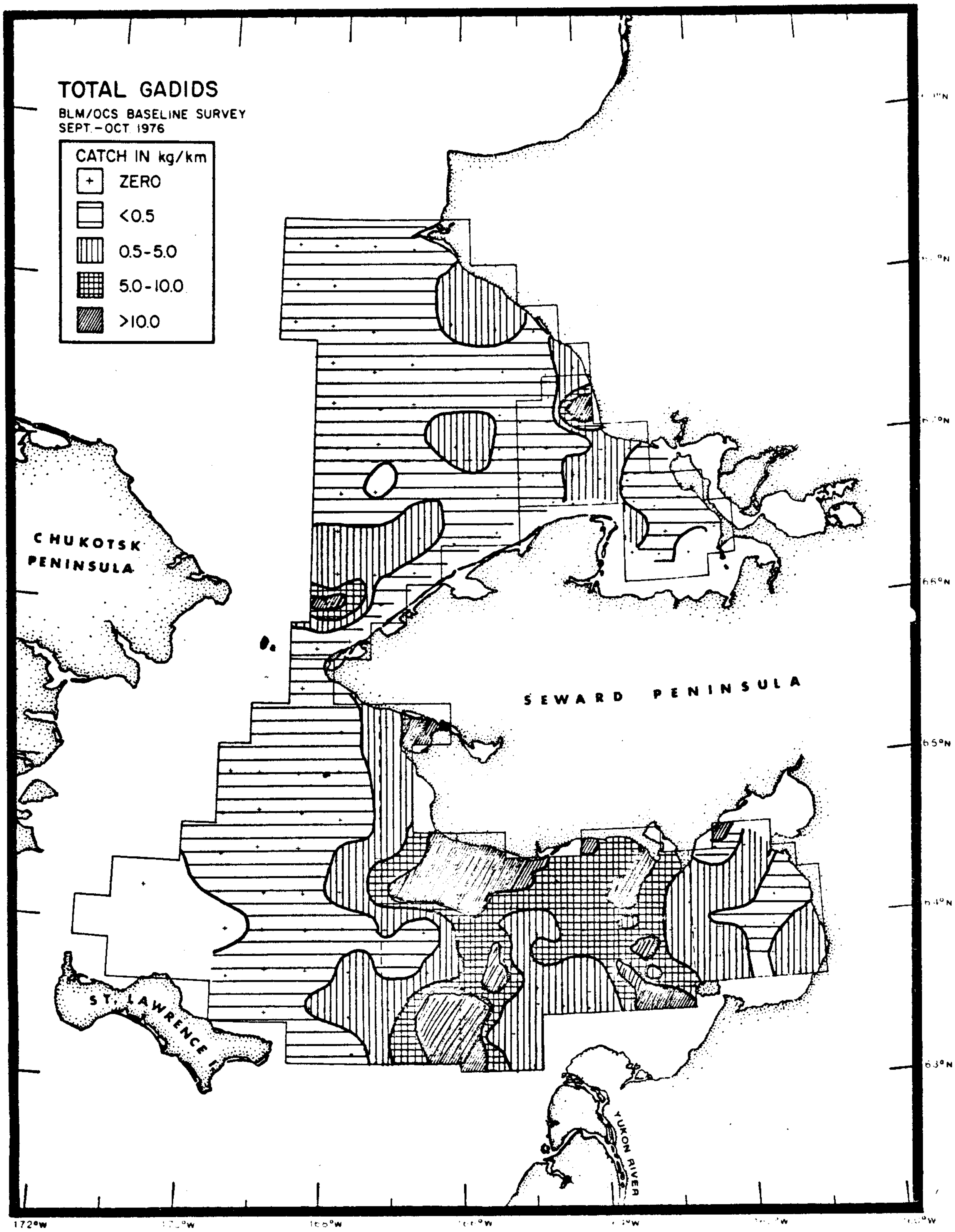


Figure VIII-15.--Distribution and abundance by weight of total gadids in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

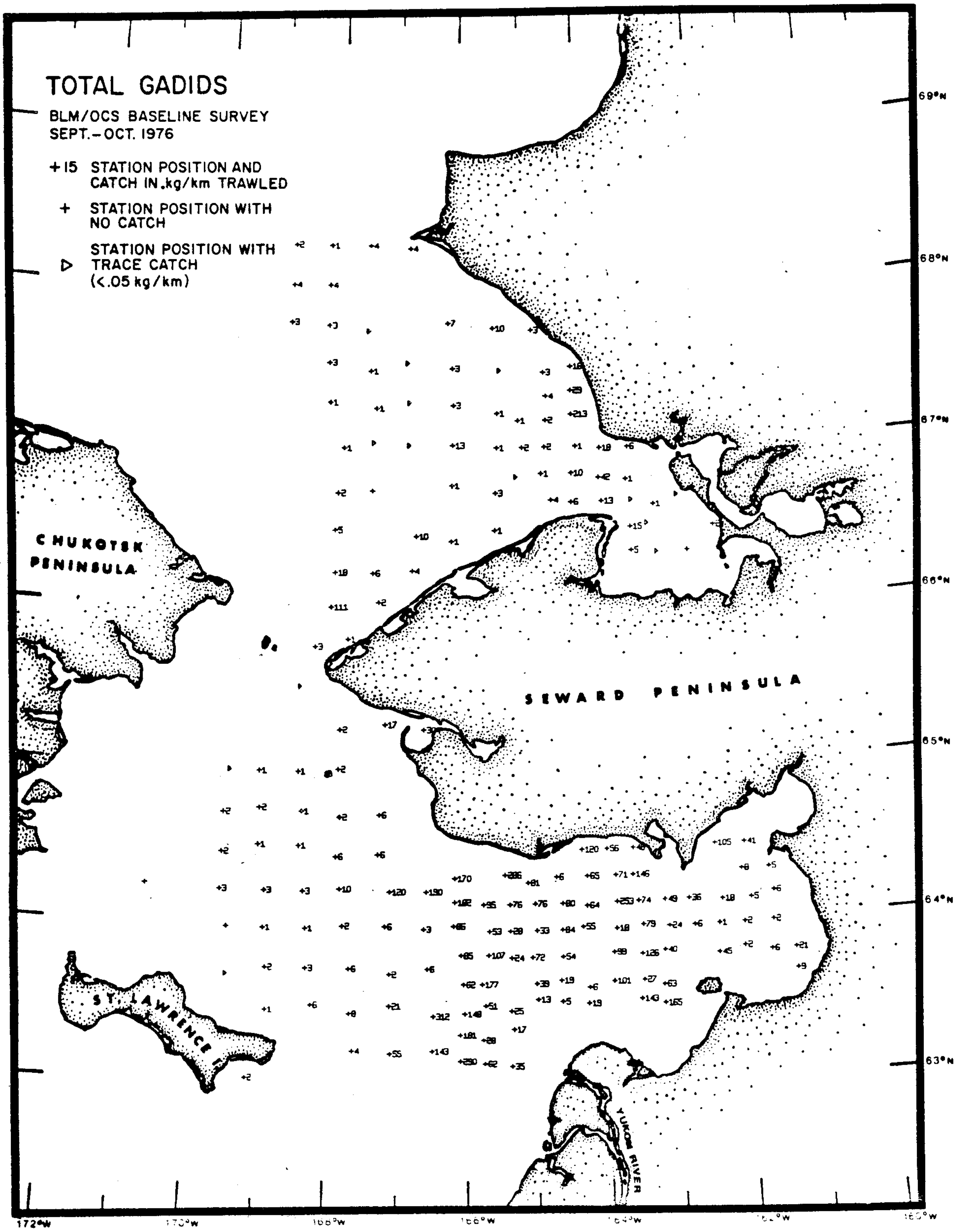


Figure VIII-16.--Distribution of catch rates by weight of total gadids in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

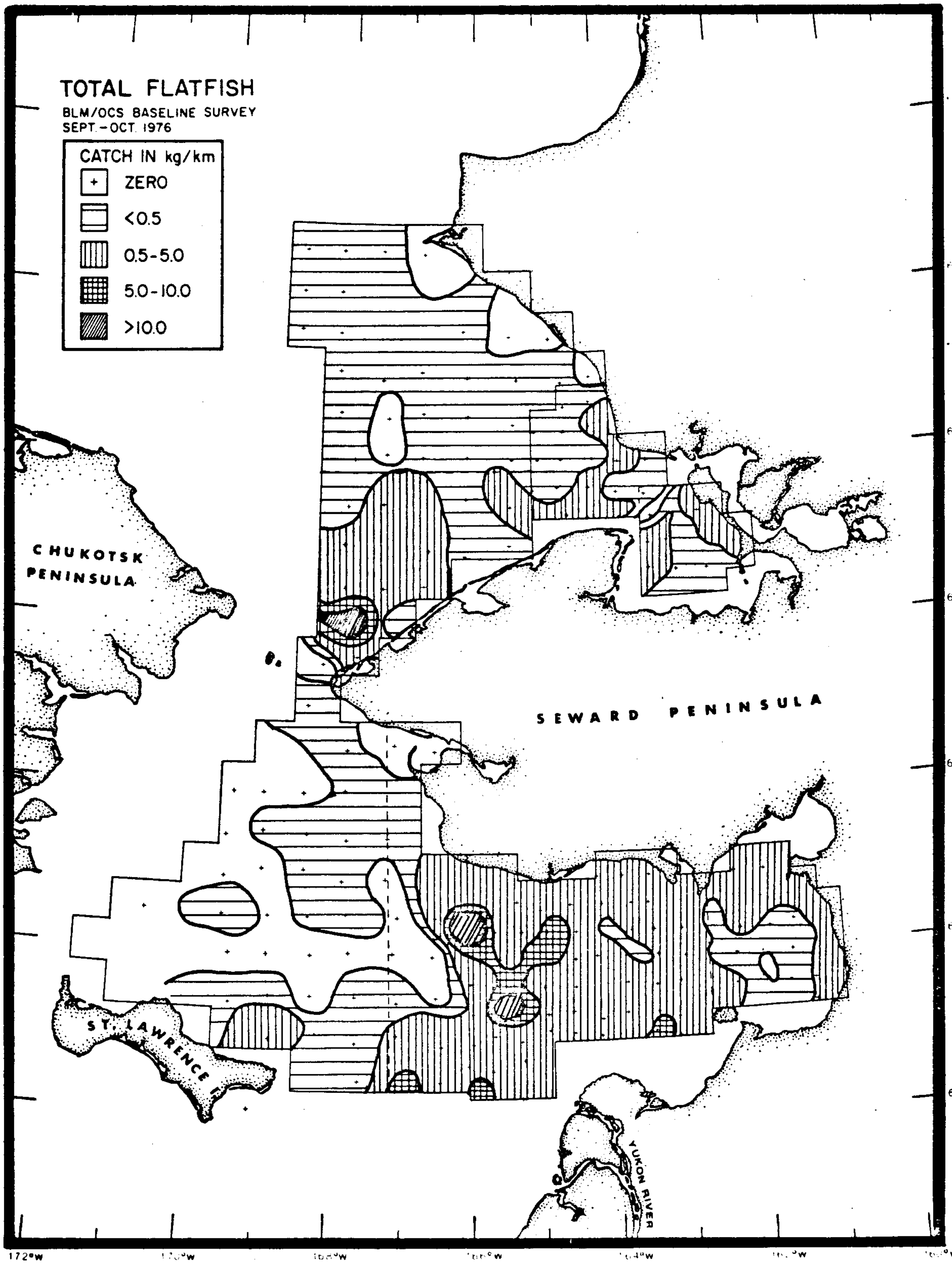


Figure VIII-17.--Distribution and relative abundance by weight of total flatfish in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

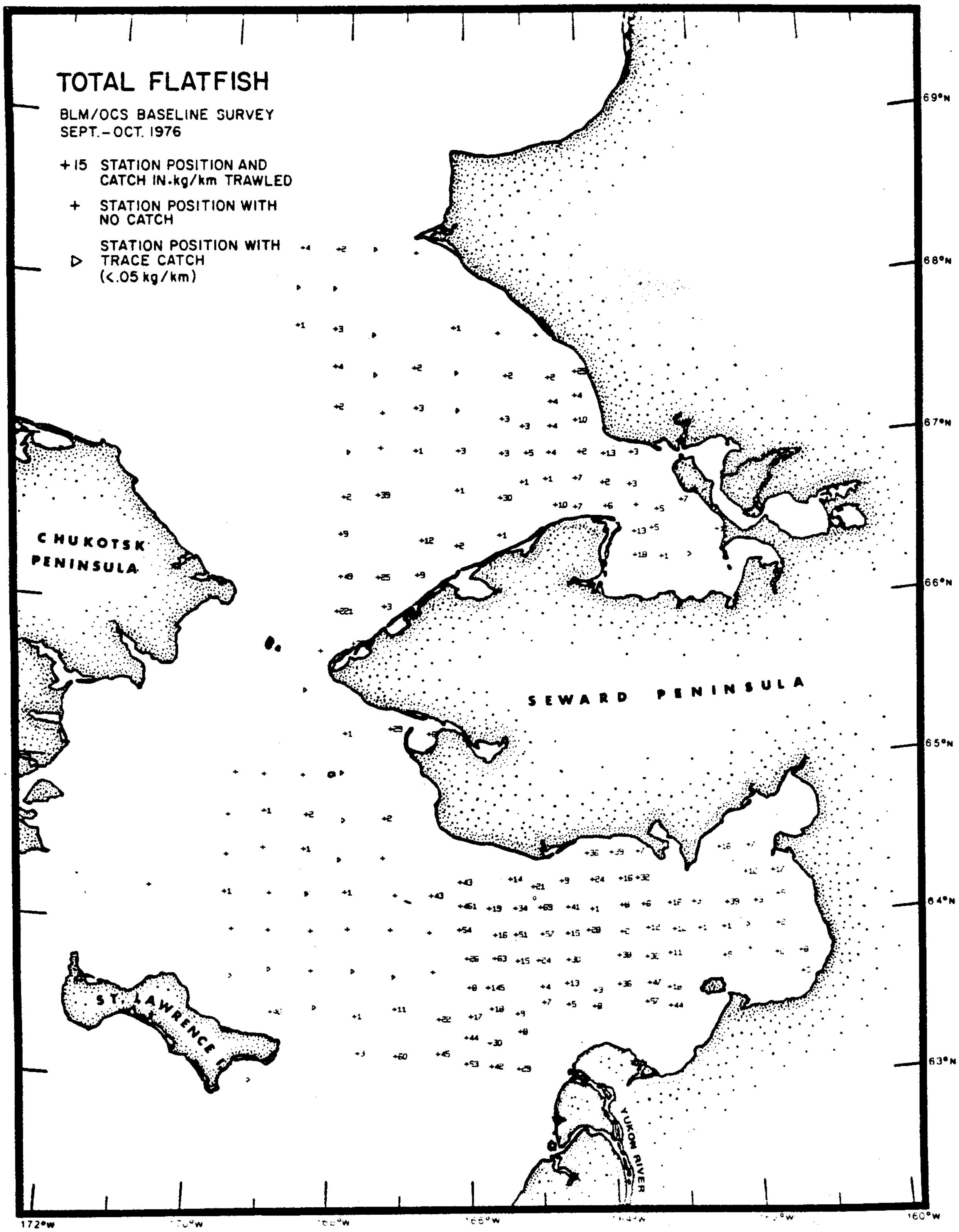


Figure VIII-18.--Distribution of catch rates by weight of total flatfish in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

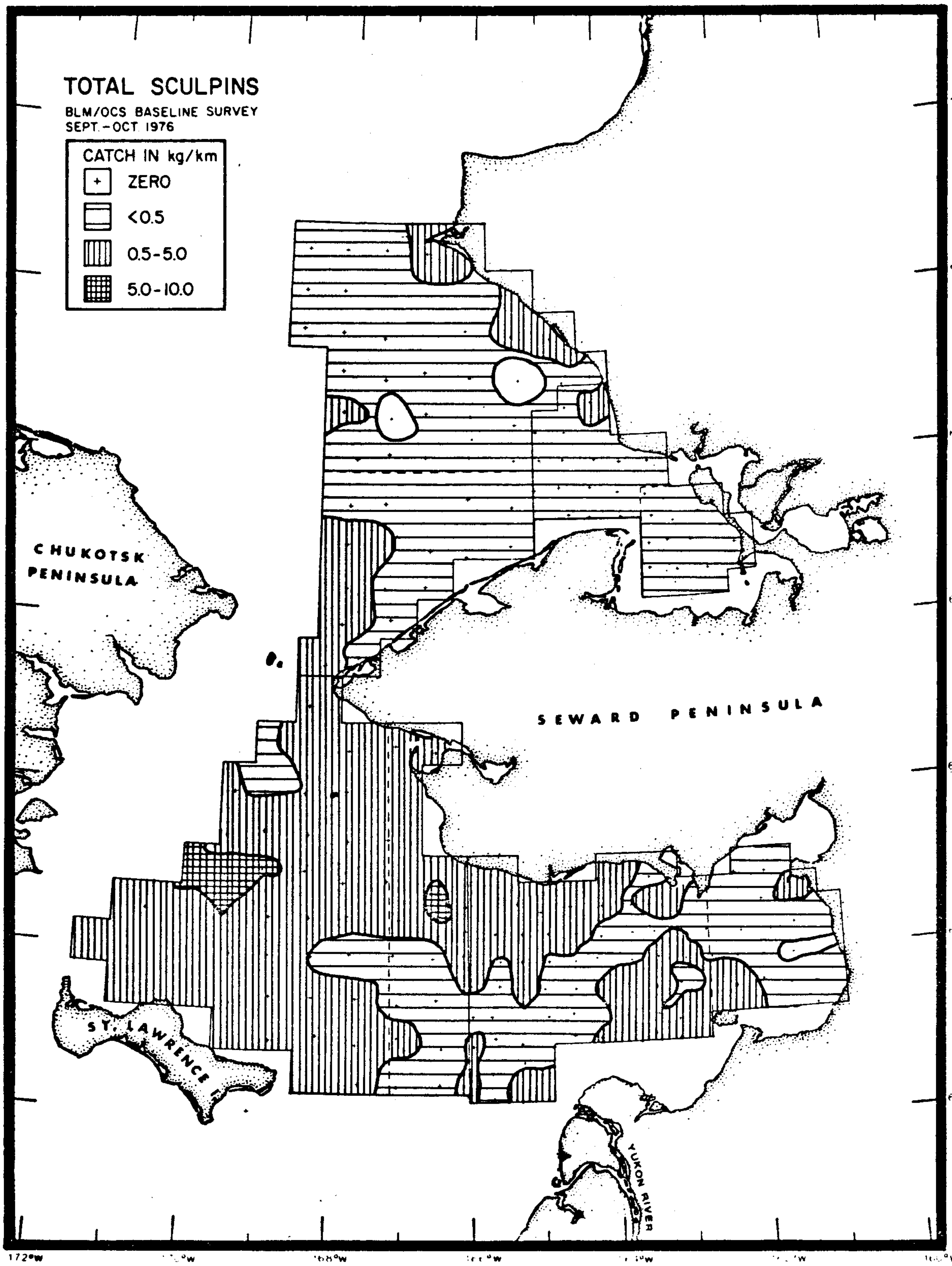


Figure VIII-19.--Distribution and relative abundance by weight of total sculpins in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

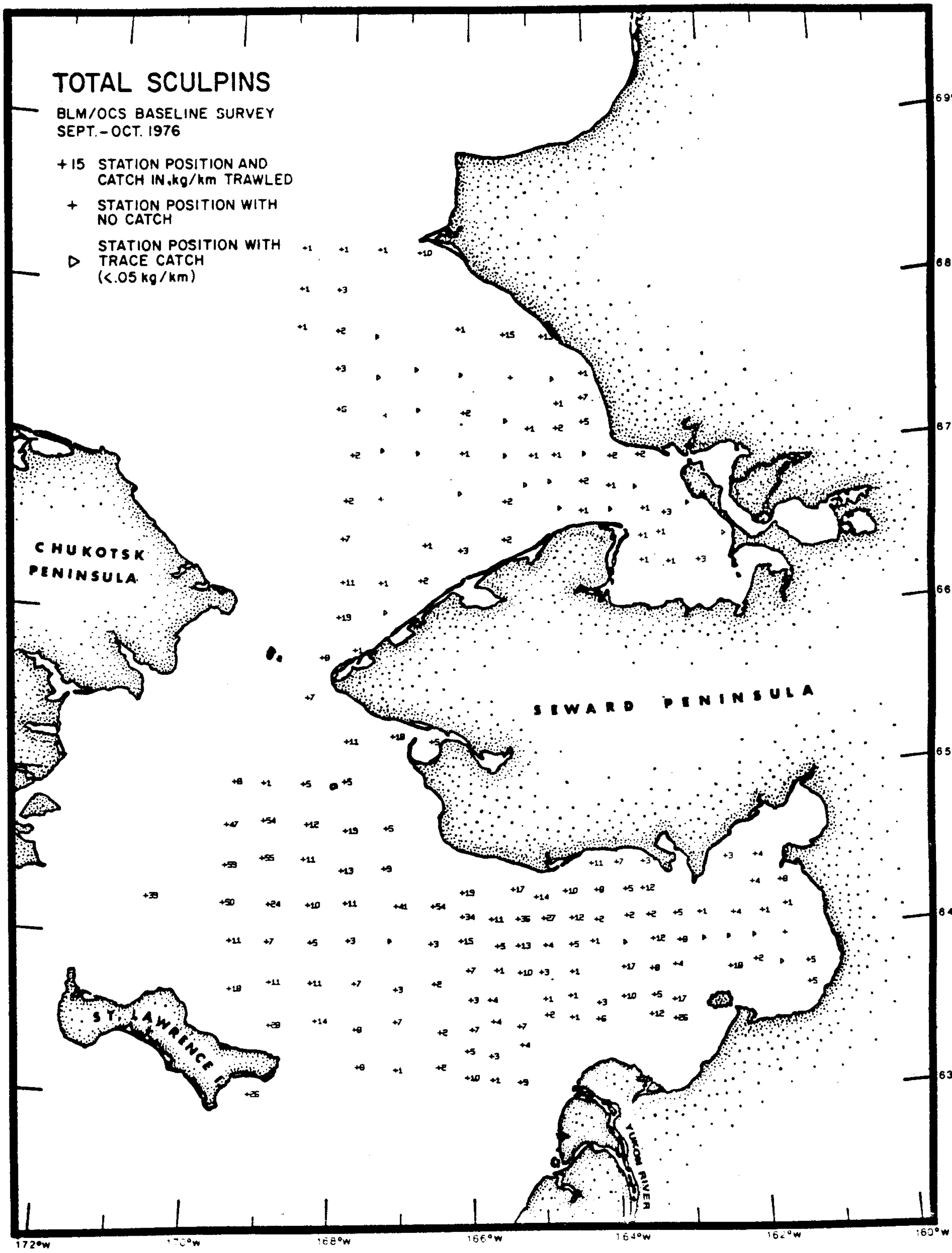


Figure VIII-20.--Distribution of catch rates by weight of total sculpins in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Clupeidae and Osmeridae (herring and smelt)

Clupeids and osmerids were represented by 4 species and genera and comprised about 11% of the total fish biomass or approximately 5,000 mt. Of this amount, 44% occurred in inshore subarea 2 with clupeids being the most abundant fish family in that subarea (Figures VIII-21 and 22). Average catch rates ranged from 3.2 kg/km in subarea 2 to 0.3 kg/km in subarea 4. The overall average catch rate for these families was 0.7 kg/km trawled with Pacific herring and toothed smelt accounting for 98% of this amount.

Zoarcidae, Cyclopteridae, Stichaeidae, and Agonidae (eelpouts, snailfish, pricklebacks, and sea poachers)

These four families were represented by 12 species from 9 genera and all were caught in trace amounts during the survey. Estimated total biomass for this fish group was about 2,000 mt with an overall average catch rate of 0.3 kg/km trawled. Centers of abundance varied by family with pricklebacks and sea poachers found in slightly greater amounts in subarea 4 (Figures VIII-23 and 24), snailfish in subarea 1 (Figure VIII-25), and eelpouts in subarea 3 (Figure VIII-26).

Invertebrate Groups

Since this study focused on invertebrates only of potential economic importance, this segment of the invertebrate fauna was the portion examined in detail. Another group, the echinoderms, were also examined because of their extremely high abundance relative to other survey region fauna.

The major component of the survey catch was echinoderms, accounting for 65% of the invertebrate catch and nearly 56% of the total demersal biomass. The proportion of catch and biomass varied over all subareas with 48 and 45%, respectively in subarea 1; and 82 and 60%,respectively,in subarea 4. Invertebrates of potential commercial importance included several types of crustaceans and molluscs and accounted for about 14% of the total invertebrate fauna. The crustacean group had their greatest biomass in subarea 2 while molluscs were most abundant in subarea 1. The remaining 22% of the invertebrate biomass primarily included coelenterates, pagurid crabs, and ascidians and were most abundant in the northern and western portions of the survey area, subareas 1 and 3.

Echinodermata (starfish, basketstars, and other echinoderms)

Echinodermata was represented by 24 species (Table VIII-4) with an estimated apparent biomass of over 180,000 mt (Table VIII-10). This phyla was by far the most abundant component of the demersal community in the survey area, occurring in large amounts in all subareas. Starfish

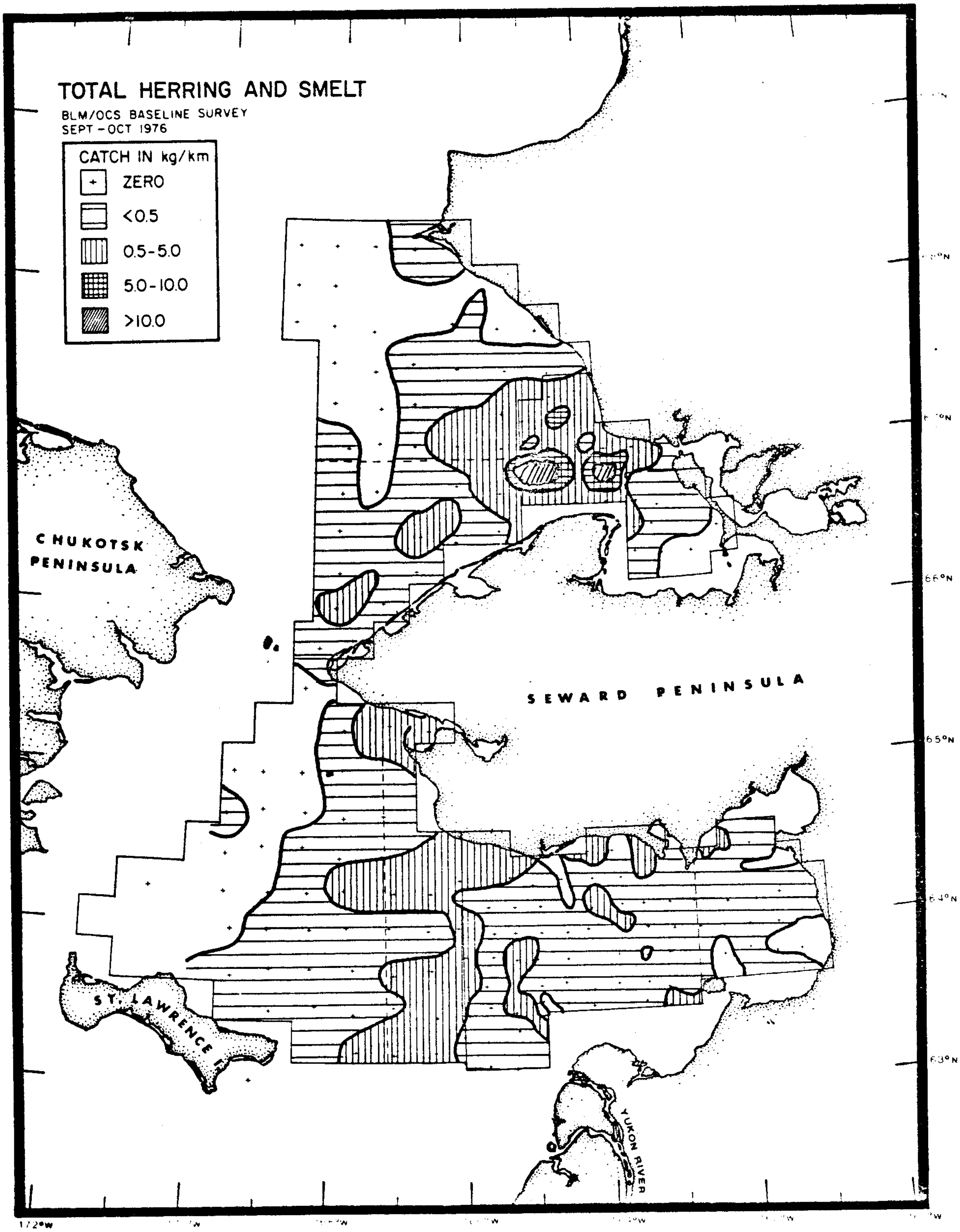


Figure VIII-21.--Distribution and relative abundance by weight of herring and smelt in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

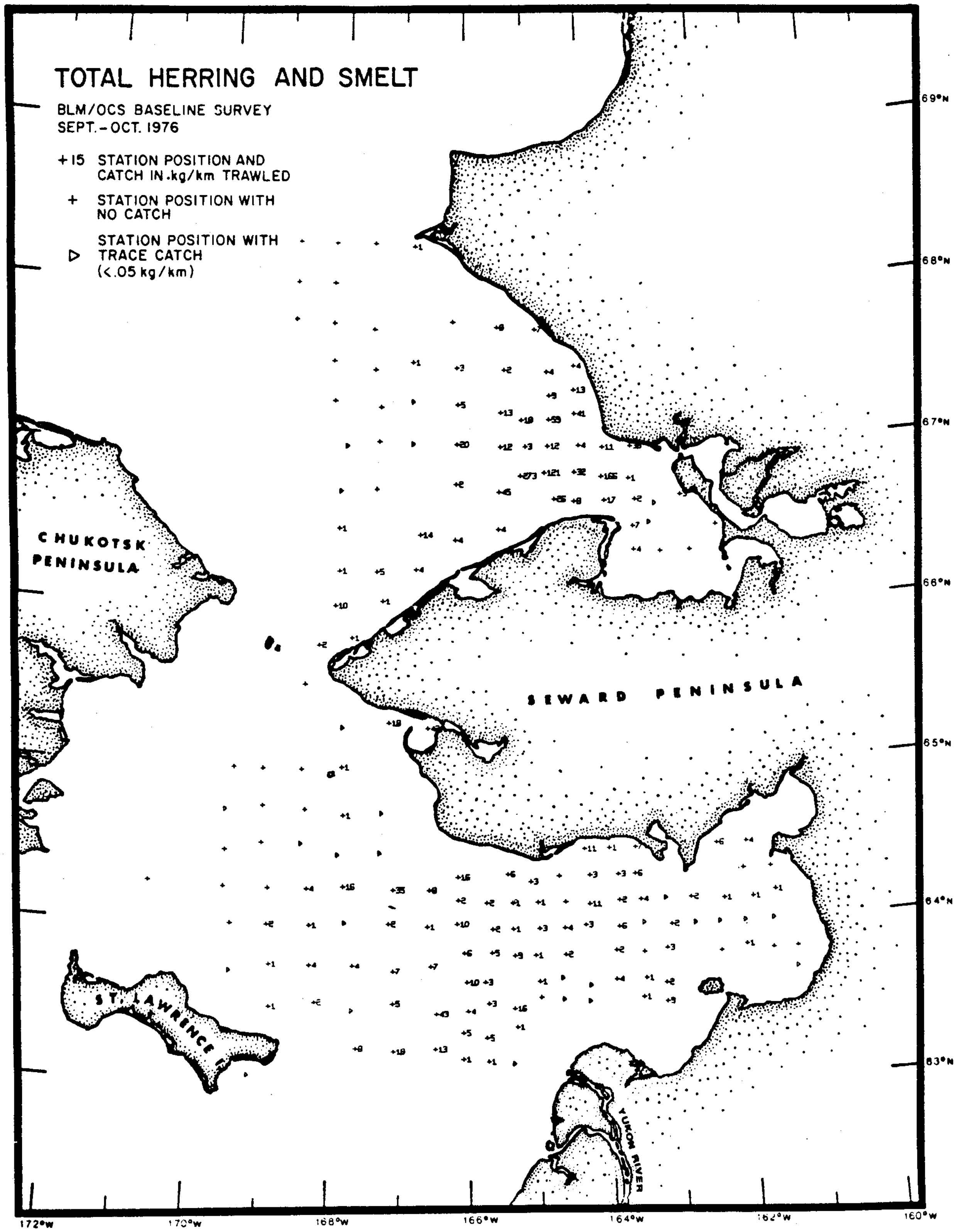


Figure VIII-22.--Distribution of catch rates by weight of herring and smelts in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

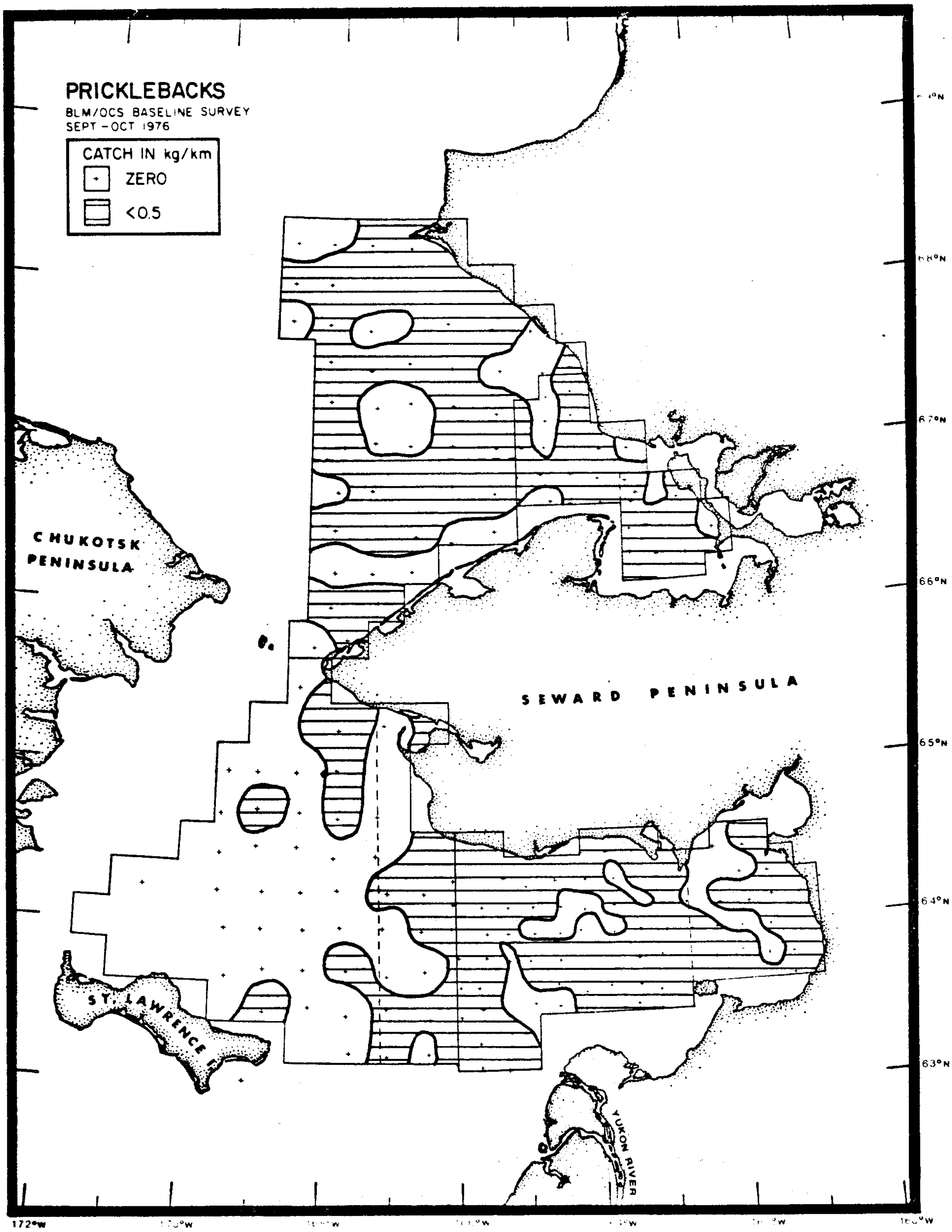


Figure VIII-23.--Distribution and relative abundance of pricklebacks in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

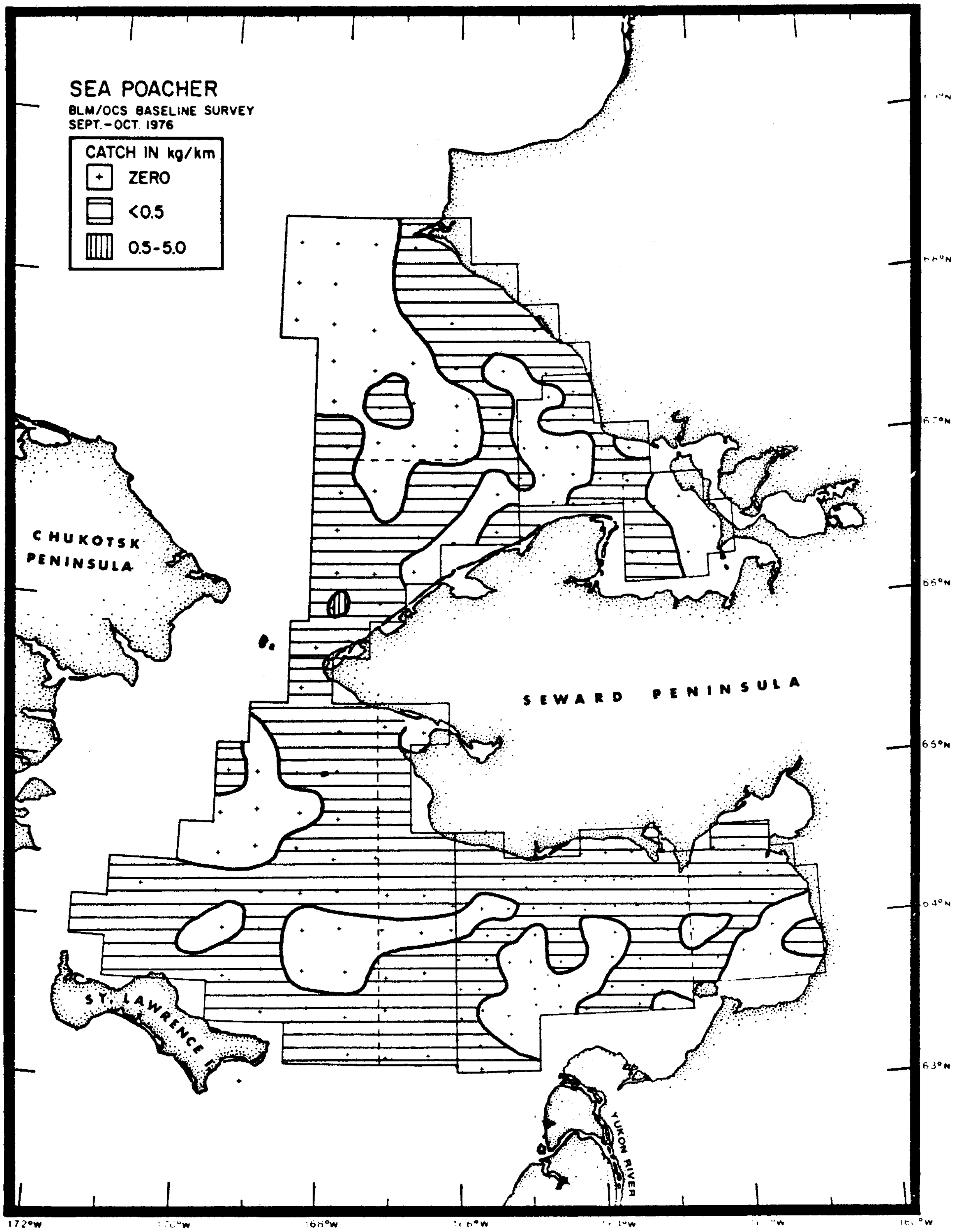


Figure VIII-24.--Distribution and relative abundance of sea poachers in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

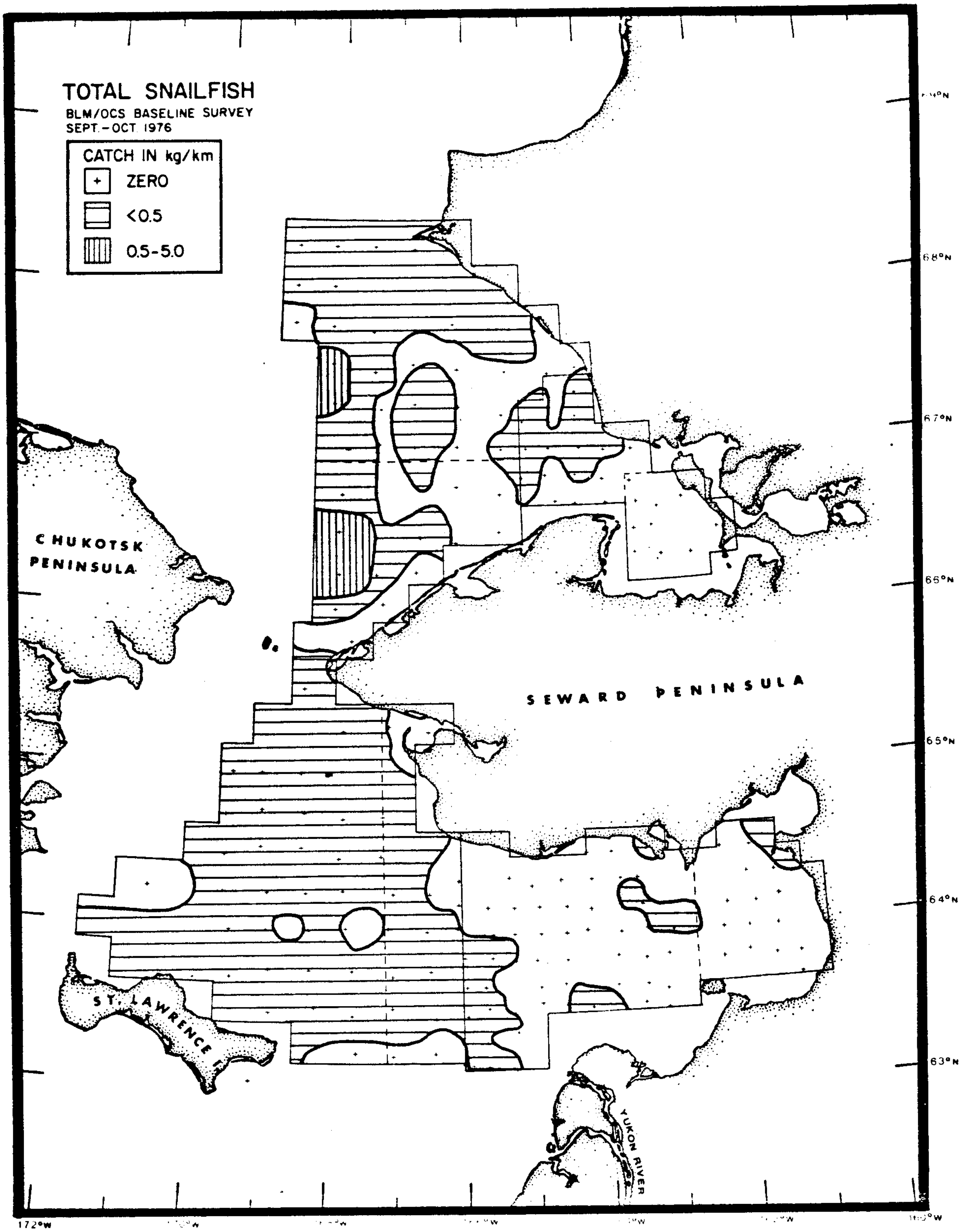


Figure VIII-25.--Distribution and relative abundance by weight of total snailfish in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

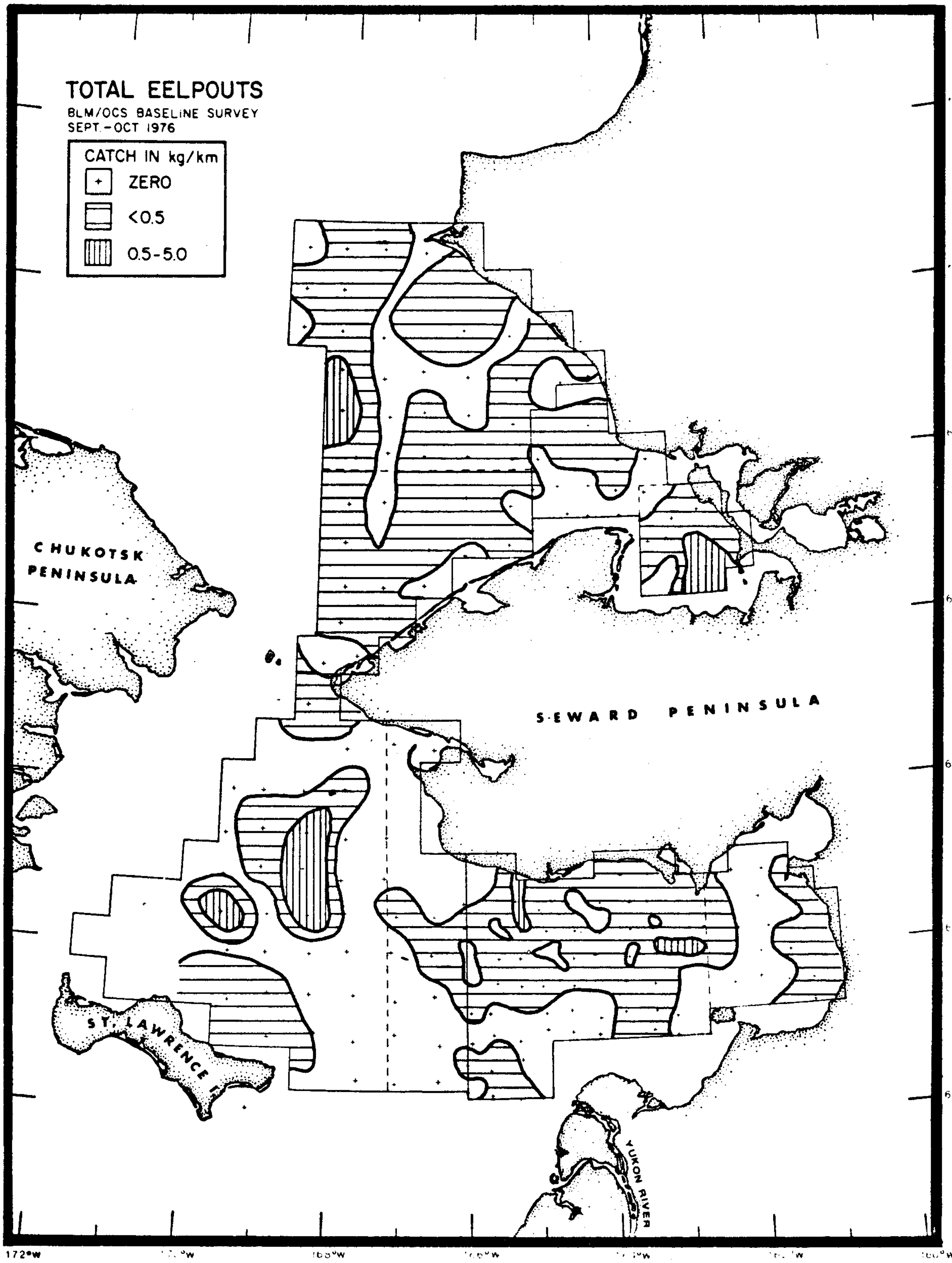


Figure VIII-26.--Distribution and relative abundance by weight of total eelpouts in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

comprised most of the echinoderm catch and were most abundant in subarea 4 (Figures VIII-27 and 28). Members of the family Asteridae accounted for the major portion of the starfish biomass while the basketstar, Gorgonocephalus caryi, was the dominant element of the remaining echinoderm catch. Maximum contribution of Echinodermata to total catch rates occurred in the embayments of Norton Sound (subarea 4, 38.2 kg/km) and Kotzebue Sound (subarea 2, 23.5 kg/km) where they accounted for 66 and 55%, respectively, of the average catch rates of all species.

Crustacea (shrimp and crabs)

Crustaceans of possible economic importance were represented by 10 species of shrimp and 3 crab species, with an apparent total biomass estimated at about 19,000 mt. The abundance and relative importance of this component of the invertebrate fauna varied by subarea. Overall maximum abundance was in subarea 1 (Table VIII-10), but by groups, maximum relative abundance and catch rates were as follows: for shrimp, subarea 1 (0.5 kg/km, Figures VIII-29 and 30); Tanner crab, subarea 2 (4.9 kg/km, Figures VIII-31 and 32); and king crab, subareas 3 and 4 (.05 and 1.9 kg/km, respectively, Figures VIII-33 and 34).

Mollusca (snails and clams)

Gastropod and pelecypod molluscs were represented by 87 species, with an apparent biomass estimated at over 20,000 mt. Relative abundance was somewhat similar by subarea with slightly greater catch rates occurring in subareas 1 and 3 (3.6 and 2.3 kg/km, respectively). Gastropods (or snails) comprised the major portion of mollusc catches (97%) with centers of abundance again in subareas 1 and 3 (Figures VIII-35 and 36). Pelecypods (clams) were caught in small amounts throughout the study region with slightly larger catch rates occurring in subarea 4 (Figures VIII-37 and 38).

Other invertebrates (coelenterates, pagurid crabs, ascidians, and others)

Other invertebrates were represented by 41 species from 10 phyla, with an apparent total biomass estimated at over 62,000 mt, of which over 50% was found in subarea 1 (Table VIII-10). Overall catch rate for this group was 8.0 kg/km.

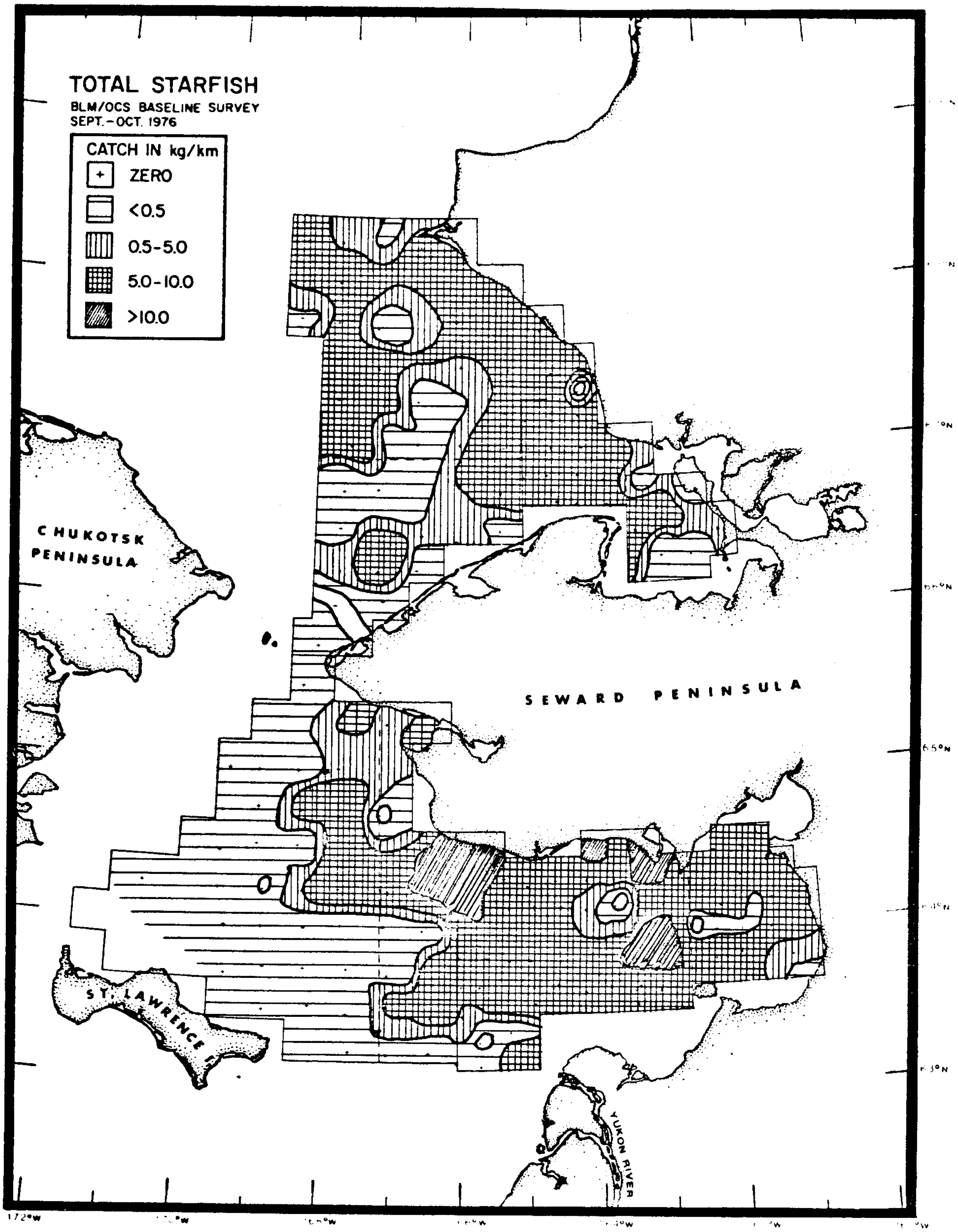


Figure VIII-27.--Distribution and relative abundance by weight of total starfish in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

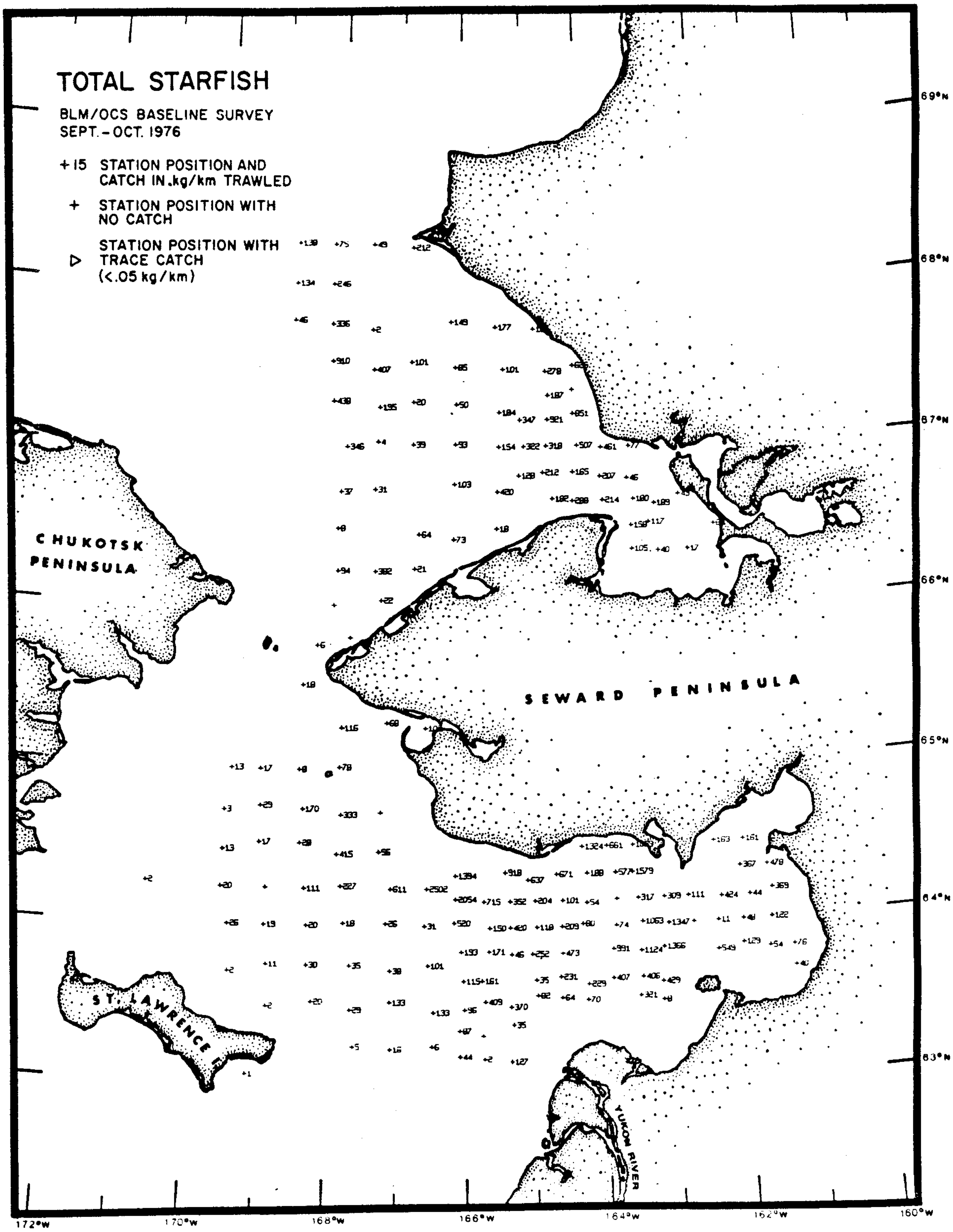


Figure VIII-28.--Distribution of catch rates by weight of total starfish in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

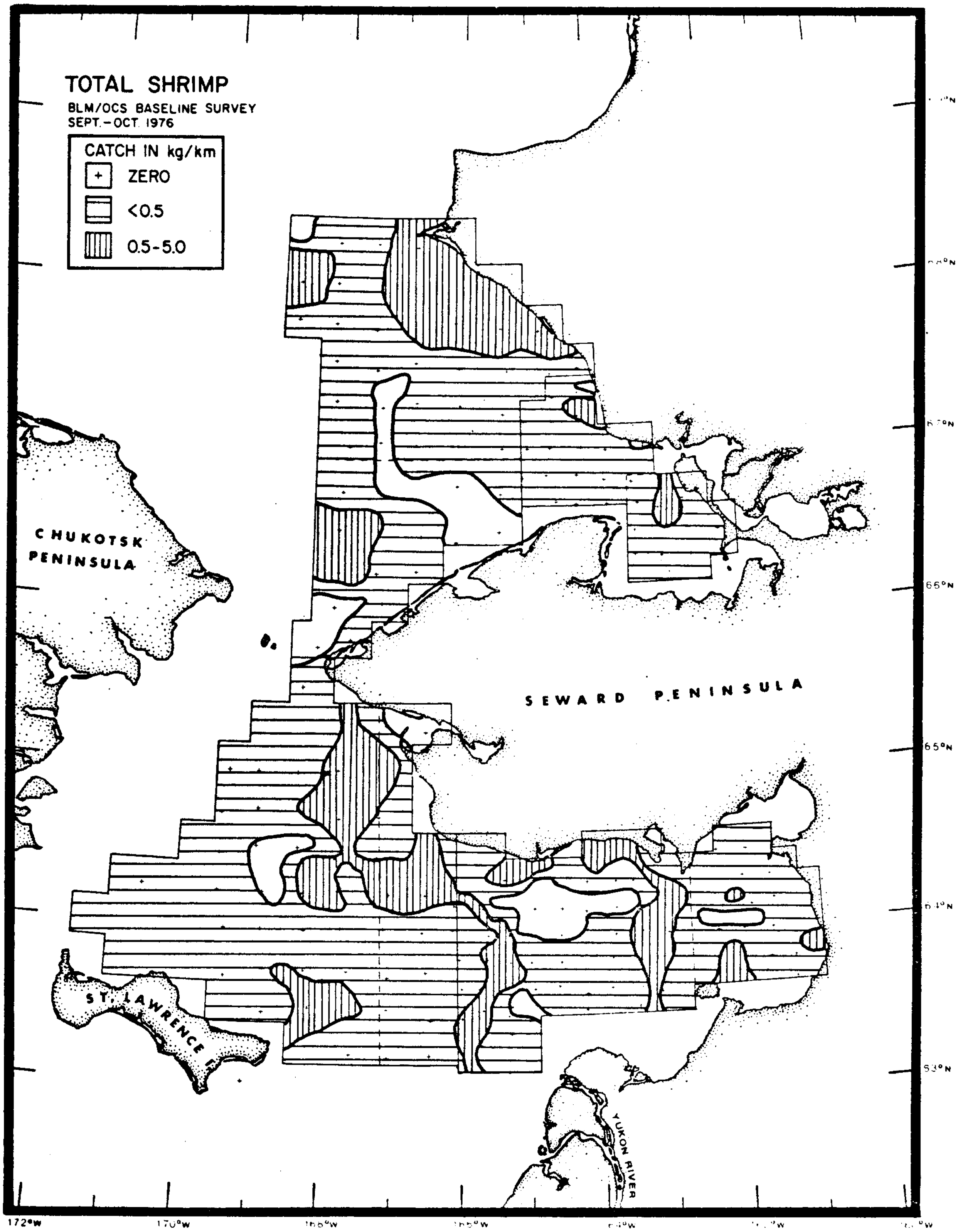


Figure VIII-29.--Distribution and relative abundance by weight of total shrimp in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

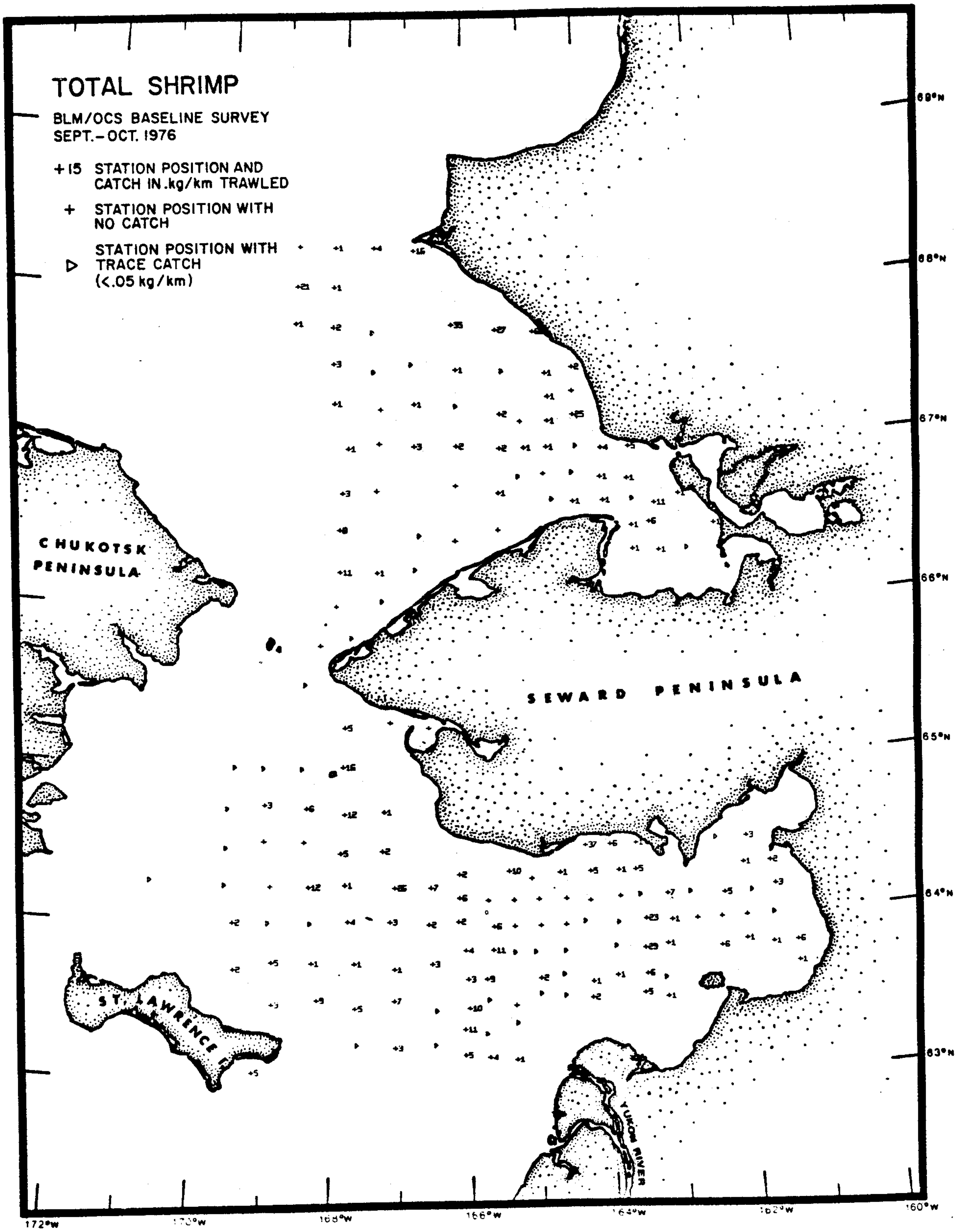


Figure VIII-30.--Distribution of catch rates by weight of total shrimp for Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

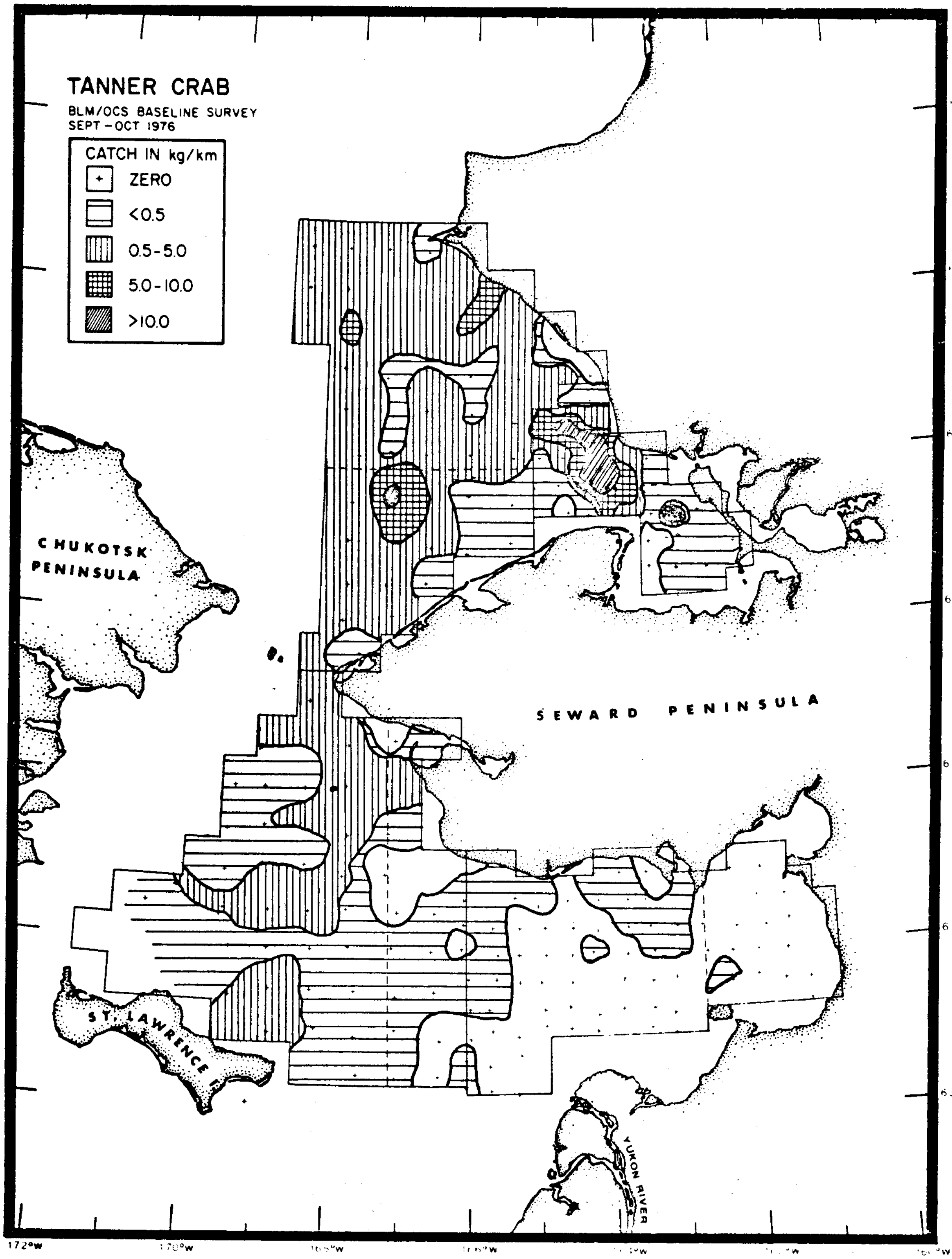


Figure VIII-31.--Distribution and relative abundance by weight of total Tanner crabs in Norton Sound, the southeastern Chukchi and adjacent waters (BLM/OCS survey, 1976).

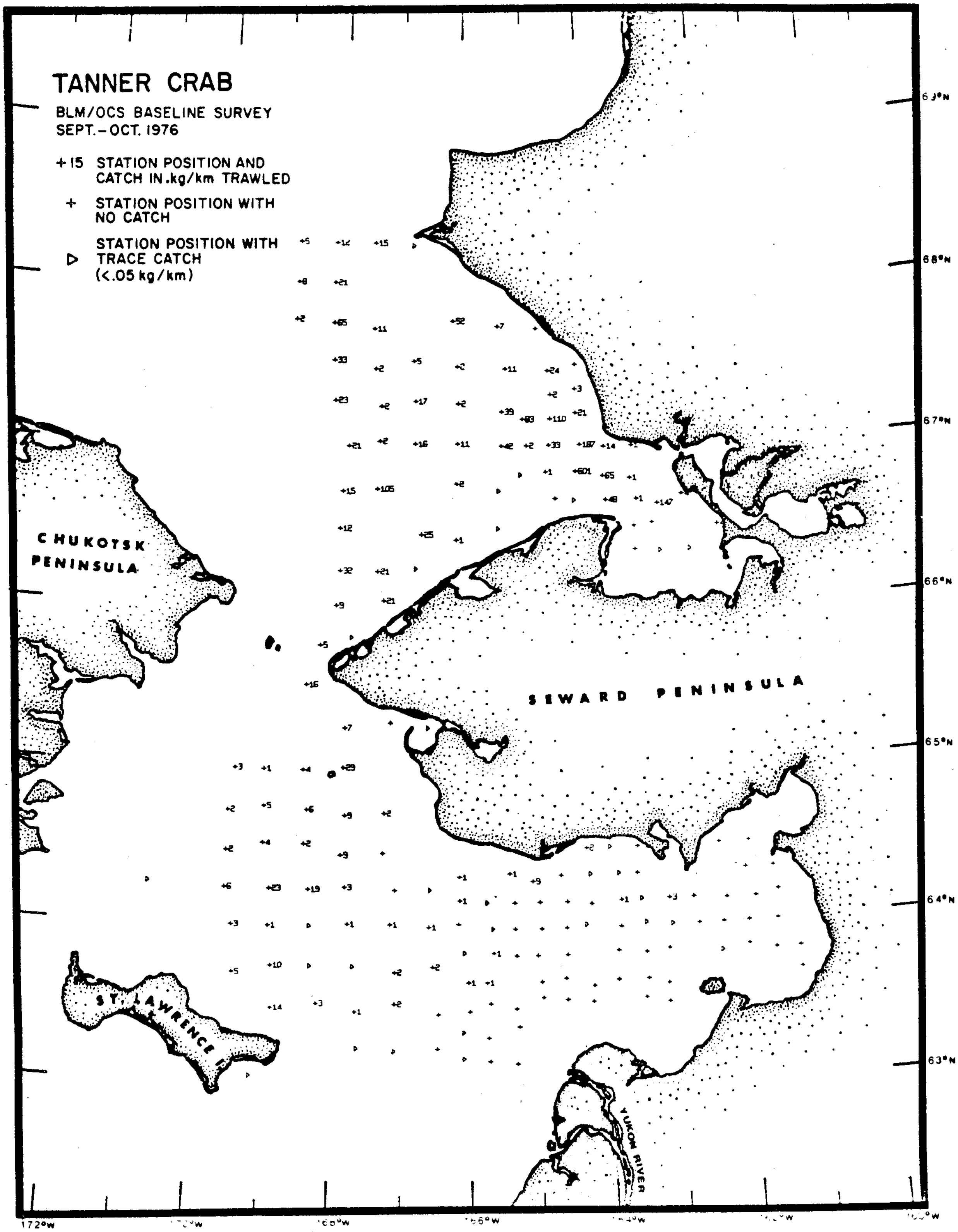


Figure VIII-32.--Distribution of catch rates by weight of total Tanner crab for Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

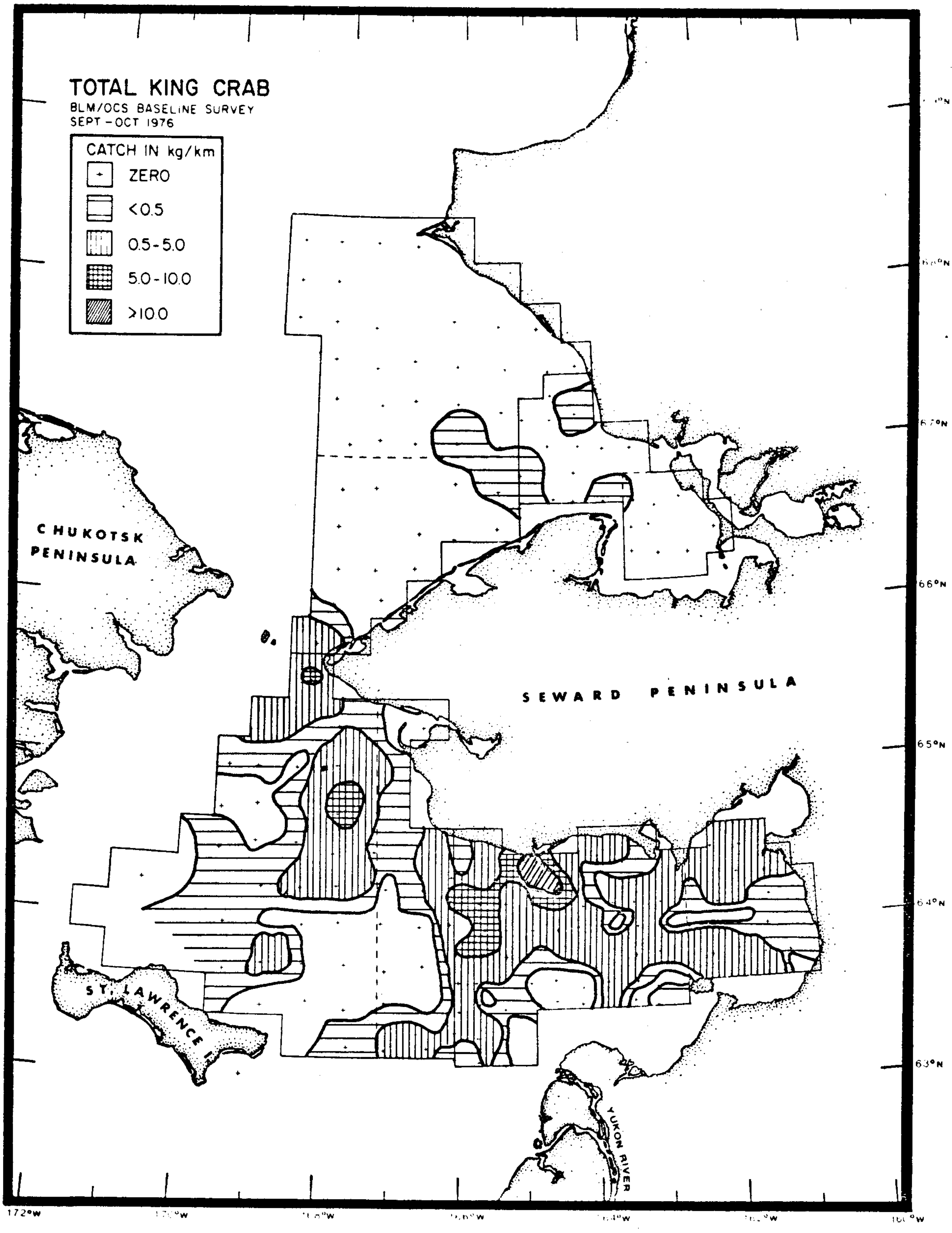


Figure VIII-33.--Distribution and relative abundance by weight of total king crabs in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

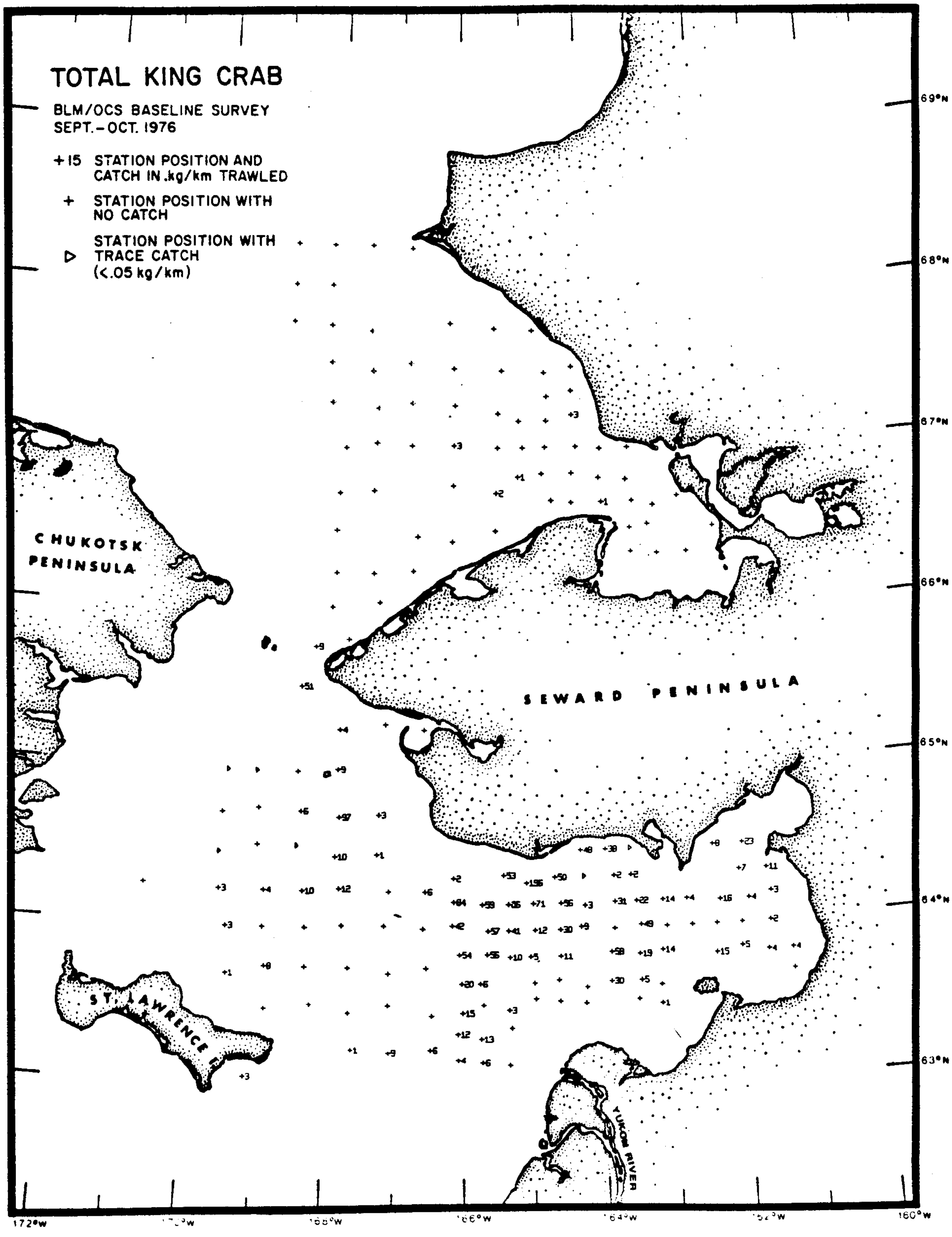


Figure VIII-34.--Distribution of catch rates by weight of total king crab of Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

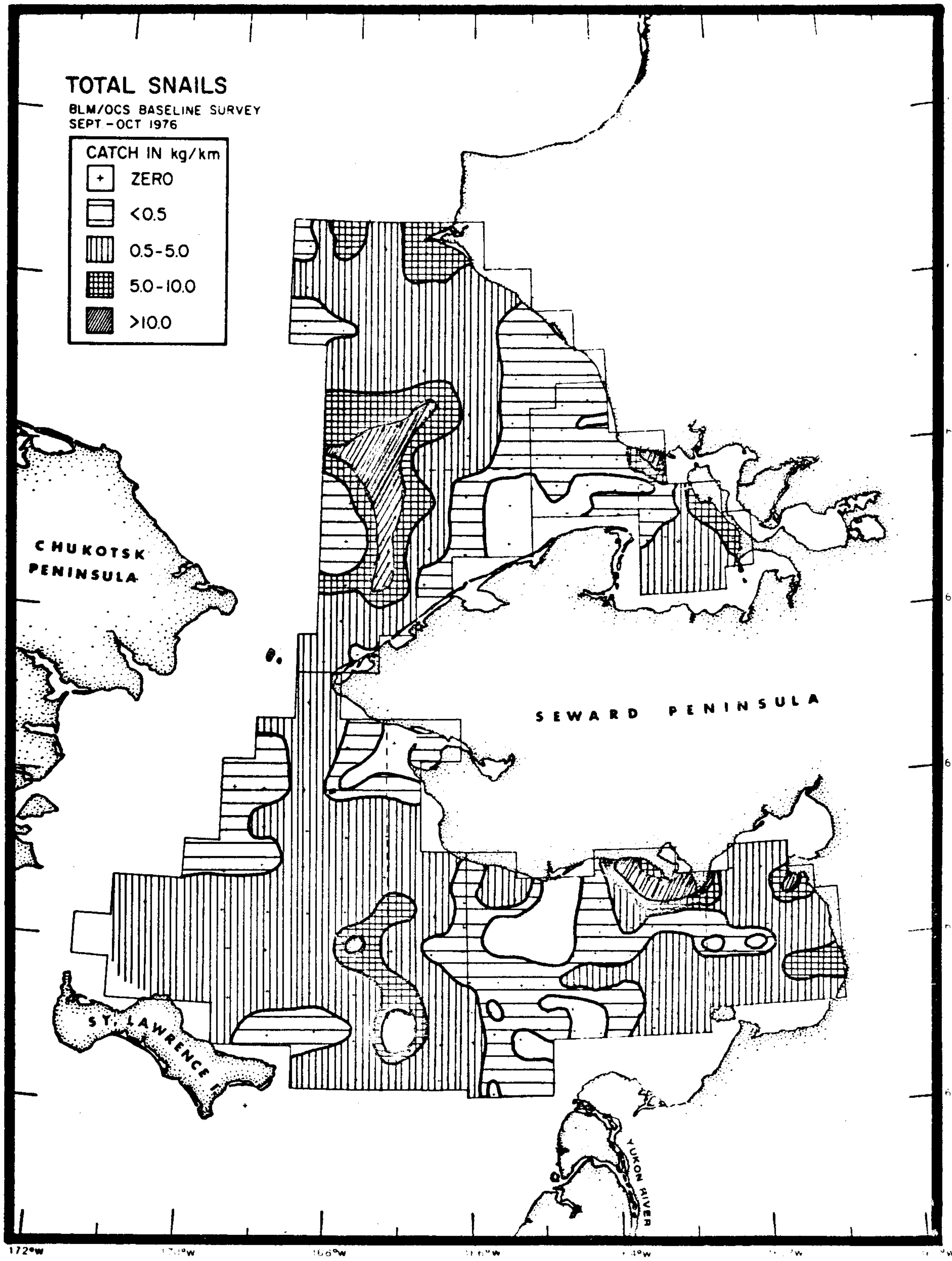


Figure VIII-35.--Distribution and relative abundance by weight of snails in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

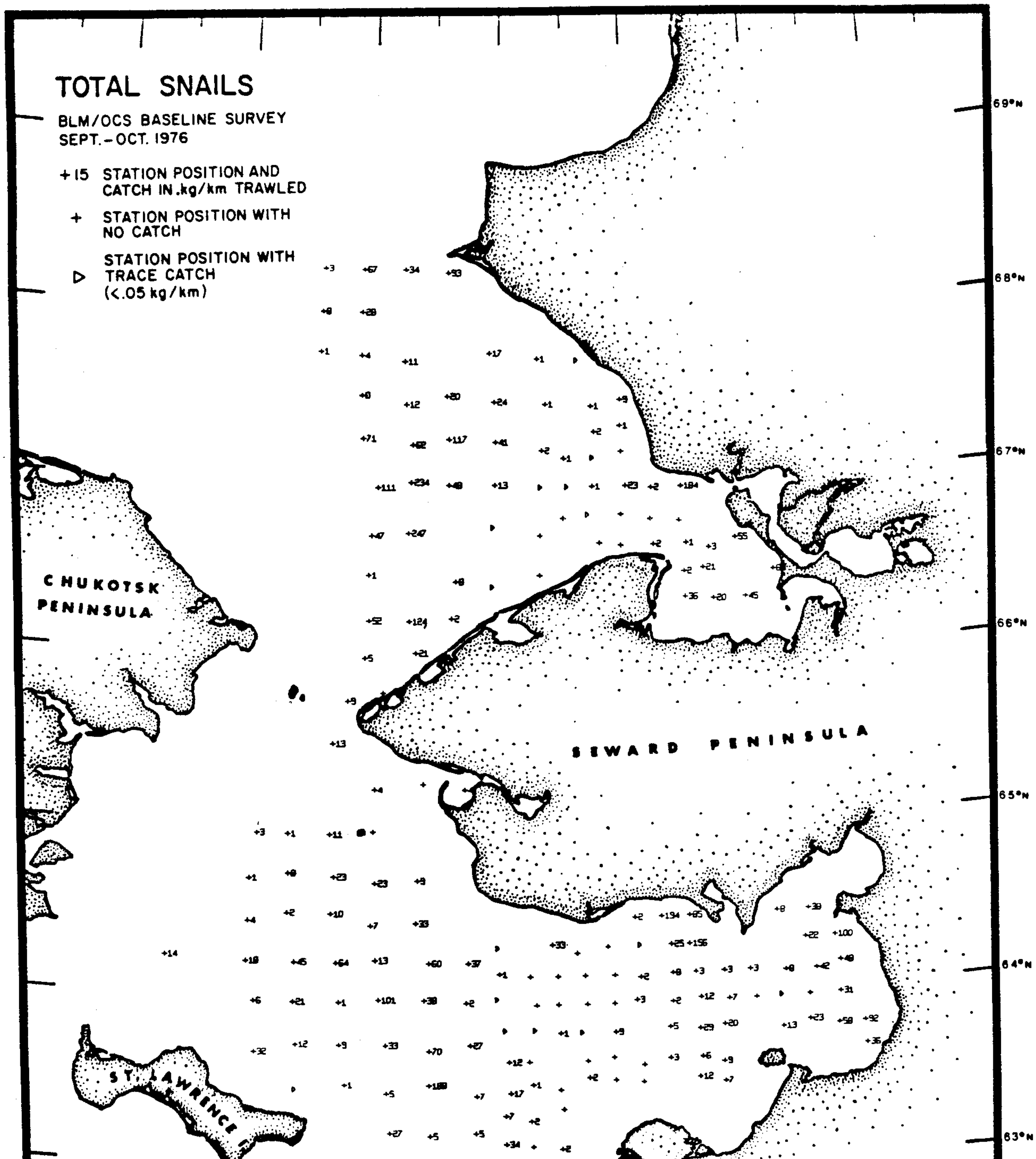


Figure VIII-36.--Distribution of catch rates by weight of total snails in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

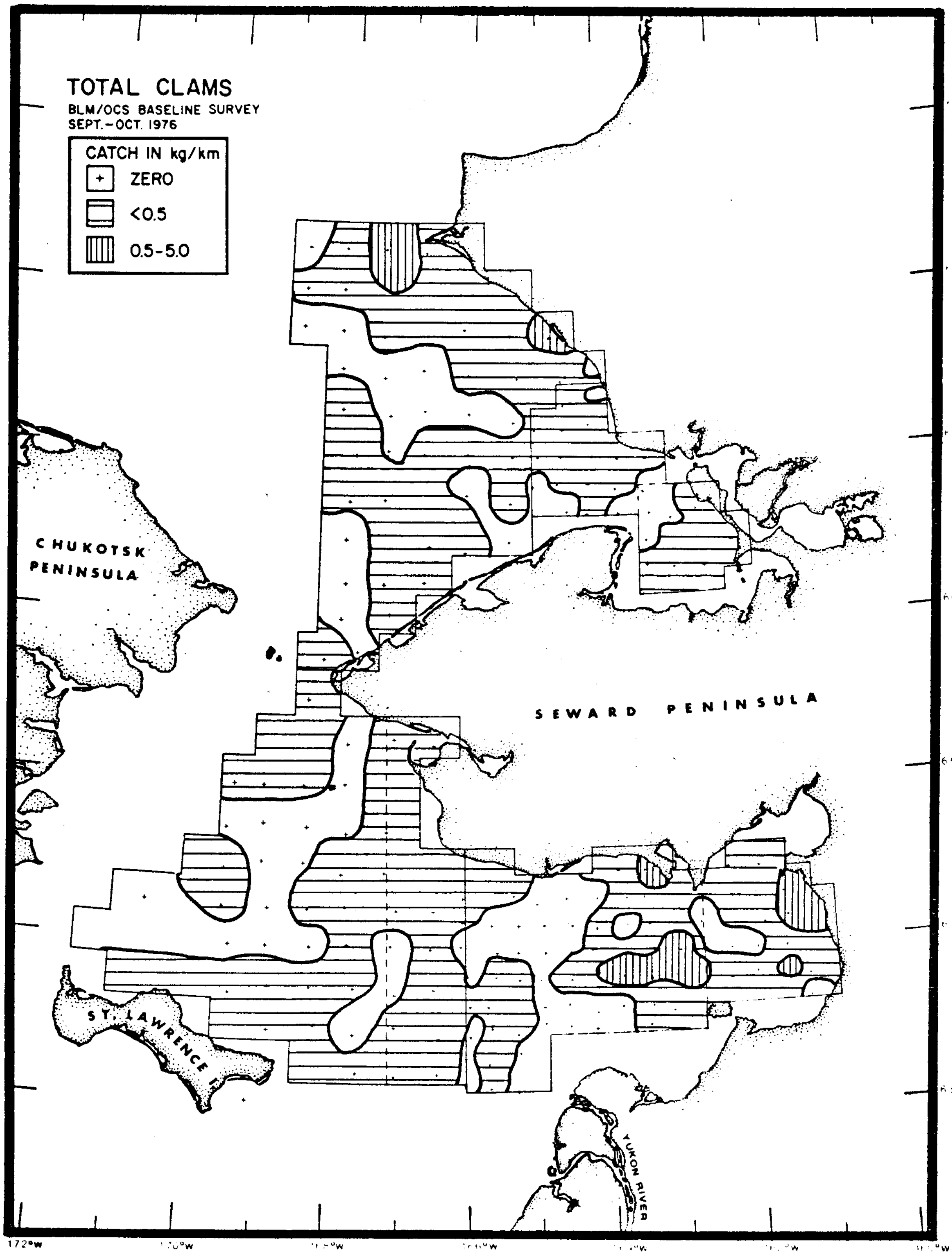


Figure VIII-37.--Distribution and relative abundance by weight of total clams in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

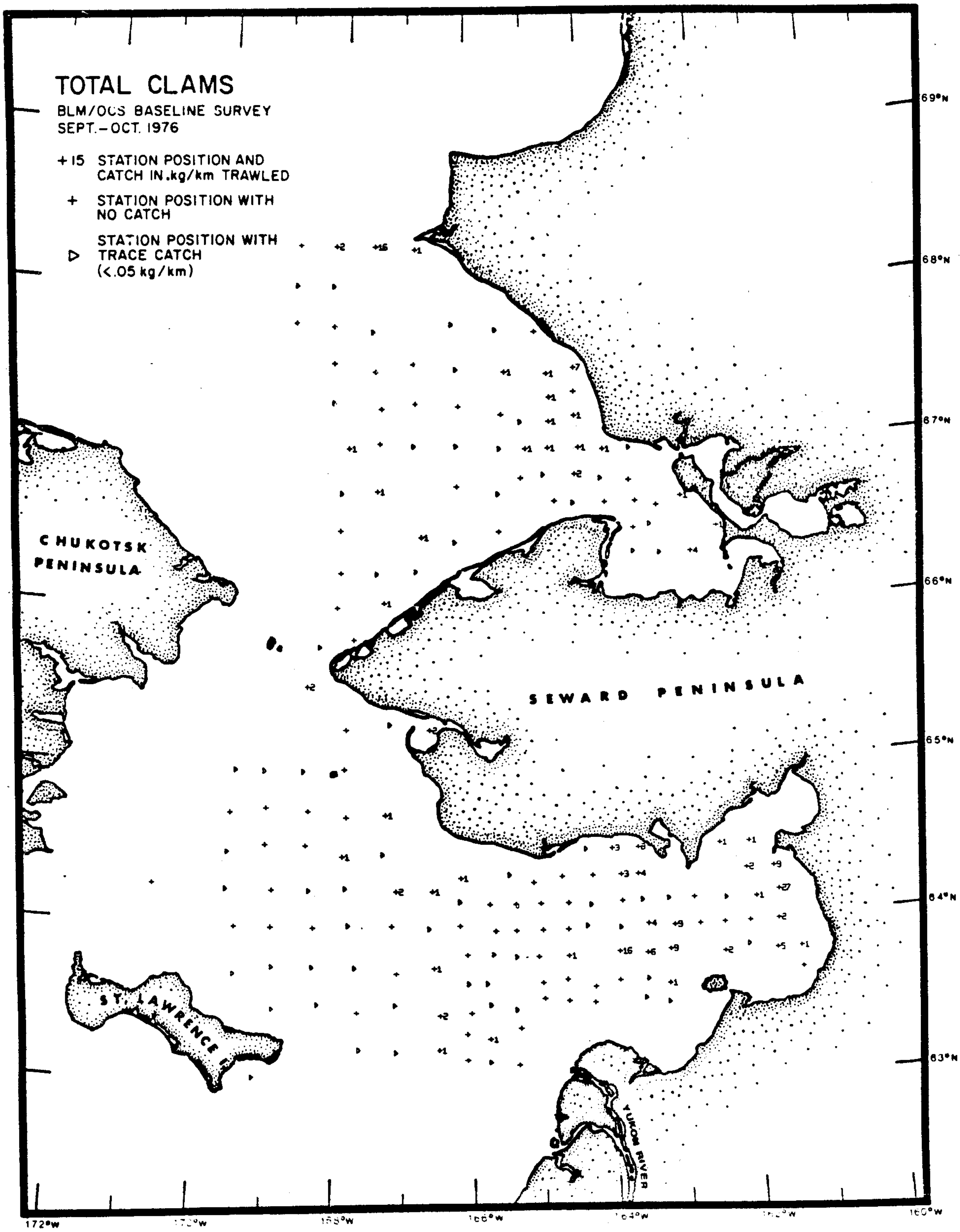


Figure VIII-38.--Distribution of catch rates by weight of total clams in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Relative Importance of Individual Species

Rank Order of Species by Frequency of Occurrence

Fish--Twelve species occurred at about 50% or more of the demersal stations occupied during the 1976 survey (Table VIII-12). The most frequently occurring species was Arctic cod, which was found at nearly 85% of all stations sampled. Other widely distributed species included saffron cod (78%), Arctic staghorn sculpin (75%), toothed smelt (67%), sturgeon poacher (62%), and yellowfin sole (56%).

The frequency of occurrence of species varied widely by subarea. Although Arctic cod and saffron cod were generally among the most common fish in all subareas, the percent occurrence of many other species showed large differences between subareas. Yellowfin sole occurred at 81% of the stations sampled in the embayments of Norton and Kotzebue sounds (subareas 4 and 2, respectively) and at only 28% of the more offshore regions surveyed in the southeastern Chukchi Sea and northern Bering Sea (subareas 1 and 3, respectively). Similar patterns were seen for Alaska plaice, toothed smelt, Pacific herring, and the slender eelblenny. Shorthorn sculpin, snailfish, and capelin showed the opposite pattern, occurring at a far greater percentage of stations in the offshore subareas as compared to subareas more nearshore. Other species exhibited large differences in percent occurrence between areas north and south of Bering Strait. Bering flounder were far more common in catches in the northern subareas while the plain sculpin displayed a greater frequency of occurrence in southern subareas, especially Norton Sound.

Invertebrates--In addition to starfish and the unidentified invertebrate groups, four shellfish species of potential economic importance occurred at over 50% of the 1976 survey stations (Table VIII-13). The most common of these species was *Argis* shrimp (*Argis* spp.) which was found at nearly 75% of the stations. The other species widely distributed over the survey area were Tanner crab (67%) and two neptunid whelks, *Neptunea heros* (64%) and *N. ventricosa* (56%). As with fish taxa, rank order of occurrence varied by subarea. Tanner crabs frequently occurred in catches in most regions but its incidence decreased substantially in Norton Sound (subarea 4). Blue and red king crabs were frequently encountered, but each only in one subarea, (3 and 4, respectively). Other species displayed marked changes in percentage occurrence between offshore and inshore regions. Basketstars and three neptunid whelks, *Neptunea heros*, *N. ventricosa*, and *N. borealis*, occurred at a far greater number of offshore stations (subareas 1 and 3) than inshore (subareas 2 and 4). The distribution of *Telemessus* crab displayed an opposite pattern, occurring more often inshore than offshore.

Rank Order by Relative Abundance

Fish--Two species, saffron cod and starry flounder, together accounted for over 57% of the total catch of all fish (Table VIII-14). In all

Table VIII-12.-Rank order by frequency of occurrence (percent) of the 20 most common fish taxa in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Rank	Taxon	All areas combined	Subarea 1	Subarea 2	Subarea 3	Subarea 4
1	Arctic cod	84.9	84	74	91	84
2	Saffron cod	78.1	50	89	63	100
3	Arctic staghorn sculpin	75.0	70	85	96	63
4	Toothed smelt	67.2	41	89	46	88
5	Alaska plaice	66.1	41	85	39	91
6	Sturgeon poacher	62.0	50	52	70	68
7	Yellowfin sole	56.3	27	55	28	91
8	Slender eelblenny	55.2	52	74	26	68
9	Shorthorn sculpin	55.2	52	37	96	39
10	Pacific herring	49.5	41	74	39	52
11	Starry flounder	47.4	25	37	17	83
12	Antlered sculpin	44.8	20	52	37	62
13	Unidentified snailfish	43.2	52	33	78	20
14	Polar eelpout	32.3	59	30	30	31
15	Plain sculpin	29.7	--	7	17	63
16	Ribbed sculpin	28.6	30	33	39	20
17	Walleye pollock	27.6	18	15	50	23
18	Wattled eelpout	27.1	34	44	2	32
19	Bering flounder	26.5	68	40	22	--
20	Capelin	24.4	39	11	48	6
Total fish species		48	34	32	36	36
Total number of hauls		192	44	27	46	75

Table VIII-13.--Rank order by frequency of occurrence (percent) of the most common invertebrate taxa in Norton Sound, the southeastern Chukchi Sea (BLM/OCS survey, 1976).

Rank	Taxon	All areas combined	Subarea 1	Subarea 2	Subarea 3	Subarea 4
1	Starfish	95.8	95	96	96	96
2	Other invertebrates	90.6	91	89	98	87
3	*Argis* spp.	74.5	80	81	80	65
4	Tanner crab	67.2	95	85	89	31
5	*Neptunea heros*	64.1	70	41	85	56
6	*Neptunea ventricosa*	55.7	55	48	78	45
7	*Beringius beringii*	46.9	41	56	40	53
8	*Serripes groenlandicus*	44.3	30	56	43	49
9	Basketstars	37.5	50	22	65	19
10	*Telemessus* crab	35.9	18	48	7	60
11	Red king crab	33.9	2	11	7	77
12	*Pandalus goniurus*	30.2	25	19	41	31
13	*Crangon dalli*	24.5	7	15	2	52
14	*Sclerocrangon boreas*	24.5	14	41	20	28
15	*Neptunea borealis*	21.9	41	7	43	11
16	*Pyrulofusus deformis*	17.2	5	11	30	19
17	*Clinocardium ciliatum*	16.1	18	48	4	11
18	*Volutopsius fragilis*	13.0	23	19	17	3
19	Blue king crab	12.0	5	—	46	--
20	*Buccinium angulossum*	11.5	16	7	20	5

Table VIII-14.--Rank order of abundance of the 20 most abundant fish taxa in Norton Sound and the southeastern Chukchi Sea, all areas combined (BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ fish CPUE	Proportion of 3/ total CPUE	Cumulative proportion of fish CPUE
1	Saffron cod	2.70	0.446	0.063	0.446
2	Starry flounder	0.77	0.127	0.018	0.573
3	Shorthorn sculpin	0.54	0.089	0.013	0.662
4	Pacific herring	0.37	0.061	0.009	0.723
5	Toothed smelt	0.29	0.048	0.007	0.771
6	Alaska plaice	0.21	0.035	0.005	0.806
7	Yellowfin sole	0.19	0.031	0.004	0.837
8	Arctic cod	0.17	0.028	0.004	0.865
9	Plain sculpin	0.12	0.020	0.003	0.885
10	Pacific halibut	0.11	0.018	0.003	0.903
11	Arctic staghorn sculpin	0.09	0.015	0.002	0.918
12	Polar eelpout	0.09	0.015	0.002	0.933
13	Unidentified snailfish	0.07	0.012	0.002	0.945
14	Antlered sculpin	0.04	0.007	0.001	0.952
15	Walleye pollock	0.04	0.007	0.001	0.959
16	Belligerent sculpin	0.03	0.005	0.001	0.964
17	Sturgeon poacher	0.03	0.005	0.001	0.969
18	Bering flounder	0.03	0.005	0.001	0.974
19	Longhead dab	0.03	0.005	0.001	0.979
20	Wattled eelpout	0.03	0.005	0.001	0.984

1/ Overall catch per unit effort, kg/km trawled. Total effort = 620.7 km.

2/ Proportion of catch per unit effort, total fish only. Fish CPUE = 6.06 kg/km trawled.

3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 43.16 kg/km trawled.

subareas, these species and one or two others usually dominated, accounting for over 50% of the total fish catch (Tables VIII-15 through 18).

Invertebrates--Starfish, basketstars, and "other" invertebrates (not identified for this report) comprised over 85% of the total mean catch for all invertebrates combined (Table VIII-19). The remaining 15% consisted of several mollusc and crustacean species which may have potential for commercial utilization and were the primary invertebrate species of interest for our study. Of this group, the neptunid whelk, Neptunea heros, Tanner crab, and red king crab were dominant, representing 68% of the commercial invertebrate catch. As with fish taxa, two or three species usually dominated each subarea catch (Tables VIII-20 through 23).

Rank order by relative abundance for all taxa identified during the baseline study is given in Appendices E and F.

Table VIII-15.--Rank order of abundance of the 20 most abundant fish taxa in the southeastern Chukchi Sea (subarea 1, BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ fish CPUE	Proportion of 3/ total CPUE	Cumulative proportion of fish CPUE
1	Starry flounder	0.53	0.205	.014	0.205
2	Pacific halibut 4/	0.32	0.118	.008	0.323
3	Saffron cod	0.31	0.114	.008	0.437
4	Pacific herring	0.26	0.096	.007	0.533
5	Arctic cod	0.20	0.076	.005	0.609
6	Shorthorn sculpin	0.18	0.067	.005	0.676
7	Alaska plaice	0.16	0.058	.004	0.733
8	Unidentified snailfish	0.14	0.050	.003	0.784
9	Toothed smelt	0.10	0.037	.003	0.821
10	Polar eelpout	0.08	0.031	.002	0.852
11	Walleye pollock	0.08	0.030	.002	0.881
12	Bering flounder	0.07	0.027	.002	0.908
13	Arctic staghorn sculpin	0.06	0.021	.001	0.929
14	Yellowfin sole	0.03	0.013	.001	0.942
15	Sturgeon poacher	0.03	0.012	.001	0.954
16	Capelin	0.03	0.012	.001	0.966
17	Antlered sculpin	0.02	0.008	.001	0.973
18	Wattled eelpout	0.02	0.007	5/	0.980
19	Belligerent sculpin	0.01	0.005	5/	0.985
20	Slender eelblenny	0.01	0.004	5/	0.989

1/ Overall catch per unit effort, kg/km trawled. Total effort = 139.2 km.

2/ Proportion of catch per unit effort, total fish only. Fish CPUE = 2.70 kg/km trawled.

3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 39.33 kg/km trawled.

4/ Total catch for this species = 1 large fish (44.2 kg).

5/ Proportion less than 0.0005.

Table VIII-16.--Rank order of abundance of the 20 most abundant fish taxa in Kotzebue Sound (subarea 2, BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ fish CPUE	Proportion of 3/ total CPUE	Cumulative proportion of fish CPUE
1	Pacific herring	2.20	0.404	0.051	0.404
2	Saffron cod	1.28	0.235	0.030	0.640
3	Toothed smelt	1.00	0.184	0.023	0.824
4	Alaska plaice	0.20	0.037	0.005	0.861
5	Starry flounder	0.15	0.028	0.003	0.889
6	Yellowfin sole	0.13	0.023	0.003	0.912
7	Arctic cod	0.12	0.021	0.003	0.934
8	Polar eelpout	0.06	0.010	0.001	0.944
9	Arctic staghorn sculpin	0.05	0.009	0.001	0.953
10	Antlered sculpin	0.04	0.008	0.001	0.961
11	Bering flounder	0.04	0.008	0.001	0.969
12	Wattled eelpout	0.03	0.006	0.001	0.975
13	Slender eelblenny	0.03	0.006	0.001	0.981
14	Shorthorn sculpin	0.02	0.004	4/	0.985
15	Longhead dab	0.02	0.004	4/	0.989
16	Unidentified snailfish	0.01	0.002	4/	0.991
17	Ribbed sculpin	0.01	0.002	4/	0.993
18	Sturgeon poacher	0.01	0.002	4/	0.994
19	Capelin	0.01	0.001	4/	0.995
20	Belligerent sculpin	0.01	0.001	4/	0.996

1/ Overall catch per unit effort, kg/km trawled. Total effort = 86.6 km.

2/ Proportion of catch per unit effort, total fish only. Fish CPUE = 5.44 kg/km trawled.

3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 42.87 kg/km trawled.

4/ Proportion less than .0005.

Table VIII-17.--Rank order of abundance of the 20 most abundant fish taxa in the northern Bering Sea, north of St. Lawrence Island (subarea 3, BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ fish CPUE	Proportion of 3/ total CPUE	Cumulative proportion of fish CPUE
1	Saffron cod	2.58	0.433	0.070	0.433
2	Shorthorn sculpin	1.23	0.205	0.033	0.638
3	Starry flounder	0.42	0.071	0.011	0.709
4	Toothed smelt	0.34	0.056	0.009	0.765
5	Pacific herring	0.16	0.027	0.004	0.793
6	Alaska plaice	0.16	0.026	0.004	0.819
7	Arctic staghorn sculpin	0.14	0.024	0.004	0.843
8	Arctic cod	0.14	0.024	0.004	0.866
9	Plain sculpin	0.13	0.022	0.004	0.888
10	Polar eelpout	0.12	0.020	0.003	0.908
11	Yellowfin sole	0.09	0.014	0.002	0.922
12	Unidentified snailfish	0.08	0.013	0.002	0.936
13	Belligerent sculpin	0.06	0.010	0.002	0.946
14	King salmon	0.04	0.007	0.001	0.953
15	Capelin	0.04	0.006	0.001	0.959
16	Antlered sculpin	0.03	0.006	0.001	0.965
17	Walleye pollock	0.03	0.005	0.001	0.970
18	Bering wolffish	0.03	0.005	0.001	0.975
19	Sturgeon poacher	0.03	0.004	0.001	0.979
20	Longhead dab	0.03	0.004	0.001	0.983

1/ Overall catch per unit effort, kg/km trawled. Total effort = 150.9 km.

2/ Proportion of catch per unit effort, total fish only. Fish CPUE = 5.97 kg/km trawled.

3/ Proportion of total catch per unit effort, all fish and invertebrates combined.

Table VIII-18.--Rank order of abundance of the 20 most abundant fish taxa in Norton Sound (subarea 4, BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ fish CPUE	Proportion of 3/ total CPUE	Cumulative proportion of fish CPUE
1	Saffron cod	6.56	0.604	0.114	0.604
2	Starry flounder	1.83	0.168	0.032	0.772
3	Yellowfin sole	0.59	0.053	0.010	0.826
4	Alaska plaice	0.35	0.032	0.006	0.858
5	Plain sculpin	0.29	0.026	0.005	0.885
6	Toothed smelt	0.20	0.018	0.003	0.903
7	Arctic cod	0.17	0.016	0.003	0.918
8	Shorthorn sculpin	0.17	0.015	0.003	0.934
9	Pacific herring	0.10	0.009	0.002	0.943
10	Arctic staghorn sculpin	0.08	0.008	0.001	0.950
11	Fourhorn sculpin	0.08	0.007	0.001	0.957
12	Antlered sculpin	0.08	0.007	0.001	0.964
13	Polar eelpout	0.06	0.006	0.001	0.970
14	Longhead dab	0.06	0.006	0.001	0.976
15	Slender eelblenny	0.04	0.005	0.001	0.980
16	Sturgeon poacher	0.04	0.003	0.001	0.983
17	Wattled eelpout	0.04	0.003	0.001	0.986
18	Arctic flounder	0.04	0.003	0.001	0.990
19	Belligerent sculpin	0.03	0.003	0.001	0.992
20	*Lumpenus mackayi*	0.03	0.003	4/	0.995

1/ Overall catch per unit effort, kg/km trawled. Total effort = 243.9 km.

2/ Proportion of catch per unit effort, total fish only. Fish CPUE = 10.87 kg/km trawled.

3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 57.46 kg/km trawled.

4/ Proportion less than 0.0005.

Table VIII-19.--Rank order of abundance of the 20 most abundant invertebrate taxa of possible commercial importance in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ commercially important invertebrate CPUE	Proportion 3/ of total CPUE	Cumulative proportion
1	Neptunea heros	1.85	0.366	0.043	0.366
2	Tanner crab	1.12	0.221	0.026	0.587
3	Red king crab	0.48	0.094	0.011	0.681
4	Telemessus crab	0.35	0.070	0.008	0.751
5	Neptunea ventricosa	0.35	0.068	0.008	0.820
6	Argis sp.	0.21	0.041	0.005	0.860
7	Blue king crab	0.19	0.037	0.004	0.897
8	Sclerocrangon boreas	0.12	0.023	0.003	0.921
9	Beringius beringii	0.09	0.019	0.002	0.939
10	Pyrulofusus deformis	0.08	0.015	0.002	0.954
11	Serripes groenlandicus	0.05	0.010	0.001	0.964
12	Volutopsius fragilis	0.02	0.004	0.001	0.968
13	Pandalus goniurus	0.02	0.003	4/	0.972
14	Crangonidae	0.02	0.003	4/	0.975
15	Volutopsius castaneus	0.01	0.003	4/	0.977
16	Cyclopecte randolphi	0.01	0.002	4/	0.979
17	Crangon dalli	0.01	0.002	4/	0.982
18	Buccinum polare	0.01	0.002	4/	0.984
19	Neptunea borealis	0.01	0.002	4/	0.986
20	Buccinum angulossum	0.01	0.001	4/	0.987

1/ Overall catch per unit effort, kg/km trawled. Total effort = 620.6 km.
2/ Proportion of catch per unit effort for invertebrates of possible commercial importance only; CPUE = 5.06 kg/km trawled.
3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 43.16 kg/km trawled.
4/ Proportion less than .0005.

Table VIII-20.--Rank order of abundance of the 20 most abundant invertebrate taxa of possible commercial importance in the southeastern Chukchi Sea (subarea 1, BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ commercially important invertebrate CPUE	Proportion 3/ of total CPUE	Cumulative proportion
1	Neptunea heros	2.77	0.477	0.071	0.447
2	Tanner crab	1.59	0.256	0.040	0.703
3	Telemessus crab	0.49	0.079	0.012	0.782
4	Neptunea ventricosa	0.48	0.078	0.012	0.861
5	Argis sp.	0.26	0.041	0.007	0.902
6	Sclerocrangon boreas	0.21	0.034	0.005	0.936
7	Beringius beringii	0.07	0.011	0.002	0.947
8	Volutopsius fragilis	0.04	0.006	0.001	0.954
9	Cyclopecte randolphi	0.04	0.006	0.001	0.960
10	Pyrulofusus deformis	0.03	0.005	0.001	0.964
11	Blue king crab	0.03	0.004	0.001	0.969
12	Buccinum polare	0.02	0.004	0.001	0.973
13	Volutopsius castaneus	0.02	0.003	0.001	0.977
14	Serripes groenlandicus	0.02	0.003	0.001	0.980
15	Neptune borealis	0.02	0.003	0.001	0.983
16	Natica clausa	0.02	0.003	4/	0.986
17	Buccinum angulossum	0.01	0.002	4/	0.989
18	Polinices pallida	0.01	0.002	4/	0.990
19	Pandalus goniurus	0.01	0.001	4/	0.992
20	Buccinum scalariforme	0.01	0.001	4/	0.993

1/ Overall catch per unit effort, kg/km trawled. Total effort = 139.2 km.
2/ Proportion of catch per unit effort for invertebrates of possible commercial importance; CPUE = 6.20 kg/km trawled.
3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 39.33 kg/km trawled.
4/ Proportion less than .0005.

Table VIII-21.--Rank order of abundance of the 20 most abundant invertebrate taxa of possible commercial importance in Kotzebue Sound (subarea 2, BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ commercially important invertebrate CPUE	Proportion 3/ of total CPUE	Cumulative proportion
1	Tanner crab	4.91	0.677	0.115	0.677
2	*Neptunea heros*	1.11	0.153	0.026	0.829
3	*Telemessus* crab	0.30	0.041	0.007	0.870
4	*Neptunea ventricosa*	0.27	0.037	0.006	0.907
5	*Argis* sp.	0.19	0.027	0.004	0.934
6	*Beringius beringii*	0.19	0.026	0.004	0.960
7	*Pyrulofusus deformis*	0.06	0.009	0.001	0.968
8	*Sclerocrangon boreas*	0.04	0.006	0.001	0.974
9	*Buccinum scalariforme*	0.03	0.004	0.001	0.978
10	*Volutopsius fragilis*	0.03	0.004	0.001	0.983
11	*Serripes groenlandicus*	0.02	0.003	4/	0.986
12	Red king crab	0.02	0.002	4/	0.988
13	*Astarte borealis*	0.01	0.002	4/	0.990
14	*Buccinum angulossum*	0.01	0.001	4/	0.992
15	*Clinocardium ciliatum*	0.01	0.001	4/	0.993
16	*Neptunea lyrata*	5/	4/	4/	0.994
17	*Pandalus goniurus*	5/	4/	4/	0.994
18	*Clinocardium californianaus*	5/	4/	4/	0.995
19	*Crangon dalli*	5/	4/	4/	0.995
20	*Natica clausa*	5/	4/	4/	0.995

1/ Overall catch per unit effort, kg/km trawled. Total effort = 86.6 km.
2/ Proportion of catch per unit effort for invertebrates of possible commercial importance only; CPUE = 7.26 kg/km trawled.
3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 42.87 kg/km trawled.
4/ Proportion less than .0005.
5/ Proportion less than .005.

Table VIII-22.--Rank order of abundance of the 20 most abundant invertebrate taxa of possible commercial importance in the northern Bering Sea (subarea 3, BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ commercially important invertebrate CPUE	Proportion 3/ of total CPUE	Cumulative proportion
1	*Neptunea heros*	1.55	0.412	0.042	0.412
2	Blue king crab	0.50	0.133	0.013	0.545
3	*Neptunea ventricosa*	0.41	0.110	0.011	0.655
4	*Argis* sp.	0.17	0.044	0.005	0.699
5	*Pyrulofusus deformis*	0.15	0.041	0.004	0.741
6	*Telemessus* crab	0.12	0.032	0.003	0.772
7	*Sclerocrangon boreas*	0.09	0.025	0.003	0.798
8	*Beringius beringii*	0.08	0.022	0.002	0.820
9	Red king crab	0.05	0.012	0.001	0.832
10	Crangonidae	0.04	0.012	0.001	0.844
11	*Pandalus goniurus*	0.03	0.007	0.001	0.852
12	*Serripes groenlandicus*	0.02	0.005	0.001	0.857
13	*Volutopsius castaneus*	0.02	0.004	4/	0.861
14	*Volutopsius fragilis*	0.02	0.004	4/	0.865
15	*Beringius fragili*	0.01	0.003	4/	0.868
16	*Neptunea borealis*	0.01	0.002	4/	0.870
17	*Buccinum polare*	0.01	0.002	4/	0.872
18	*Astarte borealis*	5/	0.001	4/	0.873
19	*Buccinum angulossum*	5/	0.001	4/	0.874
20	*Colus spitzbergensis*	5/	0.001	4/	0.875

1/ Overall catch per unit effort, kg/km trawled. Total effort = 150.9 km.
2/ Proportion of catch per unit effort for invertebrates of possible commercial importance only; CPUE = 3.75 kg/km trawled.
3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 37.05.
4/ Proportion less than .0005.
5/ Proportion less than .005.

Table VIII-23.--Rank order of abundance of the 20 most abundant invertebrate taxa of possible commercial importance in Norton Sound (subarea 4, BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ commercially important invertebrate CPUE	Proportion 3/ of total CPUE	Cumulative proportion
1	Red king crab	1.93	0.415	0.034	0.415
2	Neptunea heros	1.39	0.299	0.024	0.714
3	Telemessus crab	0.55	0.118	0.010	0.832
4	Argis sp.	0.21	0.045	0.003	0.877
5	Serripes groenlandicus	0.14	0.031	0.003	0.908
6	Beringius beringii	0.10	0.022	0.002	0.931
7	Neptunea ventricosa	0.10	0.021	0.002	0.952
8	Sclerocrangon boreas	0.06	0.012	0.001	0.964
9	Crangon dalli	0.04	0.009	0.001	0.973
10	Tanner crab	0.03	0.006	0.001	0.979
11	Unidentified snails	0.02	0.005	4/	0.984
12	Pyrulofusus deformis	0.02	0.005	4/	0.988
13	Pandalus goniurus	0.02	0.004	4/	0.992
14	Pandalus hypsinotus	0.01	0.002	4/	0.994
15	Clinocardium californianaus	0.01	0.001	4/	0.996
16	Volutopsius fragilis	0.01	0.001	4	0.997
17	Clinocardium ciliatum	5/	0.001	4/	0.998
18	Neptunea borealis	5/	0.001	4/	0.998
19	Musculus discors	5/	0.001	4/	0.999
20	Mytilus edulis	5/	4/	4/	0.999

1/ Overall catch per unit effort, kg/km trawled. Total effort = 243.9 km.
2/ Proportion of catch per unit effort for invertebrates of possible commercial importance only; CPUE = 4.65 kg/km trawled.
3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 57.46 kg/km trawled.
4/ Proportion less than .0005.
5/ Proportion less than .005.

SPECIES ASSOCIATIONS

PROCEDURES

The relationships between demersal fish and numerous invertebrate taxa were initially examined by means of species assemblages, as determined through the recurrent group procedure described by Fager (1957, 1963) and Fager and Longhurst (1968). This analysis identifies species associations on the basis of co-occurrence of species within trawl samples and a dichotomy of grouping rules. The geometric mean of the proportion of co-occurrences, corrected for sample size, was used as an index of the affinity:

$$\frac{c}{\sqrt{ab}} - \frac{1}{2\sqrt{b}}$$

where c is the number of joint occurrences, a is the number of occurrences by species A, and b is the number of occurrences by species B ($b \geq a$). Only those species pairs having indices above the specified value (0.60) were considered to have affinities.

Several criteria were used in the determination of valid groupings: each species in a group had to show an affinity with all other members of that group, the largest possible groups were formed, and no species could occur in more than one group. Species showing affinities with some but not all members of a group were considered associate members.

After recurrent groups were defined, intergroup relationships were determined as the ratio of the number of observed species - pair affinities between the groups to the maximum number of possible connections. The occurrence of groups (all group members present) among stations were also listed and plotted.

All catch data for positively identified fish and invertebrate taxa in the 192 successful demersal trawl hauls were included in the analysis. Saffron cod were classified as adults (> 10 cm) and juveniles (≤ 10 cm) because of their large numbers and relative importance. Invertebrate taxa included in the analysis were those groups mentioned earlier: starfish, basketstars, gastropod and pelecypod molluscs, shrimp, and Tanner, king, and *Telemessus* crabs.

RESULTS

Twenty-three (23) taxa were identified through the recurrent grouping procedure as having one or more affinity values greater than 0.60 and were organized into five groups. The remaining taxa examined did not occur frequently enough to show affinity at the assigned level. Group compositions and intergroup relationships are shown in Figure VIII-39.

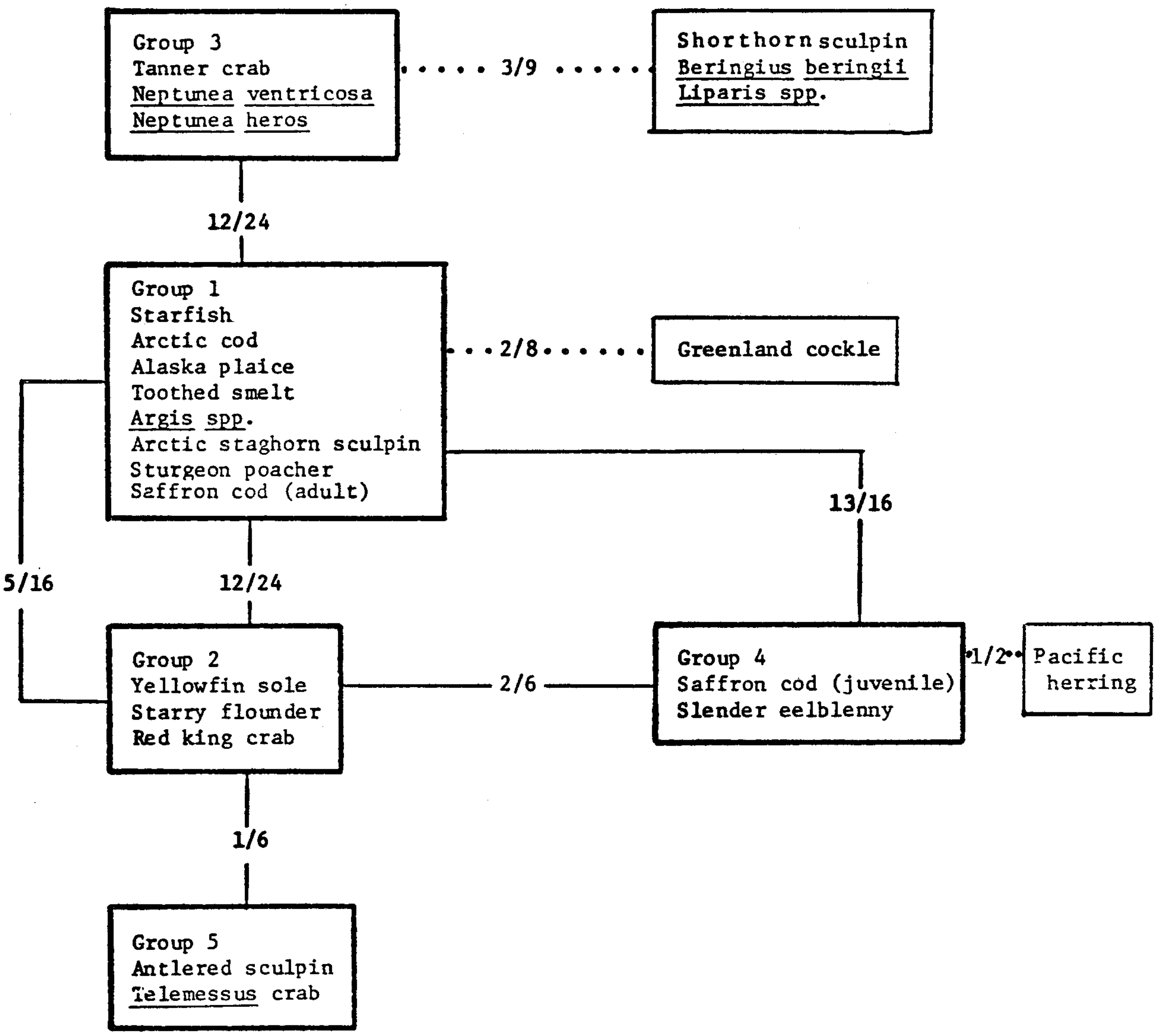


Figure VIII-39.--Recurrent species groups and their relationships in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976). Fractions indicate the ratio of the number of observed species-pair affinities between groups to the maximum numbers of possible connections (maximum possible connections for any two groups = product of number of species within both groups). Dotted lines indicate associated taxa showing affinity with some group numbers, but not all.

Although relatively few taxa were found to have significant relationships, the composition and distribution patterns of these recurrent species groups suggest that they characterize important features of the survey area environment: (1) the 23 taxa accounted for 71% of the total survey catch by weight, and (2) group occurrences were regional, with fairly limited geographical overlap.

Group 1 (total survey region group): Eight taxa formed this group which had the most widespread distribution throughout the survey area at all depths. This combination of species was also the most commonly encountered group, occurring at 79 trawl stations (Figure VIII-40) and included several taxa (starfish, adult saffron cod, and Arctic cod) which dominated the total survey catch. The Greenland cockle was associated with two group members, starfish and *Argis* shrimp.

Group 2 (Norton Sound shallow-water group): Two fish and one invertebrate species formed group 2 which was found at 52 stations, primarily at depths less than 25 m and almost exclusively in Norton Sound (Figure VIII-41). Although starry flounder and yellowfin sole were found together in several other areas of the survey region, the inclusion of red king crab into this group caused this group's highly defined regional distribution.

Group 3 (offshore group): Group 3 members (3 invertebrate species) and three associates occurred together at 62 stations, primarily in offshore regions of the survey area, in both the northern Bering and southeastern Chukchi seas (Figure VIII-42). When this group occurred in shallow water (< 25 m), their presence was generally associated with bottom waters colder than 6°C. The shorthorn sculpin and snailfish showed affinity with Tanner crab, while the whelk, *Beringius beringii*, was associated with another group member, the fat neptune whelk, *Neptunea ventricosa*.

Group 4 (all survey area shallow-water group): Group 4 members (two species and one associate) were frequently encountered throughout the survey region (72 stations) at water depths less than 25 m, and occasionally at slightly deeper depths (Figure VIII-43). Pacific herring showed affinity with juvenile saffron cod but not with the slender eelblenny.

Group 5 (nearshore shallow-water group): The two species of this group were encountered together at 52 stations in several nearshore sampling areas where water depths were less than 25 m. The heaviest concentration of occurrences of group 5 was encountered in inner Norton Sound (Figure VIII-44).

The results of these preliminary analyses provide evidence for recurrent features in the organization of demersal fauna for Norton Sound, the southeastern Chukchi Sea, and adjacent waters during late summer months in one year. A relatively small number of principal species appears to define much of the demersal community structure. These principal species were identified as members of five groups: one which occurred throughout much of the survey region at most depths, another group which appeared associated with deeper, colder water, and three combinations of taxa which occurred in shallow water but had specific distributional features which provided a means for separation.

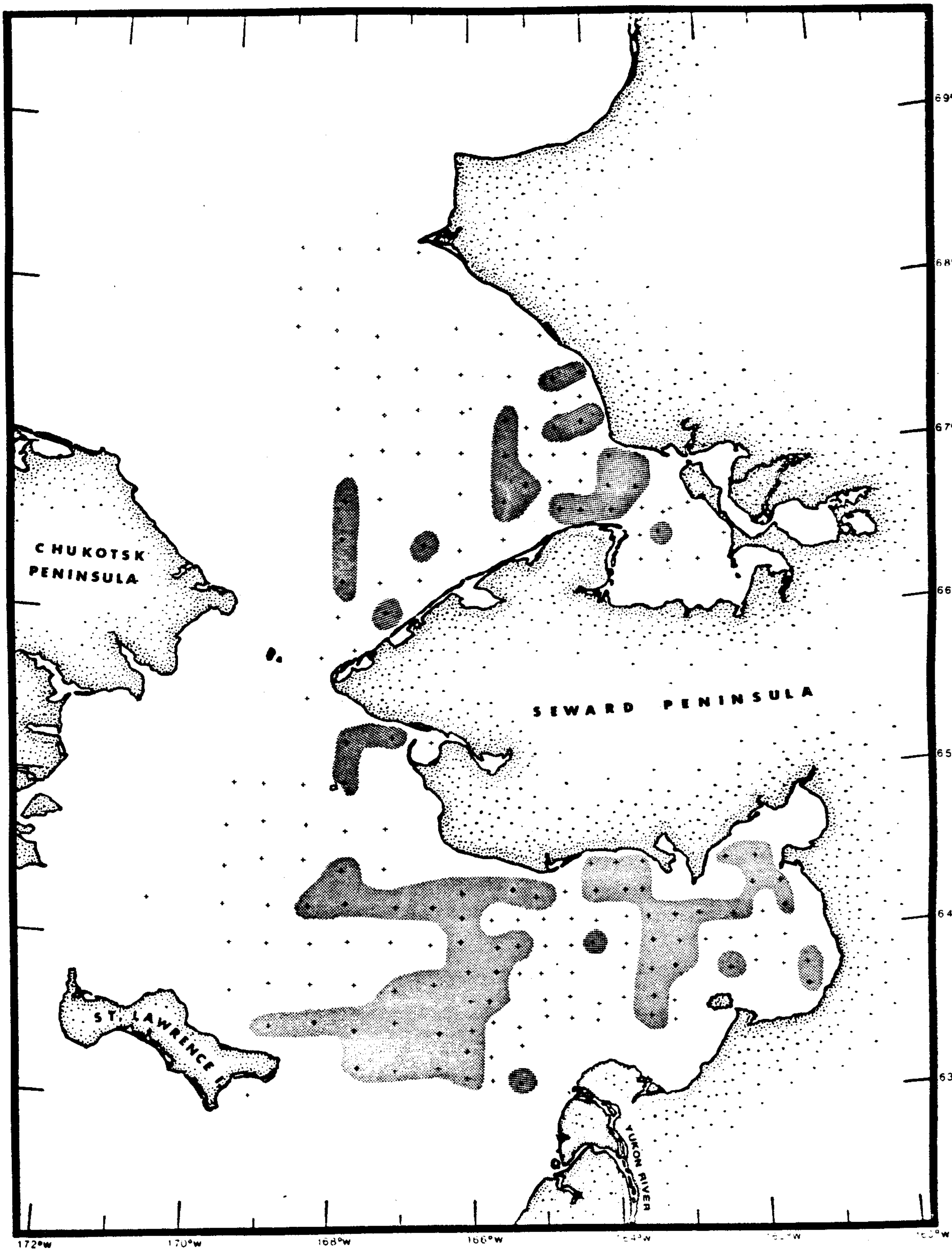


Figure VIII-40.--Occurrence of recurrent group 1 in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

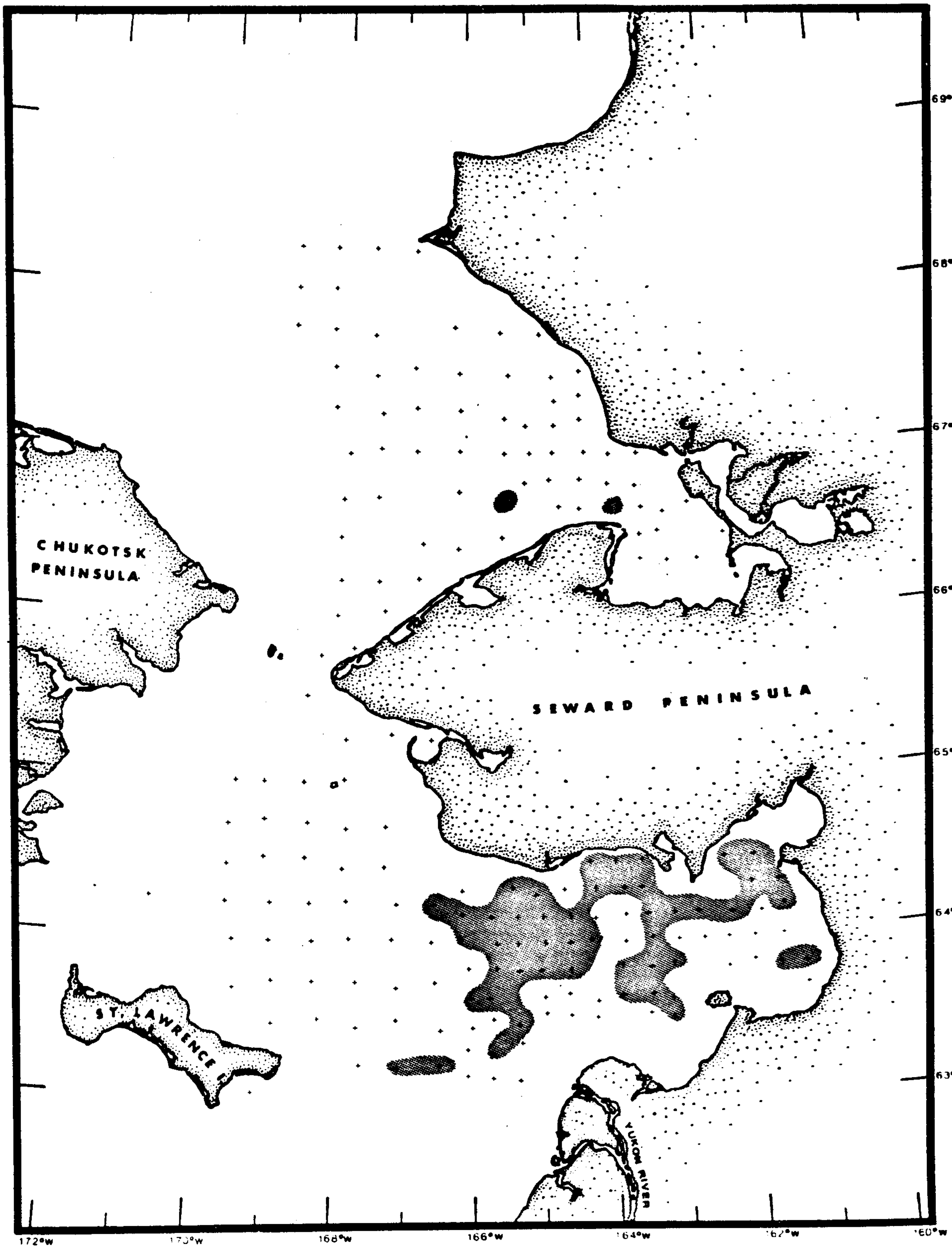


Figure VIII-41.--Occurrence of recurrent group 2 in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

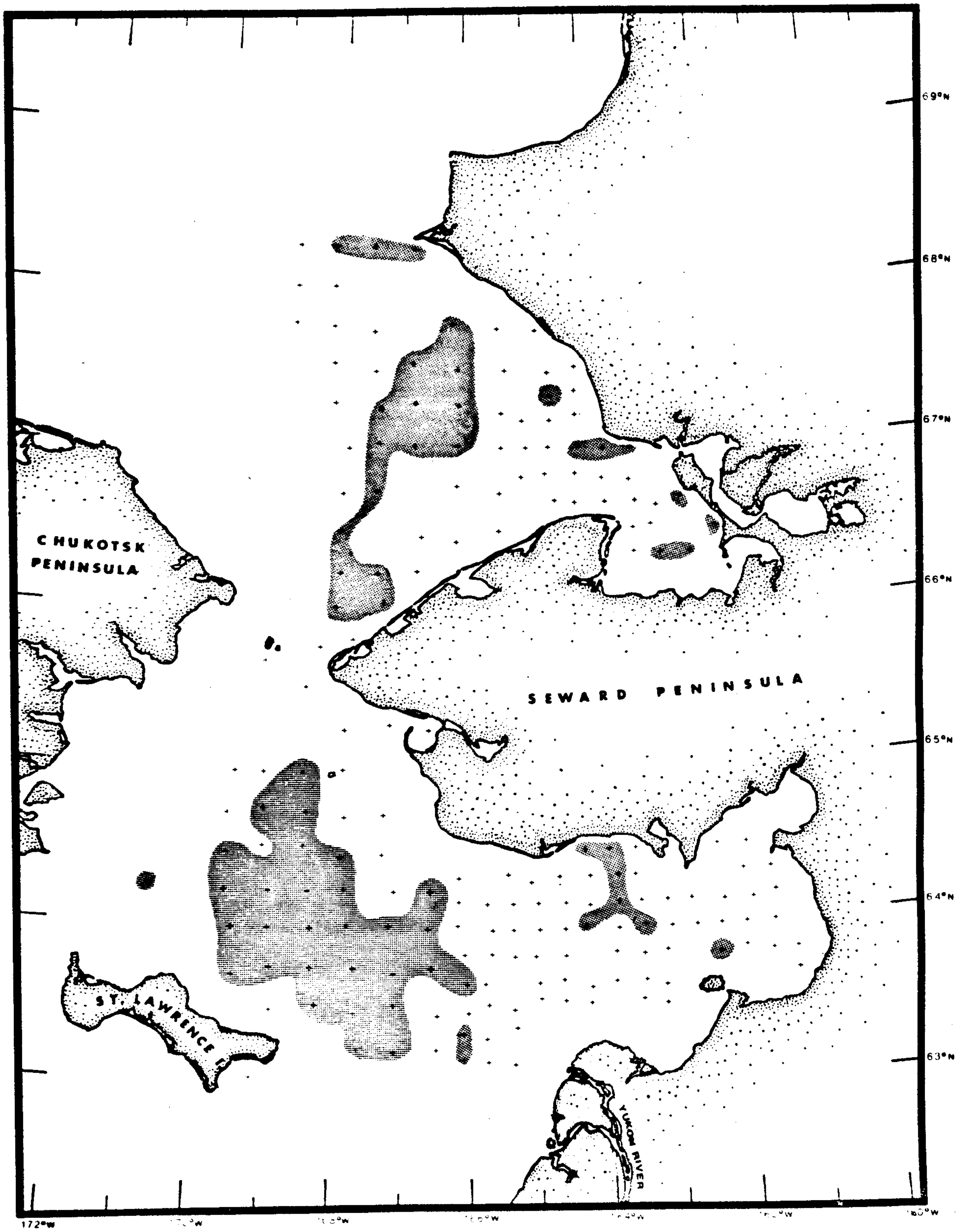


Figure VIII-42.--Occurrence of recurrent group 3 in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

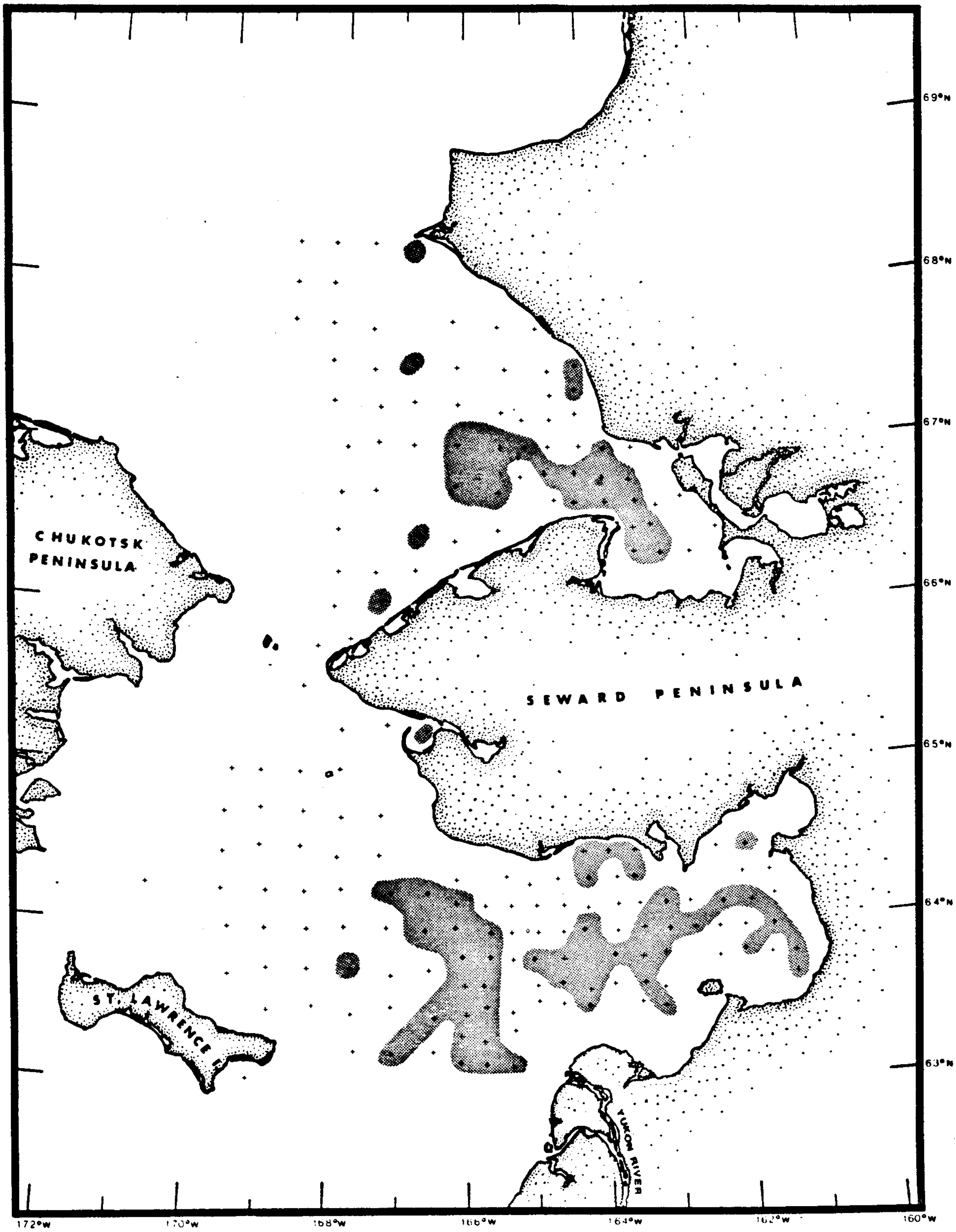


Figure VIII-43.--Occurrence of recurrent group 4 in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

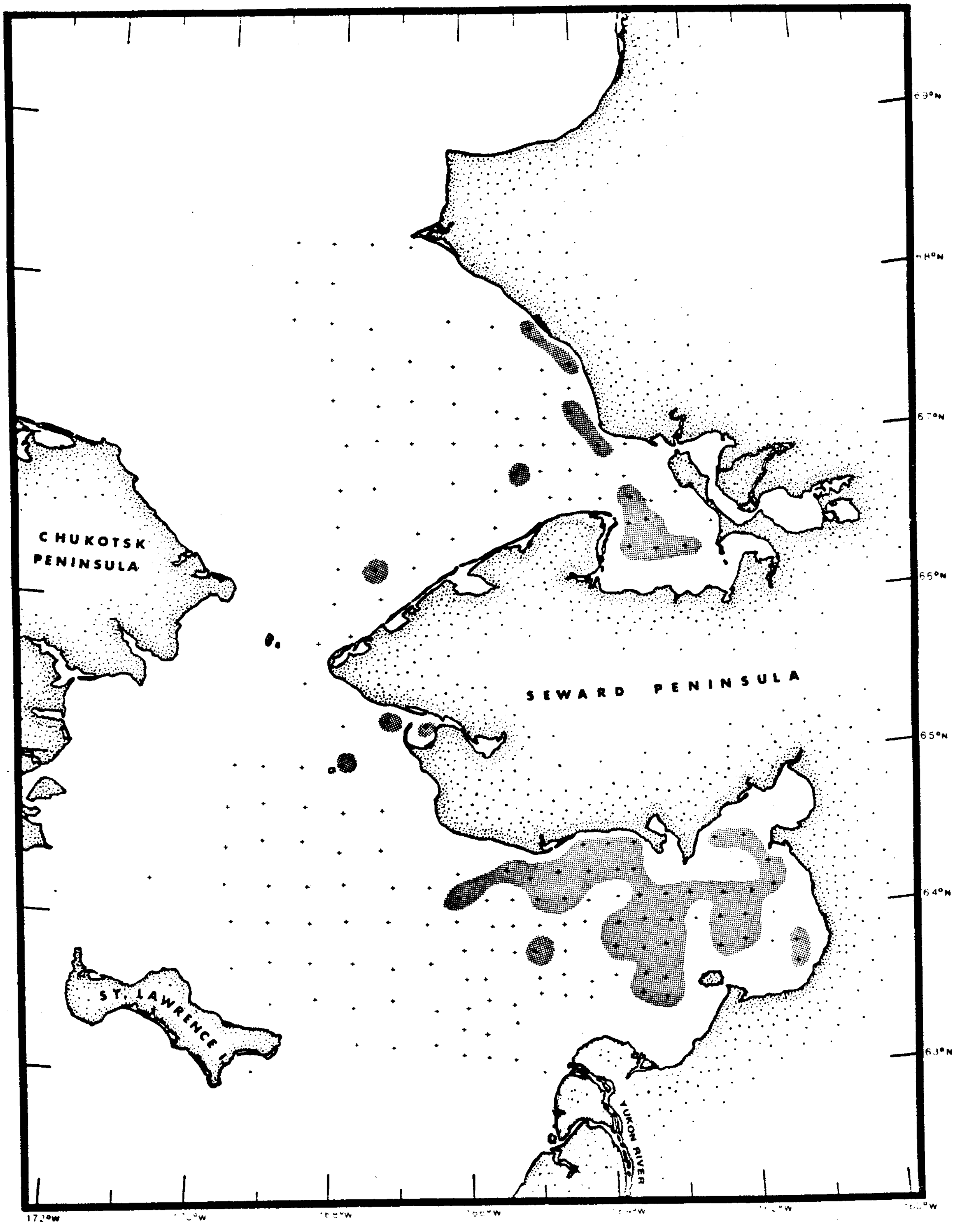


Figure VIII-44.--Occurrence of recurrent group 5 in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Distribution, Biomass, and Biological Features of Principal Species of Fish

Saffron cod

Distribution and abundance--Saffron cod was the most abundant fish species encountered in the survey area. It occurred at 78% of the demersal stations sampled (Table VIII-24) and accounted for 45% of the total apparent biomass for all fish species combined. Largest concentrations of saffron cod were located in the outer portion of Norton Sound and the eastern portion of the northern Bering Sea (strata 4Ø and 3E) (Figures VIII-45 and 46) where catches averaged 8.0 and 8.2 kg/km, respectively. Average catch rates decreased to about 1.8 kg/km in outer Kotzebue and inner Norton sounds (strata 2Ø and 4I) and further declined to between 0.1 and 0.7 kg/km in the remainder of the survey region. The overall mean catch rate for the entire survey area was about 2.2 kg/km trawled.

Table VIII-24.--Estimated biomass and population size of saffron cod in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population ($\times 10^3$)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	27.6	0.110	188	.010	43,660	.049	.004	7.74
1S	93.3	0.687	520	.028	31,948	.036	.016	8.92
2Ø	89.5	1.710	735	.040	43,802	.049	.017	10.38
2I	87.5	0.272	83	.005	6,937	.008	.012	8.25
Norton Sound and Northern Bering Sea								
3W	46.9	0.125	274	.015	5,332	.006	.051	19.07
3E	100.0	8.195	5,015	.273	158,797	.179	.032	15.02
4Ø	100.0	7.952	10,587	.576	550,172	.619	.019	11.50
4I	100.0	1.821	968	.053	48,737	.055	.020	12.07
All strata combined:	78.1 2/	2.192	18,370 3/		889,385		.020	11.51

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 14,116-22,624 mt.

The apparent biomass of saffron cod in the entire survey area was estimated at 18,400 mt (95% confidence interval 14,100-22,600 mt). This is a minimum estimate for the survey region, since saffron cod are semi-pelagic and some unknown proportion of the population occupied the water

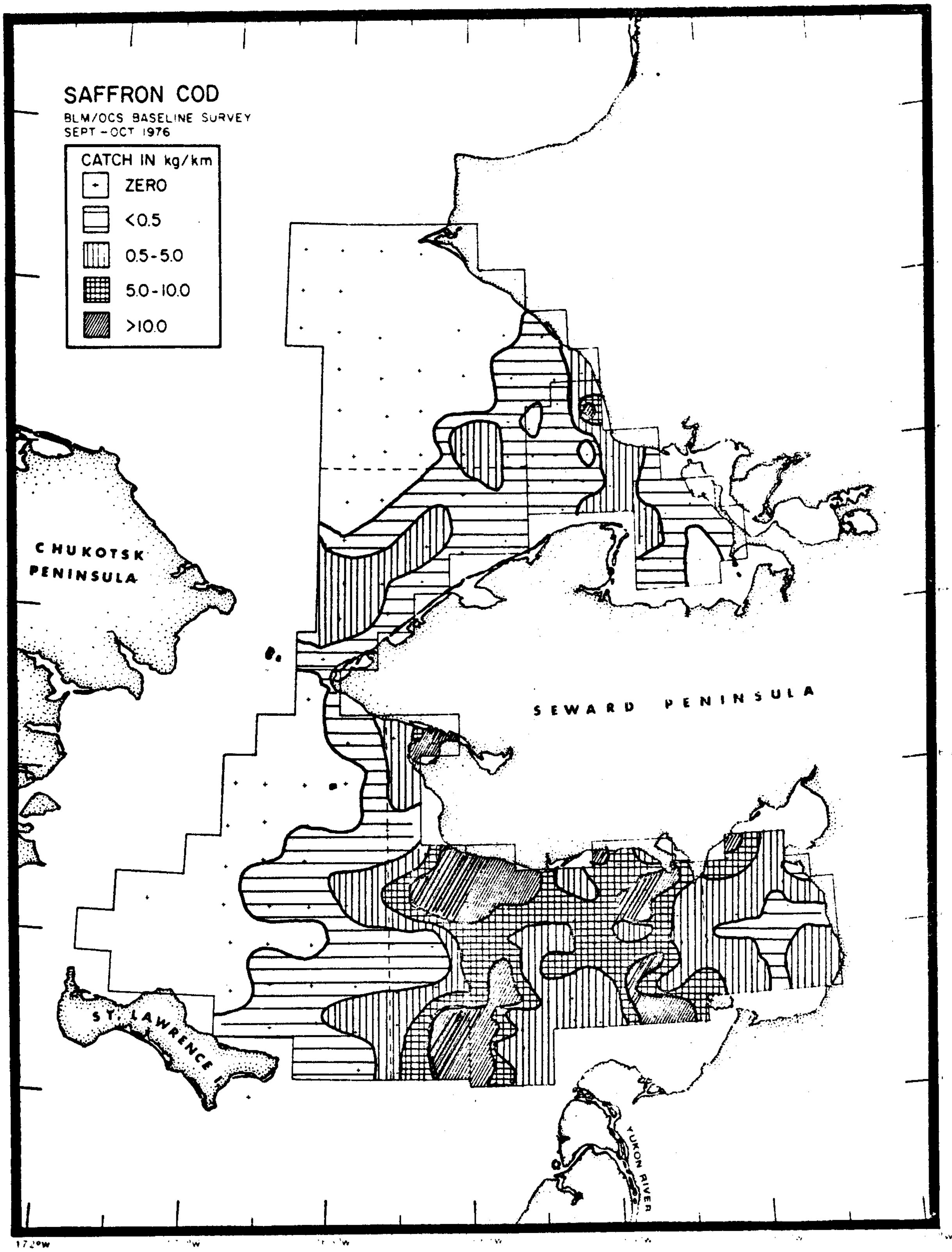


Figure VIII-45.--Distribution and relative abundance by weight of saffron cod in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

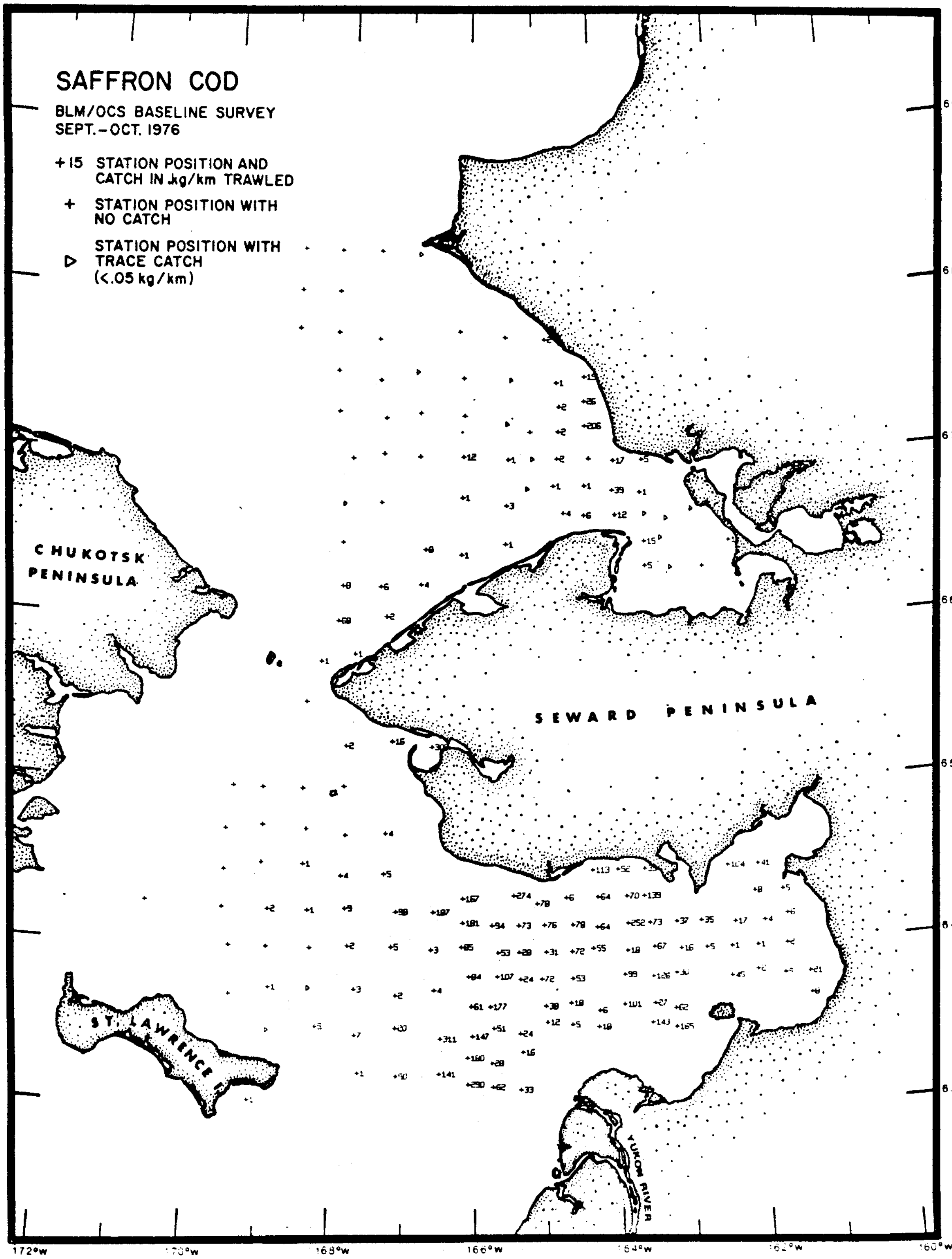


Figure VIII-46.--Distribution of catch rates by weight of saffron cod in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey 1976).

column above the demersal trawl, thus being unavailable to the sampling gear. In addition, saffron cod concentrations may have existed beyond the southern boundary of the survey region. Some of the largest catches of this species occurred near the southern limit of strata 3E and 4Ø; earlier Japanese trawl surveys in 1968-1970 indicated catches of saffron cod of up to 1000 kg/30 minute trawl hauls off Cape Romanzof, 50 km south of the survey boundary.

For the saffron cod population sampled, the major portion of the biomass (approximately 85%) was located in strata 3W and 4Ø. Of the remaining biomass, 5% was located in stratum 4I, 4% in stratum 2I, and 1-3% in all other strata.

The relative distribution of estimated numbers of fish differed somewhat from that of apparent biomass. In the southeastern Chukchi Sea, the offshore stratum 1N had an estimated apparent biomass of only 188 mt while in the more nearshore strata 1S and 2Ø, the estimated biomasses were 520 and 735 mt, respectively. Population estimates for these strata, however, were 44 million fish in 1N, 32 million in 1S, and 44 million in 2Ø. While biomass estimates for stratum 1N were only 1/4 to 1/3 that for strata 1S and 2Ø, its estimated population equalled or exceeded that for the other strata.

As with biomass, most of the estimated population of saffron cod occurred in strata 3E and 4Ø. These strata accounted for about 75% of the total population estimate of nearly 900 million fish.

Size composition--Saffron cod ranged in length from 5 to 35 cm. Females were generally larger than males, averaging 19.5 compared to 17.9 cm for all strata combined (Figure VIII-47). Length-frequency distributions for saffron cod included juvenile fish of undetermined sex. The inclusion of these unsexed fish in the calculation of mean size for both sexes combined in all strata caused mean lengths to be considerably less than those for individual sexes.

Most saffron cod found north of Bering Strait were small. Nearly all fish in strata 1N and 1S were less than 10 cm in length, while a few fish as large as 23 cm occurred in stratum 2Ø. In strata south of Bering Strait, fish smaller than 10 cm were still present in appreciable numbers; however, saffron cod as large as 25 cm were far more abundant. In stratum 4Ø, fish from 13 to 25 cm comprised about 25% of the total estimated population.

A general description of the distribution of saffron cod by size in relation to geographic areas shows small (< 10 cm) fish occured throughout the survey region. A few larger fish (10-20 cm) were found in outer Kotzebue Sound and inner Norton Sound, while most large fish (> 20 cm) occurred in outer Norton Sound and in Port Clarence.

Age composition--In terms of estimated numbers of fish, age groups 0-2 predominated (Table VIII-25), comprising over 96% of the estimated standing stock in numbers for the entire survey area. Age group 0 fish alone comprised 67% of the total, with most of these fish occurring in

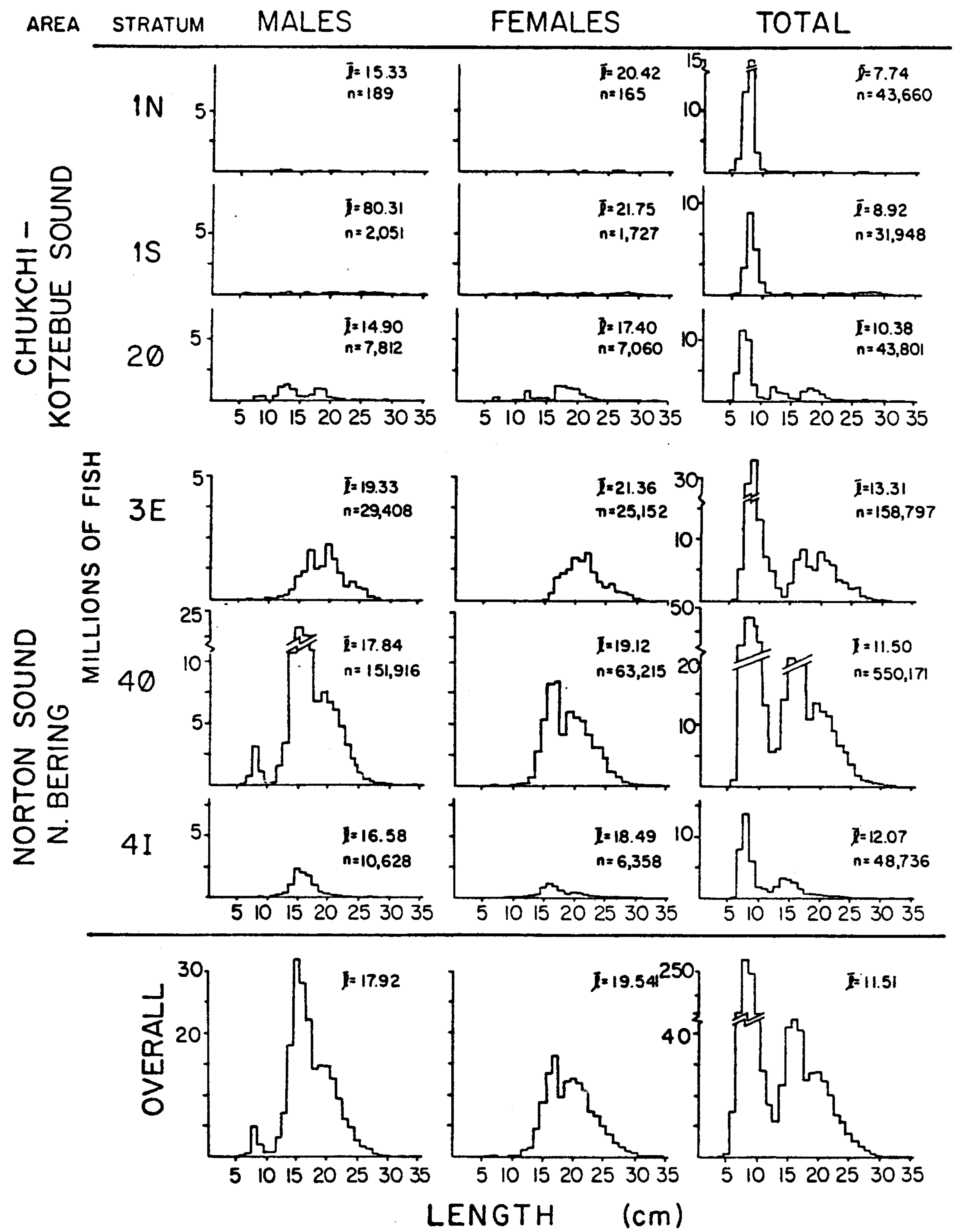


Figure VIII-47.--Size composition of saffron cod by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

strata 3E and 4Ø. Age groups 1 and 2, accounting for nearly 25% of the total population, also were most abundant in strata 3E and 4Ø. All other age groups were present in relatively small amounts throughout the survey region.

Table VIII-25.--Population numbers ($x10^5$) and sex ratios (number of males/number of females) of saffron cod by age group and stratum (BLM/OCS survey, 1976).

Age group Year class	0 1976	1 1975	2 1974	3 1973	4 1972	5 1971	6 1970	7 1969	8 1968	9 1967	10 1966	>10 ≤1965	All ages combined
Stratum													
Southeastern Chukchi Sea and Kotzebue Sound													
1N	426.1 —	3.7 (2.45)	1.6 (1.17)	0.1 (0.50)	0.4 (2/)	0.1 (2/)	--	—	—	—	—	—	432.0 (1.13)
1S	275.9 (2.16)	8.5 (2.45)	10.5 (2.04)	6.0 (148.00)	10.4 (20.58)	0.7 (2/)	3.6 (1/)	--	0.3 (1/)	0.3 (1/)	—	—	316.0 (4.79)
2Ø	290.1 (1.93)	57.2 (3.47)	82.7 (0.55)	3.6 (8.97)	3.0 (0.27)	0.6 (0.33)	--	0.1 (2/)	—	—	—	—	437.0 (1.11)
2I	61.0 —	1.7 (1.05)	3.7 (0.57)	0.6 (2.73)	0.4 (0.26)	0.1 (2/)	0.1 (2/)	—	—	—	—	—	67.6 (0.66)
Norton Sound and Northern Bering Sea													
3W	27.0 —	0.3 (1/)	13.3 (0.18)	6.7 (0.25)	2.8 (0.19)	0.8 (2/)	0.1 (2/)	—	—	—	—	—	51.0 (1.20)
3E	891.6 (1/)	200.6 (5.26)	385.9 (0.95)	85.8 (1.01)	20.1 (0.75)	0.4 (2/)	0.1 (2/)	—	—	—	—	—	1,584.4 (1.17)
4Ø	3,741.1 (1.15)	817.2 (1.98)	764.1 (1.18)	144.0 (1.01)	27.1 (1.11)	1.2 (0.22)	0.6 (2/)	—	—	—	—	—	5,495.4 (1.40)
4I	296.0 (0.71)	111.2 (2.65)	67.6 (1.23)	9.5 (0.57)	3.0 (0.55)	0.1 (2/)	0.1 (2/)	—	—	—	—	—	487.4 (1.67)
All strata combined	6,008.9 (1.64)	1,200.3 (2.28)	1,329.3 (1.05)	256.1 (1.03)	67.0 (1.09)	4.1 (0.10)	4.4 (3.41)	0.1 (2/)	0.3 (1/)	0.3 (1/)	—	—	8,870.7 (1.34)
Proportion of total population	.677	.135	.150	.029	.008	.001	.001	T	T	T	—	—	

1/ Only males in estimate.
2/ Only females in estimate.

Differences in relative age composition between sexes do not appear significant (Figure VIII-48).

Sex ratio--Estimated sex ratios (number of males/number of females) by stratum and age group are presented in Table VIII-25. Males were more abundant than females in nearly all strata although this trend was not consistent among all age classes, especially for those older than 2 years.

Age-length relationship and growth--Age and length data collected for saffron cod were as follows:

Sex	Otolith areas	Number of readable otoliths	Range in age (years)	Range in length (cm)
Male	North	130	0-9	6-35
	South	136	0-5	8-34
Female	North	135	0-7	6-34
	South	160	0-6	7-34

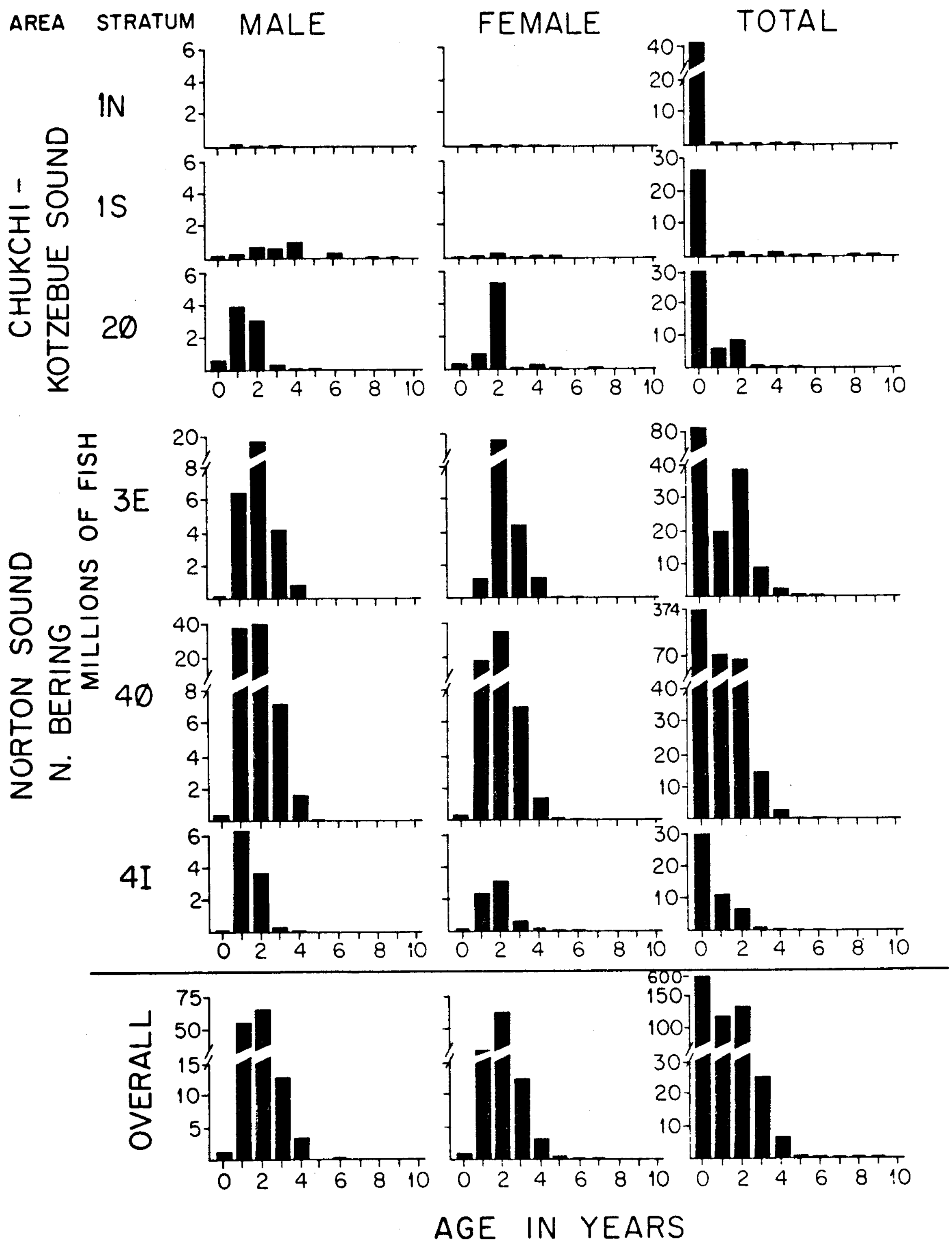


Figure VIII-48.--Age composition of saffron cod by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

These data are summarized in Figure VIII-49 by plots of mean-lengths-at-age by sex and otolith area. Age-length keys for these data groupings are presented in Appendix I and growth parameters based on this information are given in Table VIII-26.

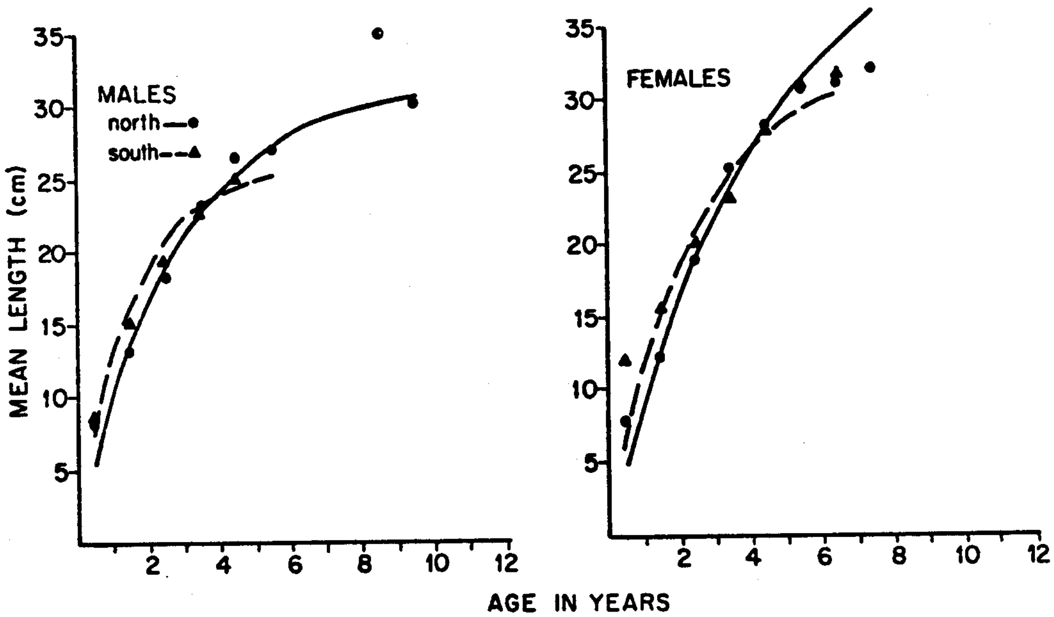


Figure VIII-49.--Mean lengths-at-age and growth curves fit to the origin for saffron cod by sex and otolith area in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Table VIII-26.--Parameters for von Bertalanffy growth curves for saffron cod in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Otolith areas	Sex	Range in age and length of analyzed data: age (yr)	length (cm)	Original data set: δ	L_∞	K	t_o	Selected data: δ	L_∞	K	t_o	Selected data with origin: δ	L_∞	K	t_o
North	Males	0.5-9.5 (1.5-5.5)	(10-32)	2.08	35.83	-0.27	-0.35	0.87	30.35	-0.42	0.18	0.79	31.57	-0.36	-0.01
	Females	0.5-7.5 (1.5-4.5)	(10-32)	1.51	37.32	-0.26	-0.32	0.99	36.26	-0.36	0.34	0.95	43.61	-0.23	-0.01
South	Males	0.5-5.5 (0.5-4.5)	(8-30)	2.35	-618.18	0.01	-1.13	0.15	30.86	-0.34	-0.47	1.27	25.76	-0.63	-0.02
	Females	0.5-6.5 (1.5-4.5)	(11-33)	1.10	46.18	-0.14	-1.58	0.77	102.93	-0.05	-1.71	1.29	32.16	-0.42	0.02

Since young of the year (age group 0) were present in all sets of saffron cod age data, adjustments to ages were necessary to provide reasonable growth curve fits for both the original data and for the selected sets which included values at the origin of the curve (age and length = 0). Age plus 0.5 years was used as the adjustment, since it is reasonable to assume that at least half of a year's growth had been completed by the September-October survey date. [1/]

In most cases, there was a reduction in the residual root mean square deviations by using selected data and fitting the curve to the origin. This was especially evident in fits for data from the north otolith area. The selected sets also improved fits for the southern area data where meaningless parameters ($\underline{K} > 0$ and $\underline{L}_\infty < 0$) were estimated before selection.

Sex and area effects were observed within the selected data for the parameters $\underline{K}$ and $\underline{L}_\infty$. Males appeared to have substantially higher growth completion rates ($\underline{K}$) than females and estimates of this parameter for either sex were considerably higher (42-45%) in the south otolith area than in the north. Additionally, values of $\underline{L}_\infty$ by sex were 18-26% greater in the north otolith area than in the south. Mean length-at-age for both sexes in the south were greater than those for fish of similar ages in the north otolith area but this relationship was observed only up to age 2.5 years. Beyond that age the reverse was usually observed with larger sizes at age in the north than south.

Overall, age-length data for saffron cod suggest that males achieved maximum size more rapidly than females while total growth was greatest for females. By area, both sexes of saffron cod grew more in the survey region north of Bering Strait, although at ages less than 3.5 years, fish of either sex in the south had larger sizes at age than in the north.

Curves describing the growth equation for selected data with a fit to the origin are presented with observed mean lengths-at-age by area and sex in Figure VIII-49.

Length-weight relationship--Table VIII-27 summarizes the length-weight observations taken for saffron cod by sex and area and gives coefficients of the regression fit to these data. Data points representing all length-weight observations collected for this species during the survey are shown graphically in Figure VIII-50.

Analysis of covariance for between-area and between-sex differences in the relationship between length and weight indicated significant levels of variation ($p < .05$) in all treatments of the data. On the basis of weights predicted by the regression coefficients, males generally weighed slightly more at-length than females, and fish of either sex from the

1/ Andriyashev (1954) indicated that saffron cod spawn during early winter in the Asian side of Bering Strait and growth into adult forms occurs by July.

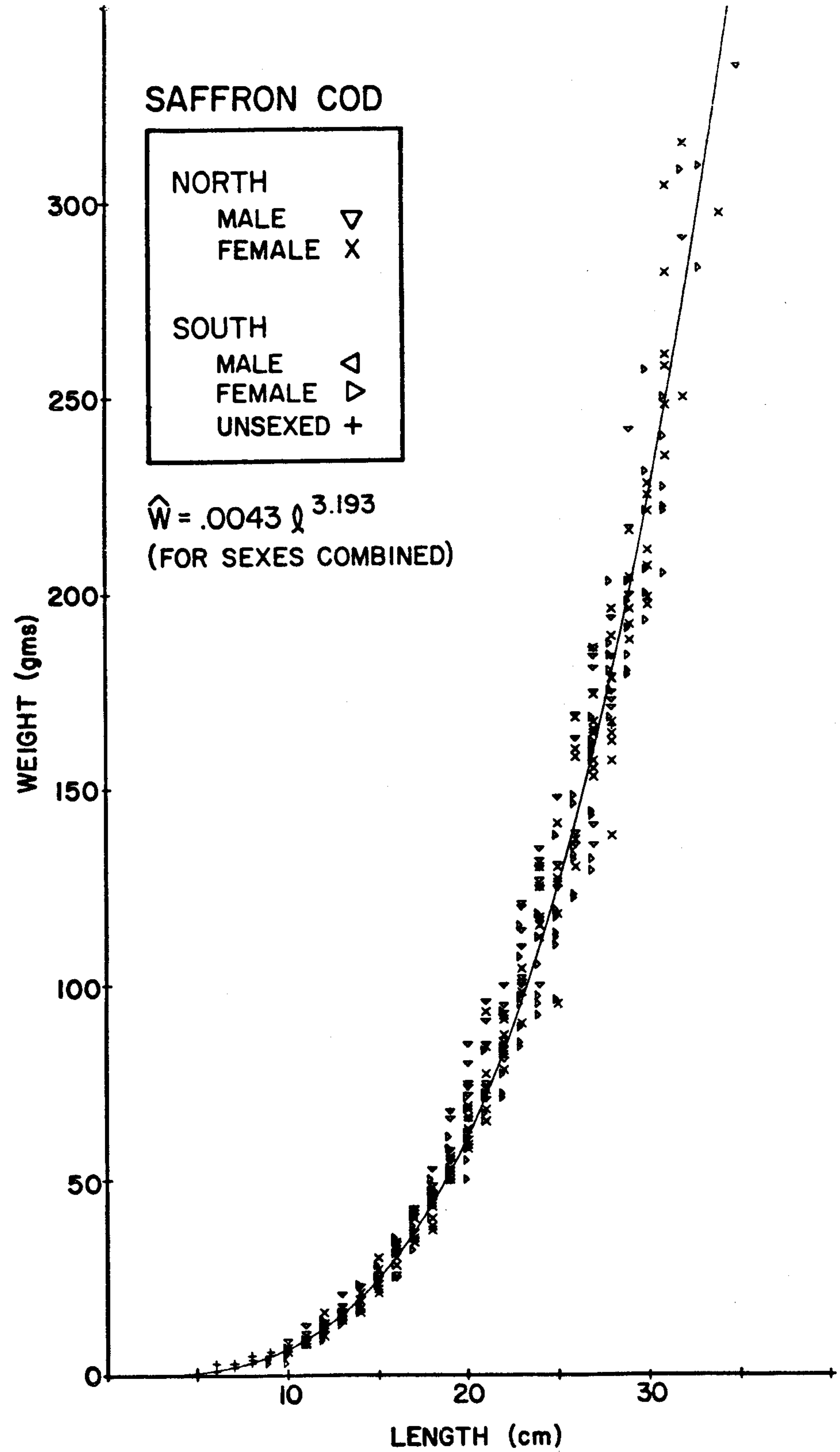


Figure VIII-50.--Weight-at-length observations for saffron cod by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

north otolith area were heavier at-length than fish of corresponding length and sex from the south. These data suggest differing stocks of saffron cod north and south of Bering Strait. Differences in weight-at-length, however, were on the order of 3-5%; thus, an overall length-weight relationship for saffron cod in the survey area could be described by the equation:

$$\hat{w} = 0.0043\ell^{3.1926}$$

where $\hat{w}$ equals the predicted weight in grams of a fish ℓ cm in length. The relationship described by this equation is shown as a solid line in Figure VIII-50.

Table VIII-27. --Parameters for the length-weight relationship (weight (g) = a · lenght^{b}) for saffron cod and results from the analysis of covariance for between-area and between-sex differences in this relationship (BLM/OCS survey, 1976).

Sex	Otolith Area	Number of Fish Measured	Range in Length (cm)	Parameters a	Parameters b
Males	North	122	10-35	.0033	3.3018
	South	128	8-30	.0045	3.1765
Females	North	141	10-34	.0041	3.2071
	South	151	9-32	.0032	3.2750

Differences between-	F slope df	F slope F	F intercept df	F intercept F	H_b 1/	H_a 1/	Pooled regression a	Pooled regression b
Areas for males	1;246	5.20*	1;247	6.18*	+	+	.0038	3.2425
Areas for females	1;288	2.91	1;289	11.50**	-	+	.0036	3.2478
Areas for sexes combined 2/	1;561	17.1**	1;562	6.52*	+	+	.0043	3.1926
Sexes for south area	1;275	4.11*	1;276	7.69**	+	+	.0039	3.2218
Sexes for north area	1;259	4.58*	1;260	10.10**	+	+	.0038	3.2399
Sexes for areas combined	1;538	.03	1;539	17.5**	-	+	.0038	3.2355

* Significant at the .05 level.

** Significant at the .01 level.

1/ Plus (+) indicates that the common slope (H_b) hypothesis or common intercept (H_a) hypothesis cannot be rejected on the basis of the values of F obtained.

2/ Includes unsexed fish.

Starry flounder

Distribution and abundance--Starry flounder was the second-most abundant fish species, by weight, in the survey region. It accounted for 13% of the total fish biomass and occurred at 47% of the stations sampled (Table VIII-28). Largest concentrations were located in outer Norton Sound (stratum 4Ø), the eastern portion of the northern Bering Sea (stratum 3E), and in the southern portion of the Chukchi Sea (stratum 1S) (Figures VIII-51 and 52) where catch rates averaged 2.3, 1.4, and 1.5 kg/km, respectively. Average catch rates were substantially lower in outer Kotzebue Sound (stratum 2Ø) and inner Norton Sound (stratum 4I), while no catches occurred offshore in both the southeastern Chukchi Sea (stratum 1N) and northern Bering Sea (stratum 3W). Overall the mean catch rate for the entire survey area was 0.6 kg/km trawled.

Table VIII-28.--Estimated biomass and population size of starry flounder in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population ($\times 10^3$)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	3.4	0.049	84	.016	167	.023	.504	32.66
1S	66.7	1.528	1,156	.214	1,185	.163	.976	40.64
2Ø	42.1	0.128	55	.010	96	.013	.575	—
2I	25.0	0.204	62	.012	68	.009	.908	38.50
Norton Sound and northern Bering Sea								
3W	—	—	—	—	—	—	—	—
3E	57.1	1.396	854	.158	1,217	.168	.703	34.85
4Ø	87.9	2.304	3,068	.569	4,067	.560	.755	35.68
4I	64.7	0.209	111	.021	460	.063	.242	24.86
All strata combined:	47.4 2/	0.643	5,390 3/		7,260		.745	35.67

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 2,957-7,823 mt.

Starry flounder biomass in the entire survey area was estimated at about 5,400 mt (95% confidence interval 2,957-7,823 mt). This survey region estimate is probably fairly good, even though relatively high catch rates occurred along the southern boundary of the study region, indicating the probable presence of relatively large starry flounder concentrations south of the survey boundary. This species is known to primarily inhabit shallow

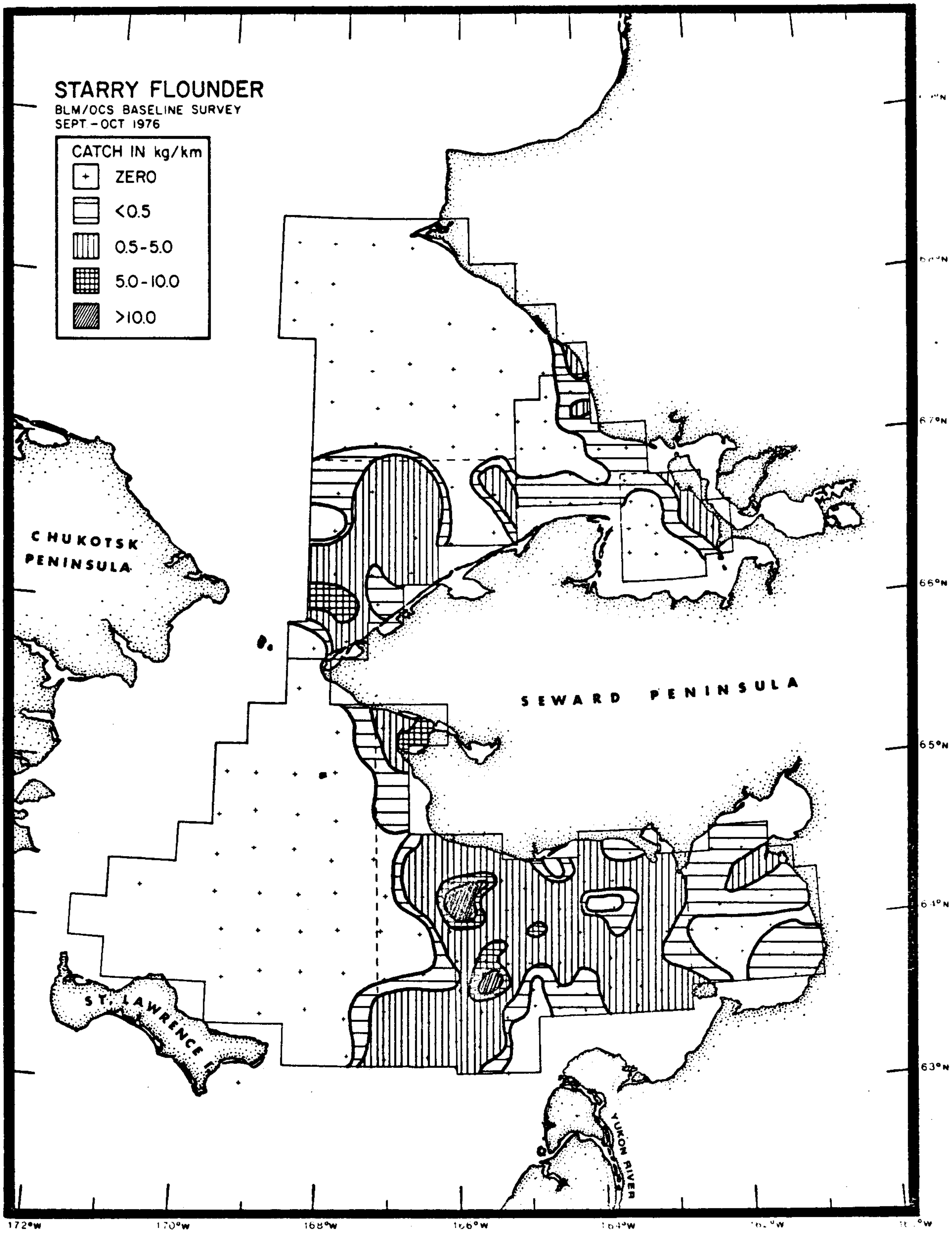


Figure VIII-51.--Distribution and relative abundance by weight of starry flounder in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

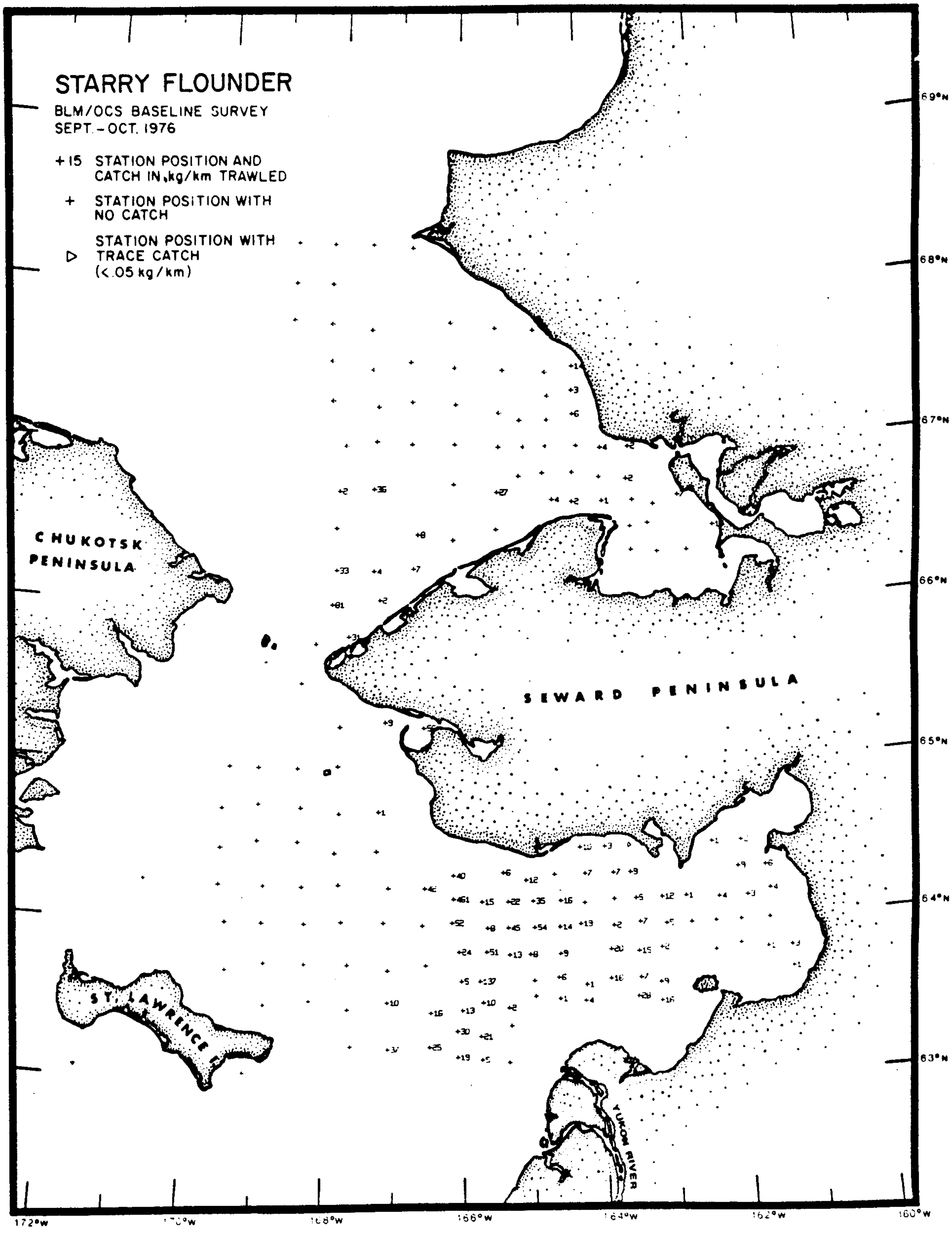


Figure VIII-52.--Distribution of catch rates by weight of starry flounder in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

water regions during fall months (Andriyashev, 1937 and 1954), thus depths trawled within the survey region provided adequate depth coverage for September-October. Of the starry flounder population in the survey area, the greatest portion of apparent biomass (approximately 57%) was located in stratum 4Ø, with another 37% in strata 1S and 3E, combined. Most of the remaining 6% of the estimated biomass was found in the nearshore strata 2Ø, 2I, and 4I.

The relative distribution of estimated numbers did not substantially differ from apparent biomass. Strata 4Ø, 3E and 1S together contained an estimated 6.4 million fish or about 89% of the total survey area population estimate. Stratum 4I contained a further 6% of the total population estimate which was slightly less than 7.3 million fish for all subareas combined.

<u>Size composition, mean length and weight</u>--Starry flounder caught during the survey ranged in length from 15 to 63 cm. Females were substantially larger than males, averaging 39.3 cm compared to 31.4 cm for all strata combined, (Figure VIII-53).

Length-frequency distributions for starry flounder suggest that average size and differences in size composition by sex varied within the survey region. In stratum 4I, the only inshore area where relatively substantial numbers were encountered, mean size by sex was very similar and the overall average length was 24.9 cm. The average size of fish exceeded 32 cm in all other strata and differences in size between sexes were quite large.

In general, starry flounder larger than 40 cm were found mostly in strata 1S and 4Ø in the southern portion of the Chukchi Sea and in outer Norton Sound. Intermediate-size fish (30-40 cm) were located in stratum 4Ø and adjacent stratum 3E while fish smaller than 30 cm were present in the shallow, more nearshore strata 4Ø and 4I.

The average weight of starry flounder was 0.75 kg, largest for any of the fish species encountered during the survey. Although several other fish species had estimated population numbers which greatly exceeded that for starry flounder, the large weight and size of this species provided an estimated biomass which was far greater than that for other more numerous fish.

<u>Age composition</u>--Differences in relative age composition by sex and stratum are shown in Figure VIII-54. Ages ranged 5 to 21 years. In terms of absolute numbers, age groups 14 and 15 somewhat predominated (Table VIII-29).

Few young fish were found north of Bering Strait. In strata 1N, 1S, 2Ø, and 2I, only about 11% of the estimated starry flounder population was less than 12 years of age. South of Bering Strait, the proportion of younger fish was much higher. For strata 3E and 4Ø, 24% of the standing stock estimate was younger than age 12, while in stratum 4I, these younger fish comprised over 42% of the apparent population.

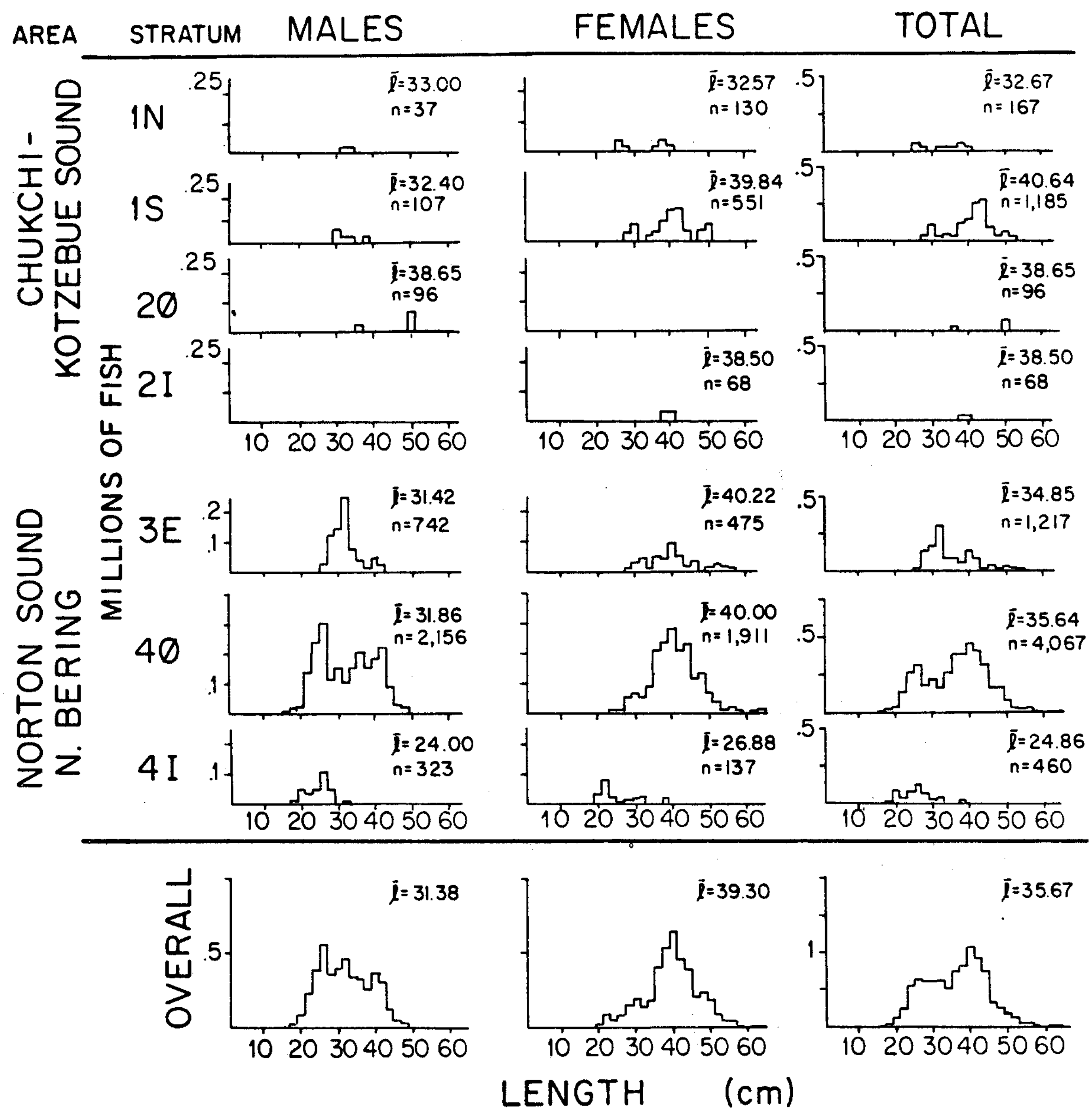


Figure VIII-53.--Size composition of starry flounder by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

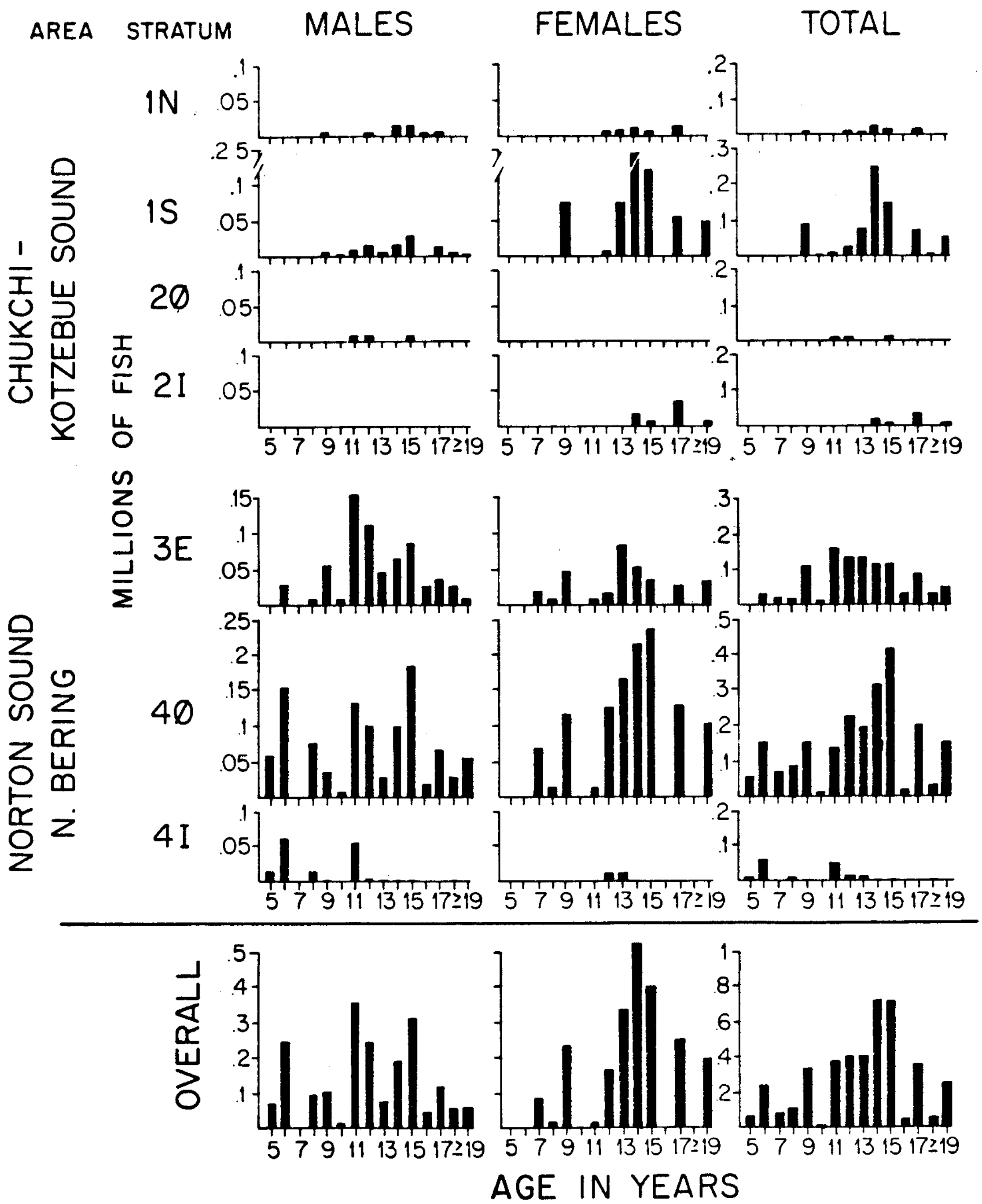


Figure VIII-54.--Age composition of starry flounder by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Table VIII-29.--Population numbers ($x10^4$) and sex ratios of starry flounder by age group and stratum (BLM/OCS survey, 1976).

Age group Year class	5 1971	6 1970	7 1969	8 1968	9 1967	10 1966	11 1965	12 1964	13 1963	14 1962	15 1961	16 1960	17 1959	18 1958	>18 <1957	All ages combined
Stratum																
Southeastern Chukchi Sea and Kotzebue Sound																
1N	—	—	—	—	0.3 (1/)	—	—	0.9 (0.50)	0.6 (2/)	2.2 (1.20)	1.8 (2.00)	— (1/)	1.5 (0.50)	—	—	7.6 (1.00)
1S	—	—	—	—	8.3 (0.11)	0.2 (1/)	1.0 (1/)	2.5 (1.78)	7.8 (0.08)	24.6 (0.06)	14.9 (0.24)	—	6.4 (0.23)	0.4 (1/)	5.0 (0.04)	7.11 (0.17)
2Ø	—	—	—	—	—	—	0.9 (1/)	0.9 (1/)	—	—	0.9 (1/)	—	—	—	—	2.7 (1/)
2I	—	—	—	—	—	—	—	—	—	1.7 (2/)	0.9 (2/)	—	3.4 (2/)	—	0.9 (2/)	6.9 (2/)
Norton Sound and Northern Bering Sea																
3W	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3E	—	2.9 (1/)	1.9 (2/)	1.7 (0.89)	10.1 (1.24)	0.9 (1/)	15.6 (17.33)	12.7 (6.94)	12.7 (0.53)	11.4 (1.24)	11.4 (2.56)	2.5 (1/)	6.3 (1.33)	2.6 (1/)	4.1 (0.28)	97.7 (2.02)
4Ø	5.7 (1/)	15.4 (1/)	6.7 (2/)	8.5 (6.73)	14.9 (0.28)	0.8 (1/)	14.0 (11.91)	22.4 (0.81)	19.2 (0.16)	31.4 (0.45)	41.5 (0.78)	1.9 (1/)	19.2 (0.51)	2.9 (1/)	15.4 (0.52)	220.1 (0.88)
4I	1.6 (1/)	6.0 (1/)	—	1.6 (1/)	0.2 (1/)	—	5.2 (1/)	1.4 (0.27)	1.3 (0.18)	0.1 (1/)	0.1 (1/)	—	—	0.1 (1/)	—	17.6 (7.00)
All strata combined	7.3 (1/)	24.3 (1/)	8.6 (2/)	11.8 (4.90)	33.8 (0.43)	1.9 (1/)	37.8 (17.9)	40.8 (1.46)	41.6 (0.23)	71.4 (0.36)	71.5 (0.79)	4.7 (1/)	36.8 (0.47)	6.0 (1/)	25.4 (0.34)	423.7 (0.90)
Proportion of total population	.017	.057	.020	.028	.080	.004	.089	.096	.098	.169	.169	.011	.087	.014	.060	

1/Only males in estimate.
2/Only females in estimate.

Sex ratio--Estimated sex ratios (number of males/number of females) by stratum and age group are presented in Table VIII-29. There appeared to be more females than males in the area of greatest abundance (stratum 4Ø) although this situation was not consistent for age groups younger than 11 years. For all strata combined, males were generally more abundant than females for age groups younger than 12 years while in older age groups, the opposite was observed.

Age-length relationship and growth--Age-length data collected for starry flounder were as follows:

Sex	Number of readable otoliths	Range in age (years)	Range in length (cm)
Male	61	5-20	24-44
Female	24	7-21	25-53

No age-length information was obtained from the north otolith area for this species. Plots of mean lengths-at-age by sex are presented in Figure VIII-55 and age-length keys for the data groupings are given in Appendix I. Growth parameters by sex are presented in Table VIII-30.

Since few age-length samples were obtained for starry flounder, only two growth curves were fitted: one to the original data and the other with the original data fit to the origin. Fitting curves to the origin did not reduce the root mean square deviations (δ) or change $\underline{L}_\infty$ from values obtained from the original data sets, but the parameters $\underline{K}$ and $\underline{t}_o$ were reduced to more realistic values.

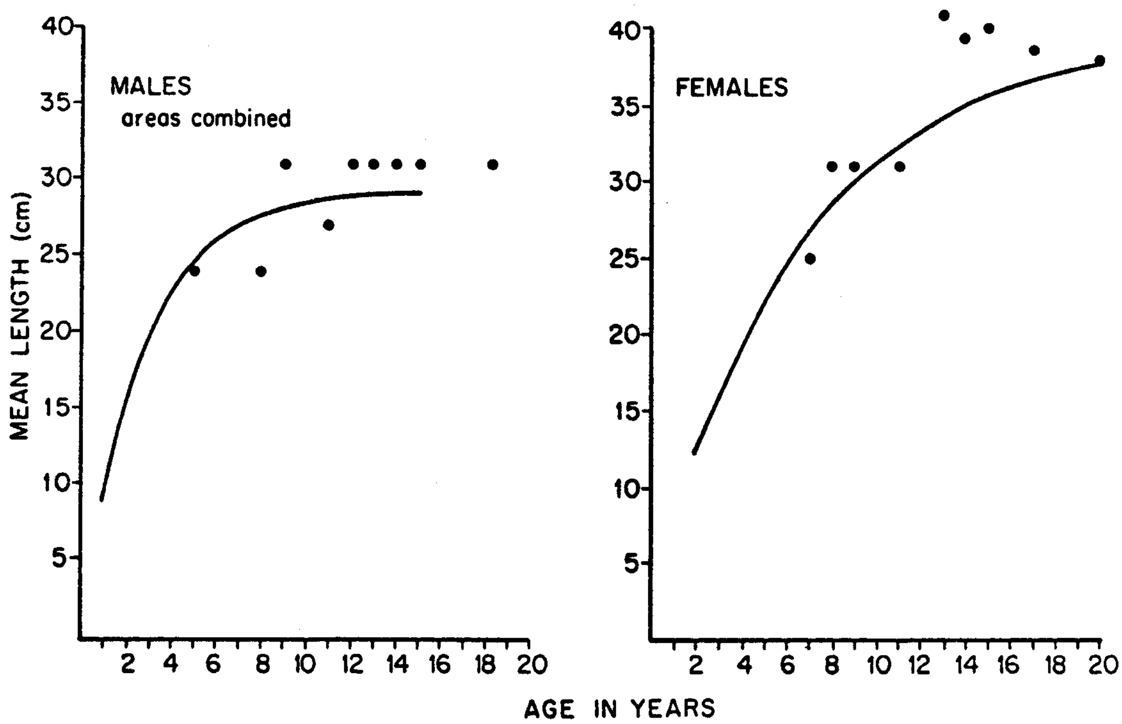


Figure VIII-55.--Mean lengths-at-age and growth curves fit to the origin for starry flounder in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Table VIII-30. --Parameters for von Bertalanffy growth curves for starry flounder in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

	Original data set				Original data with origin			
Sex	δ	L_∞	K	t_o	δ	L_∞	K	t_o
Males	2.70	29.34	-1.15	3.61	2.35	29.25	-0.37	0.02
Females	2.88	38.21	-0.39	4.29	3.69	39.42	-0.15	-0.45

Male starry flounder appear to have a more rapid growth than females and achieve maximum size at an earlier age. The value of $\underline{K}$ for males was more than twice that of females while $\underline{L}_\infty$ differed between sexes by about 25%.

Length-weight relationship--Table VIII-31 summarizes the length-weight relationships, along with corresponding regression coefficients, for starry flounder by sex. Data points representing all length-weight observations are shown graphically in Figure VIII-56.

Table VIII-31.--Parameters for the length-weight relationship (weight (g) = a · length^b) for starry flounder and results of the analysis of covariance for between-sex differences in this relationship (BLM/OCS survey, 1976).

Sex	Otolith Area	Number of Fish Measured	Range in Length (cm)	Parameters a	Parameters b
Males	North	1	25	------	------
	South	77	24-44	0.0094	3.0981
Females	North	6	32-48	------	------
	South	31	31-52	0.0037	3.3700

Differences between-	F slope df	F slope F	F intercept df	F intercept F	H_b 1/	H_a 1/	Pooled regression a	Pooled regression b
Sexes for areas combined	1;111	2.30	1;112	2.09	-	-	0.0045	3.3149

1/ Plus (+) indicates that the common slope (H_b) hypothesis or common intercept (H_a) hypothesis cannot be rejected on the basis of the values of F obtained.

Since few length-weight observations were obtained for starry flounder in the north otolith area, between-area differences were not tested and an analysis of covariance for between-sex differences failed to indicate significant levels of variation ($p < .05$). The overall length-weight relationship for starry flounder, sexes combined, was described by the equation:

$$\hat{w} = 0.0045\ell^{3.3149}$$

where $\hat{w}$ equals the predicted weight in grams of a fish ℓ cm in length. The relationship described by this equation is shown as a solid line in Figure VIII-56.

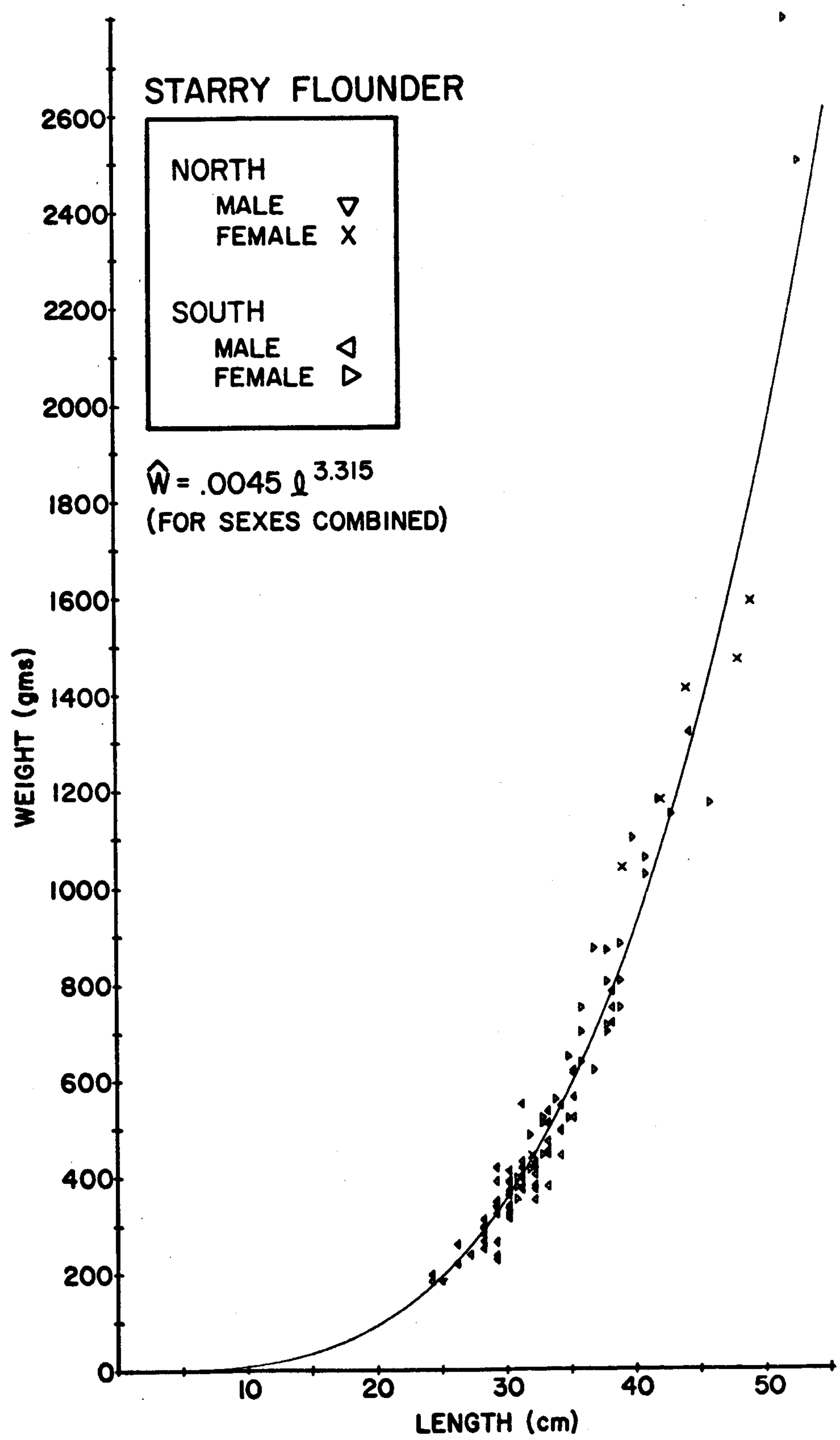


Figure VIII-56.--Weight-at-length observations for starry flounder by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Shorthorn sculpin

Distribution and abundance--Although not identified as one of the principal demersal species in the survey region, shorthorn sculpin was the third-most abundant fish species encountered. It comprised 9% of the total fish biomass and occurred at over 55% of all stations sampled (Table VIII-32). Largest concentrations of shorthorn sculpin were located in the northern Bering Sea (strata 3W and 3E), where stratum catch rates averaged 1.5 and 0.6 kg/km (Figures VIII-57 and 58). Other regions where concentrations occurred included the northwest portion of outer Norton Sound (a portion of stratum 4Ø) and the southeastern Chukchi Sea (stratum 1S) slightly north of Bering Strait, where depths exceeded 25 m. Average catch rates decreased markedly in inner Norton Sound (stratum 4I), Kotzebue Sound (strata 2I and 2Ø), and in the northern portion of the southeastern Chukchi Sea (stratum 1N). The overall mean catch rate for the entire survey area was 0.5 kg/km trawled.

Table VIII-32.--Estimated biomass and population size of shorthorn sculpin in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)[1/]	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	44.8	0.115	196	.045	10,462	.317	.019	—
1S	66.7	0.304	230	.053	6,317	.191	.036	—
2Ø	47.4	0.034	15	.003	288	.009	.051	—
2I	12.5	0.001	t	t	11	t	—	—
Norton Sound and northern Bering Sea								
3W	96.9	1.511	3,289	.752	10,945	.331	.301	—
3E	92.9	0.574	352	.080	3,372	.102	.104	—
4Ø	48.3	0.215	287	.066	1,625	.049	.177	—
4I	5.9	0.002	1	t	6	t	—	
All strata combined:	55.2[2/]	0.522	4,371[3/]		33,025		.133	—

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 2,922-5,819 mt.

The apparent biomass of shorthorn sculpin in the 1976 baseline survey area was estimated at about 4,300 mt (95% confidence interval 2,922 - 5,819 mt). Little is known concerning the extent of vertical distribution of this species, but in general, cottids are described as bottom-dwelling species (Hart, 1973), thus indicating that the biomass estimate was fairly

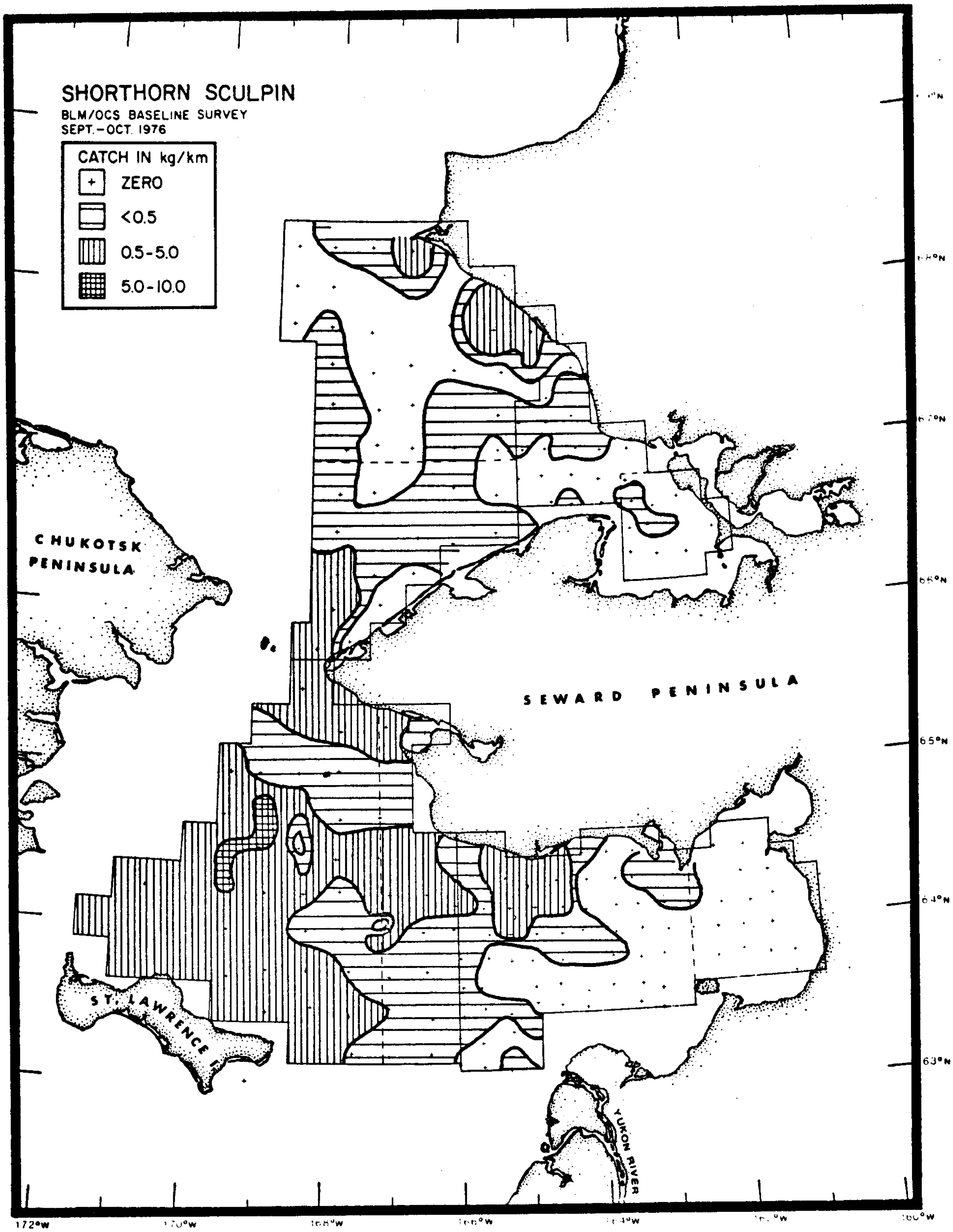


Figure VIII-57.--Distribution and relative abundance by weight of shorthorn sculpin in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

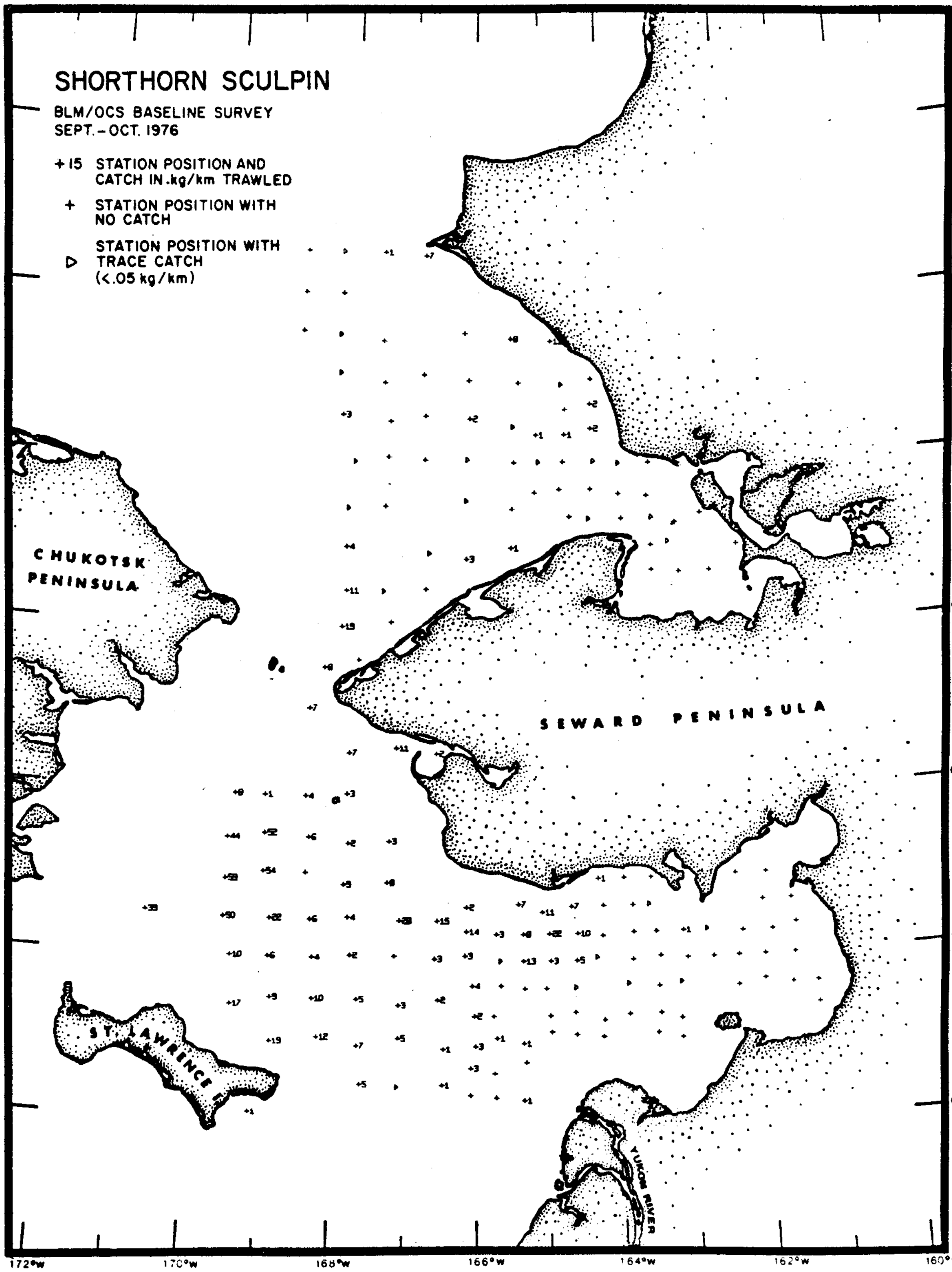


Figure VIII-58.--Distribution of catch rates by weight of shorthorn sculpin in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

good for the survey area. A problem concerning biomass, however, might result from the fact that this species showed a definite preference for deeper waters (>25m), especially in the northern Bering Sea portion of the survey area. Much of the westernmost part of stratum 3W was deeper than 25m but had rough untrawlable bottom and catches could not be obtained from most of the stations in this region.

For the population encountered, over 75% of the apparent biomass of shorthorn sculpin was located in stratum 3W. A further 15% was located in adjacent stratum 3E and stratum 4Ø, while nearly 10% occurred in strata 1N and 1S combined. Only trace amounts were found in strata 2Ø, 2I, and 4I where bottom depths were quite shallow (<25 m).

Relative distribution of estimated numbers differed from apparent biomass. Strata 1N and 1S in the southeastern Chukchi Sea together contained only 10% of the estimated biomass; however, over 50% of the survey population estimate occurred in this region. Most of the remaining portion of estimated population (43%) was located in strata 3E and 3W where the greatest biomass occurred. Bering Strait appeared to separate the shorthorn sculpin population by weight. The average weight of fish north of Bering Strait was only 25 gm, while to the south the average weight per individual exceeded 246 gm. The overall average weight of shorthorn sculpin was 133 gm.

Pacific herring

Distribution and relative abundance--Pacific herring occurred at 50% of the stations sampled (Table VIII-33) and accounted for about 6% of the apparent biomass for all fish combined. The main concentration of this species was found in outer Kotzebue Sound (stratum 2Ø) (Figures VIII-59 and 60) where the average catch rate was 3.1 kg/km trawled. Average catch rates decreased to about 0.5 kg/km along the northern shore of the Seward Peninsula (stratum 1S) and in the eastern portion of the northern Bering Sea (stratum 3E). In the remaining strata, catch rates were very low, especially in the inner portions of Norton and Kotzebue sounds (strata 4I and 2I) and in the western portion of the northern Bering Sea (stratum 3W). The overall mean catch rate for the entire survey area was 0.3 kg/km trawled.

Table VIII-33.--Estimated biomass and population size of Pacific herring in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	24.1	0.150	255	.102	2,832	.093	.090	19.02
1S	73.3	0.472	357	.143	4,376	.144	.082	18.66
2Ø	94.7	3.099	1,331	.534	14,902	.489	.089	18.88
2I	25.0	0.048	15	.006	133	.004	.111	19.43
Norton Sound and northern Bering Sea								
3W	21.9	0.048	105	.042	1,125	.037	.093	19.25
3E	78.6	0.424	259	.104	3,549	.117	.073	17.72
4Ø	60.3	0.123	164	.066	3,468	.114	.047	15.05
4I	23.5	0.008	4	.002	74	.002	.060	--
All strata combined:	49.5 2/	0.297	2,491 3/		30,458		.080	18.31

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence limits: 1,072-3,910.

The apparent biomass of Pacific herring in the survey region was estimated at 2,500 mt (95% confidence interval 1,000-3,900 mt), which is a minimum estimate for the entire survey area. Pacific herring are primarily pelagic and substantial portions of the population probably occupied the water column above the sampling gear. Thus, the demersal trawl gear only sampled some portion of the population. Additionally, dense concentrations of this species have been known to occur in Norton Sound during late spring. For

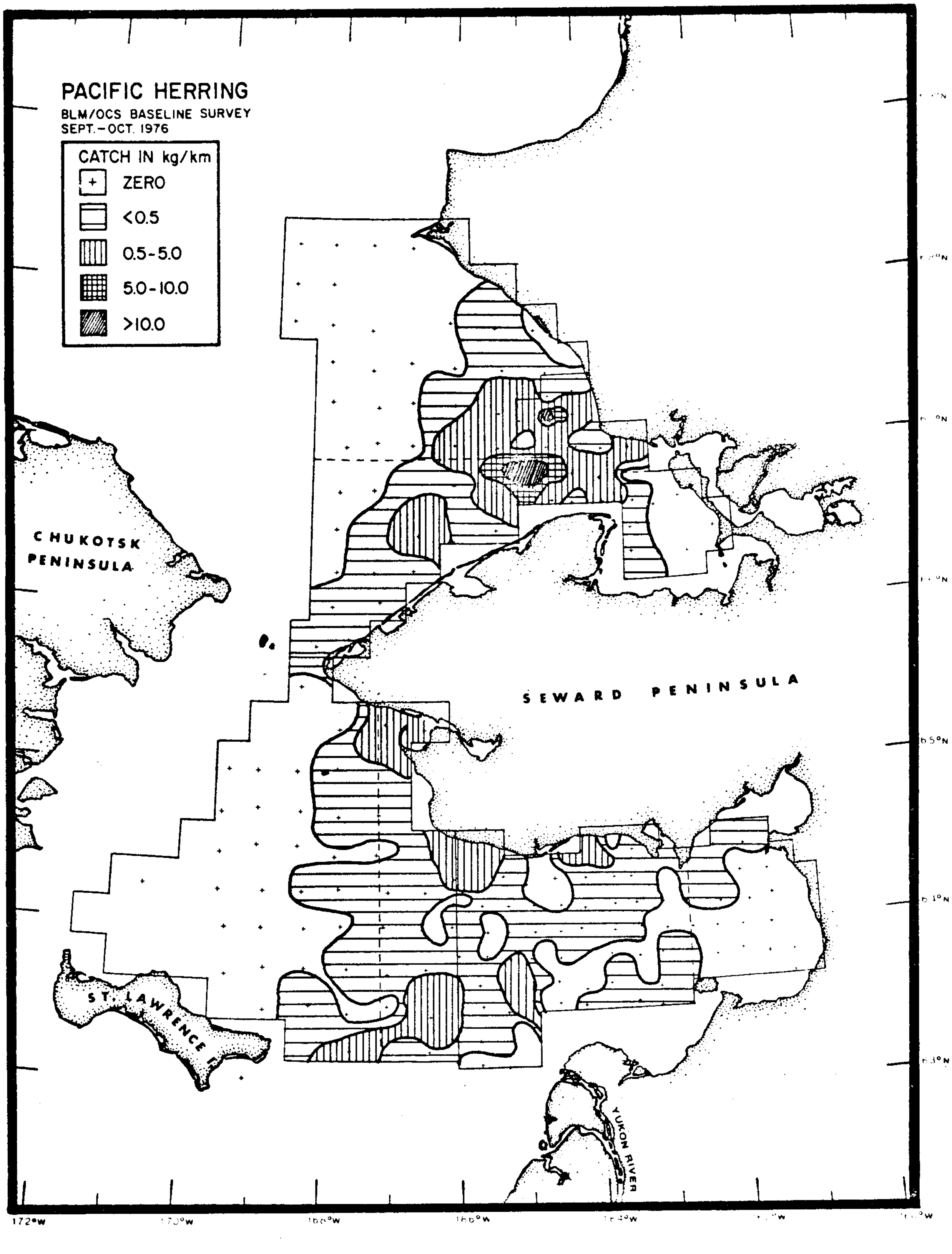


Figure VIII-59.--Distribution and relative abundance by weight of Pacific herring in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

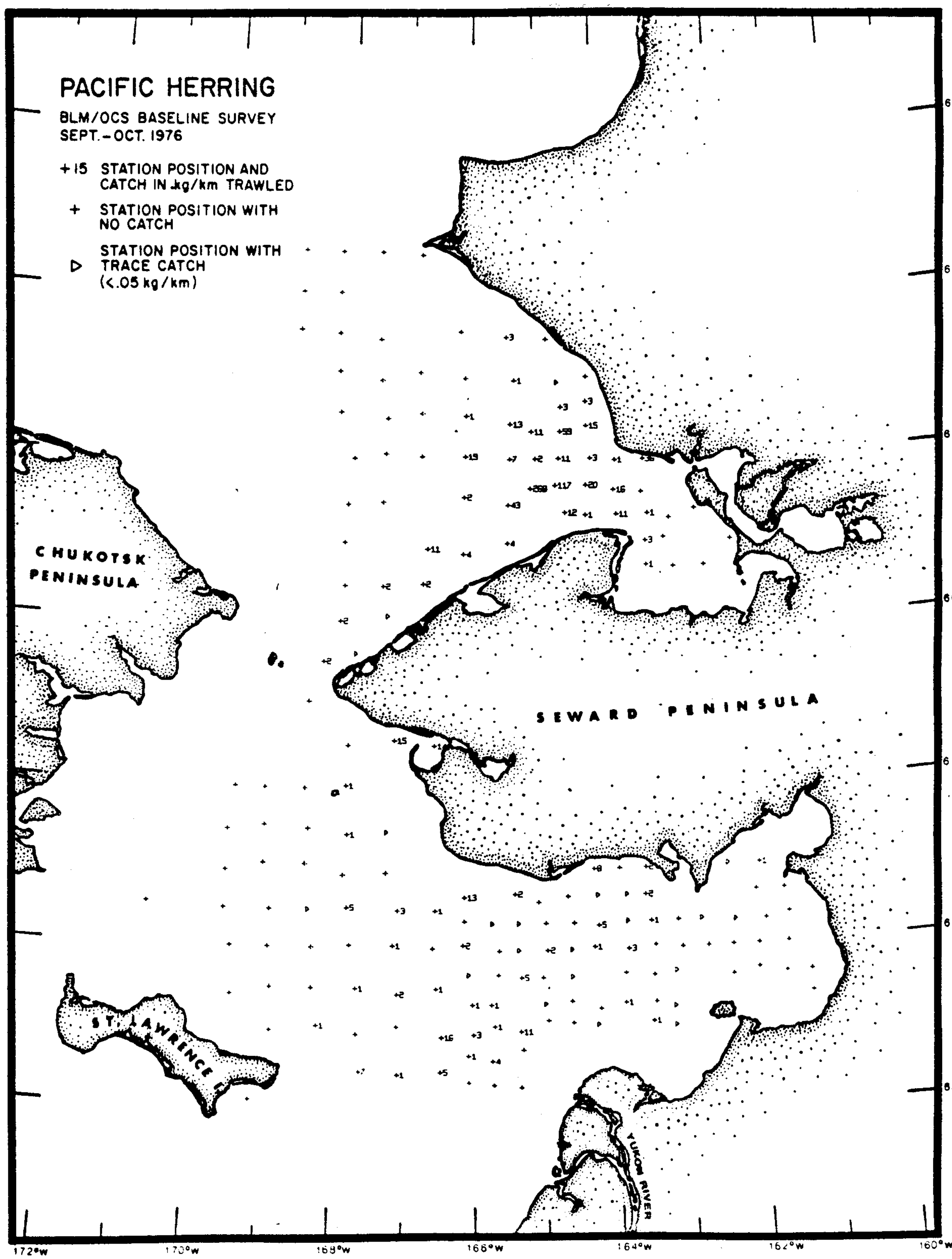


Figure VIII-60.--Distribution of catch rates by weight of Pacific herring in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

several years, Japanese gillnet fleets fished this region after the spring breakup when herring formed dense spawning schools. A survey of this region during an earlier time of the year may have produced substantially different population estimates.

For the Pacific herring population sampled, over half (53%) of the estimated biomass was located in stratum 2Ø. Most of the remaining biomass was fairly evenly distributed throughout most of the remaining survey region in strata 1S, 1N, 3W, 3E, and 4Ø. The shallow inshore waters of strata 2I and 4I contained only trace amounts of Pacific herring.

Relative distribution of estimated numbers did not appreciably differ from apparent biomass. Stratum 2Ø contained 15 million fish or approximately 50% of the total survey area estimate of 30 million Pacific herring. Strata 1N, 1S, 3W, and 4Ø each contained from 9 to 11% of the total estimate while strata 2I and 4I together accounted for less than 1% of the estimated standing stock in numbers.

Size composition, mean length and weight--Pacific herring caught during the survey ranged in length from 5 to 28 cm. Females generally were slightly larger than males, averaging 18.7 cm compared to 18.5 cm for all strata combined (Figure VIII-61). Length-frequency distributions for Pacific herring included observations on juvenile fish(which were not sexed) in the distributions for sexes combined. The inclusion of these unsexed fish in the calculation of mean size for sexes combined in stratum 4Ø caused the overall mean length in this stratum to be noticeably less than those for individual sexes. Small fish (< 11 cm) were found only in stratum 4Ø where they comprised 30% of the total fish estimated. Overall, fish less than 11 cm accounted for only 3% of the population estimate in numbers, 12-20 cm fish accounted for 83%, and fish larger than 20 cm comprised 14% of the estimated population.

Overall, mean weight of Pacific herring was 80 gm in the entire survey region. Fish in those strata north of Bering Strait averaged between 82 and 111 gms. Fish in 3W and 3E in the northern Bering Sea averaged 93 and 73 gms, respectively, while Pacific herring in Norton Sound had the smallest average weights. Fish in strata 4Ø and 4I (Norton Sound) averaged 47 and 60 gm, respectively.

Age composition--Differences in relative age composition by sex and stratum are shown in Figure VIII-62. In terms of absolute numbers, age groups 2 through 4 predominated (Table VIII-34). These age groups were prevalent in nearly all strata with older-aged fish more numerous in the strata north of Bering Strait and younger ages to the south. Stratum 4Ø was the only region where age group 0 fish occurred.

Sex ratio--Estimated sex ratios (number of males/number of females) by stratum and age group are presented in Table VIII-34. There appeared to be more females than males in strata north of Bering Strait, while to the south, males were more abundant than females. This trend, however, was not consistent for all age classes.

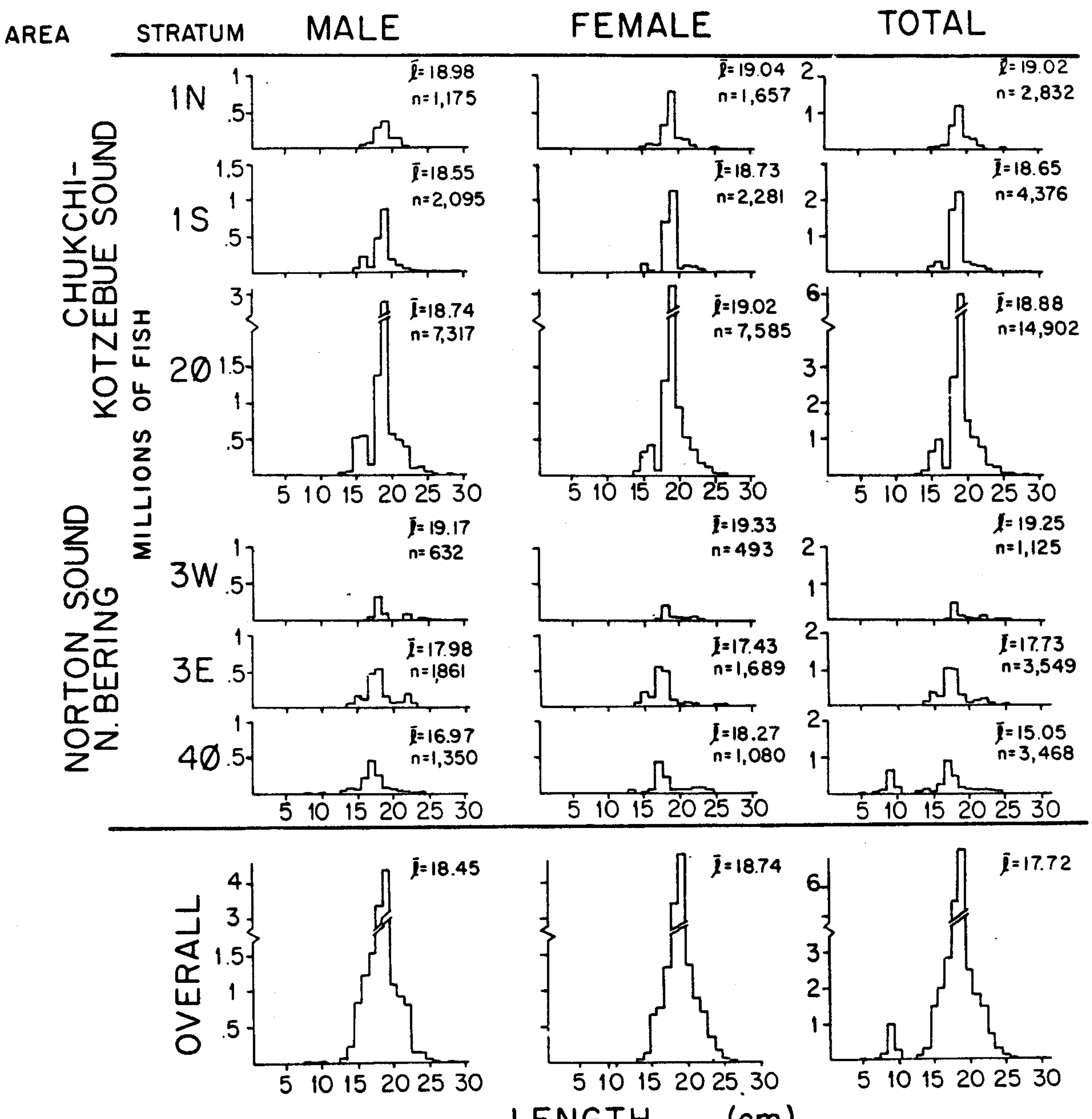


Figure VIII-61.--Size composition of Pacific herring by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

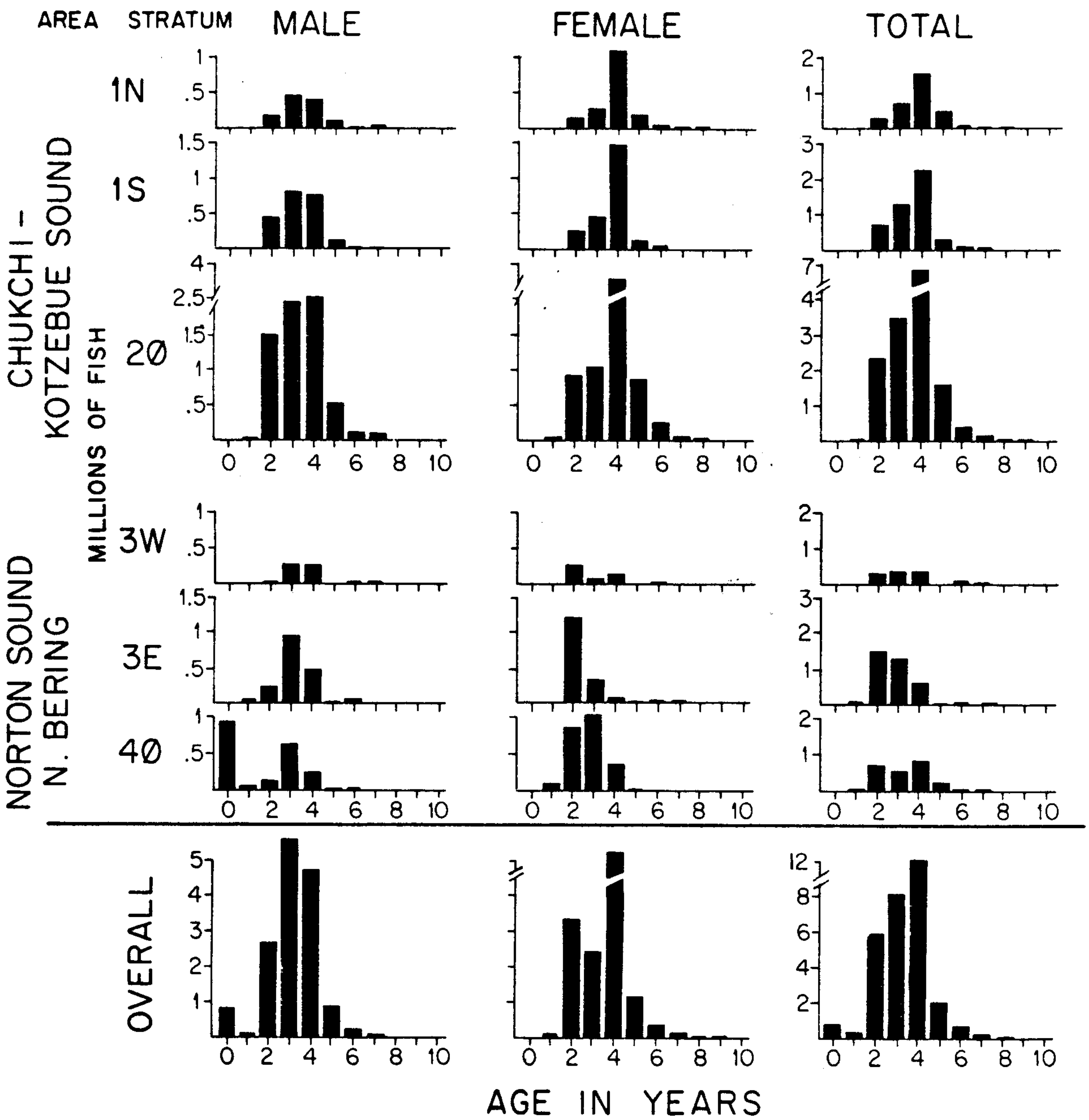


Figure VIII-62.--Age composition of Pacific herring by sex and stratum in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Table VIII-34.--Population numbers ($x10^4$) and sex ratio of Pacific herring by age group and stratum (BLM/OCS survey, 1976).

Age group Year class	0 1976	1 1975	2 1974	3 1973	4 1972	5 1971	6 1970	7 1969	8 1968	9 1967	10 1966	>10 ≤1965	All ages combined
Stratum													
Southeastern Chukchi Sea and Kotzebue Sound													
1N	—	—	26.9 (1.56)	69.1 (1.66)	152.4 (0.42)	29.7 (0.73)	3.2 (0.07)	1.4 (0.17)	0.6 2/	—	—	—	283.3 (0.71)
1S	—	—	65.5 (1.85)	123.2 (1.73)	217.7 (0.53)	24.3 (0.83)	6.1 (0.20)	1.0 (1/)	—	—	—	—	437.8 (0.92)
2O	—	10.5 (0.46)	240.1 (1.58)	345.3 (2.39)	683.5 (0.59)	151.4 (0.69)	39.3 (0.49)	15.6 (1.84)	4.5 (2/)	—	—	—	1,490.2 (0.96)
2I	—	—	2.3 (10.50)	1.4 (0.27)	7.1 (0.22)	2.4 (1.00)	0.2 (1/)	0.2 (1/)	—	—	—	—	13.6 (0.64)
Norton Sound and Northern Bering Sea													
3W	—	—	32.6 (0.15)	36.3 (3.43)	37.1 (2.17)	—	4.3 (3.78)	2.2 (1/)	—	—	—	—	112.5 (1.29)
3E	—	5.6 (1/)	148.2 (0.22)	129.7 (2.74)	59.1 (5.29)	2.4 (7.00)	8.1 (6.36)	1.6 (2/)	—	—	—	—	354.7 (1.10)
4O	84.5 (1/)	29.0 (4.47)	84.8 (0.42)	104.4 (2.75)	39.6 (1.15)	1.3 (1/)	3.0 3.14	—	—	—	—	—	346.6 (1.25)
4I	—	—	—	1.0 (1/)	5.5 (1/)	—	1.0 (1/)	—	—	—	—	—	7.5 (1/)
All strata combined	84.5 (1/)	45.1 (1.91)	600.4 (0.79)	810.4 (2.31)	1,202.0 (0.66)	211.5 (0.74)	65.2 (0.76)	22.0 (1.65)	5.1 (2/)	—	—	—	3,046.2 (0.98)
Proportion of total population	0.63	.033	.197	.266	.395	.069	.021	.007	.004	—	—	—	

1/ Only males in estimate.
2/ Only females in estimate.

Age-length relationship and growth--Age and length data collected for Pacific herring were as follows:

Sex	Otolith area	Number of readable otoliths	Range in age (years)	Range in length (cm)
Male	North	85	1-7	13-28
	South	66	0-7	8-29
Female	North	65	1-8	14-26
	South	58	0-7	9-26

These data are summarized in Figure VIII-63 by plots of mean lengths-at-age by sex and otolith area with estimated growth curves for each data group. Age-length keys for these data groupings are presented in Appendix I and growth parameters based on this information are given in Table VIII-35.

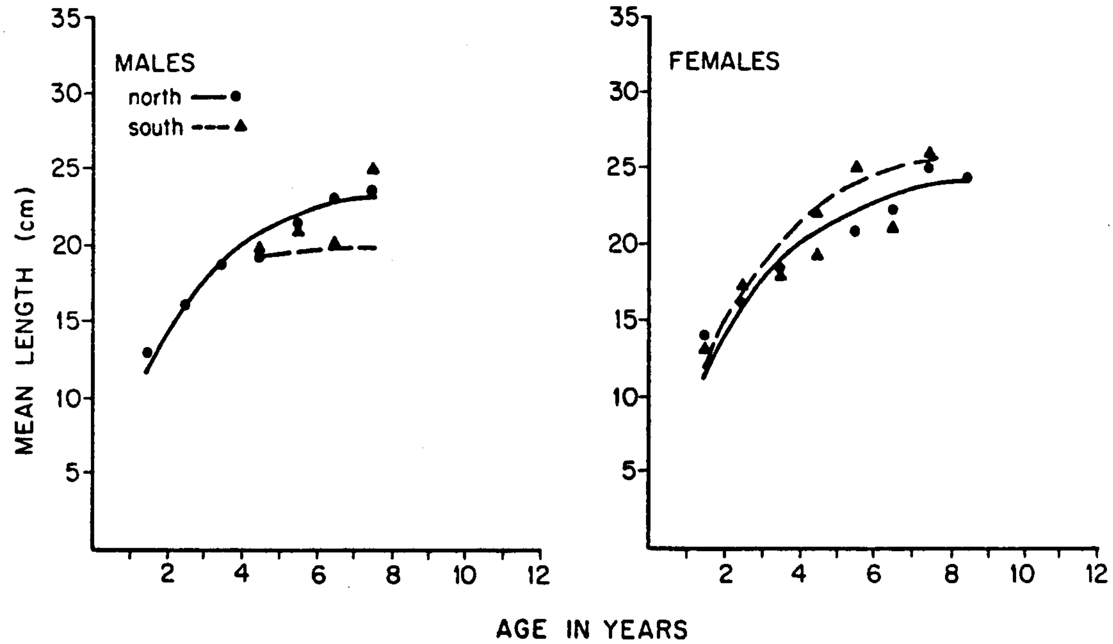


Figure VIII-63.--Mean lengths-at-age and growth curves fit to the origin for Pacific herring by sex and otolith area in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Table VIII-35.--Parameters for von Bertalanffy growth curves for Pacific herring in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (values in parenthese are ranges for selected ages and lengths) (BLM/OCS survey, 1976).

Otolith areas	Sex	Range in age and length of analyzed data: age (yr)	length (cm)	Original data set: δ	L_∞	K	t_o	Selected data: δ	L_∞	K	t_o	Selected data with origin: δ	L_∞	K	t_o
North	Males	1.5-7.5 (2.5-7.5)	(14-28)	0.63	25.58	-0.29	-0.91	0.67	26.49	-0.24	-1.45	0.89	23.93	-0.45	0.02
	Females	1.5-8.5 (2.5-8.5)	(15-25)	0.86	27.76	-0.19	-2.04	0.99	26.42	-0.25	-1.07	1.18	24.59	-0.41	0.02
South	Males	0.5-7.5 (2.5-4.5)	(14-29)	1.55	22.77	-0.45	-0.47	1/	1/	1/	1/	1.01	19.66	-0.78	0.01
	Females	0.5-7.5 (2.5-4.5, 7.5)	(14-26)	2.38	23.94	-0.62	0.37	1.61	31.80	-0.17	-1.88	1.67	26.95	-0.40	0.04

1/ Insufficient data points for calculating parameters.

Since young of the year (age group 0) were present in some of the Pacific herring age data sets, adjustments to ages were necessary to provide reasonable fits for both the original data and for the selected sets which included values for the origin of the curve (age and length = 0). Age plus 0.5 years was used as the adjustment since it is reasonable to assume that at least half of a year's growth had been achieved by the September-October survey date.

Selection of data to eliminate age groups with few (<5) observations and fitting the curve to the origin did not greatly reduce the root mean square deviations (δ) or substantially change values for $\underline{L}_\infty$. However, it did greatly affect estimates of $\underline{K}$ and $\underline{t}_0$, resulting in reasonable values for these parameters. Differences in all growth curve parameters between the data sets usually were small. Large differences in $\underline{K}$ and $\underline{L}_\infty$ were observed in one instance, but the extremely high growth completion rate ($\underline{K}$) for south males (0.78 compared to 0.40-0.45 for all other sets) and relatively low $\underline{L}_\infty$ probably resulted from an insufficient set of data points for proper fitting of the curve (Figure VIII-63). Overall, differences in growth between areas and sexes did not appear to be significant.

Length-weight relationship--Table VIII-36 summarizes the length-weight observations taken for Pacific herring by sex and otolith area and gives coefficients of regression lines fit to these data. Data points representing all length-weight observations collected for this species during the survey are shown graphically in Figure VIII-64.

Analysis of covariance for between-area or between-sex differences in the relationship between length and weight indicated significant levels of variation ($p < .05$) in three treatments of the data: the comparison of between-sex in the south otolith area, between sexes for areas combined, and between areas for sexes combined.

Significant differences between sexes for the combined otolith areas probably resulted from length-weight differences for males and females in the south otolith area. South area differences may have been influenced by observations of only females at lengths less than 13 cm.

On the basis of weights predicted by the regression coefficients, male Pacific herring generally weighed more at-length than females; however, in the south otolith area this relationship was true only up to lengths of about 21 cm. Above that length females weighed more than males. Between- sex differences in length-weight were quite large ($>10\%$) for fish less than 15 cm in length, especially in the south otolith area, but differences for fish larger than 15 cm were usually on the order of 0-5% (fish larger than 15 cm comprised most of the entire estimated population). In general, an overall length-weight relationship for Pacific herring in the survey region was described by the equation:

$$\hat{w} = 0.0110\ell^{3.0256}$$

where $\hat{w}$ equals the predicted weight in grams of a fish ℓ cm in length. The relationship described by this equation is shown as a solid line in Figure VIII-64.

Table VIII-36.--Parameters for the length-weight relationship (weight (g) = a · length^b) for Pacific herring and results from the analysis of covariance for between-area and between-sex differences in this relationship (BLM/OCS survey, 1976).

Sex	Otolith Area	of Fish Measured	Range in Length (cm)	Parameters a	Parameters b
Males	North	38	12-26	.01630	2.9033
	South	77	13-25	.01297	2.9719
Females	North	38	15-25	.0255	2.7410
	South	42	9-23	.0053	3.2669

Differences between-	F slope df	F slope F	F intercept df	F intercept F	H_a 1/	H_b 1/	Pooled regression a	Pooled regression b
Areas for males	1;184	.28	1;185	1.99	-	-	.0135	2.9611
Areas for females	1;163	14.9**	1;164	.95	+	-	.0081	3.1240
Areas for sexes combined 2/	1;355	8.09**	1;356	2.08	+	-	.0110	3.0256
Sexes for south area	1;181	7.97**	1;182	5.63	+	+	.0084	3.1148
Sexes for north area	1;166	1.03	1;167	3.72	-	-	.0207	2.8173
Sexes for areas combined	1;351	3.48	1;352	10.1**	-	+	.0107	3.0356

* Significant at the .05 level.

** Significant at the .01 level.

1/ Plus (+) indicates that the common slope (H_b) hypothesis or common intercept (H_a) hypothesis cannot be rejected on the basis of the values of F obtained.

2/ Includes unsexed fish.

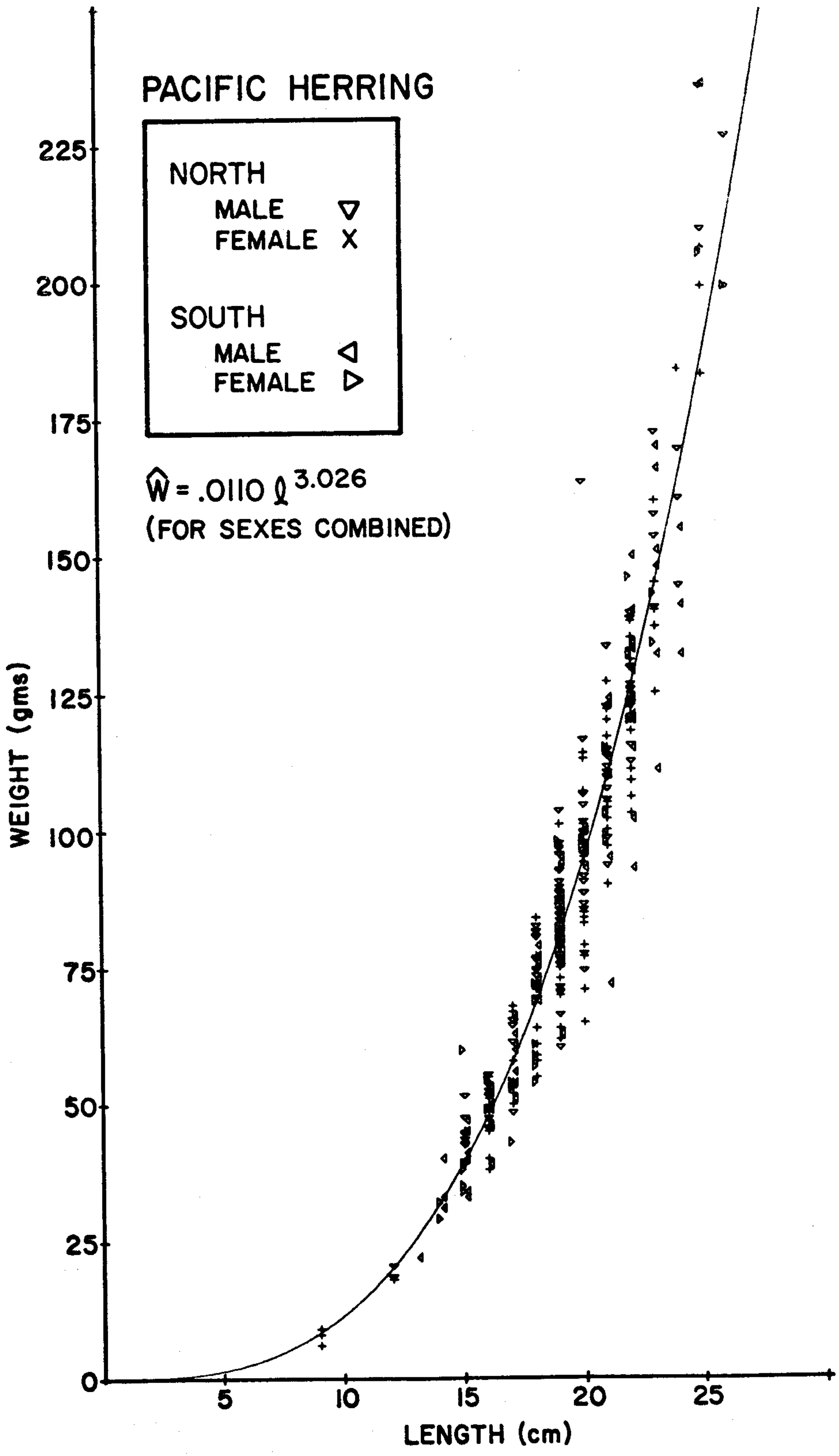


Figure VIII-64.--Weight-at-length observations for Pacific herring by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Toothed (rainbow) smelt

Distribution and abundance--Toothed smelt was the fifth-most abundant fish species encountered in the survey area and occurred at over 67% of all stations sampled (Table VIII-37). It accounted for slightly less than 5% of the total apparent biomass for all fish fauna combined. Two concentrations of this species were located in the survey region, in outer Kotzebue Sound (stratum 2Ø) and in the northern Bering Sea (stratum 3E) (Figures VIII-65 and 66) where average catch rates were 1.4 and 1.0 kg/km, respectively. Average catch rates decreased in outer Norton Sound (stratum 4Ø), along the north coast of the Seward Peninsula (stratum 1S), and in inner Kotzebue Sound (stratum 2I), to between 0.1 and 0.2 kg/km. Catch rates were very low in inner Norton Sound (stratum 4I) and in the offshore deeper-water portions of the southeastern Chukchi Sea and northern Bering Sea (strata 1N and 3W, respectively). The overall mean catch rate for the survey was 0.2 kg/km trawled.

Table VIII-37.--Estimated biomass and population size of toothed smelt in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	24.1	0.085	145	.075	3,540	.047	.041	16.87
1S	73.3	0.127	96	.050	1,699	.023	—	16.12
2Ø	100.0	1.375	591	.305	25,762	.344	.023	13.77
2I	62.5	0.123	37	.019	1,082	.014	—	15.13
Norton Sound and northern Bering Sea								
3W	28.1	0.053	117	.060	3,533	.047	.033	17.71
3E	85.7	0.981	601	.310	23,915	.319	.025	16.80
4Ø	93.1	0.227	303	.156	13,001	.174	.023	14.11
4I	70.6	0.090	48	.025	2,340	.031	.021	13.40
All strata combined:	67.2 2/	0.231	1,938 3/		74,874		.026	15.12

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 1,134-2,742 mt.

The apparent biomass of toothed smelt in our survey region was estimated at slightly less than 2,000 mt (95% confidence interval 1,134-2,742 mt). This is probably a minimum estimate for the survey region, since this species is pelagic and some unknown proportion of the population occupied

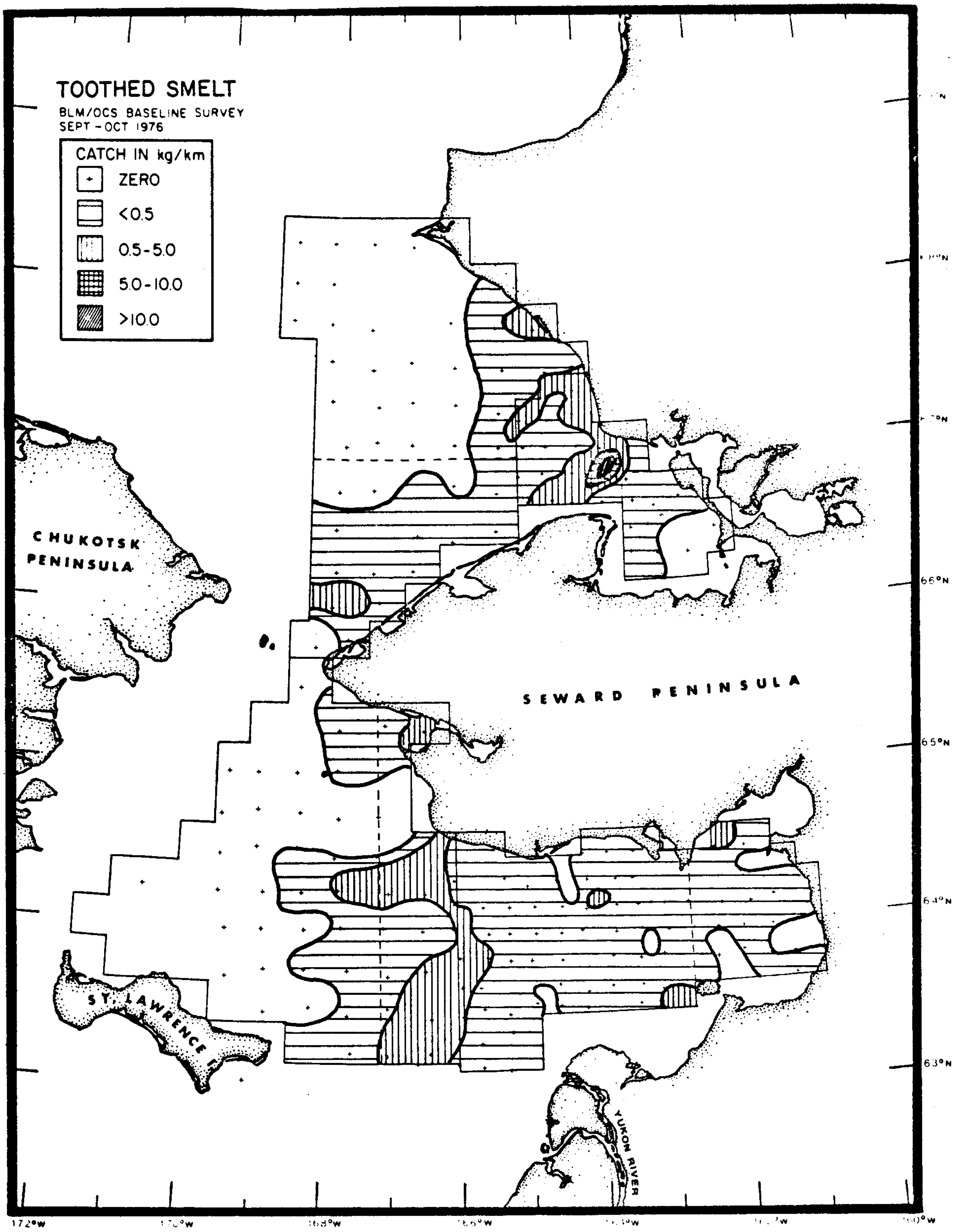


Figure VIII-65.--Distribution and relative abundance by weight of toothed smelt in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

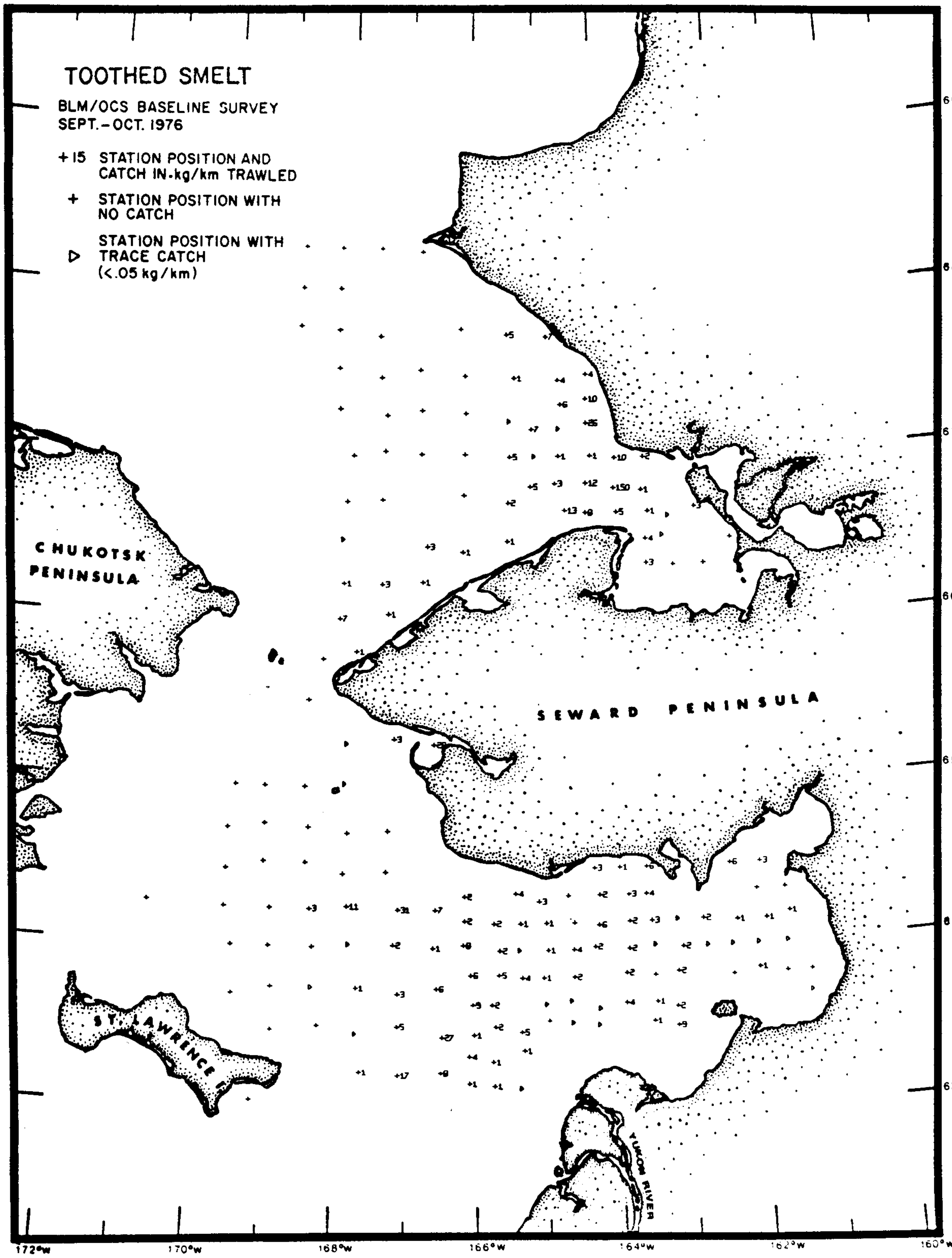


Figure VIII-66.--Distribution of catch rates by weight of toothed smelt in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

the water column above the sampling gear, thus being unavailable to the trawl. In addition, toothed smelt are anadromous, spawning in rivers from February to June (McAlister, 1963). Some other proportion of the population may have been located in the more nearshore estuarine and freshwater regions than covered by the survey. For the population sampled, however, the major portion of the estimated biomass (approximately 78%) was located in strata 2Ø, 3E, and 4Ø, mainly between the 20 and 30 m isobaths. Of the remaining amount, 8% of the total was located in stratum 1N, 6% in stratum 3W, and 5% in stratum 1S. The estimated biomass for strata 2I and 4I together comprised less than 5% of the total.

The relative distribution of estimated numbers of fish did not substantially differ from apparent biomass. Strata 2Ø, 3E, and 4Ø combined contained an estimated 62.7 million fish which was about 84% of the total population estimate for the entire survey area. Another 5% occurred in strata 1N and 3W. The total population estimate for all strata combined was slightly less than 75 million fish.

<u>Size composition, mean length and weight</u>--Toothed smelt caught during the survey ranged in length from 7 to 36 cm. Females generally were larger than males, averaging 15.7 cm compared to 14.7 cm for all strata combined (Figure VIII-67).

Length frequency distributions did not indicate major differences in relative size composition between sexes for any of the strata. Fish less than 20 cm comprised nearly the entire population in most strata, although appreciable numbers of large (> 20 cm) individuals occurred in stratum 3E. Large fish accounted for 20% of the population in stratum 3E and 6% of the overall population estimate. Generally, the average size of toothed smelt was less in the shallow and near-shore strata than in deeper offshore regions.

<u>Age composition</u>--Differences in relative age composition by sex and subarea are shown in Figure VIII-68. In terms of absolute numbers, age groups 4 and 5 predominated (Table VIII-38) with these age groups representing about 64% of the total estimated population. Age groups 3, 6, and 7 were also present in substantial numbers, together accounting for most of the remaining population. Although age groups 4 and 5 were main components of age composition in nearly all strata, 5 and 6 year-old fish comprised much of the toothed smelt populations in the offshore strata (1N and 3W) and age group 3 fish were the dominant segment of fish present in outer Kotzebue Sound (stratum 2Ø).

<u>Sex ratio</u>--Estimated sex ratios (number of males/number of females) by stratum and age group are presented in Table VIII-38. Males appeared to be more abundant than females in nearly all strata and age groups except in stratum 3W where the opposite was observed. Overall, males outnumbered females by nearly 70%.

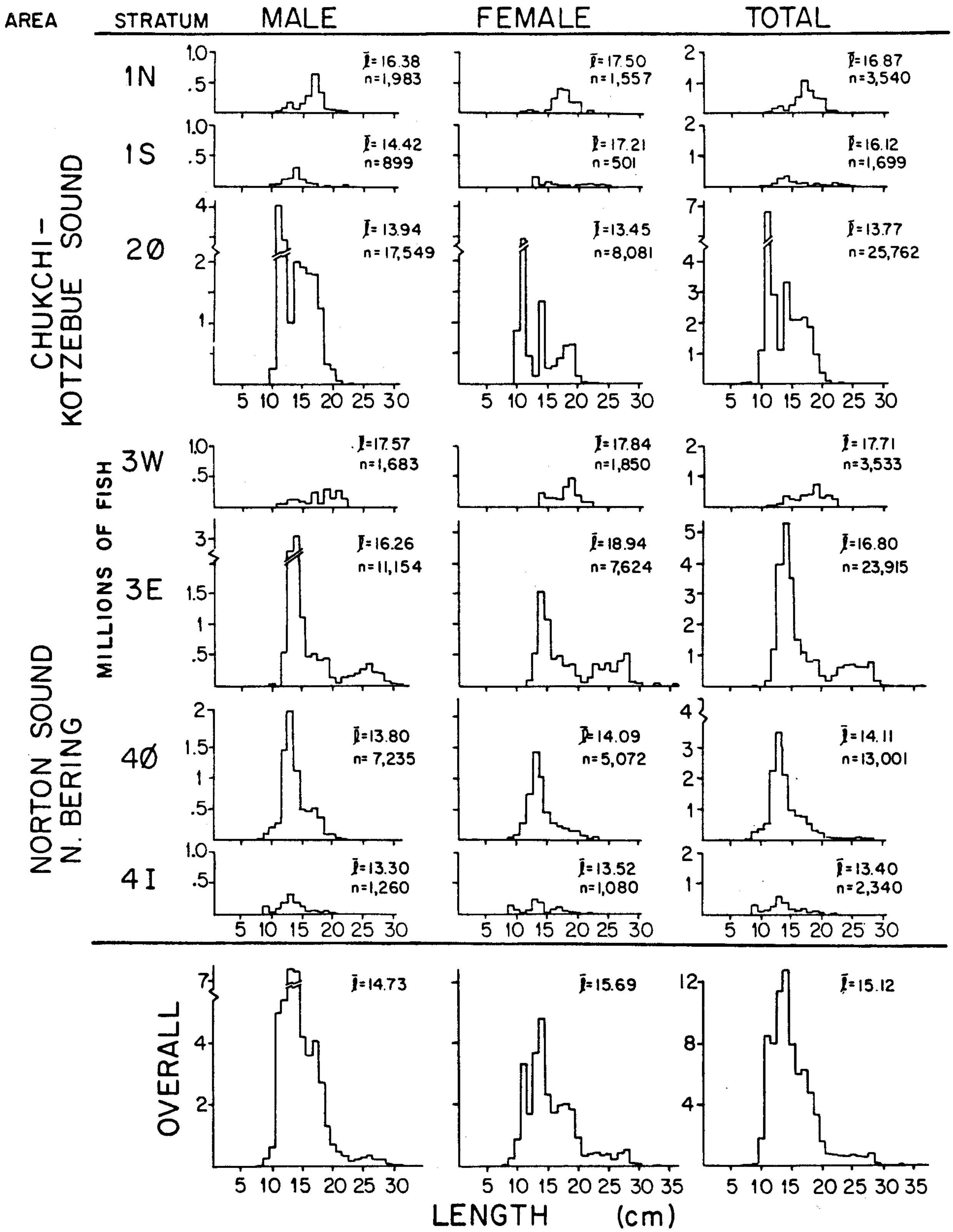


Figure VIII-67.--Size composition of toothed smelt by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

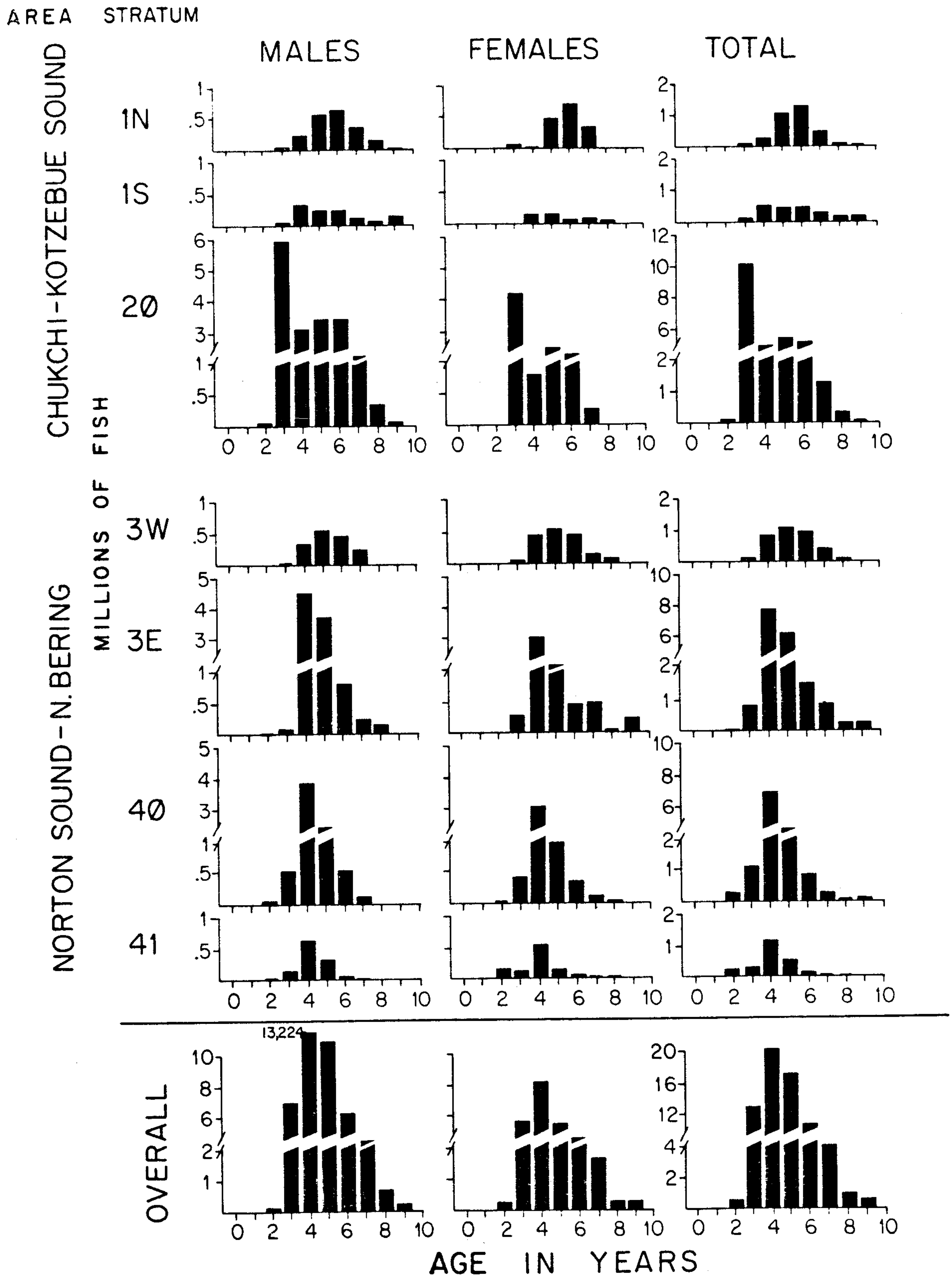


Figure VIII-68.--Age composition of toothed smelt by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Table VIII-38.--Population numbers (x10^5) and sex ratios of toothed smelt by age group and stratum (BLM/OCS survey, 1976).

Age group Year class	0 1976	1 1975	2 1974	3 1973	4 1972	5 1971	6 1970	7 1969	8 1968	9 1967	10 1966	>10 ≤1965	All ages combined
Stratum													
Southeastern Chukchi Sea and Kotzebue Sound													
1N	--	--	--	1.3 (1.10)	2.3 (11.26)	10.3 (1.27)	13.2 (0.88)	6.9 (1.10)	1.2 (1/)	0.4 (1/)	--	--	35.4 (1.27)
1S	--	--	--	1.0 (1/)	4.9 (1.96)	4.2 (1.97)	4.2 (3.62)	2.7 (1.15)	1.3 (1.25)	1.6 (1/)	--	--	17.0 (2.39)
2O	--	--	1.3 (1/)	102.2 (1.42)	39.6 (3.89)	49.0 (2.43)	46.9 (2.77)	15.6 (2.96)	3.7 (1/)	0.7 (1/)	--	--	257.5 (2.19)
2I	--	--	0.8 (2/)	1.1 (1.59)	1.0 (2.06)	3.3 (1.14)	3.2 (1.32)	1.0 (1.76)	0.4 (1/)	--	--	--	10.8 (1.24)
Norton Sound and Northern Bering Sea													
3W	--	--	--	1.2 (0.86)	8.1 (0.71)	11.4 (0.98)	9.7 (0.99)	4.0 (1.54)	1.0 (2/)	--	--	--	35.3 (0.91)
3E	--	--	0.1 (1/)	8.8 (0.33)	103.2 (1.50)	63.1 (3.23)	15.8 (1.73)	8.9 (0.55)	2.8 (1.98)	2.5 (2/)	--	--	155.4 (1.67)
4O	--	--	2.1 (3.88)	11.6 (1.40)	70.8 (1.25)	30.3 (2.04)	9.1 (1.56)	2.4 (1.05)	0.5 (2/)	1.0	--	--	122.7 (1.44)
4I	--	--	2.1 (0.15)	3.1 (1.58)	11.7 (1.18)	5.0 (1.18)	1.3 (1.49)	0.2 (0.82)	0.1 (2/)	--	--	--	23.4 (1.17)
All strata combined	--	--	6.4 (0.69)	130.2 (1.37)	241.6 (1.61)	176.6 (2.20)	103.3 (1.82)	41.7 (1.44)	11.0 (2.67)	6.1 (0.91)	--	--	657.8 (1.69)
Proportion of total population	--	--	.010	.198	.367	.268	.157	.063	.017	.009	--	--	

1/ Only males in estimate.
2/ Only females in estimate.

Age-length relationship and growth--Age and length data collected for toothed smelt were as follows:

Sex	Otolith area	Number of readable otoliths	Range in age (years)	Range in length (cm)
Male	North	53	3-9	10-23
	South	76	2-8	8-23
Female	North	45	2-8	8-25
	South	74	2-9	9-26

These data are summarized in Figure VIII-69 by plots of mean lengths-at-age by sex and otolith area with estimated growth curves for each data group. Age-length keys for these data groupings are presented in Appendix I and growth parameters based on this information are given in Table VIII-39.

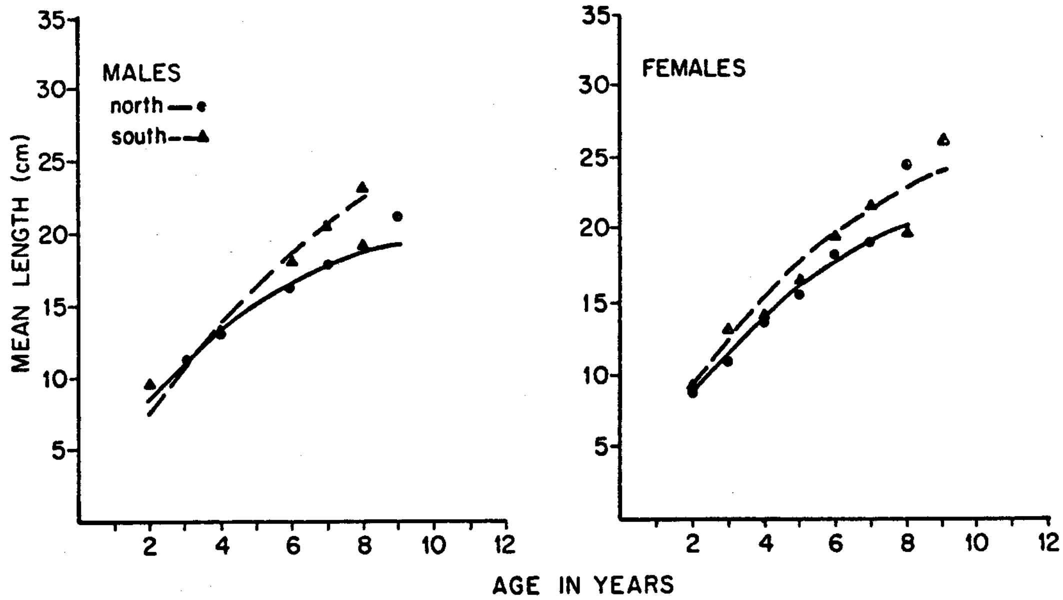


Figure VIII-69.--Mean lengths-at-age and growth curves fit to the origin for toothed smelt by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Table VIII-39.--Parameters for von Bertalanffy growth curves for toothed smelt in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Otolith areas	Sex	Range in age and length of analyzed data: age (yr)	Range in age and length of analyzed data: length (cm)	Original data set: δ	L_∞	K	t_o	Selected data: δ	L_∞	K	t_o	Selected data with origin: δ	L_∞	K	t_o
North	Males	3-9 (3-7)	(10-20)	0.49	43.05	-0.06	-1.84	0.44	22.28	-0.22	-0.15	0.36	21.60	-0.24	0.01
	Females	2-8 (2-7)	(8-23)	1.09	-12.72	0.09	-3.50	0.48	29.45	-0.14	-0.50	0.50	24.66	-0.21	0.04
South	Males	2-8 (3-7)	(9-22)	0.32	-13.21	0.08	-5.00	0.25	-57.06	0.03	-2.31	0.56	37.92	-0.11	0.08
	Females	2-9 (2-7)	(9-23)	1.92	33.36	-0.15	0.15	0.89	37.61	-0.11	-0.44	0.96	29.61	-0.18	0.06

Selection of data to eliminate age groups with few (< 5) observations and fitting the curve to the origin reduced the root mean square deviations (δ), especially for female groupings in both otolith areas. The selected sets also improved curve fits for south males and north females, where meaningless parameters ($\underline{K}$ > 0 and $\underline{L}_\infty$ < 0) were determined in the original data sets. Sex effects varied by area. In the north otolith area, the estimates of $\underline{L}_\infty$ for females was higher than for males but in the south otolith region, the opposite was observed. Estimates of $\underline{K}$ varied as well. Female toothed smelt in the south otolith area had a higher growth completion rate ($\underline{K}$) than males, but in the north, again the reverse was observed.

In general, growth of toothed smelt appears to differ significantly by area. For both sexes, largest mean lengths-at-age, highest estimates for $\underline{L}_\infty$ and lowest values for $\underline{K}$ occurred in the south otolith area. This suggests that toothed smelt south of Bering Strait achieve their maximum size at a slower rate than fish to the north although the maximum size in the south exceeds that for fish in the north.

Length-weight relationships--Table VIII-40 summarizes length-weight observations taken for toothed smelt by sex and otolith area and gives coefficients of the regression lines fit to these data. Data points representing all length-weight observations from these data are shown graphically in Figure VIII-70.

Table VIII-40.--Parameters for the length-weight relationship (weight (g) = a · lenght^b) for toothed smelt and results from the analysis of covariance for between-area and between-sex differences in this relationship (BLM/OCS survey, 1976).

Sex	Otolith Area	Number of Fish Measured	Range in Length (cm)	Parameters a	Parameters b
Males	North	49	11-22	.0015	3.5460
	South	100	8-23	.0007	3.8543
Females	North	31	14-21	.0054	3.0925
	South	89	4-26	.0006	3.8761

Differences between-	F slope df	F slope F	F intercept df	F intercept F	H_b1/	H_a1/	Pooled regression a	Pooled regression b
Areas for males	1;145	4.07*	1;146	1.64	+	-	.0008	3.7996
Areas for females	1;116	7.59**	1;117	.18	+	-	.0007	3.8314
Areas for sexes combined	1;265	9.07**	1;266	.85	+	-	.0008	3.7933
Sexes for south area	1;185	.06	1;186	7.60**	-	+	.0007	3.8396
Sexes for north area	1;76	3.84	1;77	.47	-	-	.0020	3.4424
Sexes for areas combined	1;265	.16	1;266	7.78**	-	+	.0008	3.7933

* Significant at the .05 level.

** Significant at the .01 level.

1/ Plus (+) indicates that the common slope (H_b) hypothesis or common intercept (H_a) hypothesis cannot be rejected on the basis of the values of F obtained.

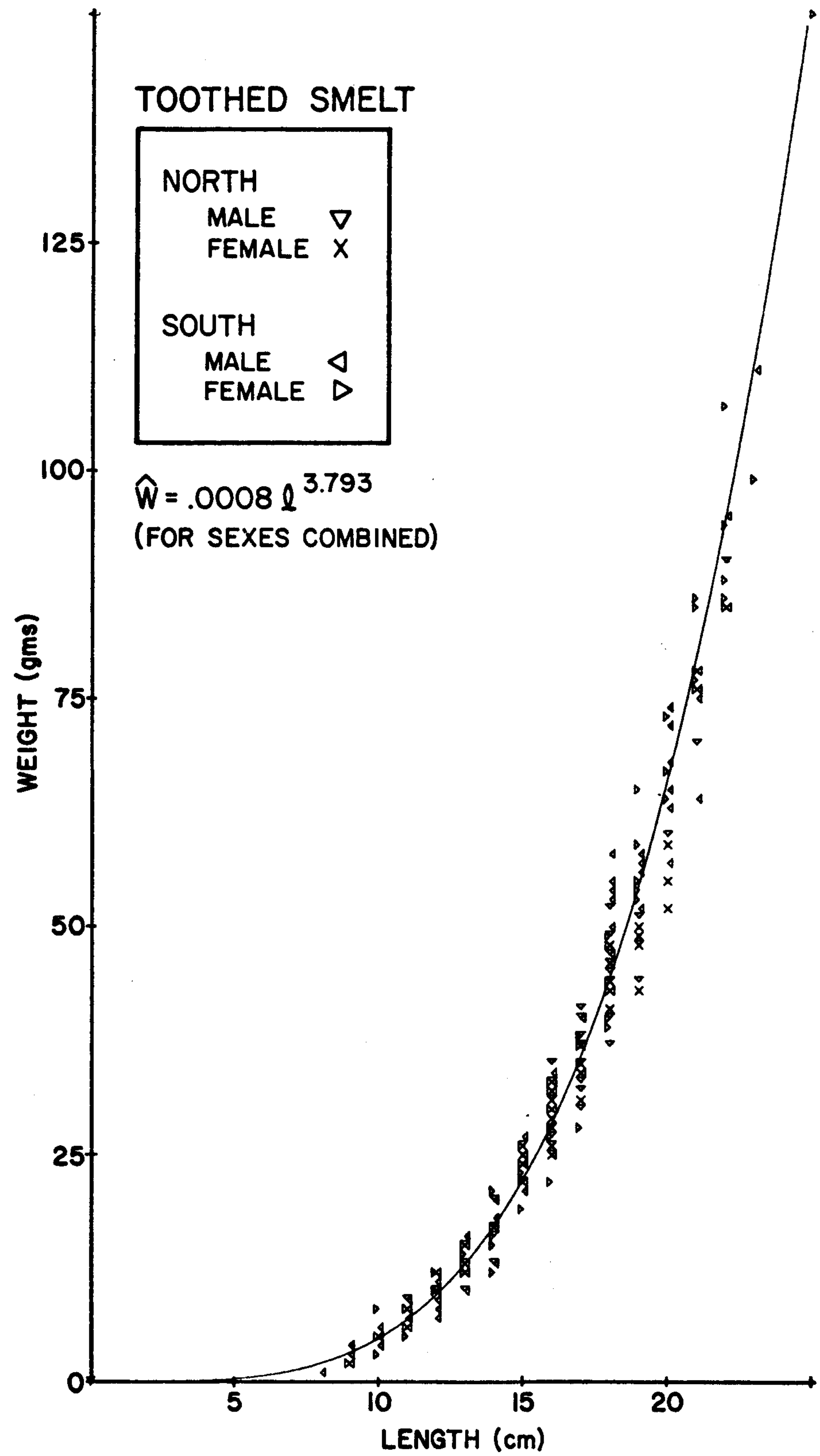


Figure VIII-70.--Weight-at-length observations for toothed smelt by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Analysis of covariance for between-area or between-sex differences in the relationships between length and weight indicated significant levels of variation ($p < .05$) in all treatments of the data, with the exception of between-sex differences in the north otolith area. On the basis of weights predicted by the regression coefficients, males were slightly heavier at-length than females in both otolith areas. Fish of either sex from the north otolith area weighed more at-length than fish of a corresponding length and sex in the south otolith area, but only up to lengths of about 15 cm. Above that size, fish from the south area were heavier than fish from the north. For sizes less than about 11 cm and greater than 20 cm, length-weight differences between sexes and areas were quite large ($> 10\%$). Differences for the 11-20 cm size range were on the order of 3-7%. Although toothed smelt from the two otolith areas appeared to have different weights-at-length, a general overall relationship for the entire survey region was described by the equation:

$$\hat{w} = 0.0008\,\ell^{3.7933}$$

where $\hat{w}$ equals the predicted weight in grams of a fish ℓ cm in length. The relationship described by this equation is shown as a solid line in Figure VIII-70.

Alaska plaice

Distribution and abundance--Alaska plaice occurred at over 66% of the stations sampled (Table VIII-41) and accounted for about 3.5% of the total apparent fish biomass. No large large concentrations of this species were found in the survey area (Figures VIII-71 and 72); however, highest average catch rates occurred along the north coast of the Seward Peninsula (stratum 1S) and in outer Norton Sound (stratum 4Ø) where Alaska plaice were caught at the average rates of 0.3 and 0.4 kg/km, respectively. Average catch rates for all other strata ranged from 0.1 to 0.2 kg/km and the overall mean catch rate for the entire survey region was slightly less than 0.2 kg/km trawled.

Table VIII-41.--Estimated biomass and population size of Alaska plaice in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	17.2	0.069	118	.075	365	.025	0.323	22.17
1S	86.7	0.322	244	.155	2,117	.143	0.115	20.68
2Ø	84.2	0.181	78	.050	589	.040	0.133	18.01
2I	87.5	0.242	74	.047	786	.053	0.094	17.81
Norton Sound and northern Bering Sea								
3W	34.4	0.134	293	.186	817	.055	0.359	27.64
3E	50.0	0.209	128	.082	2,111	.143	0.061	16.20
4Ø	91.4	0.394	525	.334	4,925	.333	0.107	17.98
4I	88.2	0.211	112	.071	3,068	.208	0.037	13.96
All strata combined:	66.1 2/	0.188	1,572 3/		14,777		0.106	17.91

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 994-2,200 mt.

The apparent Alaska plaice biomass for the entire survey area was estimated at about 1,600 mt (95% confidence interval 994-2,200 mt). This estimate is probably quite representative for the survey region even though some of the relatively larger catches occurred at stations along the southern border of the survey area. These catches along the survey

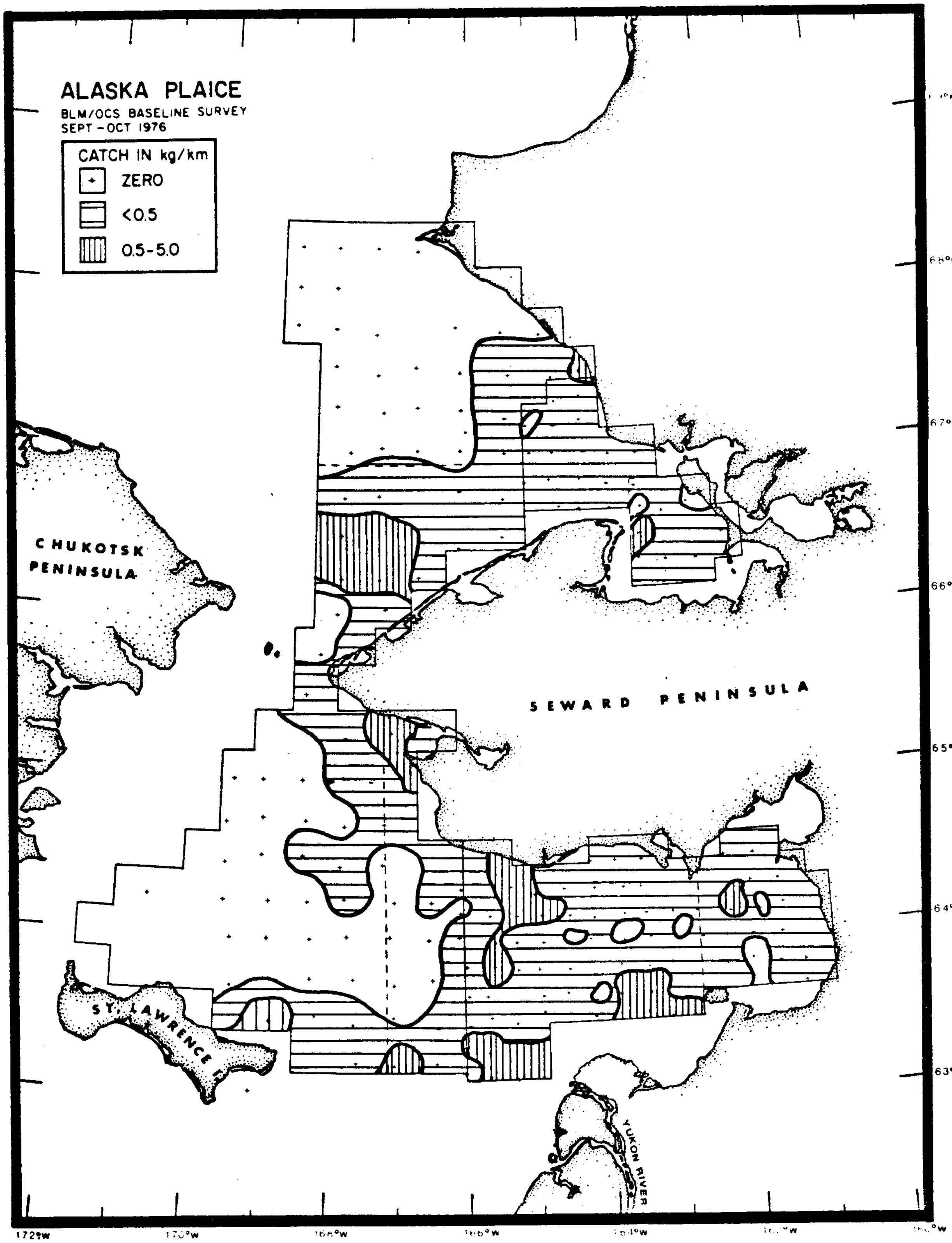
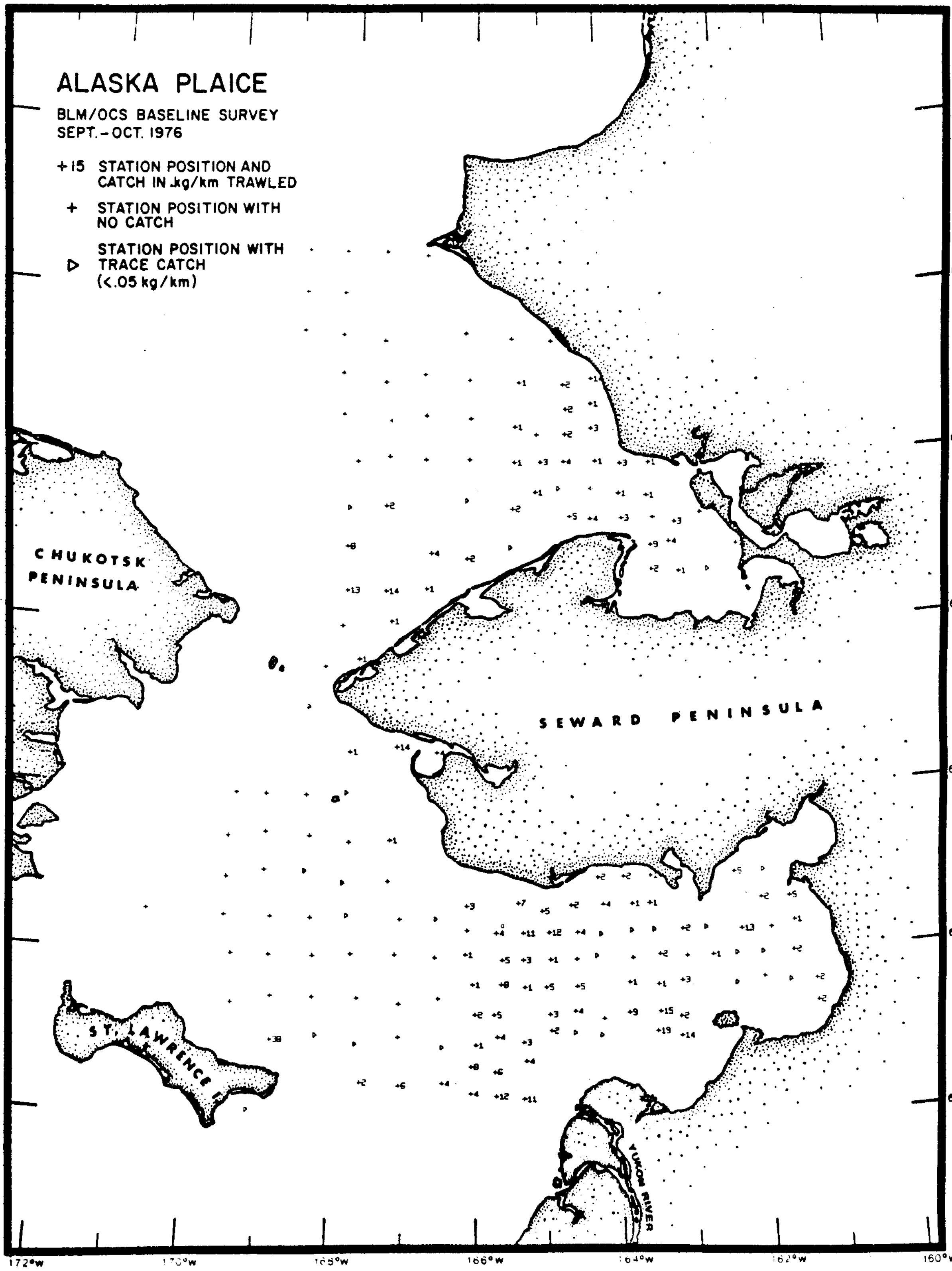


Figure VIII-71.--Distribution and relative abundance by weight of Alaska plaice in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).



Figuve VIII-72.--Distribution of catch rates by weight of Alaska plaice in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

boundary indicate a likely presence of Alaska plaice to the south of the survey region. It is unknown to what degree any fish outside the survey area might influence survey area populations; however, since Alaska plaice had a fairly uniform low distribution throughout the survey region, it seems doubtful that any extensive concentrations were located in close proximity to our survey region. For the population estimated in the survey region, about half (49%) of the apparent biomass was located in strata 1S and 4Ø. Another 19% occurred in stratum 3W but this amount was heavily influenced by one relatively large catch northeast of St. Lawrence Island. Apparent biomass within each of the other strata ranged from 5 to 8% of the overall total. In general, most of the Alaska plaice biomass in the survey area was found in shallow-water regions where depths were less than 25 m.

The relative distribution of estimated numbers differed somewhat from apparent biomass. Although only 7% of the apparent biomass occurred in stratum 4I, the population estimate in numbers for this region was over 3 million fish or about 21% of the total survey estimate. The opposite situation occurred in stratum 3W where the estimated biomass comprised 19% of the total while numbers of fish present was less than 6% of the survey total. The overall estimate for the entire survey region was 14.8 million fish.

Size composition, mean length and weight--Alaska plaice captured during the survey ranged from 6 to 42 cm. Females were considerably larger than males, averaging 20.3 cm compared to 16.1 cm for all strata combined (Figure VIII-73). A variation in size composition by area was evident, with a greater proportion of smaller fish associated with strata 4Ø and 4I.

Mean weight per individual varied by strata. Largest average weights occurred in the offshore deeper-water strata, 1N and 3W, where weights averaged 323 and 359 gm, respectively. Shallower near-shore strata contained Alaska plaice with much smaller average weights, especially in stratum 4I where individuals averaged only 37 gm. The overall mean weight per individual for the entire survey region was 106 gm.

Age composition--Relative age composition by sex and stratum for Alaska plaice is shown in Figure VIII-74. In terms of estimated numbers of fish (Table VIII-42), age groups 4 through 7 predominated, accounting for over 71% of the total estimated population. Differences in age composition occurred by region. In all strata north of Bering Strait and in the offshore waters of the northern Bering Sea (stratum 3W), nearly all fish (99%) were five years old or older. In Norton Sound and the eastern portion of the northern Bering Sea (strata 4Ø, 4I, and 3E) fish in age groups 5 and older comprised a majority of the population; however age groups 2 through 4 constituted 38% of the estimated population.

Sex ratio--Estimated sex ratios (number of males/number of females) by stratum and age group are presented in Table VIII-42. Males were more numerous than females in age groups 6 and younger, while in age groups 7 and older the opposite was observed. This trend was consistent for most strata. Additionally, for all ages combined, males were more numerous than females in every strata except stratum 3W.

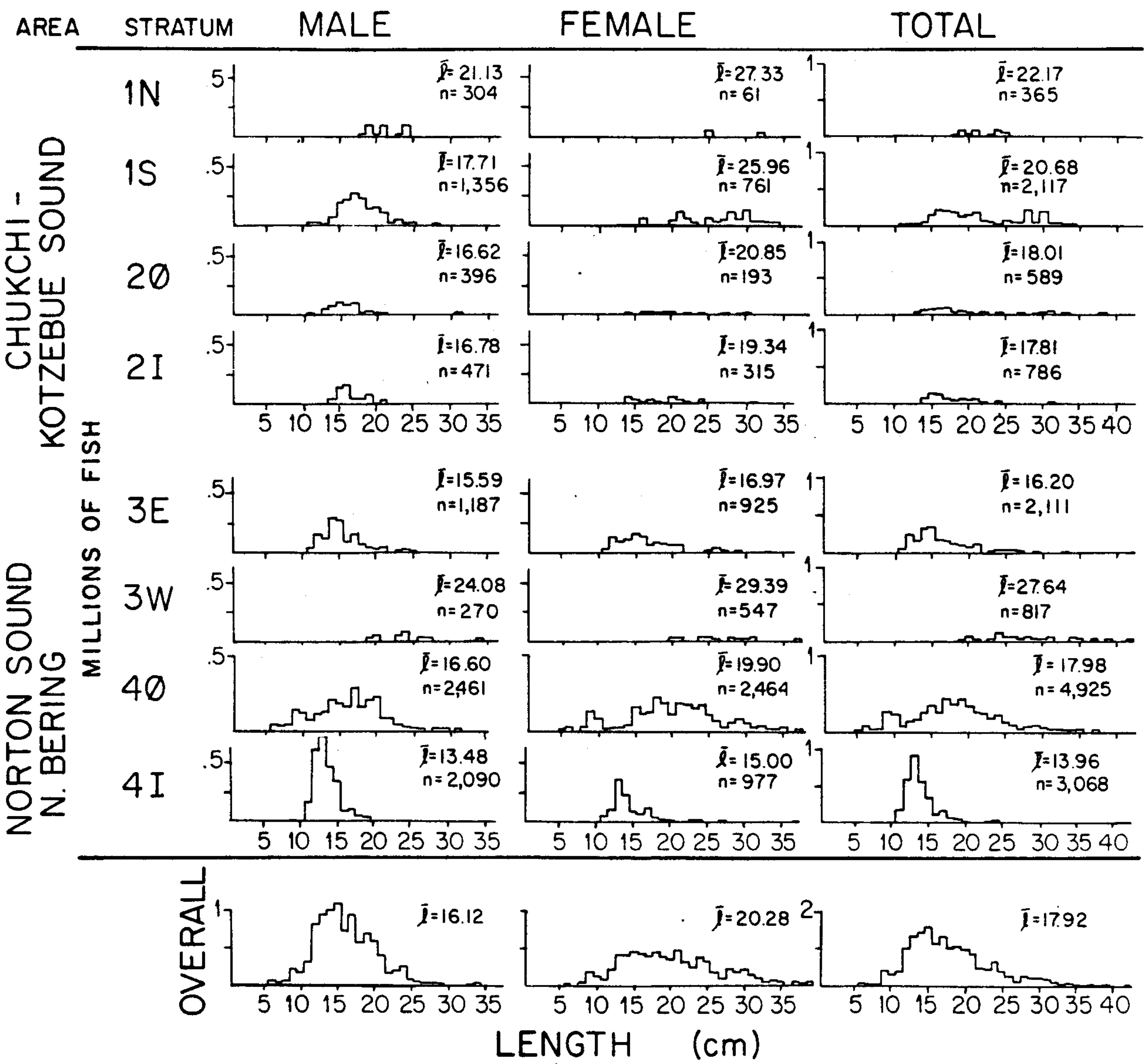


Figure VIII-73.--Size composition of Alaska plaice by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

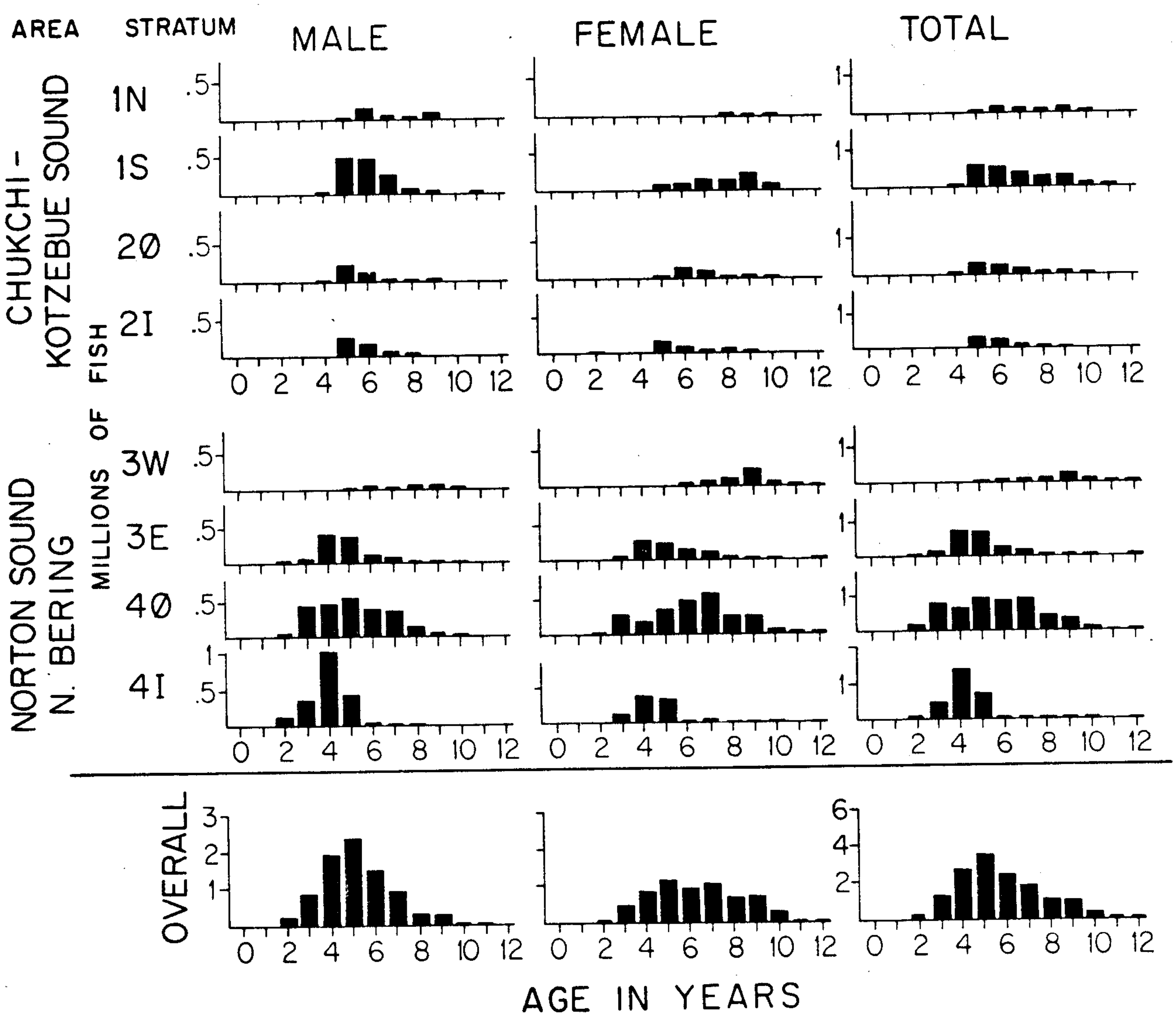


Figure VIII-74.--Age composition of Alaska plaice by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Table VIII-42.--Population numbers ($x10^4$) and sex ratios of Alaska plaice by age group and stratum (BLM/OCS survey, 1976).

Age group Year class	0 1976	1 1975	2 1974	3 1973	4 1972	5 1971	6 1970	7 1969	8 1968	9 1967	10 1966	>10 ≤1965	All ages combined
Stratum													
Southeastern Chukchi Sea and Kotzebue Sound													
1N	--	--	--	--	--	0.4 (1/)	14.7 (1/)	6.2 (1/)	4.8 (0.20)	9.1 (8.10)	1.0 (2/)	--	36.2 (5.33)
1S	--	--	--	--	3.5 (1/)	54.8 (7.43)	55.5 (6.50)	36.5 (1.83)	22.1 (0.55)	23.6 (0.09)	8.2 (2/)	2.0 (1/)	246.2 (1.22)
2O	--	--	--	--	0.7 (1/)	26.7 (7.09)	24.5 (0.75)	12.3 (0.23)	2.5 (0.67)	3.8 (0.81)	0.5 (2/)	--	71.0 (1.26)
2I	--	--	--	--	--	36.2 (1.68)	25.2 (2.00)	9.2 (1.63)	6.1 (0.42)	1.8 (2/)	--	--	81.0 (1.38)
Norton Sound and Northern Bering Sea													
3W	--	--	--	--	--	0.5 (1/)	8.8 (1.93)	10.7 (0.32)	16.3 (0.75)	29.2 (0.32)	11.8 (0.55)	4.4 (2/)	81.7 (0.50)
3E	--	--	4.3 (1/)	15.5 (1.07)	66.7 (1.49)	62.4 (1.55)	22.9 (0.97)	20.1 (0.90)	9.0 (0.80)	6.7 (0.91)	2.5 (0.19)	0.8 (2/)	210.9 (1.28)
4O	--	--	11.6 (3.14)	69.8 (1.54)	59.6 (2.37)	91.6 (1.48)	81.9 (0.90)	89.4 (0.63)	40.5 (0.49)	32.7 (0.34)	12.5 (0.44)	3.3 (2/)	492.9 (1.00)
4I	--	--	13.3 (1/)	46.5 (3.01)	139.1 (2.71)	75.0 (1.22)	7.7 (1.33)	9.5 (0.61)	4.0 (0.43)	1.6 (2/)	1.0 (2/)	0.3 (2/)	298.0 (2.05)
All strata combined	--	--	29.2 (8.80)	131.8 (1.83)	269.6 (2.29)	347.6 (1.98)	241.2 (1.65)	193.9 (0.83)	105.3 (0.54)	108.5 (0.39)	37.5 (0.29)	10.0 (0.23)	1,475.4 (1.34)
Proportion of total population	--	--	.020	.089	.183	.236	.163	.131	.071	.074	.025	.007	

1/ Only males in estimate.
2/ Only females in estimate.

Age-length relationship and growth--Age and length data collected for Alaska plaice were as follows:

Sex	Otoliths areas	Number of readable otoliths	Range in age (years)	Range in length (cm)
Male	North	52	4-11	11-33
	South	93	2-10	6-34
Female	North	33	5-10	14-34
	South	118	2-12	5-42

These data are summarized in Figure VIII-75 by plots of mean lengths-at-age by sex and otolith area with estimated growth curves for each data group. Age-length keys for these data groupings are presented in Appendix I and growth parameters based on this information are given in Table VIII-43.

Selection of data to eliminate age groups with few (<5) observations and fitting the curve to the origin resulted in reductions in the residual root mean square deviations ($\underline{\delta}$), as well as providing more realistic

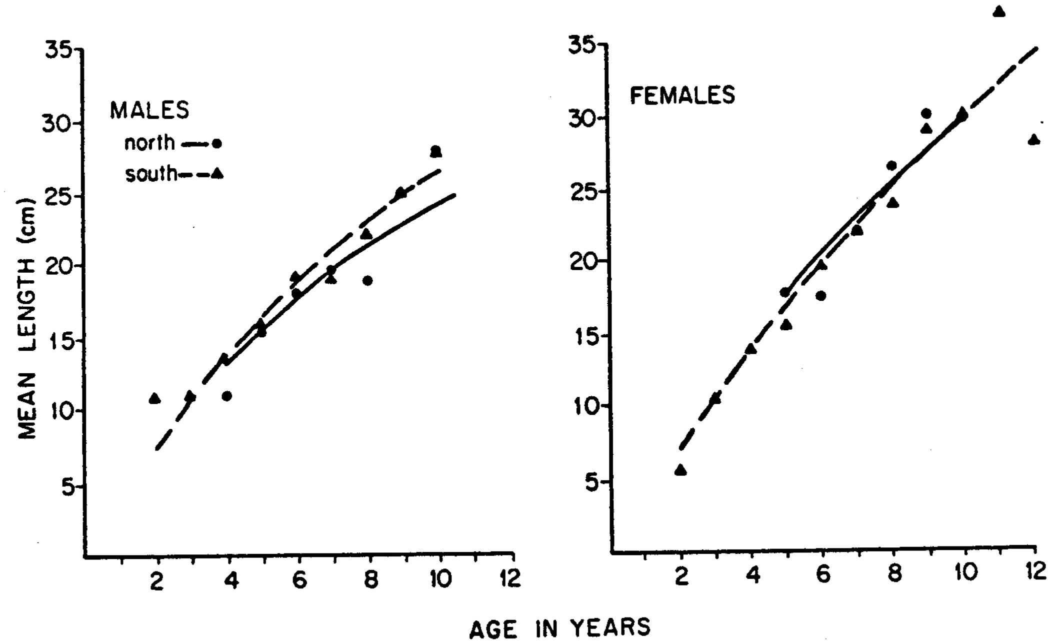


Figure VIII-75.--Mean lengths-at-age and growth curves fit to the origin for Alaska plaice by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Table VIII-43.--Parameters for von Bertalanffy growth curves for Alaska plaice in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Otolith areas	Sex	Range in age and length of analyzed data: age (yr)	Range in age and length of analyzed data: length (cm)	Original data set: δ	Original data set: L_∞	Original data set: K	Original data set: t_o	Selected date: δ	Selected date: L_∞	Selected date: K	Selected date: t_o	Selected data with origin: δ	Selected data with origin: L_∞	Selected data with origin: K	Selected data with origin: t_o
North	Males	4-8 (5-7)	(12-25)	2.04	33.32	-0.19	2.08	1/	1/	1/	1/	0.74	34.45	-0.12	-0.06
	Females	5-10 (5-10)	(14-32)	2.48	42.20	-0.13	1.06	2.48	42.20	-0.13	1.06	2.20	50.69	-0.09	0.08
South	Males	2-10 (3-9)	(7-29)	0.92	36.83	0.04	-4.97	0.90	88.52	-0.03	-0.96	0.99	41.34	-0.10	0.15
	Females	2-12 (3-10)	(8-37)	3.81	30.40	-0.27	1.43	1.05	70.32	-0.06	0.12	0.97	71.75	-0.05	0.07

1/ Insufficient data points for calculating parameters.

values for t_o (theoretically equal to zero). Sex and area effects were observed for the parameters L_∞ and K in selected data with the origin. Females appeared to have substantially greater L_∞ values than males and estimates of this parameter by sex were considerably larger in the south otolith area than in the north. Values for K differed only slightly between sexes and otolith areas, but a trend was apparent. Males had larger estimates of the growth completion rate (K) than females and, by area, values of this parameter by sex were larger in the north otolith area than in the south. This information suggests that growth differed by sex. Also, the rate of growth completion for both sexes in the survey area south of Bering Strait appears slower than to the north, but largest maximum size was achieved for Alaska plaice south of Bering Strait.

<u>Length-weight relationship</u>--Table VIII-44 summarizes the length-weight observations taken for Alaska plaice by sex and otolith area and gives coefficients of the regression lines fit to these data. Data points representing all length-weight observations collected for this species during the survey are shown graphically in Figure VIII-76.

Table VIII-44.--Parameters for the length-weight relationship (weight (g) = a · length^b) for Alaska plaice and results from the analysis of covariance for between-area and between-sex differences in this relationship (BLM/OCS survey, 1976).

Sex	Otolith Area	Number of Fish Measured	Range in Length (cm)	Parameters a	Parameters b
Males	North	48	11-28	.0053	3.3058
	South	93	9-28	.0057	3.2660
Females	North	33	17-32	.0059	3.2826
	South	121	11-34	.0042	3.3746

Differences between-	F slope df	F slope F	F intercept df	F intercept F	H_b 1/	H_a 1/	Pooled regression a	Pooled regression b
Areas for males	1;137	.18	1;138	6.60*	-	+	.0056	3.2775
Areas for females	1;150	.71	1;151	2.76	-	-	.0042	3.3759
Areas for sexes combined	1;291	.80	1;292	8.09**	-	+	.0046	3.3493
Sexes for south area	1;210	3.38	1;211	1.28	-	-	.0045	3.3497
Sexes for north area	1;77	.04	1;78	1.14	-	-	.0049	3.3336
Sexes for areas combined	1;291	3.64	1;292	.76	-	-	.0046	3.3493

* Significant at the .05 level.

** Significant at the .01 level.

1/ Plus (+) indicates that the common slope (H_b) hypothesis or common intercept (H_a) hypothesis cannot be rejected on the basis of the values of F obtained.

Analysis of covariance for between-area and between-sex differences in the relationship between length and weight indicated significant levels of variation ($p < .05$) in two treatments of the data; the comparisons between areas for males and between areas for sexes combined. The significant difference for the comparison between areas for sexes combined probably resulted from the between-area differences for males. Inasmuch as these differences were identified only in tests for the intercepts and not for the slopes, the variations between areas could have resulted from limited samples of small-sized males in the north otolith area. Despite the differences, one length-weight relationship was used for all Alaska plaice in the survey area, as described by the equation:

$$\hat{w} = 0.0056 \ell^{3.0645}$$

where $\underline{\hat{w}}$ equals the predicted weight in grams for a fish $\underline{\ell}$ cm in length. The relationship described by this equation is shown as a solid line in Figure VIII-76.

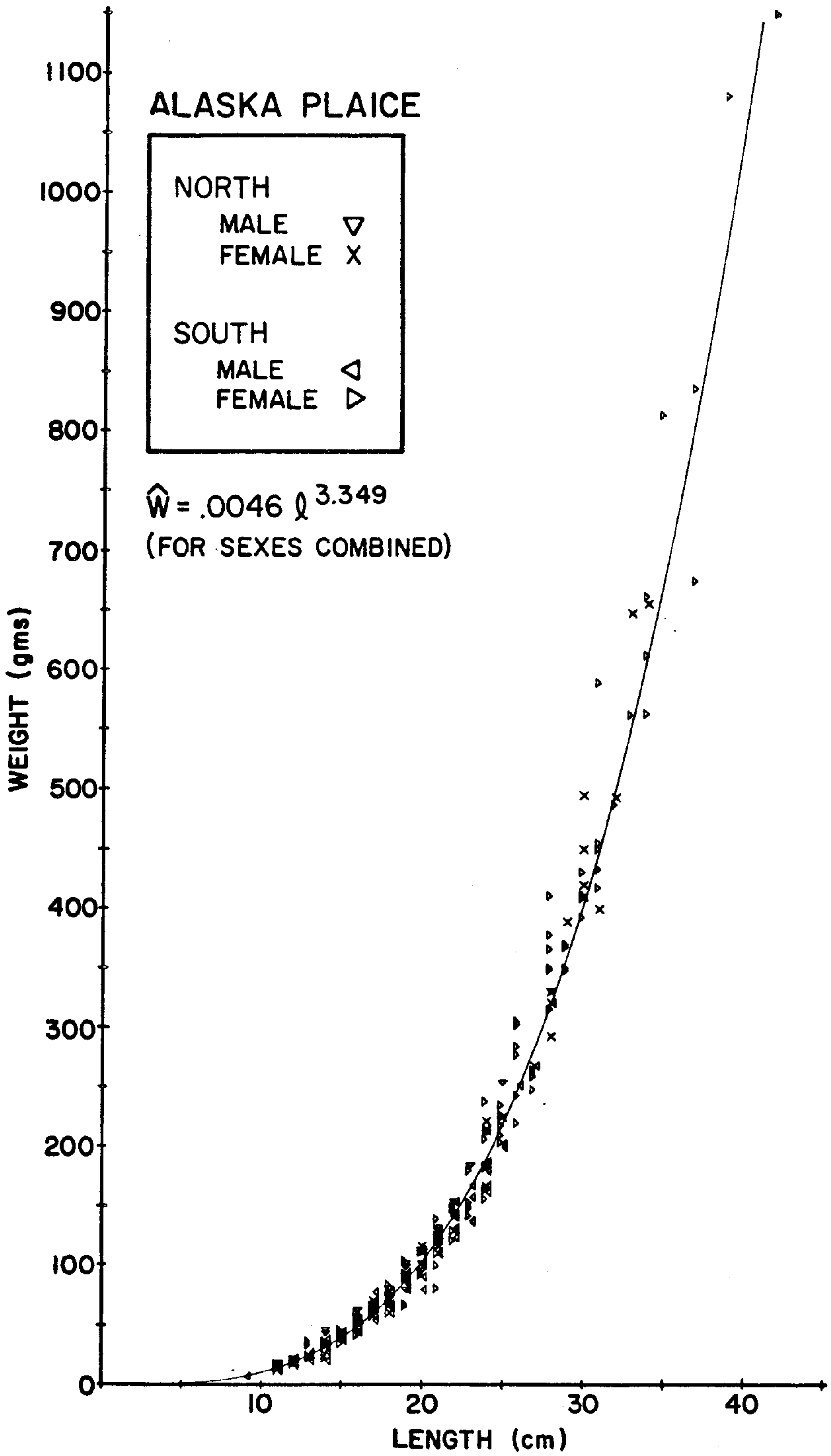


Figure VIII-76.--Weight-at-length observations for Alaska plaice by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Yellowfin sole

Distribution and abundance--Yellowfin sole occurred at 56% of the stations sampled (Table VIII-45) and accounted for about 3% of the total apparent fish biomass. The largest concentration was located in outer Norton Sound (strata 4Ø) (Figures VIII-77 and 78) where catch rates averaged 0.7 kg/km. Average catch rates decreased to about 0.3 kg/km in inner Norton Sound, the eastern portion of the northern Bering Sea, and in inner Kotzebue Sound (strata 4I, 3W, and 2I, respectively). Only trace amounts of yellowfin sole were taken in the southern section of the southeastern Chukchi Sea, outer Kotzebue Sound, and the western portion of the northern Bering Sea (strata 1S, 2Ø, and 3W, respectively). No catches of this species occurred in stratum 1N in the southeastern Chukchi Sea. The overall mean catch rate for the entire survey area was less than 0.2 kg/km trawled.

Table VIII-45.--Estimated biomass and population size of yellowfin sole in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	—	—	—	—	—	—	—	—
1S	80.0	0.099	75	.053	1,415	.039	.053	15.78
2Ø	42.1	0.060	26	.018	361	.010	.071	16.74
2I	87.5	0.284	86	.061	3,728	.103	.023	12.07
Norton Sound and northern Bering Sea								
3W	15.6	0.013	29	.020	173	.005	.166	22.55
3E	57.1	0.252	155	.109	3,658	.101	.042	15.80
4Ø	94.8	0.665	886	.623	20,440	.564	.043	14.94
4I	76.5	0.311	165	.116	6,452	.178	.026	13.29
All strata combined:	56.3 2/	0.170	1,422 3/		36,228		.040	14.60

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 1,068-1,776 mt.

The apparent yellowfin sole biomass in our survey area was estimated at about 1,400 mt (95% confidence interval 1,068-1,776 mt). This is probably a good estimate for this species in our survey region even though some larger catches occurred along the southern border of the survey area. Concentrations of fish along the southern limit of the survey re-

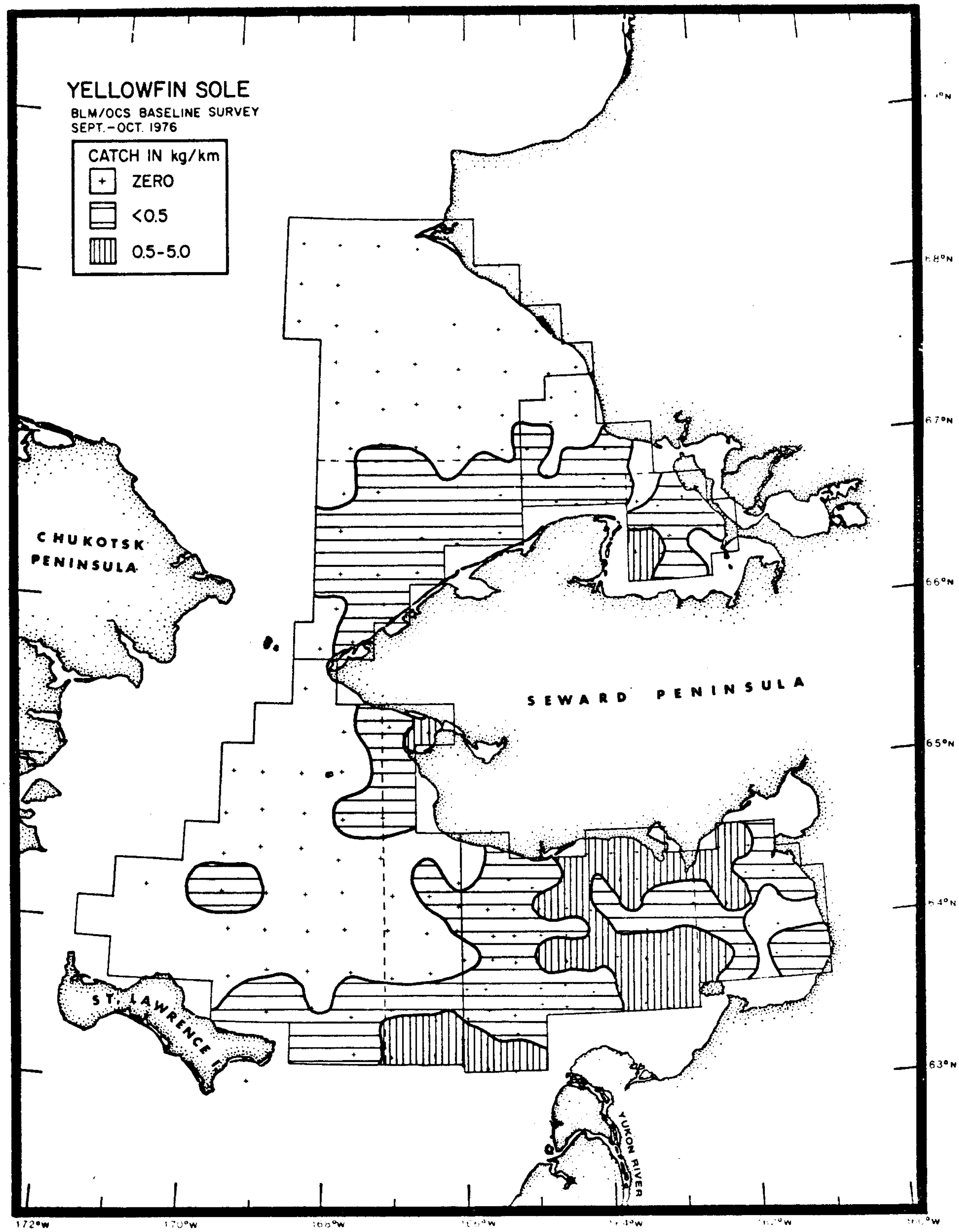


Figure VIII-77.--Distribution and relative abundance by weight of yellowfin sole in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

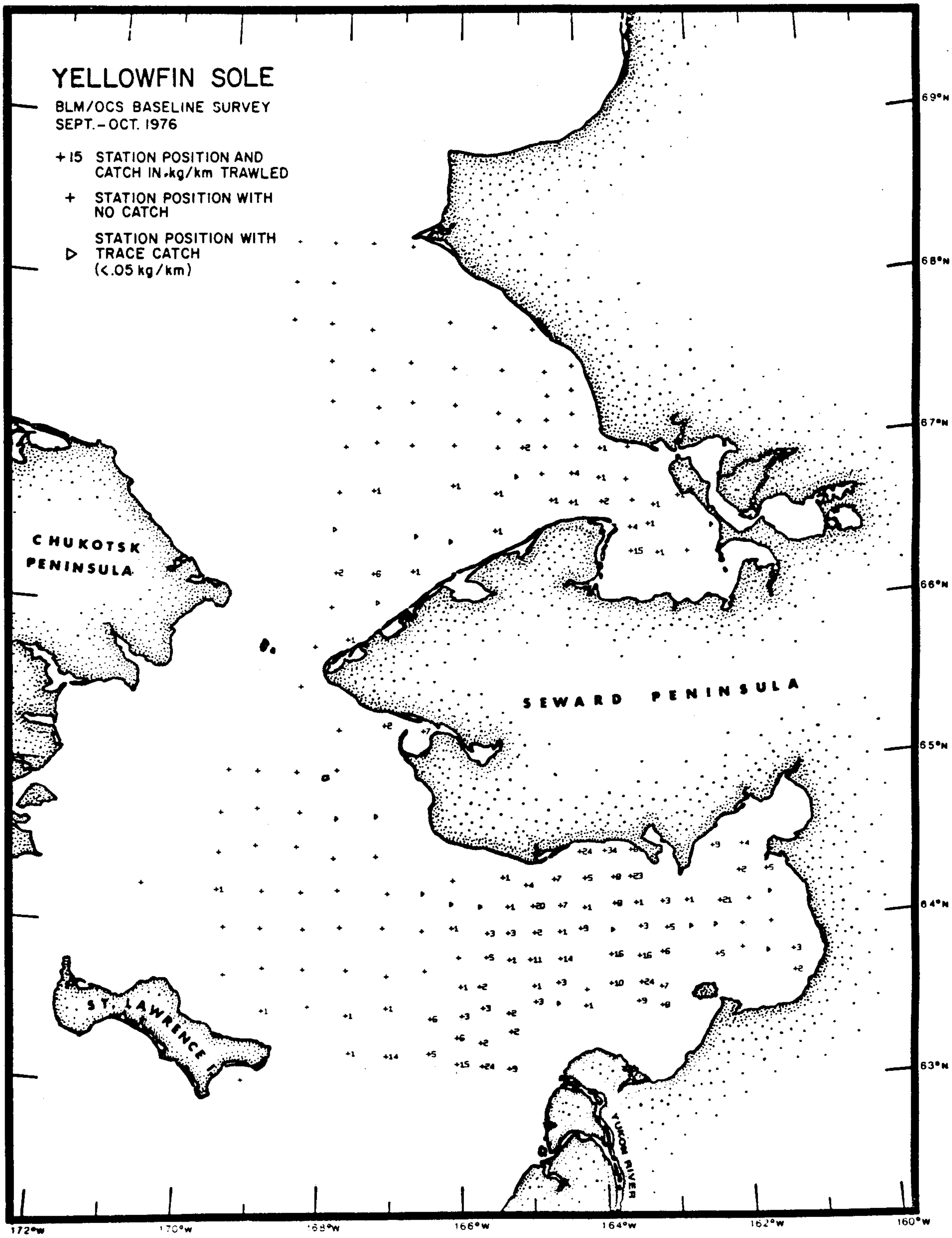


Figure VIII-78.--Distribution of catch rates by weight of yellowfin sole in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

gion indicated a probable presence of fish to the south of the survey area, but the extent of movements of fish between the survey region and areas to the south are unknown. For the population sampled, the greatest proportion of apparent biomass (approximately 74%) was located in strata 4Ø and 4I combined, while a further 11% occurred in adjacent stratum 3E. All other strata accounted for 0-6% of the total biomass estimated. No yellowfin sole were found in stratum 1N, the northern portion of the southeastern Chukchi Sea.

Relative distribution of estimated numbers of yellowfin sole did not significantly differ from apparent biomass. The total population estimate for all strata combined was about 36 million fish.

Size composition, mean length and weight--Yellowfin sole caught during the survey ranged in length from 4 to 33 cm. Females were generally larger than males, averaging 15.6 cm compared to 13.5 cm for all strata combined (Figure VIII-79).

Length-frequency distributions of yellowfin sole indicated differences in relative size composition by area and between sexes within strata. Smallest average sizes by strata occurred in the shallow inner portions of both Kotzebue and Norton Sounds (strata 2I and 4I). Mean size increased with deeper and more offshore strata. This trend was especially evident in the set of strata south of Bering Strait where average size increased from 13.3 cm in stratum 4I to 14.9 cm in 4Ø, 15.8 in 3E, and 22.6 cm in stratum 3W. Differences in relative size compositions between sexes appeared in strata 1S and 2Ø. Average length of females in these strata was about 4 cm larger than for males.

Age composition--Differences in relative age composition by sex and stratum are shown in Figure VIII-80. Overall, age groups 4-7 accounted for 76% of the estimated standing stock in numbers of yellowfin sole in the survey area (Table VIII-46) and occurred in relatively substantial numbers in most strata. Young fish (< age 4) comprised 8% of the total and were primarily found in strata 4Ø and 4I while older fish (> age 7) accounted for the remaining 16% of the population estimate and occurred in all strata in the survey region.

Sex ratio--Estimated sex ratios (number of males/number of females) by stratum and age group are presented in Table VIII-46. There appeared to be more females than males in areas of low relative abundance and in all strata north of Bering Strait. In areas of highest relative abundance, males and females occurred in equal amounts.

Age-length relationship and growth--Age and length data collected for yellowfin sole were as follows:

Sex	Otolith areas	Number of readable otoliths	Range in age (years)	Range in length (cm)
Male	North	39	2-10	7-23
	South	93	1-10	4-26
Female	North	78	4-12	8-24
	South	110	2-14	5-34

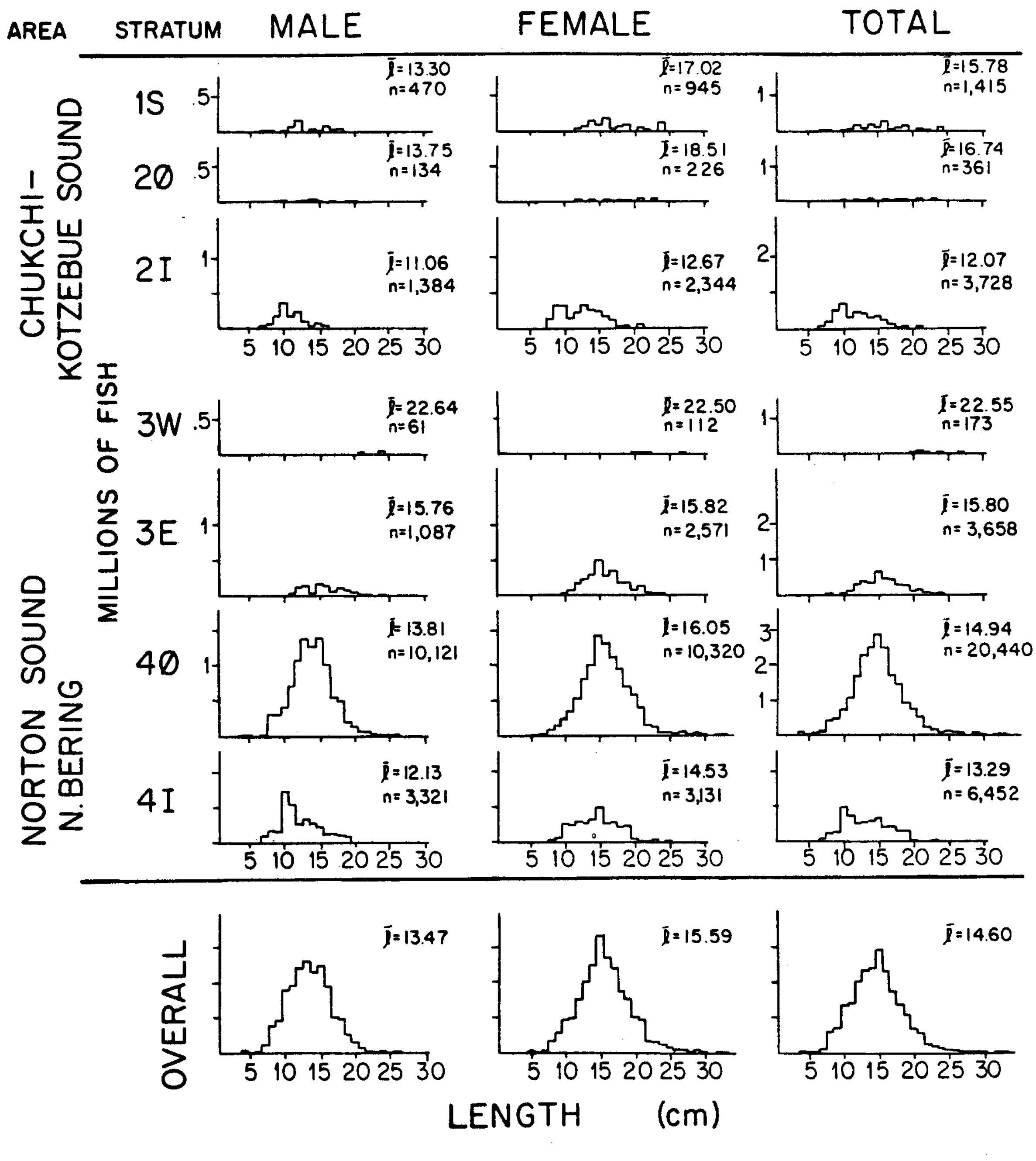


Figure VIII-79.--Size composition by sex and stratum for yellowfin sole in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

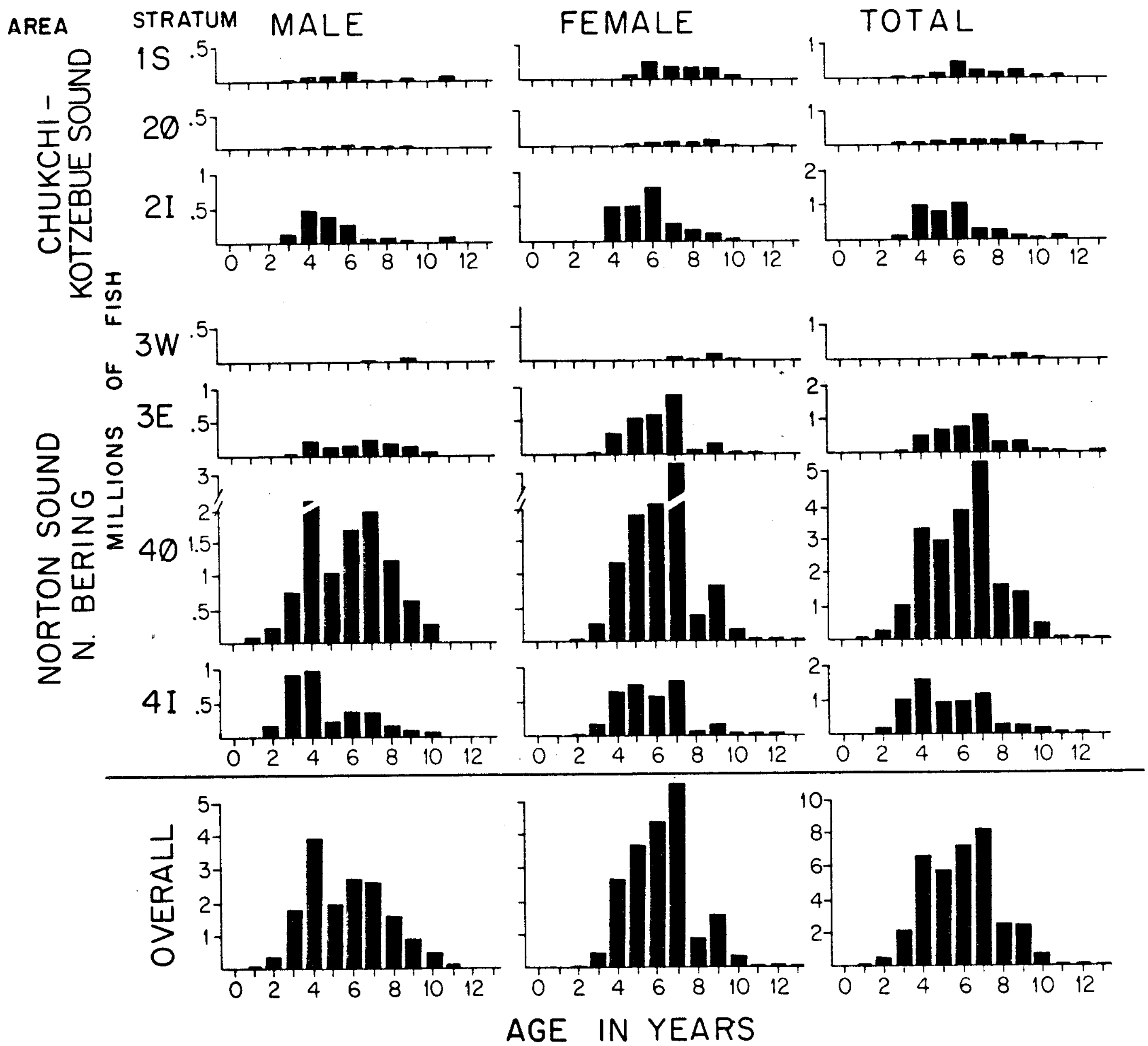


Figure VIII-80.--Age composition of yellowfin sole by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Table VIII-46.--Population numbers (x10^4) and sex ratios of yellowfin sole by age group and stratum (BLM/OCS survey, 1976).

Age group Year class	0 1976	1 1975	2 1974	3 1973	4 1972	5 1971	6 1970	7 1969	8 1968	9 1967	10 1966	>10 ≤1965	All ages combined
Stratum													
Southeastern Chukchi Sea and Kotzebue Sound													
1N	--	--	--	--	--	--	--	--	--	--	--	--	--
1S	--	--	--	0.5 (1/)	6.9 (1/)	14.1 (1.56)	44.7 (0.66)	22.1 (0.13)	17.0 (0.03)	20.6 (0.11)	7.5 (2/)	8.3 (1/)	141.7 (0.50)
2O	--	--	--	0.6 (1/)	1.6 (1/)	3.6 (1.40)	7.9 (1.19)	4.4 (0.42)	5.0 (0.19)	11.0 (0.17)	0.5 (2/)	0.3 (2/)	34.3 (0.52)
2I	--	--	--	10.8 (1/)	9.73 (0.96)	89.6 (0.76)	105.6 (0.33)	27.9 (0.09)	21.2 (0.29)	12.0 (0.22)	2.8 (2/)	5.9 (1/)	373.1 (0.59)
Norton Sound and Northern Bering Sea													
3W	--	--	--	--	--	--	--	5.7 (0.46)	1.8 (0.64)	9.5 (0.61)	0.4 (2/)	--	17.4 (0.54)
3E	--	--	--	4.6 (1.19)	50.7 (0.69)	63.5 (0.24)	76.3 (0.29)	109.8 (6.26)	23.5 (2.41)	29.1 (0.66)	8.0 (2.08)	1.3 (2/)	336.0 0.42
4O	--	8.5 (1/)	25.3 (6.23)	102.8 (2.56)	338.0 (1.88)	293.8 (0.55)	382.4 (0.82)	531.2 (0.58)	161.2 (3.19)	145.7 (0.76)	47.2 (1.73)	7.1 (2/)	2,044.0 0.98
4I	--	--	18.7 (16.00)	106.1 (5.89)	161.6 (1.60)	95.1 (0.32)	95.3 (0.60)	115.6 (0.45)	22.2 (2.26)	20.0 (0.65)	9.0 (2.75)	1.7 (2/)	645.3 (1.06)
All strata combined	--	8.5 (1/)	44.0 (8.57)	225.4 (3.86)	656.1 (1.53)	559.7 (0.51)	712.2 (0.62)	816.7 (0.47)	251.9 (1.79)	247.9 (0.59)	75.4 (1.25)	13.8 (1.48)	3,612.9 (0.84)
Proportion of total population	--	.002	.012	.062	.182	.155	.197	.226	.070	.069	.021	.007	

1/ Only males in estimate.
2/ Only females in estimate.

These data are summarized in Figure VIII-81 by plots of mean lengths-at-age by sex and otolith area with estimated growth curves for each data group. Age-length keys for these data groupings are presented in Appendix I and growth parameters based on this information are given in Table VIII-47.

Fitting the selected data to the origin failed to substantially reduce the root mean square deviation and actually increased δ for age groupings in the north otolith area. Increased δ was most noticeable for the north area females. Original data for this group suggested almost linear growth (Figure VIII-81) with t_o estimated at about age 2 years (t_o = 2.04). The selected data with the origin, however, did improve values for L_∞, K, and t_o, especially for area south females where meaningless parameters (L_∞ < 0 and K > 0) were obtained before selection.

An area effect was observed for both sexes for the parameters L_∞ and K in the selected data with the origin. For males and females, estimates of L_∞ in the south otolith area were larger than estimates in the north by 28% and 14%, respectively. Also, lower estimated growth completion rates (K) by sex were indicated for the south otolith area than for the north area.

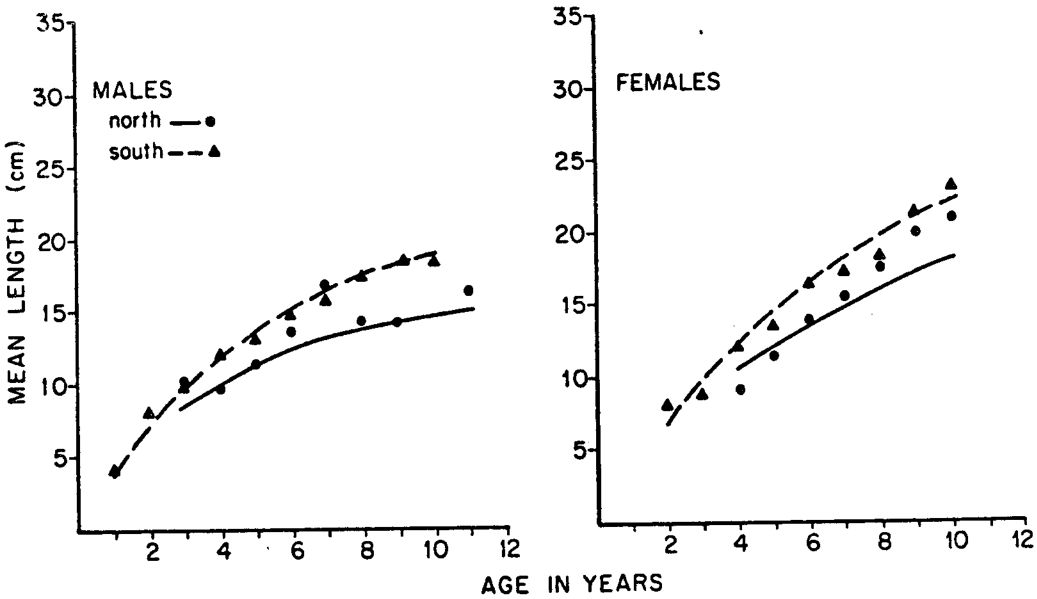


Figure VIII-81.--Mean lengths-at-age and growth curves fit to the origin for yellowfin sole by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Table VIII-47.--Parameters for von Bertalanffy growth curves for yellowfin sole in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (values in parentheses are ranges for selected ages and lengths) (BLM/OCS survey, 1976).

		Range in age and length of analyzed data		Original data set				Selected data				Selected data with origin			
Otolith areas	Sex	age (yr)	length (cm)	δ	L_∞	K	t_0	δ	L_∞	K	t_0	δ	L_∞	K	t_0
North	Males	3-11 (4-9)	(7-14)	1.65	15.81	-0.34	0.59	1.60	14.47	-0.91	2.95	1.97	15.94	-0.23	-0.19
	Females	4-12 (4-12)	(8-24)	1.12	21.35	-0.28	2.04	1.12	21.35	-0.28	2.04	2.03	24.54	-0.12	-0.51
South	Males	1-10 (4-9)	(9-26)	0.53	20.40	-0.22	-0.00	0.26	62.94	-0.03	-3.87	0.50	22.23	-0.19	0.08
	Females	2-13 (2-11)	(9-29)	1.65	-38.01	0.10	-8.83	0.85	41.73	-0.07	-1.08	1.08	28.64	-0.15	0.20

These data suggest a possible difference in growth for yellowfin sole found north and south of Bering Strait. Maximum size of this species appears to be substantially smaller for stocks north of Bering Strait than for fish to the south and the rate at which maximum size is achieved also differs between these regions. Mean lengths-at-age were smaller by sex north of Bering Strait than for yellowfin sole south of that strait.

Length-weight relationship--Table VIII-48 summarizes the length-weight observations taken for yellowfin sole by sex and otolith area and gives coefficients of regression lines fit to these data. Data points representing all length-weight observations collected for this species during the survey are shown graphically in Figure VIII-82.

Table VIII-48.--Parameters for the length-weight relationship (weight (g) = a · length^{b}) for yellowfin sole and results from the analysis of covariance for between-area and between-sex differences in this relationship (BLM/OCS survey, 1976).

Sex	Otolith Area	Number of Fish Measured	Range in Length (cm)	Parameters a	Parameters b
Male	North	38	9-25	.0072	3.1696
	South	92	7-24	.0081	3.1100
Female	North	80	10-24	.0067	3.2091
	South	108	9-34	.0083	3.1225

Differences between-	F slope df	F slope F	F intercept df	F intercept F	H_b 1/	H_a 1/	Pooled regression a	Pooled regression b
Areas for males	1;126	.14	1;127	.59	-	-	.0082	3.1072
Areas for females	1;184	1.32	1;185	.82	-	-	.0079	3.1438
Areas for sexes combined	1;314	1.74	1;315	2.96	-	-	.0076	3.1507
Sexes for south area	1;196	.03	1;197	7.14**	-	+	.0079	3.1340
Sexes for north area	1;114	.08	1;115	1.01	-	-	.0064	3.2235
Sexes for areas combined	1;314	.35	1;315	10.3**	-	+	.0076	3.1507

* Significant at the .05 level.

** Significant at the .01 level.

1/ Plus (+) indicates that the common slope (H_b) hypothesis or common intercept (H_a) hypothesis cannot be rejected on the basis of the values of F obtained.

Analysis of covariance for between-area or between-sex differences in the length-weight relationship indicated a significant difference in two treatments of the data, the comparisons of between-sex differences in the south otolith area and for areas combined (F= 7.14 and 10.3, respectively, p <.01). A significant difference for the area-combined comparison between sexes probably resulted from differences between sexes in the south otolith area. Since significance was determined only for tests of the treatment intercepts and not the slopes, the two treatment differences may have been due to limited observations of small-sized fish of either sex. Despite the differences, one length-weight relationship was used for all yellowfin sole in the survey area, as described by the equation:

$$\hat{w} = 0.0076\ell^{3.1507}$$

where $\hat{w}$ equals the predicted weight in grams of a fish ℓ cm in length. The relationship described by this equation is shown as a solid line in Figure VIII-82.

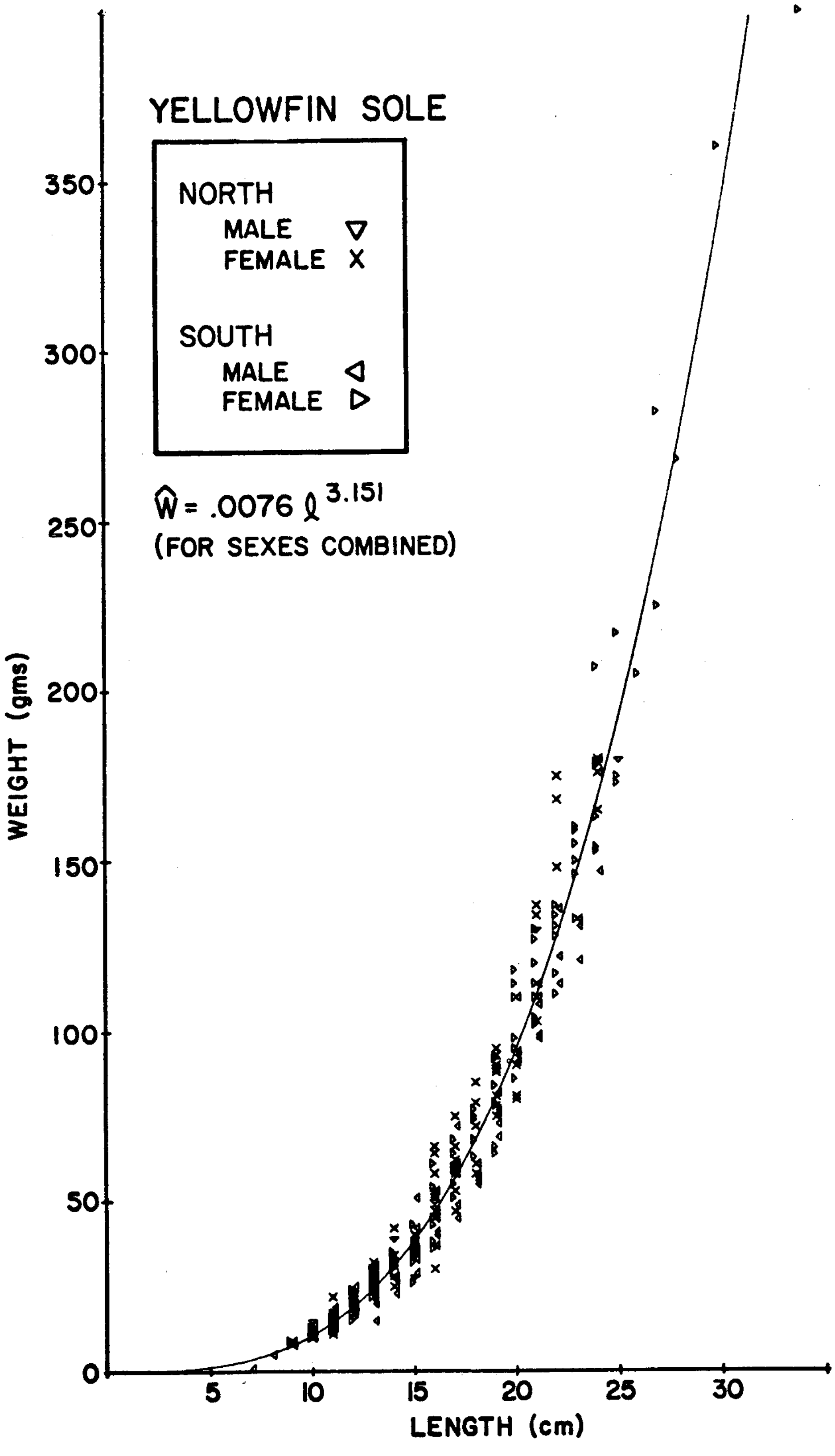


Figure VIII-82.--Weight-at-length observation for yellowfin sole by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Arctic cod

Distribution and abundance--Arctic cod was the most frequently encountered species, occurring at nearly 85% of all stations sampled (Table VIII-49); however, it accounted for less than 3% of the total apparent fish biomass. Small concentrations were found throughout the survey region (Figures VIII-83 and 84), with the southeastern Chukchi Sea, outer Kotzebue Sound, outer Norton Sound, and the eastern portion of the northern Bering Sea (strata 1N, 1S, 2Ø, 4Ø, and 3E) all having catch rates of about 0.2 kg/km. Catch rates were even lower in the inshore portions of Norton and Kotzebue sounds (2I and 4I) where only trace amounts of Arctic cod were encountered. The overall mean catch rate for the entire survey area was slightly more than 0.1 kg/km trawled.

Table VIII-49.--Estimated biomass and population size of Arctic cod in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population ($\times 10^3$)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	96.6	0.208	353	.286	25,270	.330	.014	10.41
1S	66.7	0.197	149	.121	8,774	.115	.017	12.53
2Ø	89.5	0.155	67	.054	3,149	.041	.021	12.65
2I	37.5	0.018	6	.005	344	.004	—	12.25
Norton Sound and northern Bering Sea								
3W	90.6	0.099	217	.176	18,544	.242	.012	8.63
3E	92.9	0.233	143	.116	4,959	.065	.029	14.13
4Ø	82.8	0.208	278	.225	14,410	.188	.019	13.38
4I	88.2	0.041	22	.018	1,065	.014	.021	12.99
All strata combined:	84.9 2/	0.147	1,234 3/		76,516		.016	11.32

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 918-1,550 mt.

The Arctic cod biomass for the entire survey area was estimated at just over 1,200 mt (95% confidence interval 912-1,550 mt). This is a minimum estimate for the region, since Arctic cod are considered semi-pelagic. Quast (1974) indicated this species was by far the most abundant taken in midwater sampling during an earlier study in the Chukchi Sea. Some unknown proportion of the population, therefore, occupied the water column above

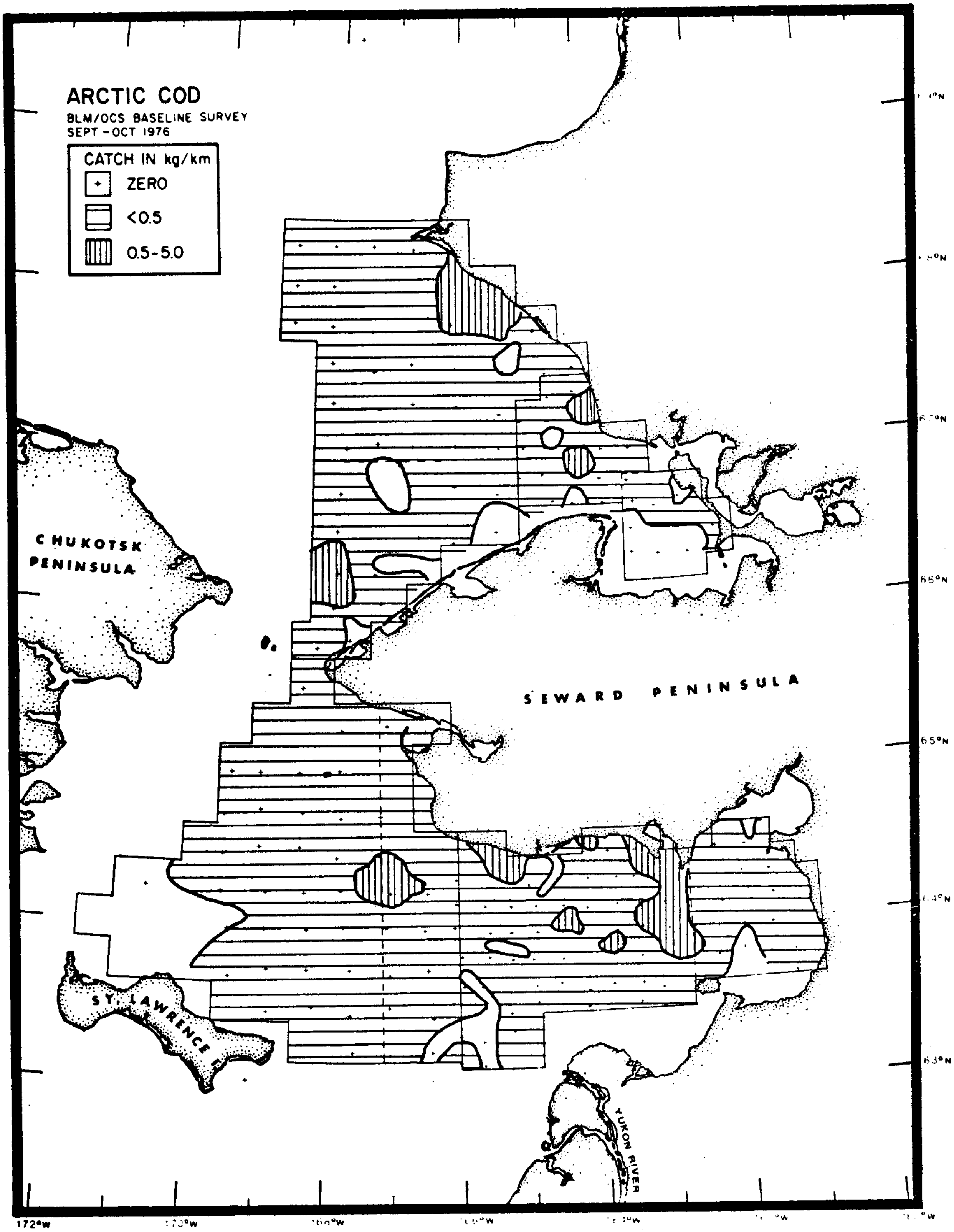


Figure VIII-83.--Distribution and relative abundance by weight of Arctic cod in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

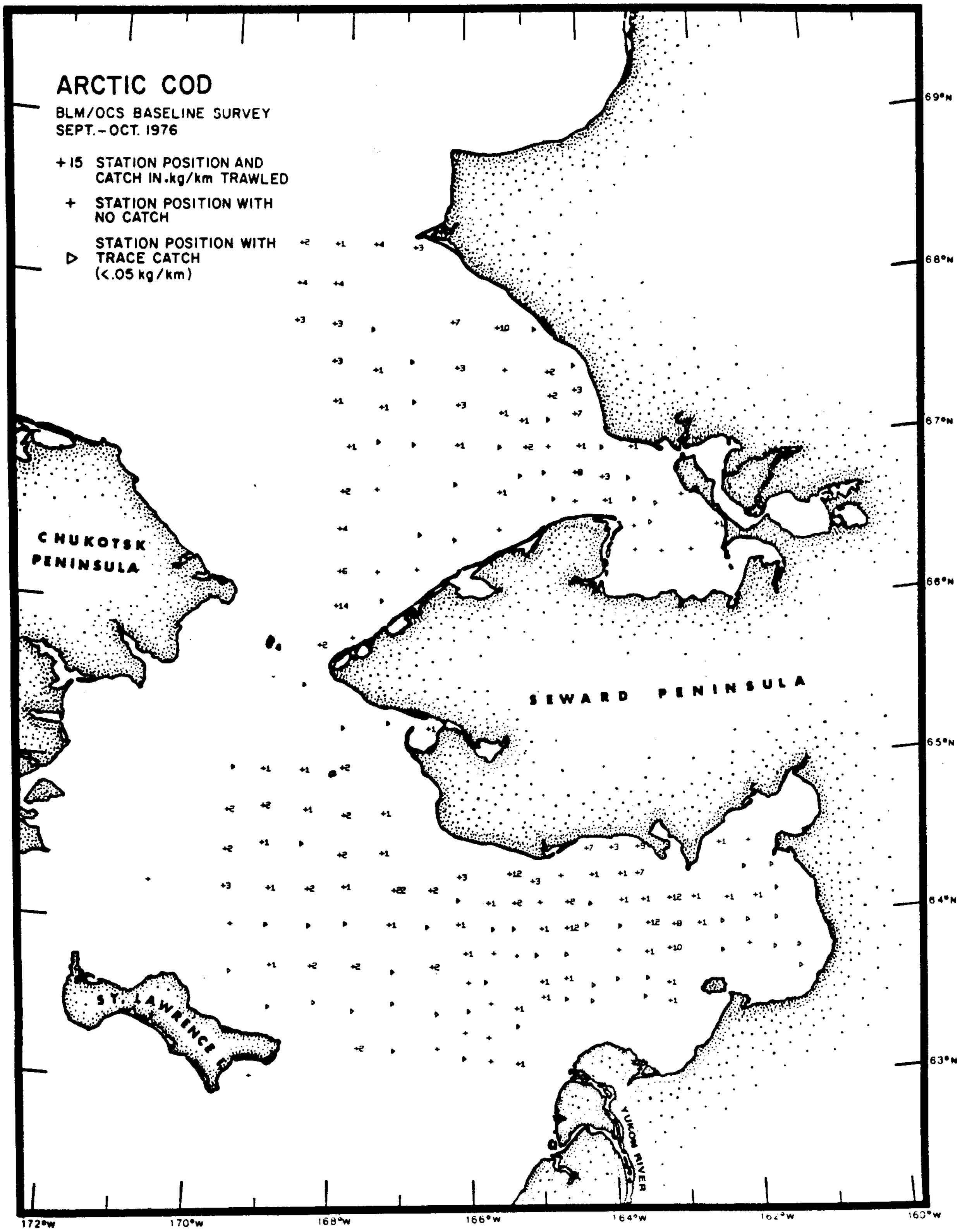


Figure VIII-84.--Distribution of catch rates by weight of Arctic cod in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

the sampling gear and was unavailable to the trawl. Also, concentrations may have existed north of the survey region. Earlier work by Alverson and Wilimovsky (1966) mentioned relatively large catches of Arctic cod slightly north of Pt. Hope. The degree to which these peripheral stocks may influence the survey area population is unknown. Additionally, this species exhibits a preference for colder waters (Svetovidov, 1968) and the relatively warm water temperatures measured during the survey may have had still another effect on Arctic cod distribution and abundance.

For the Arctic cod population sampled, over 40% of the estimated population occurred in strata 1N and 1S combined. Of the remaining biomass, 29% occurred in strata 3W and 3E combined, 22% in stratum 4Ø, and less than 2% each in strata 2I and 4I.

The relative distribution of the estimated number of fish did not appreciably differ from the apparent biomass. The total population estimate for the entire survey area was about 76.5 million fish.

Size composition, mean length and weight--Arctic cod caught during the survey ranged in size from 4 to 26 cm. Males were slightly larger than females, averaging 13.6 cm compared to 13.5 cm for all strata combined (Figure VIII-85). Length frequency distributions for Arctic cod include juvenile fish for which sex was not determined. The inclusion of these unsexed fish in the calculation of mean size for sexes combined caused the mean length in most strata to be considerably less than for individual sexes.

Small fish (< 8 cm) were almost entirely located in the offshore deeper water strata 1N and 3W. Larger Arctic cod (> 8 cm) were found in all strata, but were most abundant in strata 1N, 1S, and 4Ø.

Highest mean weight for Arctic cod (29 gm) was observed in stratum 3E where catches of small fish were not encountered. Overall mean weight per individual for the entire survey region was only 16 gm.

Age composition--Differences in relative age composition between sexes was not significant (Figure VIII-86). In terms of estimated numbers of fish (Table VIII-50), age groups 0 and 2 predominated, accounting for over 72% of the total estimated population. Most of the remaining estimated population consisted of 3 and 4 year-old fish. It is most interesting that age 1 fish appeared very low in estimated abundance, comprising less than 2% of the total estimate. No obvious reason could be identified for this low abundance.

Sex ratio--Estimated sex ratios (number of males/number of females) by stratum and age group are presented in Table VIII-50. Overall, males were slightly more numerous than females, but females predominated in age groups 4 and older.

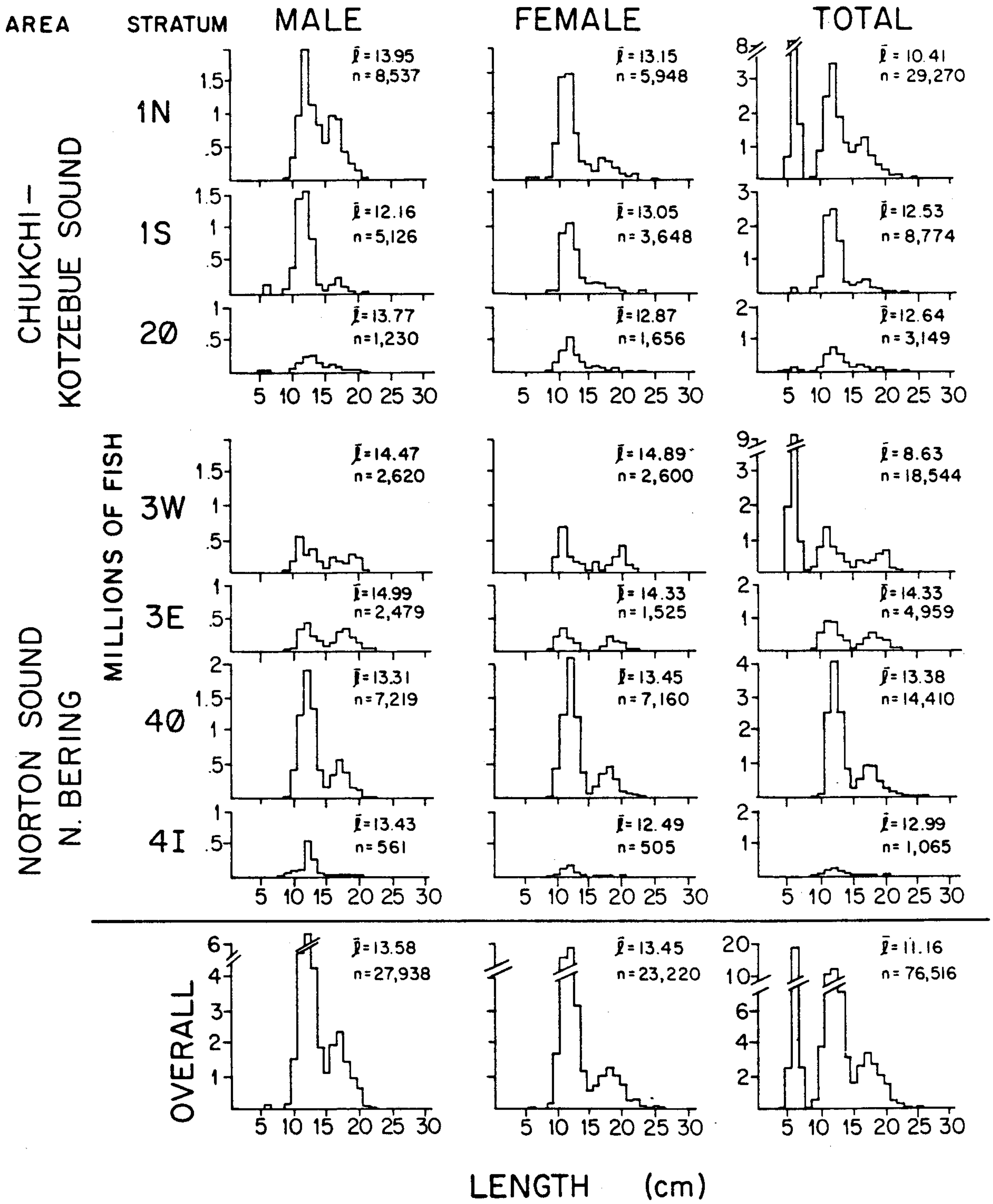


Figure VIII-85.--Size composition of Arctic cod by sex and stratum in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

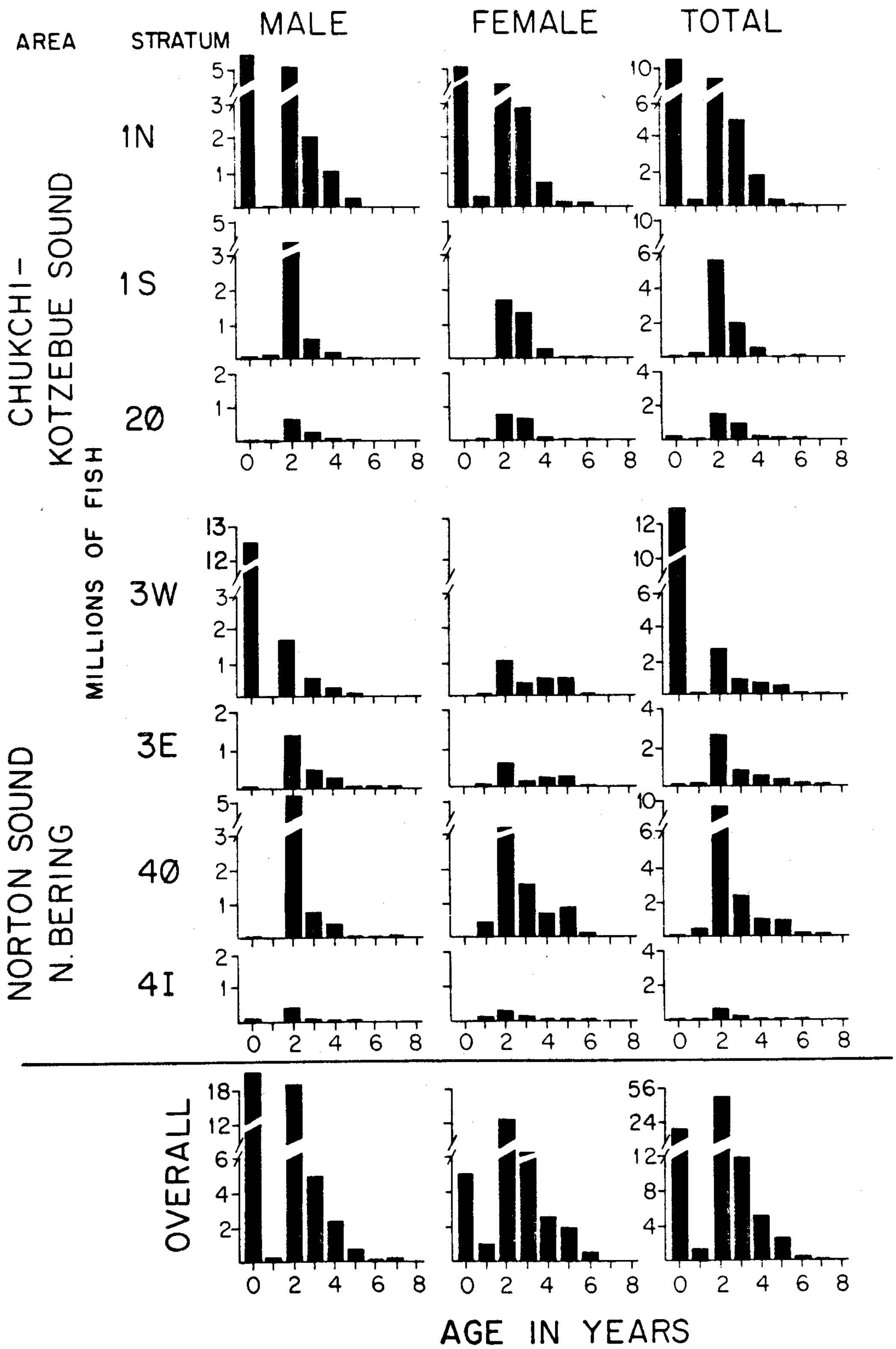


Figure VIII-86.--Age composition of Arctic cod by sex and stratum in Norton Sound, the southeastern Chukchi Sea and adjcent waters (BLM/OCS survey, 1976).

Table VIII-50.--Population numbers (x10^5) and sex ratios for Arctic cod by age group and stratum (BLM/OCS survey, 1976).

Age group Year class	0 1976	1 1975	2 1974	3 1973	4 1972	5 1971	6 1970	7 1969	8 1968	9 1967	10 1966	>10 ≤1965	All ages combined
Stratum													
Southeastern Chukchi Sea and Kotzebue Sound													
1N	108.4 (1.88)	4.2 (0.22)	94.4 (1.14)	49.3 (0.71)	17.4 (1.52)	4.8 (2.35)	1.0 (2/)	--	--	--	--	--	279.6 (0.99)
1S	1.4 (1/)	1.9 (4.46)	57.1 (2.21)	20.1 (0.45)	5.3 (0.71)	0.8 (2.42)	0.7 (2/)	--	--	--	--	--	85.0 (1.43)
4Ø	2.7 (1/)	0.8 (0.14)	15.2 (0.91)	9.3 (0.47)	2.5 (1.08)	0.7 (4.15)	0.2 (2/)	--	--	--	--	--	31.2 (0.74)
2I	--	0.2 (0.50)	2.0 (0.87)	0.6 (1.76)	0.3 (3.83)	0.1 (2.50)	T (2/)	--	--	--	--	--	3.1 (1.08)
Norton Sound and Northern Bering Sea													
3W	124.9 (1/)	1.4 (2/)	34.9 (1.69)	8.9 (1.21)	7.7 (0.51)	6.6 (0.20)	0.8 (2/)	0.2 (1/)	--	--	--	--	185.4 (1.01)
3E	0.2 (1/)	1.0 (2/)	29.2 (2.11)	8.3 (4.00)	5.8 (1.33)	3.8 (0.19)	1.0 (0.51)	0.4 (1/)	--	--	--	--	49.7 (1.62)
4Ø	0.3 (1/)	4.6 (2/)	93.4 (1.74)	24.1 (0.50)	10.9 (0.59)	9.2 (0.08)	1.7 (0.04)	0.1 (1/)	--	--	--	--	144.2 (1.01)
4I	0.1 (1/)	0.5 (2/)	7.5 (1.51)	1.6 (0.62)	0.7 (0.89)	0.3 (0.26)	T (2/)	--	--	--	--	--	10.6 (1.11)
All strata combined	232.9 (4.71)	14.6 (0.23)	333.5 (1.54)	122.2 (0.69)	50.7 (0.94)	26.2 (0.36)	5.4 (0.08)	0.7 (1/)	--	--	--	--	785.7 (1.08)
Proportion of total population	.296	.019	.424	.156	.064	.033	.007	.001	--	--	--	--	

1/ Only males in estimate.
2/ Only females in estimate.

Age-length relationship and growth--Age and length data collected for Arctic cod were as follows:

Sex	Otolith area	Number of readable otoliths	Range in age (years)	Range in length (cm)
Male	North	66	0-5	5-21
	South	57	0-7	9-23
Female	North	68	0-6	6-25
	South	73	1-6	9-26
Unsexed	North	5	0	4-8
	South	--	--	--

These data (except unsexed) are summarized in Figure VIII-87 by plots of mean lengths-at-age by sex and otolith area with estimated growth curves for each data group. Age-length keys for these data groupings are presented in Appendix I and growth parameters based on this information are given in Table VIII-51.

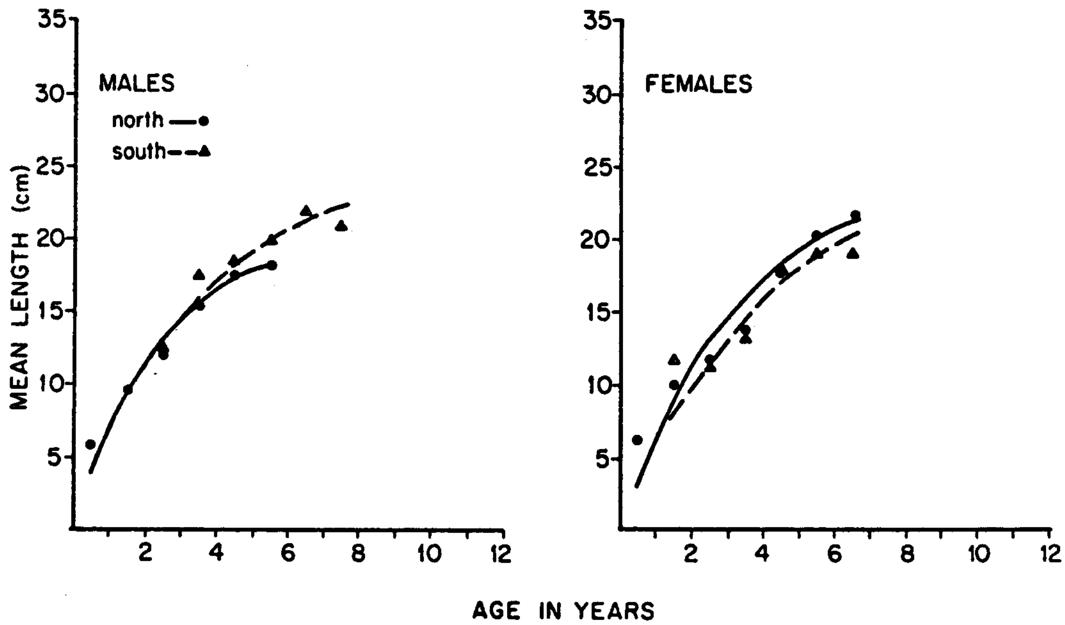


Figure VIII-87.--Mean lengths-at-age and growth curves fit to the origin for Arctic cod by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Table VIII-51.--Parameters for von Bertalanffy growth curves for Arctic cod in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (values in parentheses are ranges for selected ages and lengths) (BLM/OCS survey, 1976).

Otolith areas	Sex	Range in age and length of analyzed data: age (yr)	length (cm)	Original data set: δ	L_∞	K	t_0	Selected data: δ	L_∞	K	t_0	Selected data with origin: δ	L_∞	K	t_0
North	Males	0.5-5.5 (1.5-5.5)	(9-20)	0.45	25.97	-0.20	-0.78	0.66	23.08	-0.26	-0.54	0.64	20.40	-0.41	0.01
	Females	0.5-6.5 (1.5-6.5)	(10-25)	1.01	34.27	-0.13	-1.07	1.13	77.15	-0.04	-2.06	1.60	24.59	-0.31	0.08
South	Males	2.5-7.5 (2.5-5.5)	(10-20)	0.99	21.10	-0.83	1.44	0.86	19.80	-1.15	1.65	1.19	25.13	-0.29	-0.04
	Females	1.5-6.5 (2.5-5.5)	(10-23)	1.96	23.98	-0.19	-1.92	1.43	20.30	-0.48	0.84	1.23	25.58	-0.24	0.02

Since young of the year (age group 0) were present in nearly all sets of Arctic cod age data, adjustments to ages were necessary to provide reasonable growth curve fits for both the original data and for the selected sets, with values at the origin of the curve (age and length = 0). Age plus 0.5 years was used as the adjustment, since it is reasonable to assume that at least half of a year's growth had been completed by the September-October survey date.[1/]

Selection of data to eliminate age groups not fully recruited to the gear or with few (<5) observations and fitting the curve to the origin resulted in slight increases in the root mean square deviations (δ). The selected data fitted to the origin, however, did improve estimates of $\underline{K}$ and provided more realistic values for $\underline{t}_o$.

Sex and area effects were observed for the parameters $\underline{L}_\infty$ and $\underline{K}$ within the selected Arctic cod data. Females appeared to have slightly greater $\underline{L}_\infty$ values than males and estimates of this parameter by sex were larger in the south otolith area than in the north. Values of the growth completion rate ($\underline{K}$) substantially differed by sex and otolith areas. Male groups had higher $\underline{K}$ values than females, and, by area, estimates of this parameter were higher in the north otolith area than for south area groups. This information suggests that growth may differ by sex and that the rate of growth completion for both sexes of Arctic cod in that part of the survey region south of Bering Strait is slightly slower than to the north. Greatest maximum size within the survey region, however, is achieved by fish occurring south of Bering Strait.

Length-weight relationship--Table VIII-52 summarizes length-weight observations taken for Arctic cod by sex and otolith area and gives coefficients of the regression lines fit to these data. Data points representing all length-weight observations collected for this species from the survey are shown graphically in Figure VIII-88.

Analysis of covariance for between-area and between-sex differences indicated significant differences for most treatments of the data. Interesting trends resulted from consideration of weights predicted by the regression coefficients. Overall, males weighed more at-length than females, and these differences in weight-at-length increased with size. Additionally, males from the north otolith area were heavier at-length than fish of corresponding sex and size in the south, but only up to a length of about 18 cm. Above that size, south area males were heavier. A similar situation was observed for females, although the change to south area females weighing more than north fish did not occur until a length of 33 cm was attained. This is considerably larger than the size of Arctic cod encountered during the survey. The between-area differences suggest that Arctic cod stocks north and south of Bering Strait grow at differing rates

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1/ Rass (1968) indicated that Arctic cod spawn during January-February and transition from the larval to juvenile form occurs in August at a size of 3-5 cm.

and more than one localized population may occur in the survey region. Absolute differences in the length-weight relationships for both areas and both sexes, however, were on an order of 3-7% and an overall length-weight relationship could be used to describe the entire population in the survey region. This overall relationship was described by the equation:

$$\hat{w} = 0.0057\ell^{3.0645}$$

where $\hat{w}$ equals the predicted weight in grams of a fish ℓ cm in length. The relationship described by this equation is shown as a solid line in Figure VIII-88.

Table VIII-52.--Parameters for the length-weight relationship (weight (g) = a · length^{b}) for Arctic cod and results from the analysis of covariance for between-area and between-sex differences in this relationship (BLM/OCS survey, 1976).

Sex	Otolith Area	Number of Fish Measured	Range in Length (cm)	Parameters a	Parameters b
Males	North	70	9-21	.0081	2.9509
	South	66	9-23	.0029	3.2991
Females	North	70	6-25	.0067	3.0084
	South	70	10-25	.0051	3.0876

Differences between-	F slope df	F slope F	F intercept df	F intercept F	H_b 1/	H_a 1/	Pooled regression a	Pooled regression b
Areas for males	1;131	12.00**	1;132	10.60**	+	+	.0050	3.1200
Areas for females	1;136	.98	1;137	8.57**	-	+	.0061	3.0317
Areas for sexes combined	1;271	9.09**	1;272	19.50**	+	+	.0057	3.0645
Sexes for south area	1;131	4.34*	1;132	1.55	+	-	.0040	3.1766
Sexes for north area	1;136	.53	1;137	3.96**	-	+	.0072	2.9850
Sexes for areas combined	1;271	1.74	1;272	4.34**	-	+	.0057	3.0645

* Significant at the .05 level.

** Significant at the .01 level.

1/ Plus (+) indicates that the common slope (H_b) hypothesis or common intercept (H_a) hypothesis cannot be rejected on the basis of the values of F obtained.

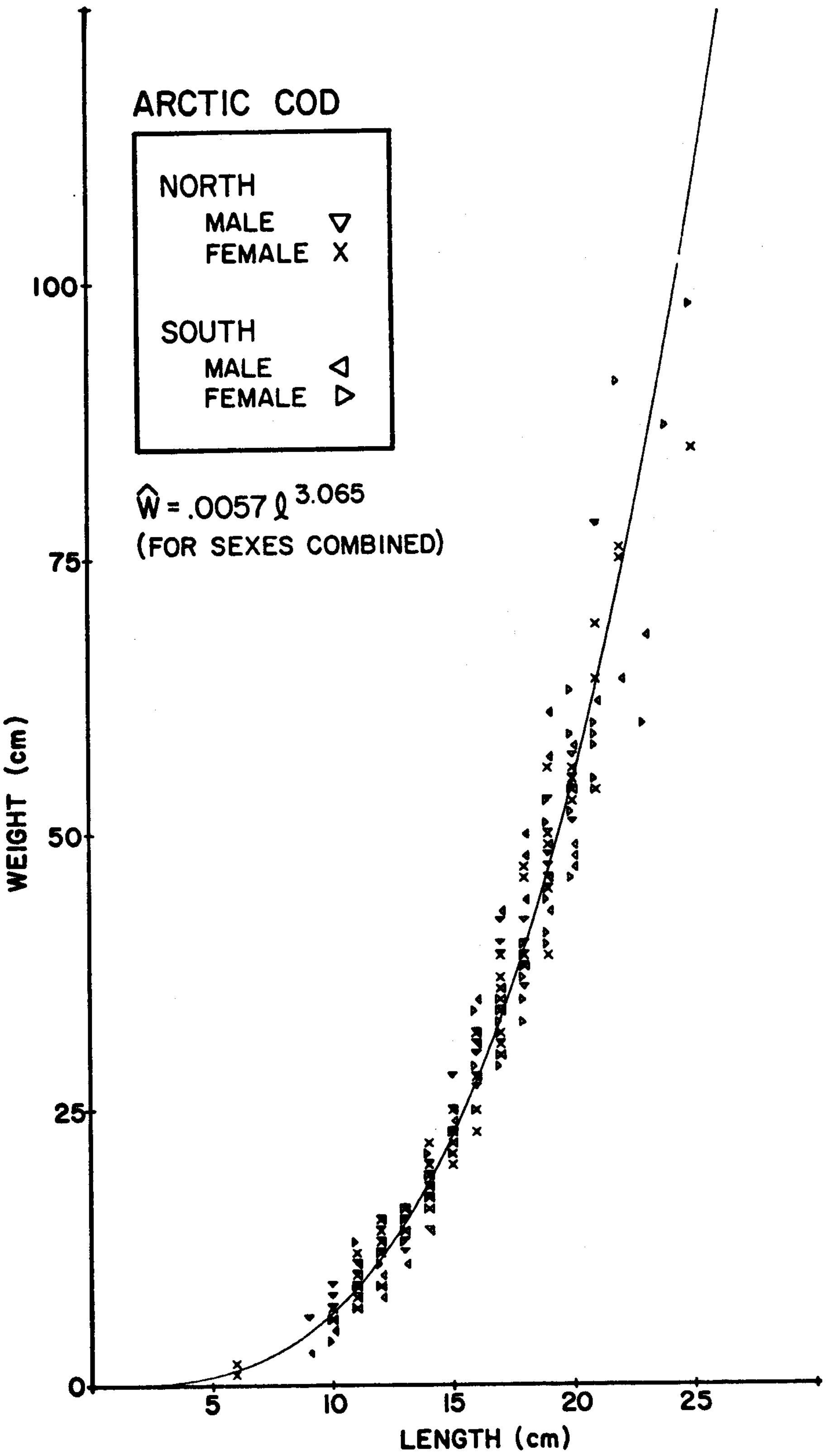


Figure VIII-88.--Weight-at-length observations for Arctic cod by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Other fish species

During the demersal survey, several other fish species were encountered, but limited biological information was obtained for them. The following are brief descriptions of the distributions and abundances for these other species with a presentation of biological information when available.

Walleye pollock was the other member of family Gadidae which occurred in the survey region. 1/ Their distribution (Figure VIII-89) was primarily limited to offshore waters in the northern Bering Sea and southeastern Chukchi Sea (strata 3W, 3E, and 1S), where only trace amounts were encountered. The apparent total biomass of this species in the survey region was about 267 mt (95% confidence interval 0-579 mt) (Table VIII-53). All pollock encountered were small (< 20 cm), age 1 juveniles (Figure VIII-90). Catches in the southeastern Chukchi Sea during our survey appear to be the first record of pollock occurring north of Bering Strait.

Table VIII-53.--Estimated biomass and population size of walleye pollock in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	6.9	0.003	5	.021	279	.017	—	12.48
1S	40.0	0.227	172	.643	804	.649	.016	14.32
2Ø	15.8	0.002	1	.003	25	.001	—	—
2I	12.5	0.005	2	.006	36	.002	—	—
Norton Sound and northern Bering Sea								
3W	50.0	0.015	34	.128	2,110	.127	.016	10.82
3E	57.1	0.066	40	.151	2,548	.153	.016	12.90
4Ø	29.3	0.009	13	.047	845	.051	.015	12.17
All strata combined:	27.6 2/	0.032	267 3/		16,646		.016	13.44

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 0-579 mt.

1/ One specimen of Pacific cod (Gadus morhua macrocephalus) was captured in the southernmost trawl haul of the survey, southeast of St. Lawrence Island.

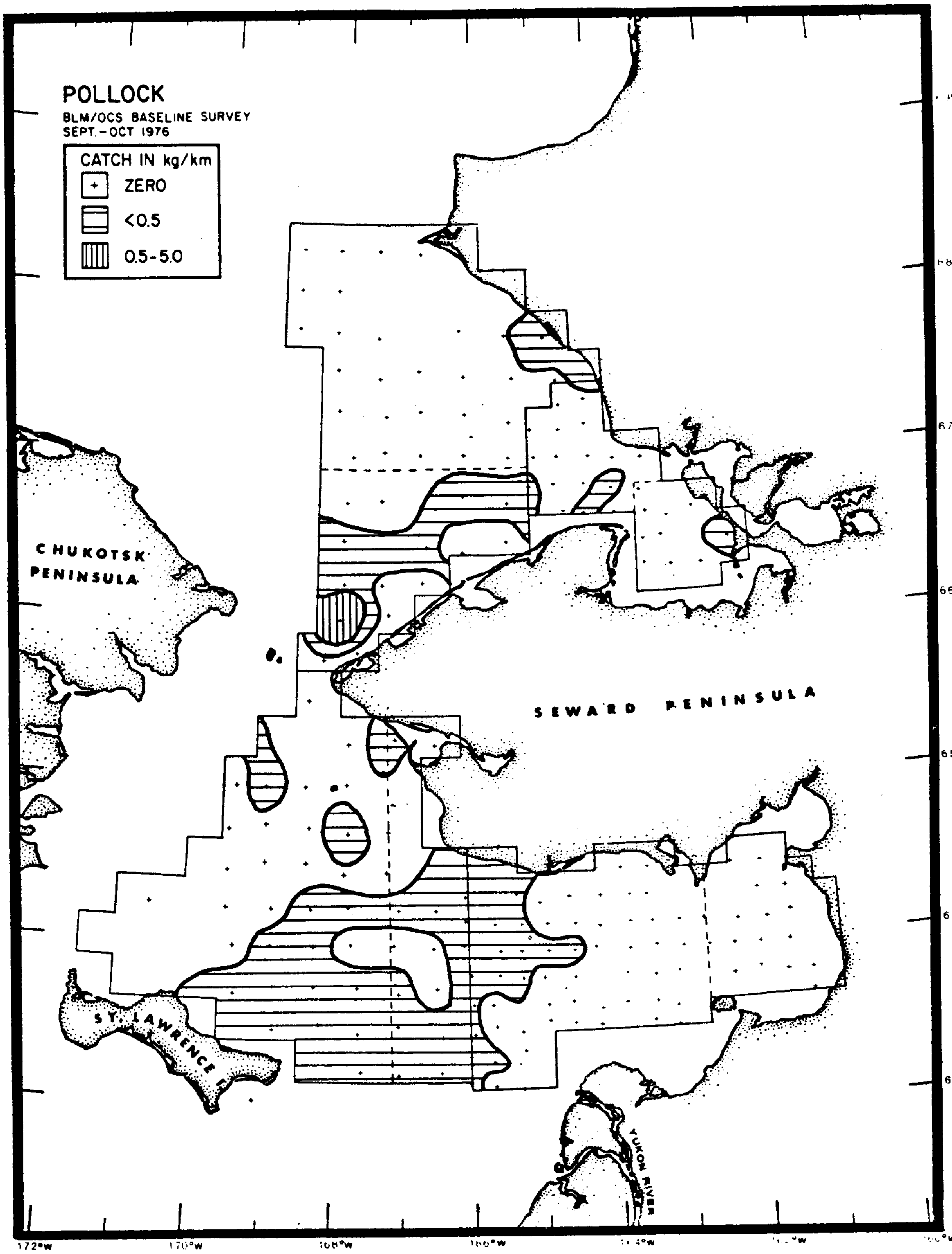


Figure VIII-89.--Distribution and relative abundance by weight of walleye pollock in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

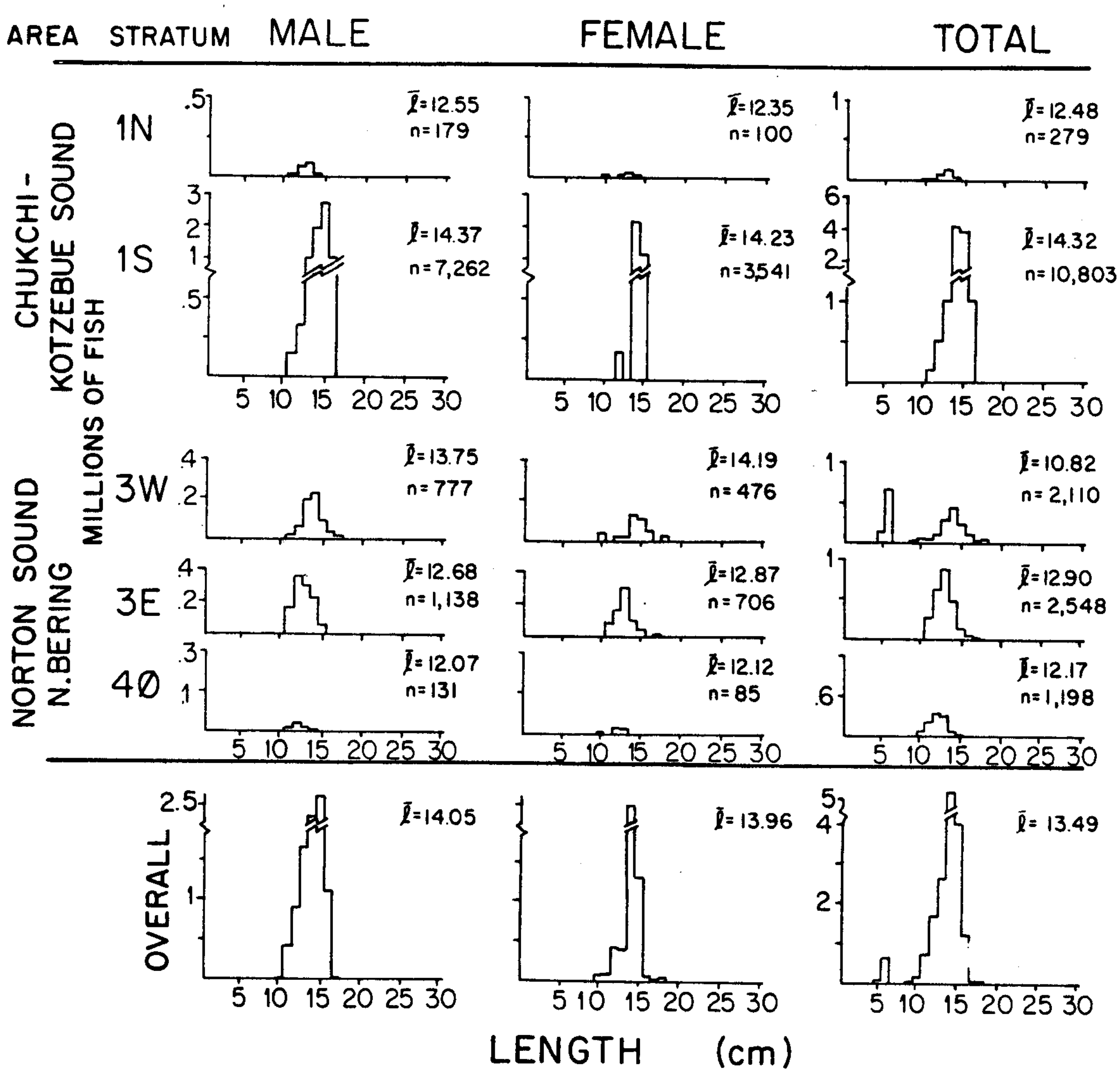


Figure VIII-90.--Size composition of walleye pollock by sex and stratum in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Bering flounder, longhead dab, Arctic flounder, and Pacific halibut were the other members of family Pleuronectidae encountered during the 1976 baseline survey. Bering flounder were found in trace amounts throughout much of the survey region (Figure VIII-91) but were absent from Norton Sound (strata 4Ø and 4I) and inner Kotzebue Sound (stratum 2I). Total apparent biomass for this flatfish species was 232 mt (95% confidence interval 150-315 mt) for the entire survey region (Table VIII-54) and nearly 75% of this amount was found in stratum 1N in the southeastern Chukchi Sea. For the limited samples obtained, size distribution ranged from 8 to 25 cm (Figure VIII-92) and predominant ages were 5 year olds for males and 5 and 9 year olds for females (Figure VIII-93).

Table VIII-54.--Estimated biomass and population size of Bering flounder in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	79.3	0.102	173	.744	2,077	.741	.083	17.23
1S	46.7	0.014	11	.048	193	.069	—	19.97
2Ø	57.9	0.058	25	.108	307	.109	.082	17.85
2I	—	—	—	—	—	—	—	—
Norton Sound and northern Bering Sea								
3W	25.0	0.010	22	.094	198	.071	.110	—
3E	14.3	0.002	1	.006	29	.010	—	—
4Ø	—	—	—	—	—	—	—	—
4I	—	—	—	—	—	—	—	—
All strata combined:	26.6 2/	0.028	232 3/		2,803		.083	17.51

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 150-315 mt.

Longhead dab was found in most shallow water areas of the survey region with slightly higher concentrations occurring in outer Norton Sound (Figure VIII-94). Estimated biomass of longhead dab in the survey region was 172 mt (95% confidence interval 63-282 mt) with 60% of this amount occurring in stratum 4Ø (Table VIII-55).

Arctic flounder had a very limited distribution, occurring in very shallow waters of the survey region off the Yukon River, in Norton Bay, Port Clarence, and in Kotzebue Sound (Figure VIII-95). The total apparent biomass for this species was only 69 mt (95% confidence interval 21-118 mt) with nearly 83% of this amount found in stratum 4Ø (Table VIII-56).

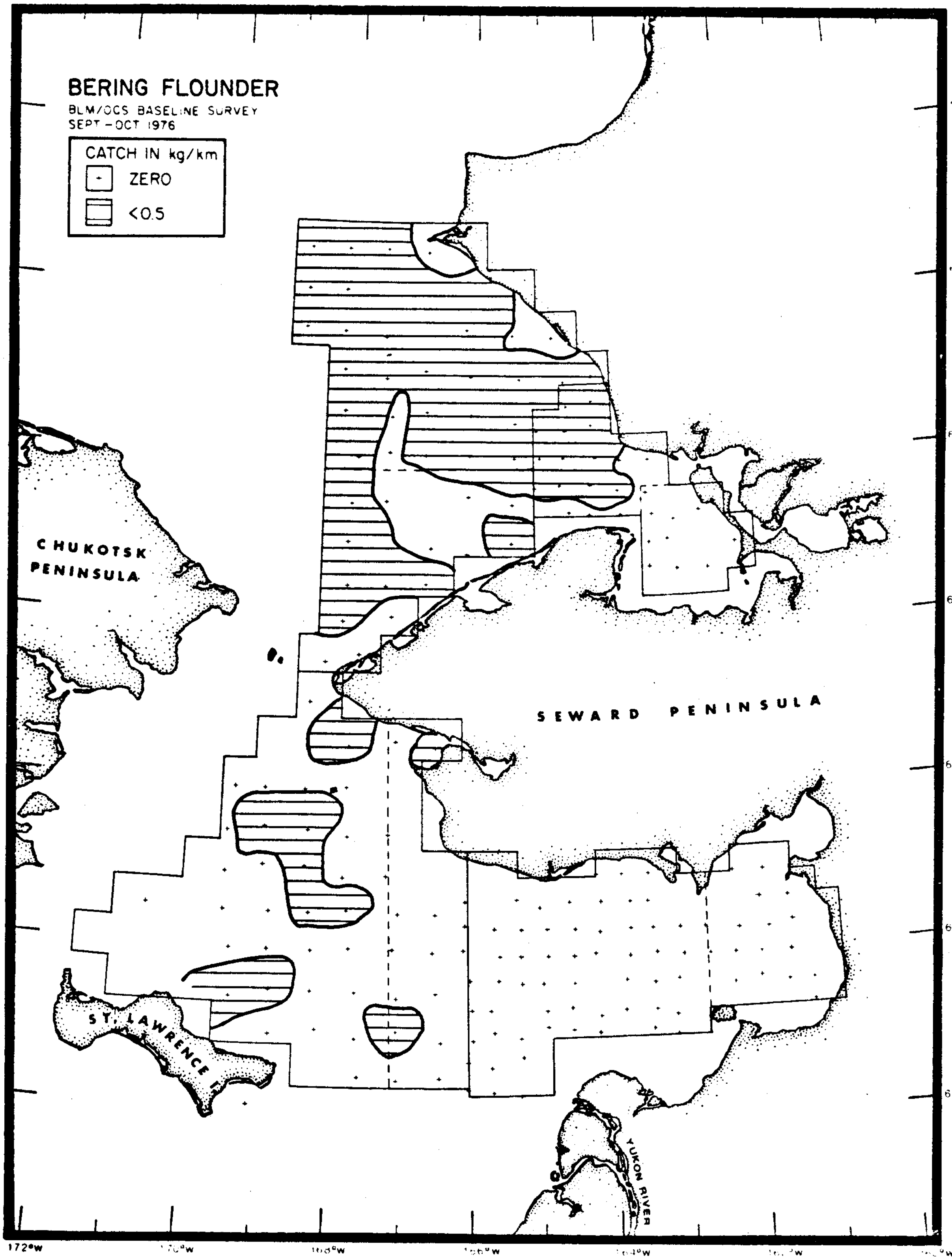


Figure VIII-91.--Distribution and relative abundance by weight of Bering flounder in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

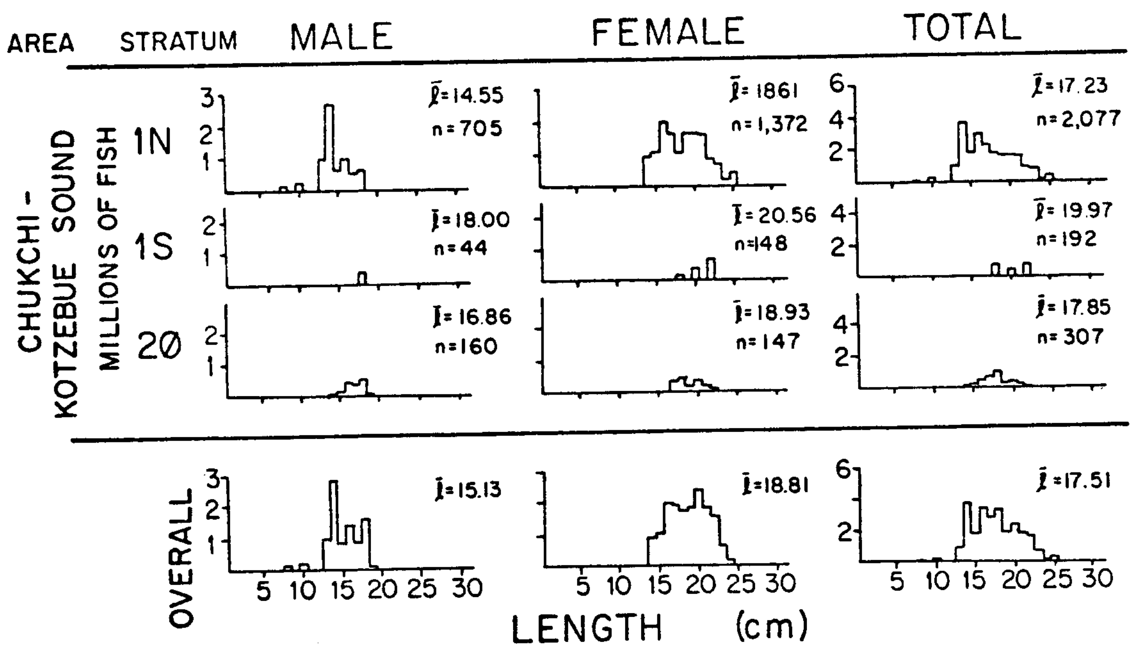


Figure VIII-92.--Size composition of Bering flounder by sex and stratum in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

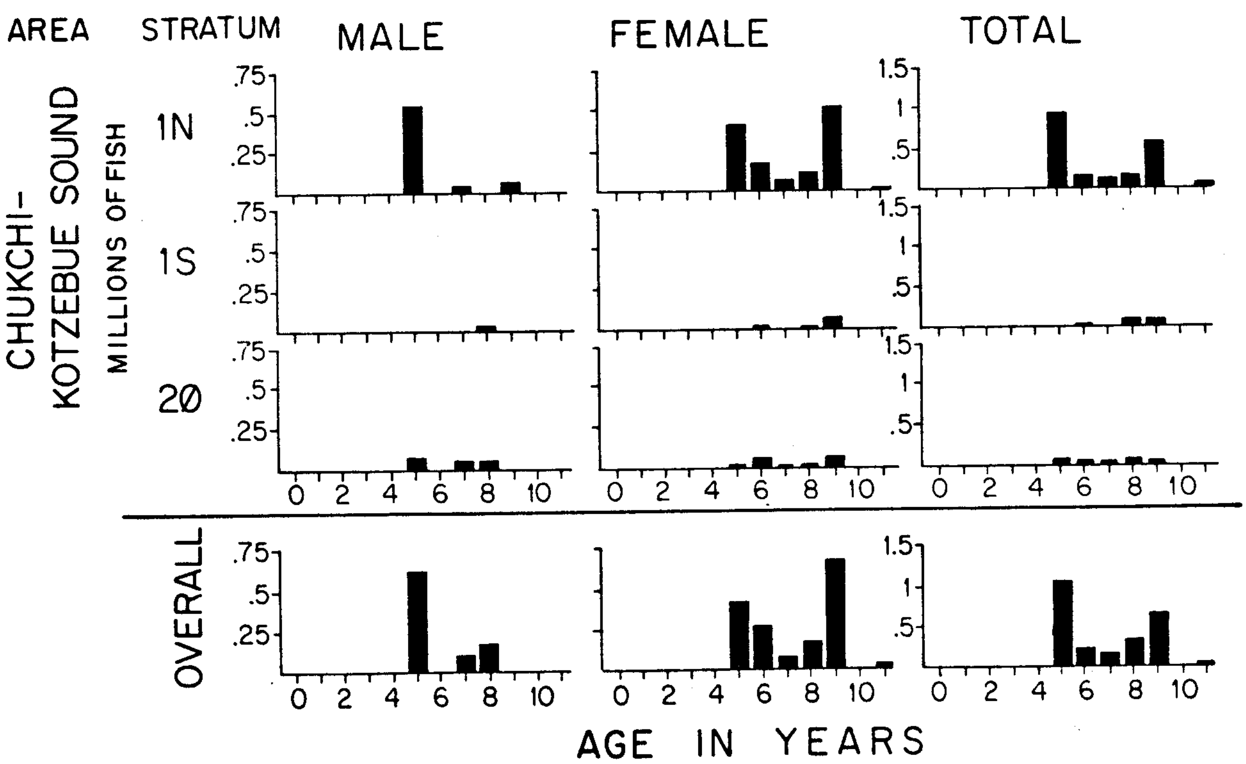


Figure VIII-93.--Age composition of Bering flounder by sex and stratum in Norton Sound, the southeastern chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

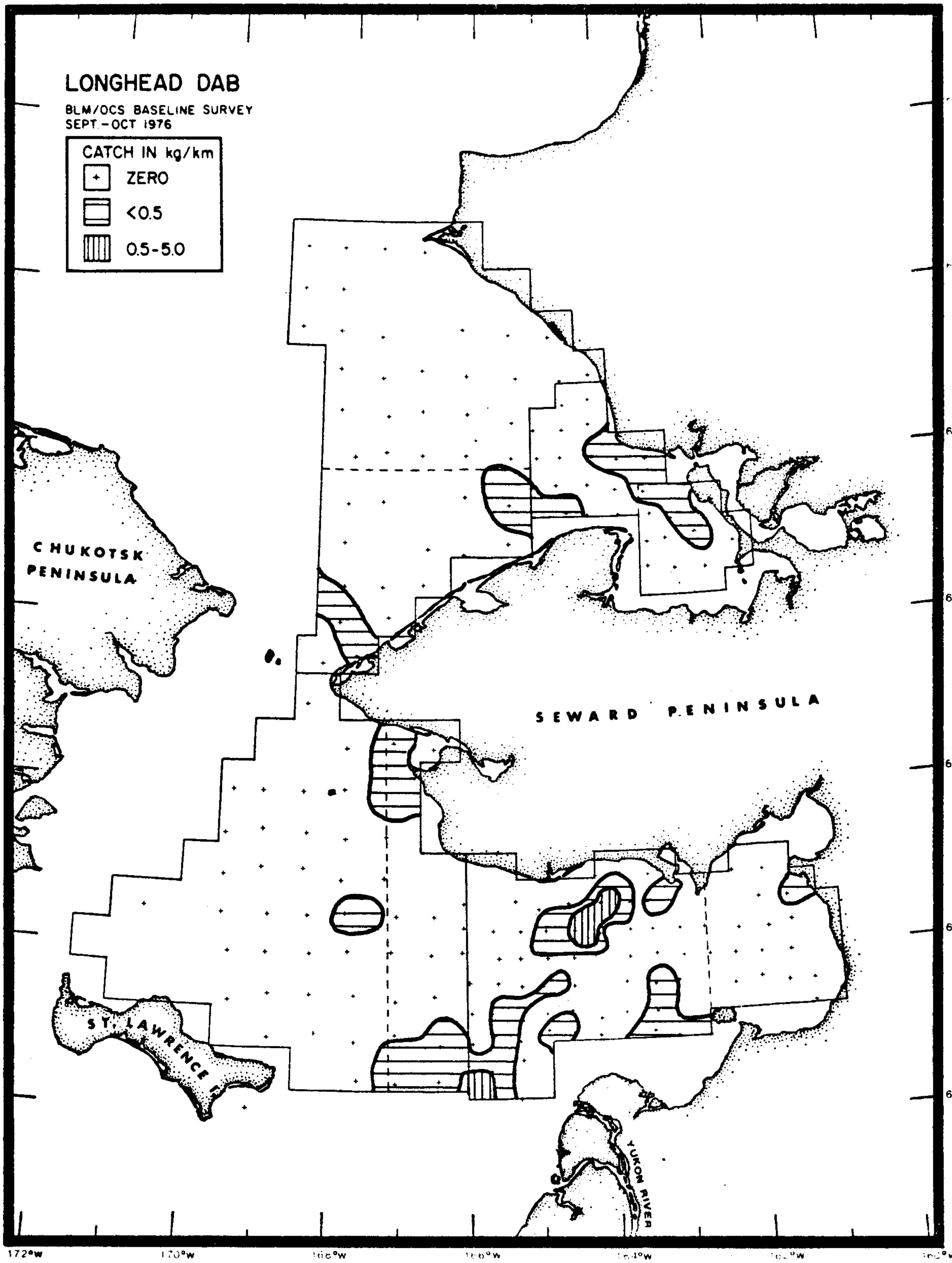


Figure VIII-94.--Distribution and relative abundance by weight of longhead dab in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Table VIII-55.--Estimated biomass and population size of longhead dab in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	—	—	—	—	—	—	—	—
1S	20.0	.011	8	.049	220	.065	.039	—
2Ø	26.3	.024	10	.061	176	.052	.060	—
2I	12.5	.013	4	.023	29	.009	.136	—
Norton Sound and northern Bering Sea								
3W	3.1	t	2	.010	19	.006	.091	—
3E	28.6	.072	44	.257	900	.267	.049	16.49
4Ø	27.6	.077	103	.598	2,012	.598	.051	16.30
4I	5.9	t	t	.002	8	.003	.045	—
All strata combined:	16.1 2/	.021	172 3/		3,364		.051	16.21

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 63-282 mt.

Table VIII-56.--Estimated biomass and population size of Arctic flounder in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	3.4	t	1	.012	19	.022	—	—
1S	13.3	.001	1	.017	27	.032	—	—
2Ø	5.3	.002	1	.017	39	.047	.030	13.17
2I	25.0	.011	4	.052	325	.394	.011	10.30
Norton Sound and northern Bering Sea								
3W	—	—	—	—	—	—	—	—
3E	7.1	t	1	.009	13	.016	—	—
4Ø	19.0	.043	57	.827	370	.448	.155	20.83
4I	11.8	.001	5	.066	34	.041	—	—
All strata combined:	10.4 2/	.008	69 3/		826		.095	16.78

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 21-118 mt.

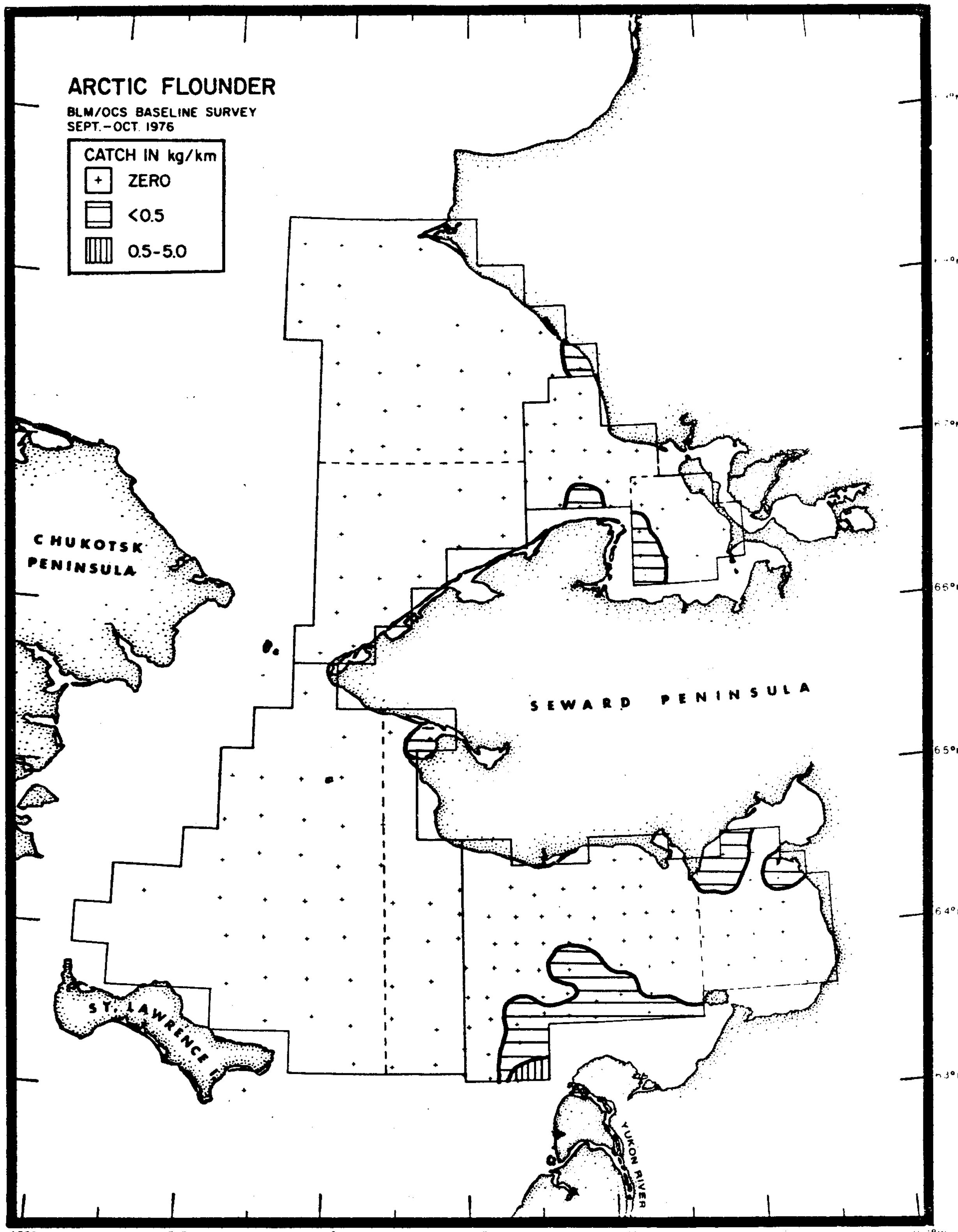


Figure VIII-95.--Distribution and relative abundance by weight of Arctic flounder in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Two Pacific halibut were captured during the survey, one in Norton Sound and the other at the northern end of Bering Strait. The specimen caught in Bering Strait was a 150 cm female and is the northernmost record for distribution of this species.

Capelin was thought to be very abundant in our survey region, but only trace amounts were encountered, mostly in offshore and deeper waters (Figure VIII-96). Total estimated biomass for this species was 190 mt (95% confidence interval 99-281 mt) with over 52% of this amount occurring in offshore stratum 3W and an additional 34% in stratum 1N in the southeastern Chukchi Sea (Table VIII-57). Sizes encountered ranged from 6 to 21 cm (Figure VIII-97). Capelin larger than 17 cm occurred only in stratum 3W.

Table VIII-57.--Estimated biomass and population size of capelin in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	34.5	0.037	64	.337	3,206	.189	.020	13.78
1S	46.7	0.017	13	.071	706	.042	.019	17.96
2Ø	15.8	0.008	4	.020	344	.020	.011	10.89
2I	—	—	—	—	—	—	—	—
Norton Sound and northern Bering Sea								
3W	56.3	0.045	99	.521	11,168	.659	.009	11.36
3E	28.6	0.011	7	.039	1,490	.088	.005	9.03
4Ø	8.6	0.001	2	.013	41	.002	—	—
4I	—	—	—	—	—	—	—	—
All strata combined:	24.5 2/	0.023	190 3/		16,955		.011	11.88

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 99-281 mt.

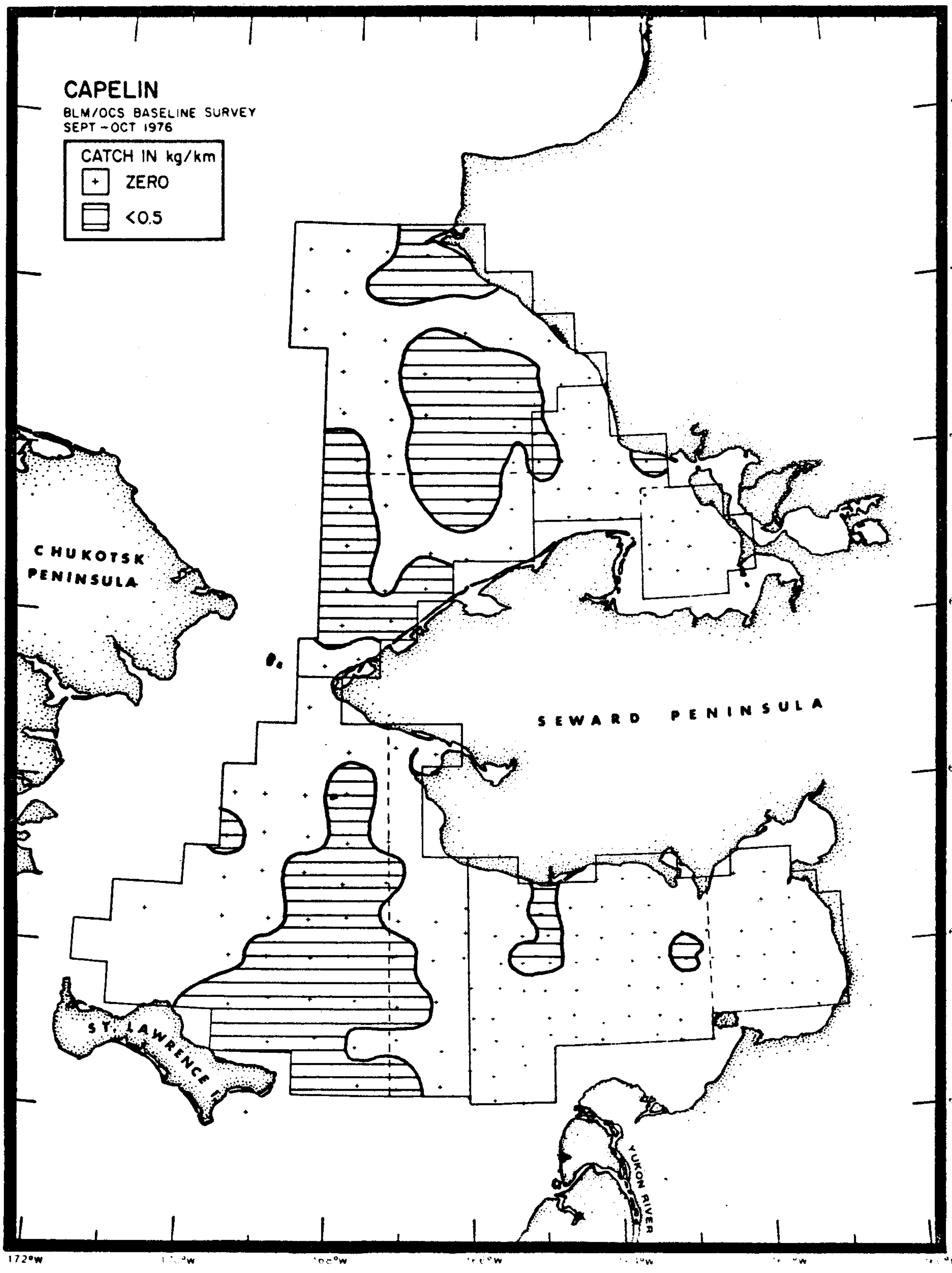


Figure VIII-96.--Distribution and relative abundance by weight of capelin in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

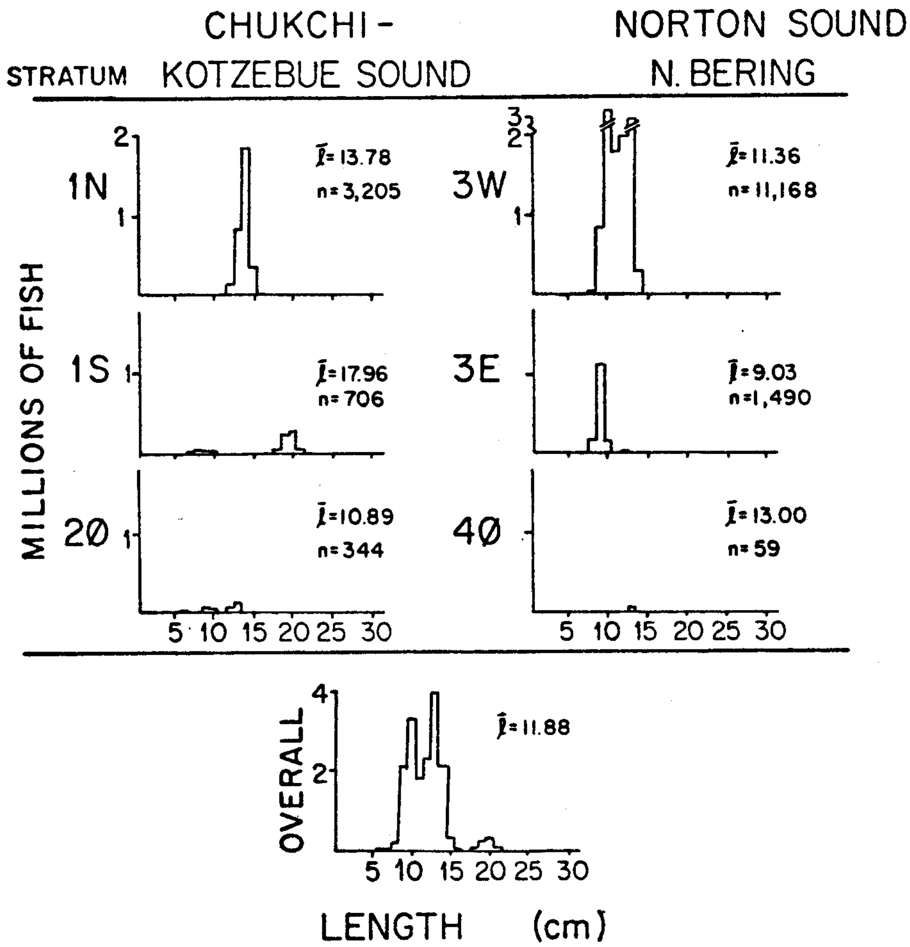


Figure VIII-97.--Size composition of capelin by sex and stratum in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Distribution, Abundance, and Biological Features of Principal Species of Crabs

In this section the distribution, abundance, and size composition of king crab and Tanner crab are presented from results of the 1976 baseline survey. In addition, shell age composition and egg clutch size are examined to provide some baseline information on crab growth and to identify the relative size of mature or maturing females.

Shell age is an important index of crab growth since it reflects the frequency of molting which, taken with the increase in size per molt, determines the absolute rate of growth for individual crabs. An examination of a time series of data on shell age composition is necessary to establish any trends in growth of crabs. The baseline survey data provide only one interval in a time series and thus cannot describe crab growth by itself. The baseline data, however, do provide a set of information to which future data may be compared.

Red king crab

Distribution and abundance--Red king crab were found at only 34% of the trawl stations sampled, but were concentrated in Norton Sound (Figures VIII-98 and 99) where their frequency of occurrence exceeded 76% (Table VIII-58). Outer Norton Sound (stratum 4Ø) had the highest average catch rate of all strata, averaging 2.3 kg/km. Mean catch rate decreased to 0.6 kg/km in inner Norton Sound (stratum 4I) and further dropped to only trace levels in the eastern part of the northern Bering Sea (stratum 3E) and in the vicinity of outer Kotzebue Sound (strata 1S and 2Ø). Red king crab were not found at any of the stations in the western portion of the northern Bering Sea (stratum 3W) or in the southeastern Chukchi Sea (stratum 1N) where deeper and colder waters occurred.

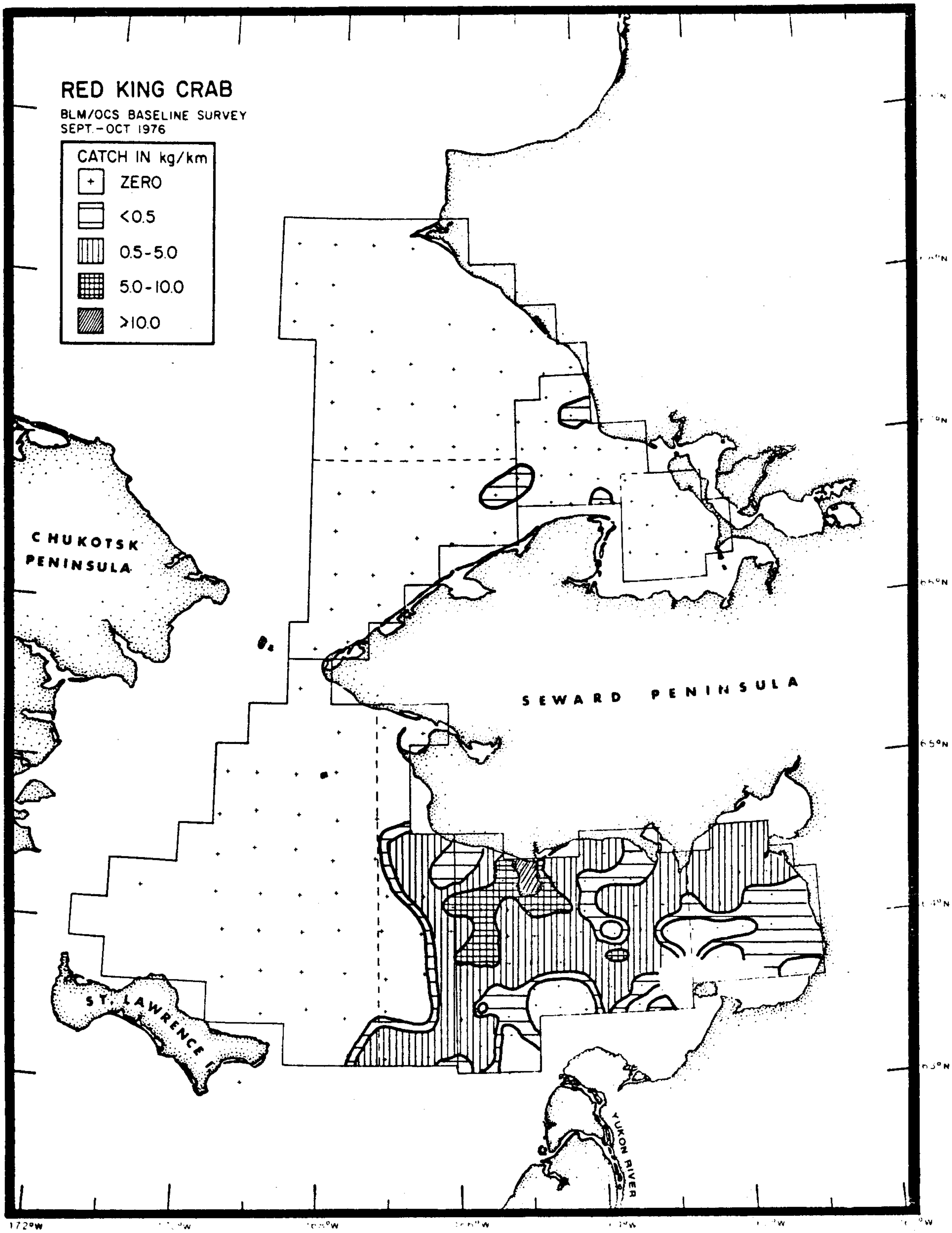


Figure VIII-98.--Distribution and relative abundance by weight of red king crab in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

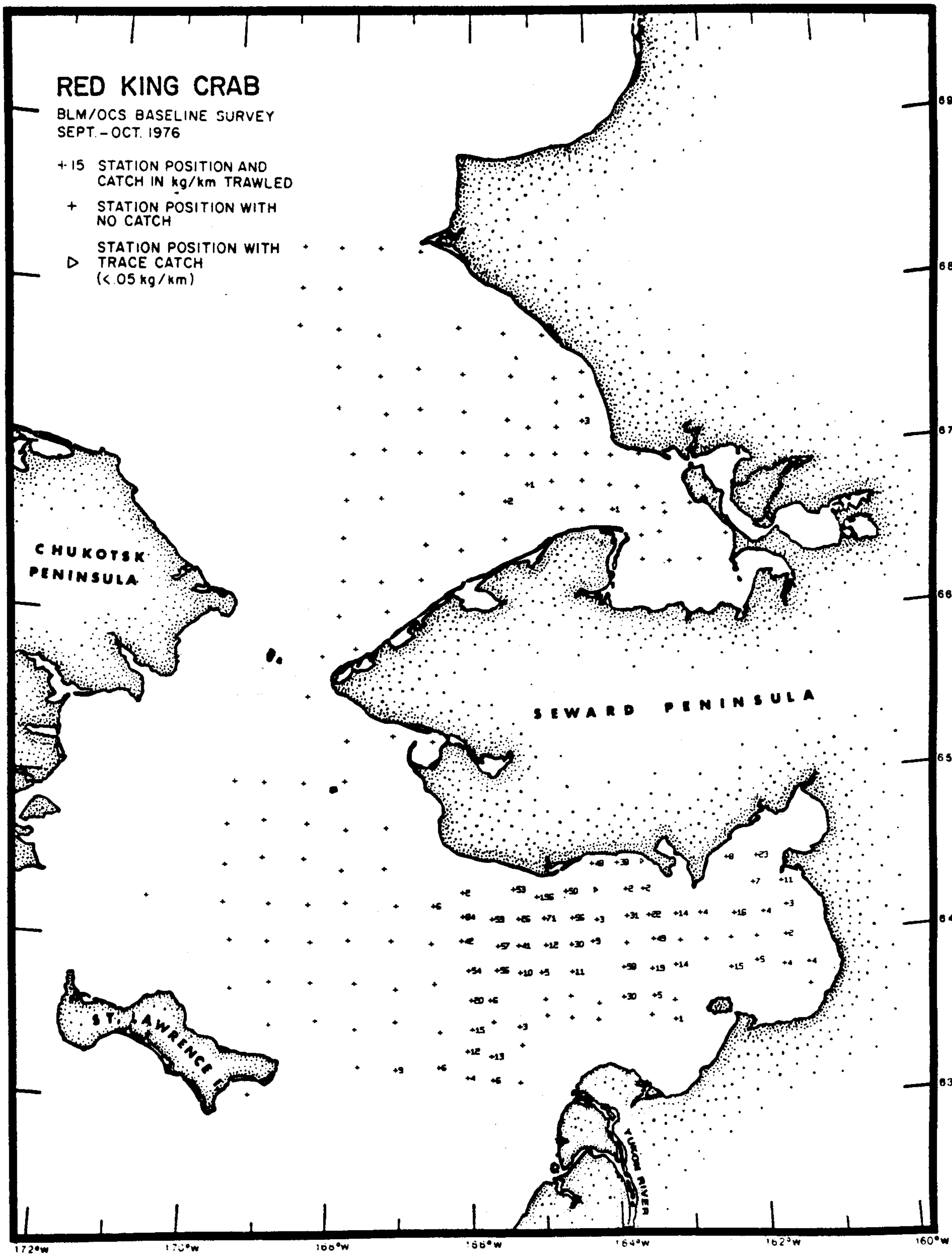


Figure VIII-99.--Distribution of catch rates by weight of red king crab in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Table VIII-58.--Estimated biomass and population size of red king crab in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Strata	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (X10^3)	Proportion of total estimated population	Mean weight per individual (kg)
Southeastern Chukchi Sea and Kotzebue Sound							
1N	-	-	-	-	-	-	-
1S	6.7	0.011	9	.003	19	.004	.454
2Ø	15.8	0.025	11	.003	21	.004	.506
2I	-	-	-	-	-	-	-
Norton Sound and Northern Bering Sea							
3W	-	-	-	-	-	-	-
3E	21.4	0.152	93	.027	112	.022	.836
4Ø	77.6	2.311	3,077	.874	4,291	.858	.718
4I	76.5	0.619	329	.094	557	.111	.591
All strata combined:	33.92/	0.420	3,5193/		5,0003/		.707

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: biomass--2,369 - 4,670 mt; population--3,245,000 - 6,756,000.

The apparent red king crab biomass for the entire survey area was estimated at over 3,500 mt (95% confidence interval 2,369-4,670 mt). Several catches of this species occurred at stations along the southern border of the survey area indicating a likely presence of red king crab south of the survey region. It is unknown to what degree crab south of the survey limit might interact with stocks within the survey region. The highest concentrations of red king crab encountered, however, were well within the survey boundaries and our estimate should be quite good for the survey region. For the population sampled, the major portion of the biomass (approximately 87%) was located in outer Norton Sound in stratum 4Ø, and much of this amount was found near the community of Nome. Of the remaining biomass, nearly 10% of the total was located in stratum 4I and 3% in stratum 3E.

The relative distribution of the estimated number of red king crab was very similar to apparent biomass. Strata 4Ø and 4I accounted for nearly

97% of the total population estimate of 5 million crabs (95% confidence interval 3.2-6.8 million crabs).[1/]

Size composition--Size composition data for red king crab by sex and stratum are presented in Figure VIII-100. Sizes ranged from 15 to 165 mm carapace length and females exhibited a smaller size range (15-100 mm) than males (15-165 mm). Only one mode in size composition was observed per sex at about 105-110 mm for males and 75-80 mm for females.

Population estimates by size groups, strata, and sexes are presented in Table VIII-59. Intermediate sized males (100-125 mm) were the most abundant group in most regions where red king crabs were found. They represented over 69% of the estimated male population and 60% of the overall apparent population. Large females (> 70 mm) comprised 85% of the estimated female population (11% of total numbers estimated). No females were observed north of Bering Strait, and for males present in this region, no large crabs (> 125mm) were encountered. Overall, males comprised the vast majority of the estimated population, outnumbering females by a factor of nearly 7.5 to 1.

Mean size for male red king crab was larger than for females in all strata (Figure VIII-100). Average size of males varied only slightly by stratum with males in stratum 4I having the smallest mean size. Differences in female mean size by stratum were slightly greater with smallest average size occurring in stratum 3E, increasing in stratum 4Ø, and largest in stratum 4I.

1/ Another population estimate for red king crab was determined by the computer program SIZEPOP to obtain population estimates by size and sex for size composition analysis. Program SIZEPOP utilized the 192 standard survey trawl hauls as well as the 44 trawl hauls performed during the day-night catch comparisons. For this population estimate, an estimated station population was obtained by analyzing catch rates for all trawl hauls at a station. This means that at five stations both a standard survey tow and several other trawl hauls were examined. The total red king crab population estimate obtained through this procedure was about 9.8 million crabs (95% confidence interval 4.8-14.8 million crabs), substantially higher than the estimate determined solely from the standard survey tows. The marked difference between the two population estimates was the result of catches at one station in stratum 4Ø. At this station, the standard survey tow produced a catch rate (in numbers) of 6.7 crabs/km. Catch rates for the eight day-night comparative tows at this station (fished about 1 month after the standard survey tow) ranged from 10.2 to 86.4 crabs/km. When both the standard tow and comparative tows were combined, the overall station catch rate had jumped to 30.5 crabs/km or 4.5 times that obtained solely from the standard tow. Since these catches were the largest encountered during the entire survey and because nearly all of the survey's red king crab population occurred in stratum 4Ø, the catch rate for this one station had a dramatic effect on the total population estimate. Differences between standard and comparative tow catch rates were substantially less for all other stations where both types of trawl hauls occurred. Additionally, major differences between standard survey/comparative tow catch rates did not occur for other fish and crab species examined.

Table VIII-59.--Estimated population ($x10^3$) of red king crab by stratum, sex and size groups[1/] in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

	MALES				FEMALES			
Stratum	<100mm	100-125mm	>125mm	All sizes	<70mm	≥70mm	All sizes	Sexes combined
Southeastern Chukchi Sea and Kotzebue Sound								
1N	--	--	--	--	--	--	--	--
1S	4.4	15.0	--	19.4	--	--	--	19.4
2Ø	4.7	16.4	--	21.1	--	--	--	21.1
2I	--	--	--	--	--	--	--	--
Norton Sound and northern Bering Sea								
3W	--	--	--	--	--	--	--	--
3E	28.1	62.5	7.4	98.0	7.0	7.0	14.0	112.0
4Ø	1,035.8	2,715.4	127.7	3878.9	79.2	333.0	412.2	4,291.1
4I	107.3	198.3	8.5	314.1	8.5	234.7	243.2	557.3

1/ Carapace length (mm).

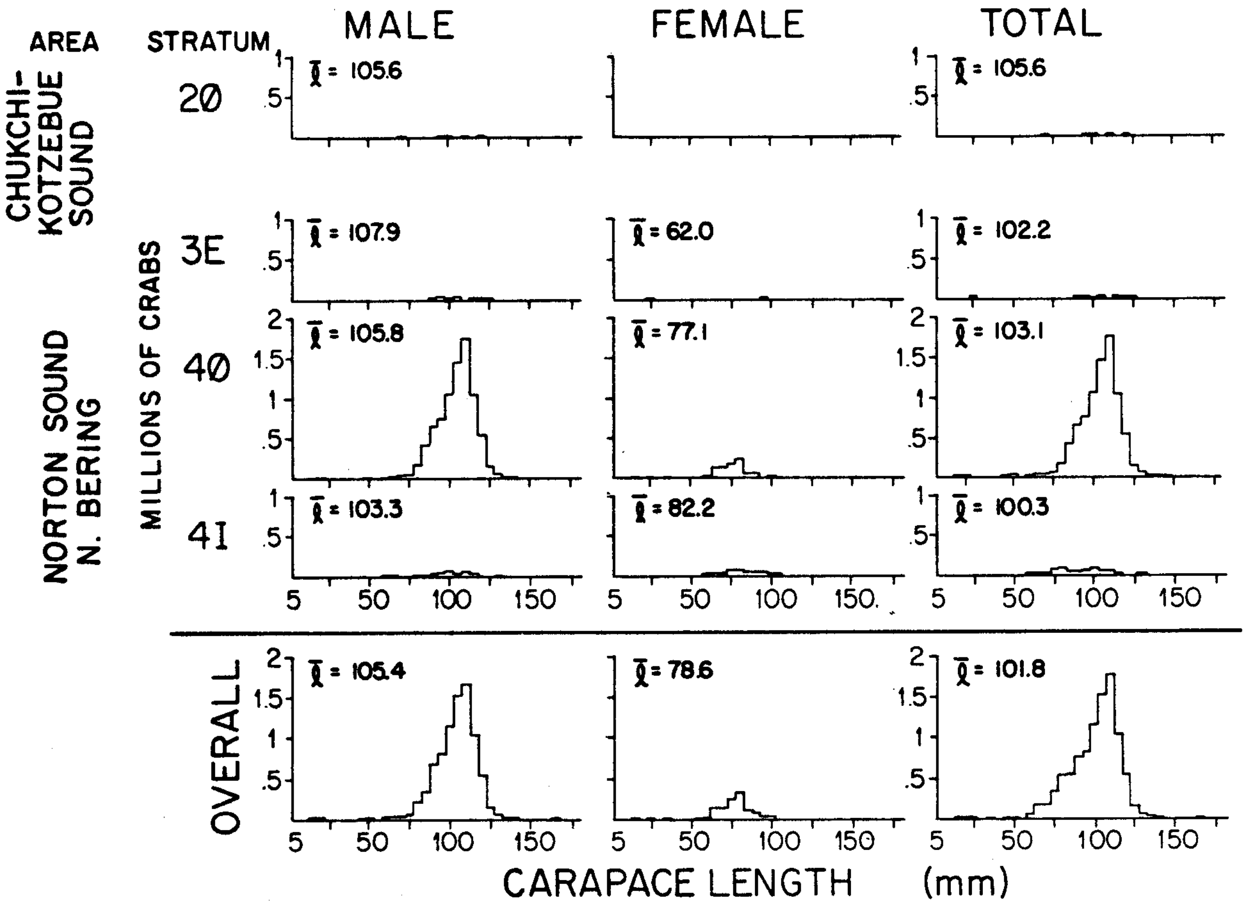


Figure VIII-100.--Size composition of red king crab by sex and stratum in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Shell condition—Shell age composition by region and sex for red king crab and other crab species is presented in Table VIII-60. In the southeastern Chukchi Sea and Kotzebue Sound, all red king crab encountered were new-shell crabs. In the northern Bering Sea and Norton Sound, new-shell crabs still were predominant but relatively large proportions of both sexes were old-shell crabs, indicating one or more skip molts. Overall, new-shell crabs accounted for 67% of the total estimated male population and over 75% of the female red king crabs while old-shell crab comprised 26% and 15% of the population of males and females, respectively.

Egg clutch size--Size of egg clutch and the proportion of females with eggs by length groups is shown in Table VIII-61. The smallest carapace length with egg clutches present were 60-64 mm. Several barren females (no egg clutch) were present in the sample at sizes up to 70-74 mm; however, from these limited data, in general it appeared that 70 mm was the approximate minimum size at which over half the female red king crab of the survey area were gravid.

Table VIII-60.--Shell age composition for king and Tanner crab (percent by sex) by subareas and total survey area for Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

	Southeastern Chukchi Sea (strata 1N and 1S)	Kotzebue Sound (strata 2Ø and 2I)	Northern Bering Sea (strata 3W and 3E)	Norton Sound (strata 4Ø and 4I)	Percent overall
Red king crab					
Males					
Molting	--	--	--	0.2	0.1
Soft	--	--	25.0	6.5	6.5
New	100.0	100.0	75.0	65.8	66.8
Old	--	--	--	27.6	26.5
Females					
Molting	--	--	--	--	--
Soft		--	--	0.7	9.3
New	100	--	100.0	83.1	76.2
Old	--	--	--	16.2	14.6
Blue king crab					
Males					
Molting	--	--	--	--	--
Soft	--	--	7.0	--	7.0
New	--	--	86.0	--	86.0
Old	--	--	7.0	--	7.0
Females					
Molting	--	--	--	--	--
Soft	--	--	3.9	--	3.9
New	--	--	90.8	--	90.8
Old	--	--	5.3	--	5.3
Tanner crab (Opilio)					
Males					
Molting	--	--	--	--	--
Soft	--	--	1.0	--	0.1
New	99.7	99.9	97.3	100.0	99.5
Old	0.3	0.1	1.7	--	0.4
Females					
Molting	--	--	--	--	--
Soft	--	0.1	1.2	--	0.1
New	99.3	99.9	98.1	100.0	99.5
Old	0.7	--	0.7	--	0.4

Table VIII-61.--Numbers of female red king crab by size of egg clutch and carapace length and poportion of gravid females by size group (BLM/OCS survey, 1976).

Carapace length (mm)	No eggs	Trace-1/8 full	1/4 full	1/2 full	3/4 full	full	Proportion with eggs
15-54	2	--	--	--	--	--	--
55-59	1	--	--	--	--	--	--
60-64	2	--	--	--	1	1	0.50
65-69	6	--	--	4	1	3	0.57
70-74	4	--	--	4	3	2	0.69
75-79	1	--	--	9	8	13	0.97
80-84	1	--	4	7	8	14	0.97
85-89	2	1	--	3	4	4	0.86
90-94	--	--	--	2	5	7	1.00
95-99	--	--	--	--	--	1	1.00
100-104	--	--	--	--	1	1	1.00

Blue king crab

Distribution and abundance--Blue king crab occurred in only 12% of all stations sampled, having a highly localized distribution. They occurred in over 59% of the stations surveyed in northern Bering Sea waters in stratum 3W (Table VIII-62), where two concentrations occurred; one south of Bering Strait and the other southwest of Port Clarence (Figures VIII-101 and 102). Average catch rate for stratum 3W was by far the highest of all strata, averaging over 0.7 kg/km, while in the southeastern Chukchi Sea (strata 1N and 1S) and the eastern portion of the northern Bering Sea (stratum 3E), only trace amounts were encountered. Blue king crab were not found at any of the stations fished in Kotzebue Sound (strata 2Ø and 2I) and Norton Sound (strata 4Ø and 4I). The distribution of blue king crab appeared to be associated with areas where depths exceeded 25 m and bottom temperatures were less than 4°C.

Table VIII-62.--Estimated biomass and population size of blue king crab in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Strata	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population ($X10^3$)	Proportion of total estimated population	Mean weight per individual (kg)
Southeastern Chukchi Sea and Kotzebue Sound							
1N	3.4	0.011	19	.012	3	.009	.568
1S	6.7	0.057	43	.027	130	.036	.336
2Ø	--	--	--	--	--	--	--
2I	--	--	--	--	--	--	--
Norton Sound and Northern Bering Sea							
3W	59.4	0.702	1,529	.950	3,379	.943	.453
3E	14.3	0.028	18	.011	40	.011	.438
4Ø	--	--	--	--	--	--	--
4I	--	--	--	--	--	--	--
All strata combined:	12.0 2/	0.192	1,608 3/		3,582 3/		.449

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence intervals: biomass--125 - 3,092 mt; population--401,000 - 6,762,000.

The apparent blue king crab biomass for the entire survey region was estimated at over 1,600 mt (95% confidence interval 125-3,092 mt). Since catches occurred along the western boundary of the survey area, it seems likely that blue king crab stocks extended westward across the US-USSR convention line toward the Chukotsk Peninsula. The extent of this westward distribution is unknown, but since only relatively low catch rates occurred along most of the survey's western boundary, our biomass estimate

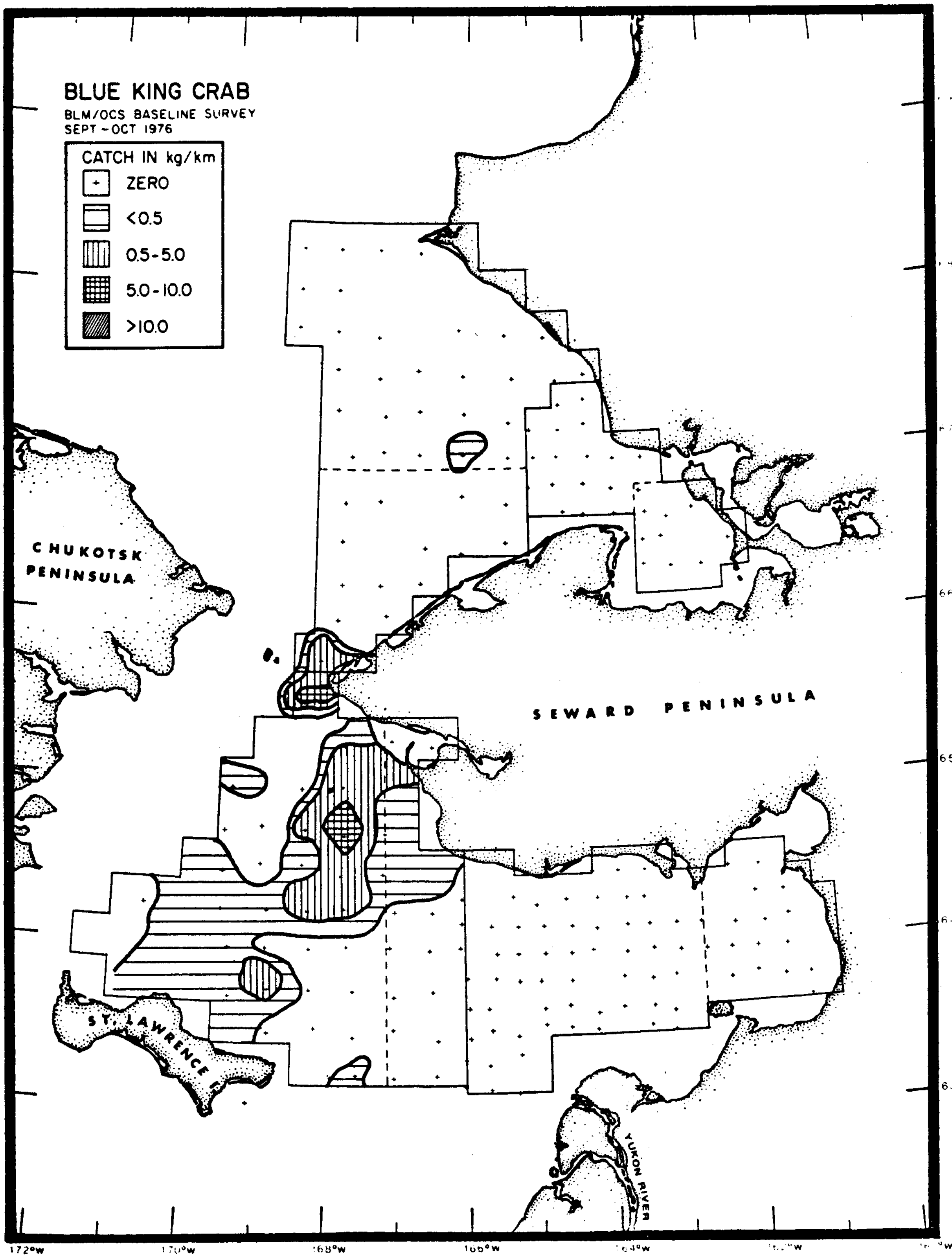


Figure VIII-101.--Distribution and relative abundance by weight of blue king crab in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

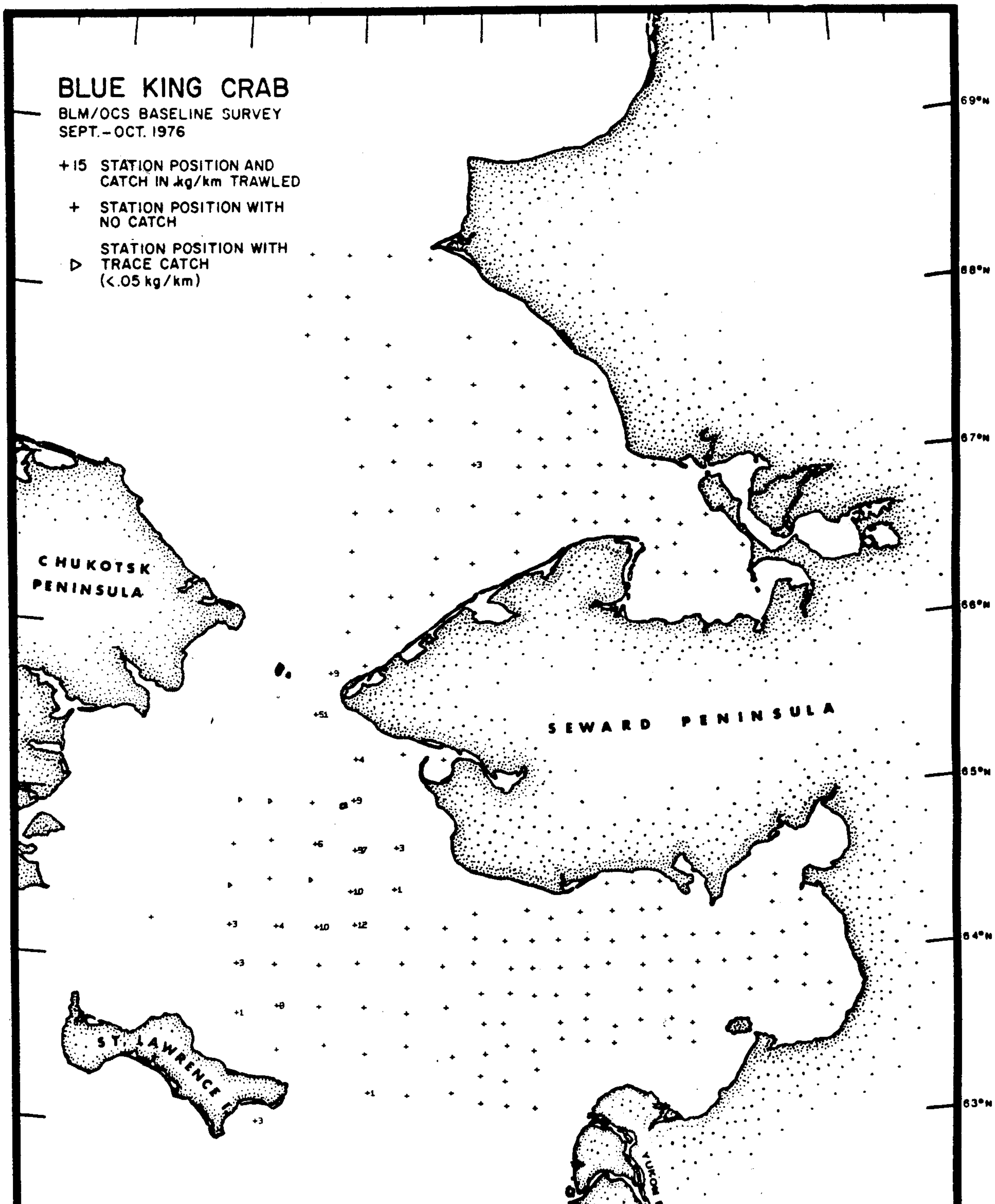


Figure VIII-102.--Distribution of catch rates by weight of blue king crab in Norton Sound the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

for the survey region should be fairly good. For the population sampled, 95% of the estimated biomass was found in stratum 3W. Of the remaining portion, 3% was located in stratum 1S, all of which occurred near Bering Strait.

The distribution of the estimated number of blue king crab was nearly identical to apparent biomass. The total population estimate for the entire survey region was about 3.6 million crabs (95% confidence interval 401 thousand-6.8 million crabs).

Size composition--Size composition data for blue king crab by sex and stratum are shown in Figure VIII-103. Sizes ranged from 25 to 135 mm carapace length, with females displaying a smaller mean size than males, 72.8 mm and 85.6 mm, respectively. There appeared to be two modes for males at about 75 and 100 mm and only one major mode for females at about 75 mm.

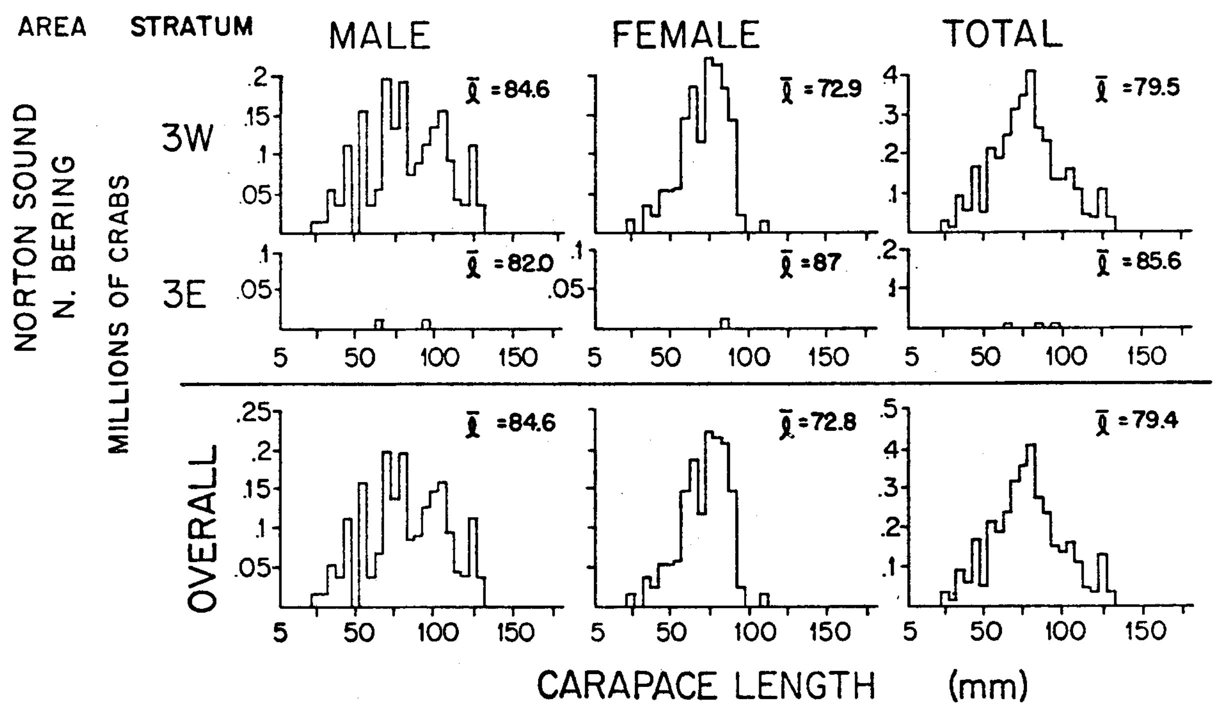
Population estimates by size groups, strata, and sexes are presented in Table VIII-63. Small-sized males (< 100 mm) comprised the majority of the estimated population, accounting for 68% of all males and 38% of the entire number estimate. Large females (> 70 mm) were the next most abundant size group, comprising 27% of the total estimated population while intermediate sized males (100-125 mm) and small females (< 70 mm) accounted for a further 14 and 15%, respectively. Small-sized males and large females were present in all strata where blue king crab occurred. Intermediate and large males were found only in stratum 3W. Overall, males were slightly more numerous than females and accounted for 56% of the total population estimate.

Table VIII-63.--Estimated population ($x10^3$) of blue king crab by stratum, sex and size groups[1/] in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

	MALES				FEMALES			
Stratum	<100mm	100-125mm	>125mm	All sizes	<70mm	≥70mm	All sizes	Sexes combined
Southeastern Chukchi Sea and Kotzebue Sound								
1N	16.6	—	—	16.6	—	16.6	16.6	33.2
1S	64.8	—	—	64.8	38.9	25.9	64.8	129.6
2∅	—	—	—	—	—	—	—	—
2I	—	—	—	—	—	—	—	—
Norton Sound and northern Bering Sea								
3W	1,261.4	487.7	154.5	1,903.6	554.5	920.7	1,475.2	3,378.8
3E	27.3	—	—	27.3	—	12.8	12.8	40.1
4∅	—	—	—	—	—	—	—	—
4I	—	—	—	—	—	—	—	—

1/ Carapace length (mm).

Figure VIII-103.--Size composition of blue king crab by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).



Shell condition—New-shell crabs constituted the major portion of both the male and female components of the blue king crab population (Table VIII-60), comprising 86 and 91%, respectively. No molting blue king crabs were observed.

Egg clutch size—Since few females were caught during the entire survey, information on blue king crab clutch size was quite limited. Of the 70 females examined, only 2 individuals in the 85–89 mm size group possessed egg clutches (Table VIII-64).

Table VIII-64.--Number of female blue king crab by size of egg clutch and carapace length and proportion of gravid females by size group (BLM/OCS survey, 1976).

Carapace length (mm)	No. eggs	Trace-1/8 full	1/4 Full	1/2 Full	3/4 Full	Full	Proportion with eggs
0-84	57	--	--	--	--	--	0.00
85-89	7	--	--	--	1	1	0.22
90-94	1	--	--	--	--	--	0.00
95-99	1	--	--	--	--	--	0.00
100-104	1	--	--	--	--	--	0.00
105-109	--	--	--	--	--	--	--
110-114	1	--	--	--	--	--	0.00

Tanner crab (C. opilio)

Distribution and abundance--Tanner crab was the most abundant crab species encountered, comprising 52% of the total biomass of commercially important crabs and occurring at over 67% of the stations sampled (Table VIII-65). The largest concentration of Tanner crab occurred in outer Kotzebue Sound (stratum 2Ø) (Figures VIII-104 and 105) where catch rates averaged 6.1 kg/km. Catch rates decreased to between 1.5 and 1.9 kg/km in the remaining strata north of Bering Strait (strata 1N, 1S, and 2I), and further dropped to 0.6 kg/km in the western portion of the northern Bering Sea (stratum 3W). In the remainder of the survey region, Tanner crab were caught only in trace amounts. The overall mean catch rate for the entire survey area was 1.1 kg/km trawled.

Table-65.--Estimated biomass and population size of Tanner crab (C. opilio) in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean weight per individual (kg)
Southeastern Chukchi Sea and Kotzebue Sound							
1N	93.1	1.549	2.619	.308	110,911	.365	.024
1S	100.0	1.658	1,254	.148	51,220	.168	.024
2Ø	94.7	6.169	2,649	.312	74,114	.244	.036
2I	62.5	1.932	586	.069	15,476	.051	.038
Norton Sound and northern Bering Sea							
3W	100.0	0.594	1,253	.152	49,262	.162	.026
3E	64.3	0.069	42	.009	1,379	.005	.031
4Ø	32.9	0.032	50	.006	1,627	.009	.031
4I	5.9	T	.4	T	8	T	.046
All strata combined	67.2 2/	1.088	8,493 3/		303,997 3/		.028

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: biomass--5,067-11,922 mt; population--208,259,000-399,736,000.

The apparent total biomass for the entire survey region was estimated at about 8,500 mt (95% confidence interval 5,067-11,922 mt). This estimate may be somewhat suspect because of the possible influence of Tanner crab in regions adjacent to the survey area. Relatively large catches of this species occurred along the entire outer boundary of the survey area in the southeastern Chukchi Sea. This suggests a continuation of Tanner crab stocks into other waters, but an estimate of the size of this

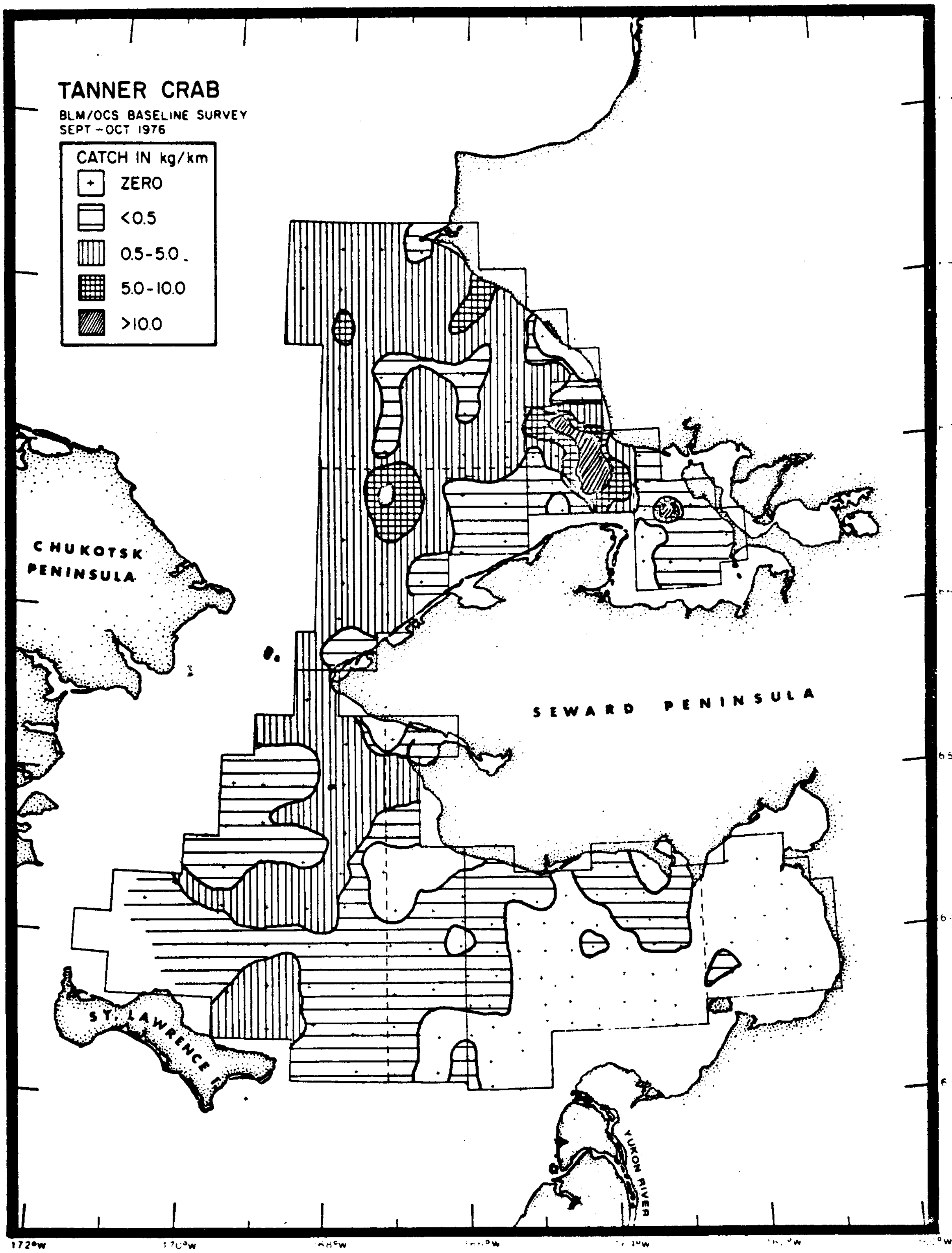


Figure VIII-104.--Distribution and relative abundance of Tanner crab (C. opilio) in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

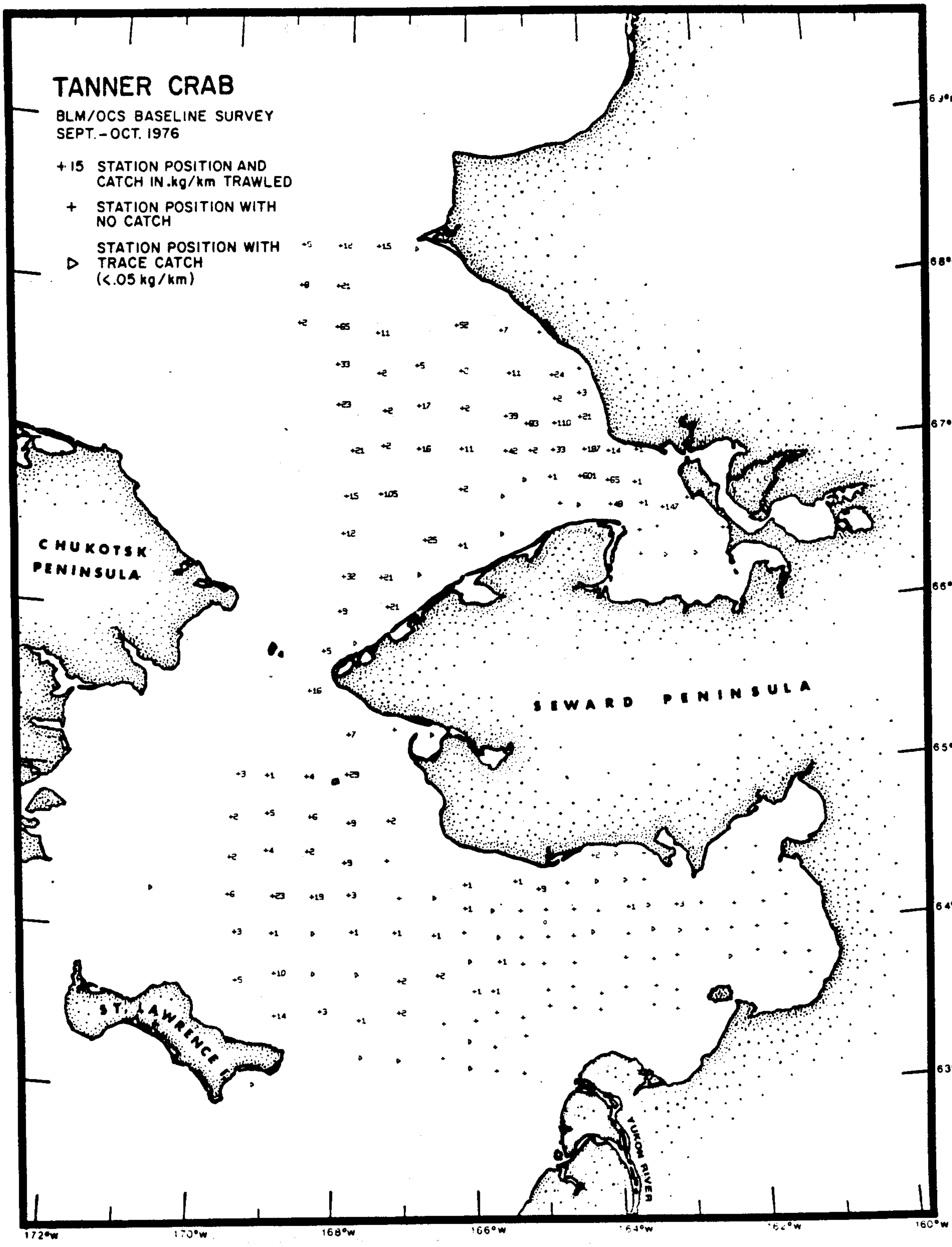


Figure VIII-105.--Distribution of catch rates by weight of Tanner crab (C. opilio) in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

unsampled portion of the population is unknown. Of the population within the survey area, over 62% of the estimated biomass was located in strata 1N and 2Ø combined. Another 30% occurred in strata 1S with most of the remaining portion located in stratum 2I.

The relative distribution of the estimated number of Tanner crab was very similar to apparent biomass. Strata 1N, 1S, and 2Ø north of Bering Strait accounted for nearly 78% of the total population estimate, or over 236 million crabs. Stratum 3W was the only region south of Bering Strait where sizeable numbers of Tanner crab were present. The apparent population in this stratum comprised 16% of the total population estimate of 304 million crabs for the entire survey region (95% confidence interval 208.3 million-399.7 million crabs).

Size composition--Size composition data for Tanner crab by sex and stratum are presented in Figure VIII-106. Sizes ranged from 3 to 98 mm carapace width and females exhibited a larger size range (3-98 mm) than males (7-87 mm). Two modes in size composition were observed per sex. A major mode in female size occurred at about 45-49 mm and for males at 40-49 mm while minor modes for both sexes were observed at about 15-19 mm.

Mean size of Tanner crab varied slightly by sex and strata (Figure VIII-106). Largest average size for both sexes occurred in strata 2Ø and 2I, areas where few very small crab (< 25 mm) were encountered. Overall, females were slightly larger (40.0 mm) than males (38.5 mm) based on data for all strata combined.

Population estimates by size group, strata, and sex are presented in Table VIII-66. Small-sized males (25-64 mm) were the most abundant size group found in the survey region. They represented 85% of the estimated male population, and over 50% of the overall apparent stock. Similar size females were the next most abundant group, comprising 86% of all females and 28% of the overall total. Very small males and females (< 25 mm) together accounted for the majority of the remaining population, while individuals of both sexes larger than 65 mm were found in only trace amounts. Overall, males were more abundant than females, accounting for about 67% of the total number of Tanner crab estimated for the entire survey region.

Shell Condition--Shell age composition by region and sex for Tanner crab and other crab species is presented in Table VIII-60. Overall, new shell crabs comprised nearly the entire population, accounting for over 99% of the total. Skip molt and soft shell individuals were present, but in very small amounts, and no molting crabs were encountered.

Egg clutch size--Size of egg clutch and the proportion of gravid females by carapace width are presented in Table VIII-67. Females without eggs were present throughout nearly the entire range of sizes while the smallest size group of Tanner crab which had egg clutches present was at 35-39 mm. The proportion of gravid females per size group remained very low for all sizes between 35-54 mm and increased to about 8% for

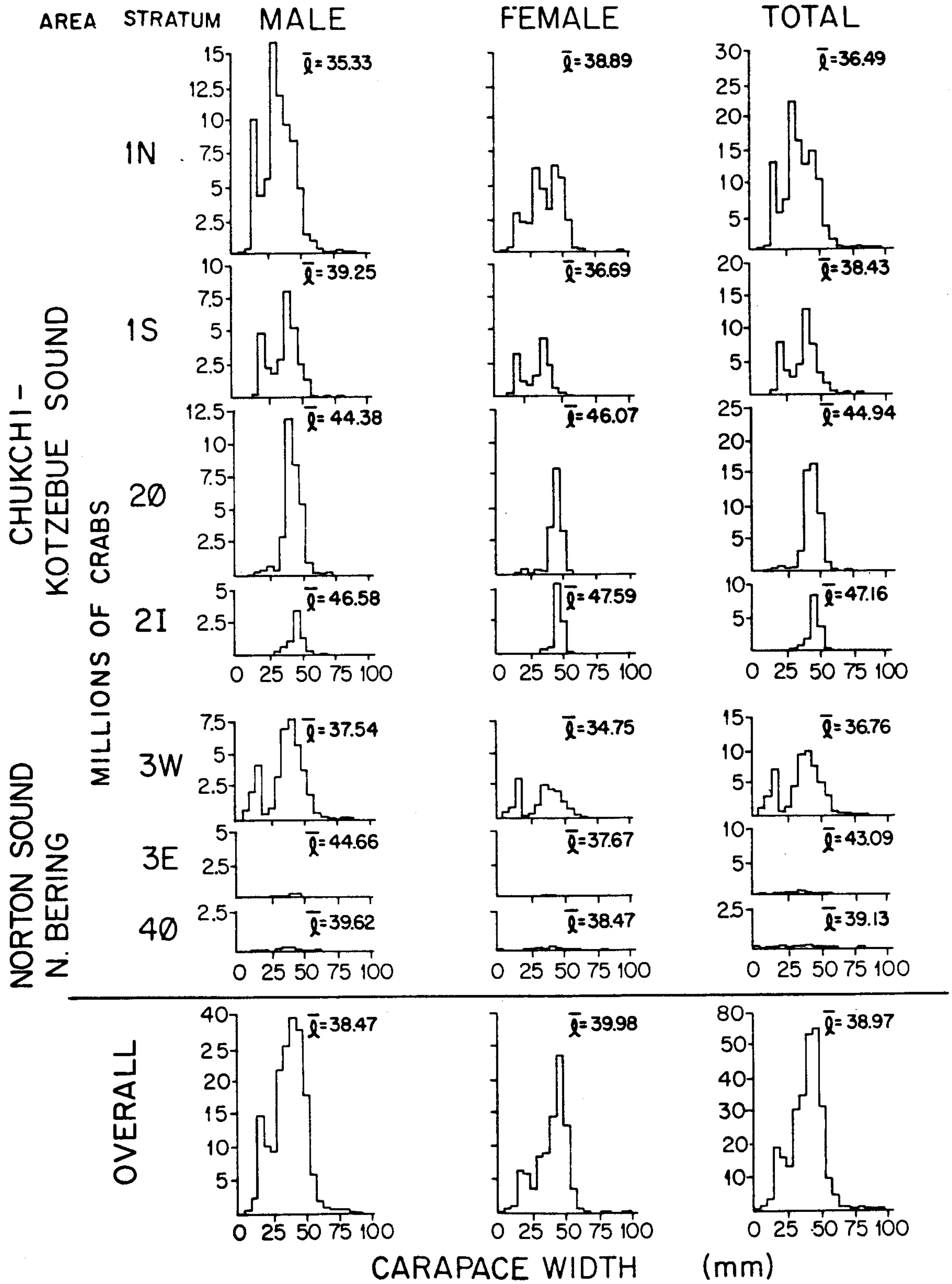


Figure VIII-106.--Size composition of Tanner crab (C. opilio) by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

individuals in the 55-59 mm size range. Gravid females comprised the majority of individuals larger than 59 mm; however, only a few of the larger specimens were encountered during the survey.

No gravid female Tanner crab were captured in either Norton or Kotzebue sounds.

Table VIII-66.--Estimated population ($x10^6$) of Tanner crab (*Chionoecetes opilio*) by stratum, sex and size group[1/] in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

	MALES				FEMALES				
Stratum	<25mm	25-64mm	>65mm	All sizes	<25mm	25-64mm	>65mm	All sizes	Sexes combined
Southeastern Chukchi Sea and Kotzebue Sound									
1N	14.9	59.9	0.8	74.8	5.4	30.8	T	36.2	111.0
1S	5.9	28.5	0.4	34.8	3.8	12.6	—	16.4	51.2
2Ø	1.3	48.0	0.3	49.6	0.6	23.9	—	24.5	74.1
2I	—	6.4	0.1	6.5	—	8.9	—	8.9	15.4
Norton Sound and northern Bering Sea									
3W	6.8	28.8	—	35.9	4.0	9.4	T	13.4	49.3
3E	T	1.1	—	1.1	T	0.3	—	0.3	1.4
4Ø	0.1	0.9	—	1.0	0.1	0.6	—	0.7	1.7
4I	—	T	—	T	—	—	—	—	T

1/ Carapace width (mm).

Table VIII-67.--Number of female Tanner crab by size of egg clutch and carapace width and the proportion of gravid females by size group (BLM/OCS survey, 1976).

Carapace width (mm)	No eggs	Trace-1/8 Full	1/4 Full	1/2 Full	3/4 Full	Full	Proportion with eggs
0-34	1,532	—	—	—	—	—	0
35-39	498	—	—	—	—	1	<0.01
40-44	1,437	—	—	—	—	13	0.01
45-49	2,246	—	1	3	2	101	0.05
50-54	1,134	—	—	4	5	11	0.02
55-59	208	—	3	3	1	11	0.08
60-64	4	—	—	1	2	6	0.69
65-69	1	—	—	—	—	2	0.67
70-74	—	—	—	—	—	—	—
75-79	—	—	—	—	—	—	—
80-84	1	—	—	—	—	—	0
85-89	—	—	—	—	—	—	—
90-94	—	—	—	—	—	—	—
95-98	—	—	—	—	—	—	1.00

Distribution, Abundance, and Biological Features of Principal Species of Snails

Nearly 50 species of snails were collected during the 1976 baseline study of the Norton Sound-southeastern Chukchi Sea region. Of these species, a few occurred in relatively substantial amounts. In this section are descriptions of the distribution, abundance, and size composition of the four most abundant snail species (by weight) encountered during the survey. These species together comprised over 95% of the total estimated snail biomass.

Neptunea heros

Distribution and abundance--*Neptunea heros* was by far the most abundant snail species encountered. It occurred at over 61% of the demersal stations sampled (Table VIII-68) and accounted for 75% of the total apparent biomass of all snail species combined (5% of the entire invertebrate biomass). Largest concentrations of *N. heros* were found in the southeastern Chukchi Sea (strata 1N and 1S) and in inner Norton Sound (stratum 4I) (Figures VIII-107 and 108) where catch rates averaged about 2.8 kg/km. Mean catch rates decreased to about 2.3 kg/km in inner Kotzebue Sound and the eastern portion of the northern Bering Sea (strata 2I and 3E, respectively) and further dropped to between 0.6-1.0 kg/km in the remainder of the survey region. Overall, the mean catch rate for the entire survey area was over 1.7 kg/km trawled.

Table VIII-68.--Estimated biomass and population size of *Neptunea heros* in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Strata	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population ($X10^3$)	Proportion of total estimated population	Mean weight per individual (kg)
Southeastern Chukchi Sea and Kotzebue Sound							
1N	75.9	2.802	4,739	.325	47,200	.347	.100
1S	60.0	2.719	2,056	.141	21,906	.161	.094
2Ø	26.3	0.654	281	.019	2,683	.020	.105
2I	75.0	2.183	662	.045	8,589	.063	.077
Norton Sound and Northern Bering Sea							
3W	84.4	1.201	2,616	.180	23,719	.174	.110
3E	85.7	2.330	1,426	.098	9,859	.072	.145
4Ø	48.3	0.986	1,313	.090	8,709	.064	.151
4I	82.4	2.777	1,475	.101	13,358	.098	.111
All strata combined:	64.1 2/	1.739	14,568 3/		136,023 3/		.108

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: biomass-- 9,992 - 19,144mt; population--92,242,000 - 179,807,000.

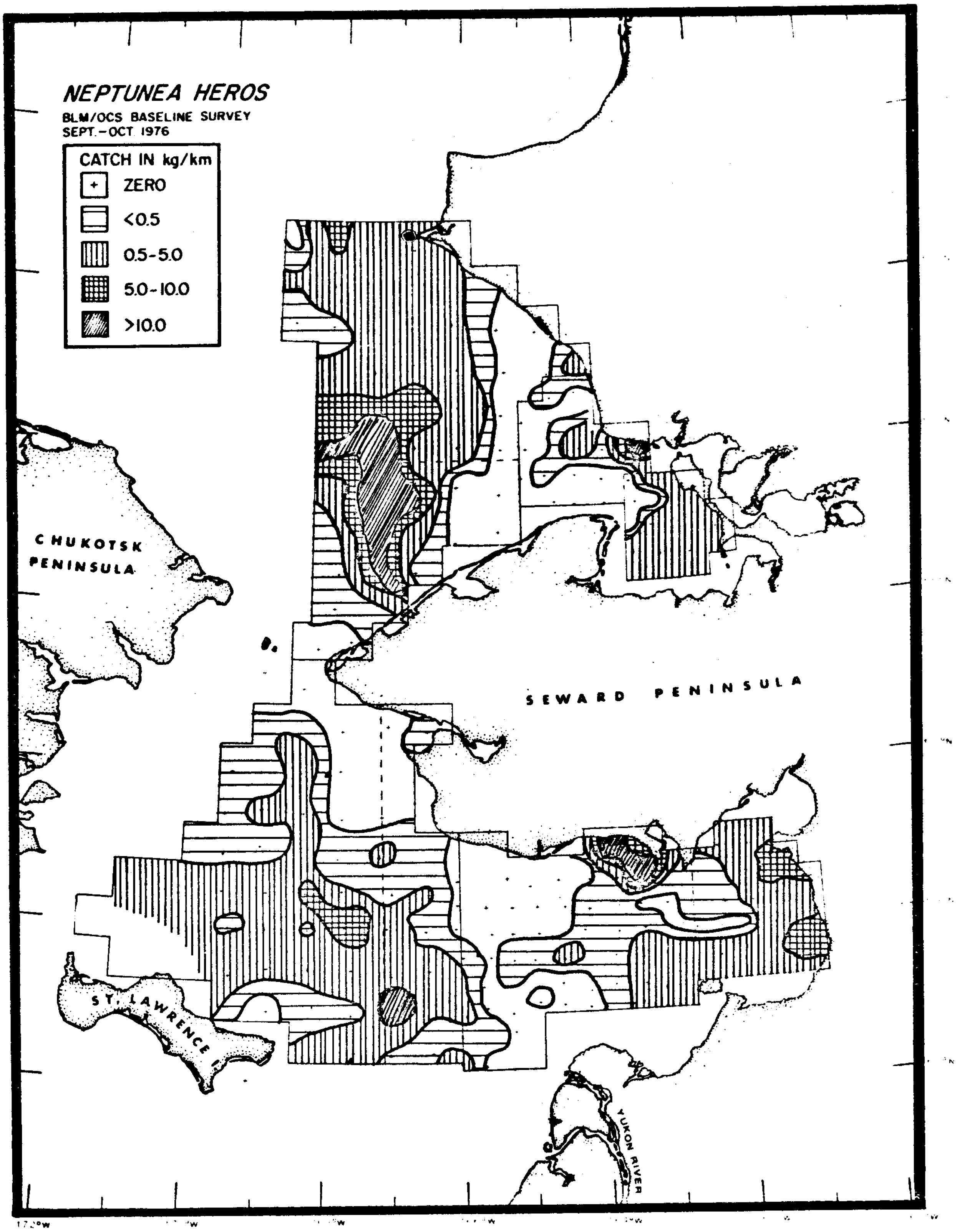


Figure VIII-107.--Distribution and relative abundance by weight of Neptunea heros in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

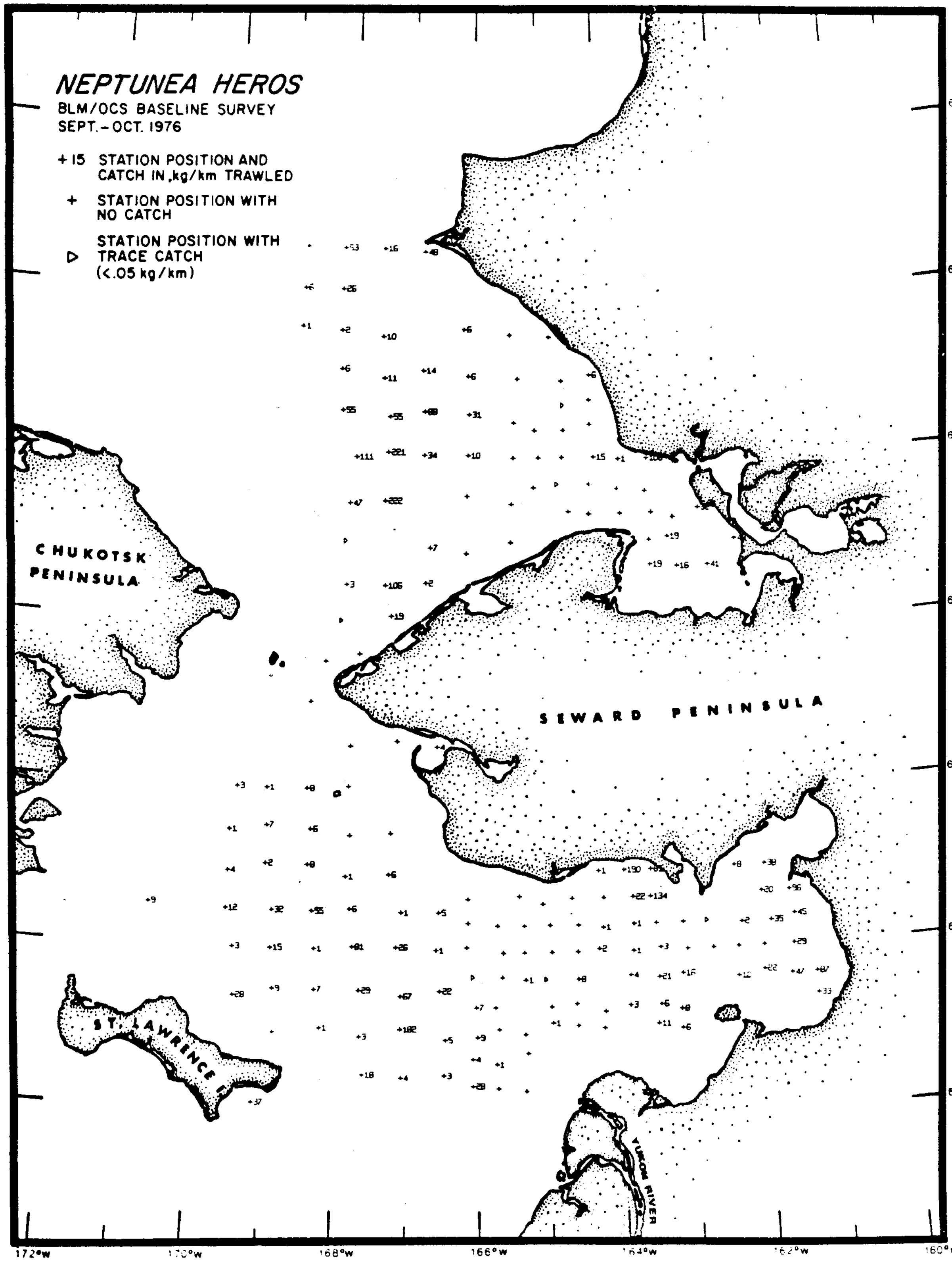


Figure VIII-108.--Distribution of catch rates by weight of Neptunea heros in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

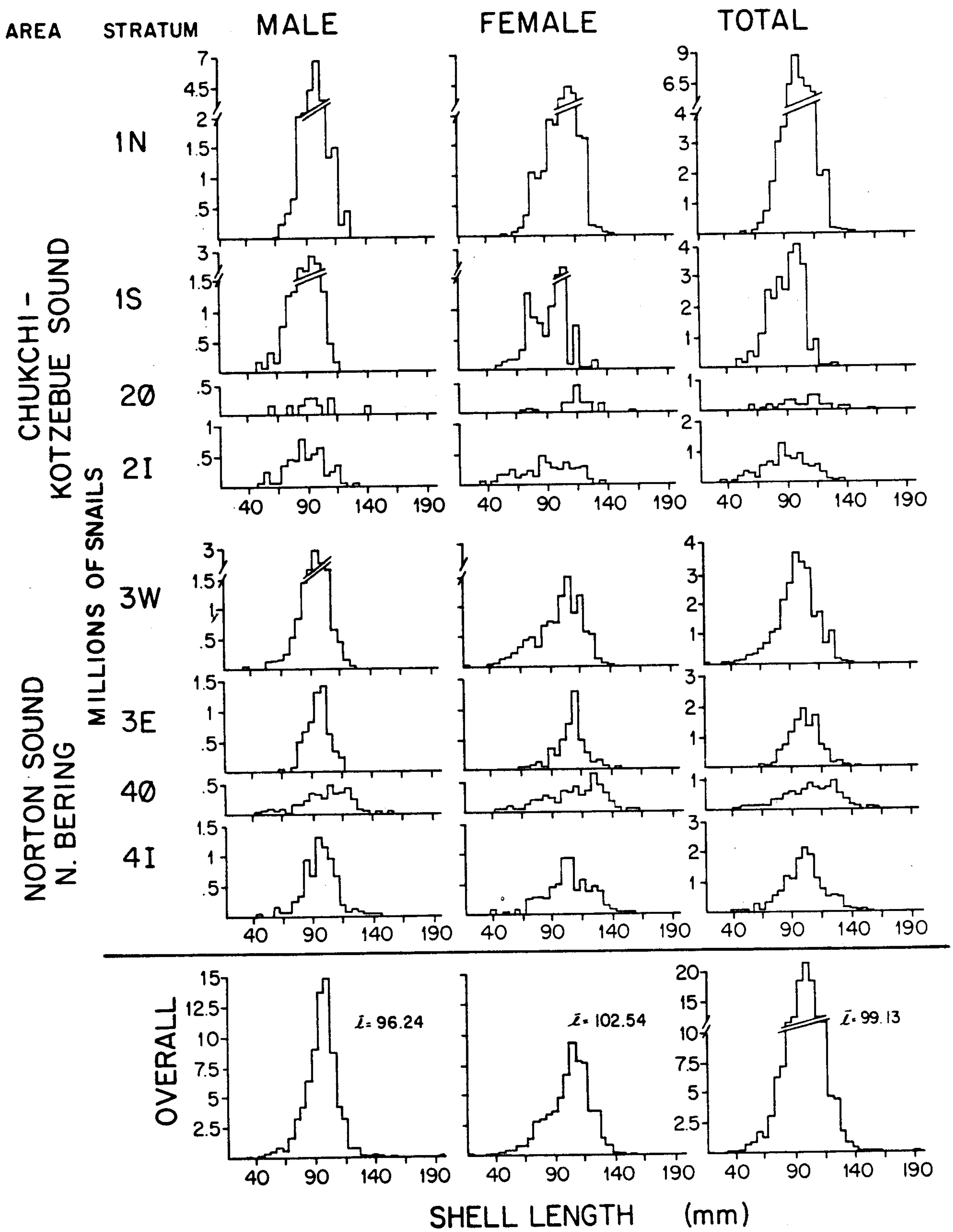


Figure VIII-109.--Size composition by sex and stratum for Neptunea heros in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

The apparent biomass of N. heros in the entire survey area was estimated at about 14,500 mt (95% confidence interval 9,992-19,144 mt). This is a minimum estimate for the survey region, since snails are burrowing animals and some unknown portion of the population may have occurred slightly below the sea bed surface, thus being unavailable to the trawl. Additionally, relatively large catches of this species occurred along the outer boundary of the survey area in the southeastern Chukchi Sea. This suggests a continuation of N. heros stocks into non-survey waters. Of the population within the survey area, over half of the total estimated biomass was found in strata 1N and 3W, offshore and where depths generally exceeded 25 m. A further 9-14% occurred in strata 1S, 3E, 4Ø, and 4I. Nearly the entire biomass estimated for stratum 4Ø (outer Norton Sound) was located in a small portion of the northeast section of this region. Only about 6% of the total estimated biomass occurred in strata 2Ø and 2I combined.

The relative distribution of estimated numbers of N. heros did not differ greatly from apparent biomass. Strata 1N and 3W together contained 52% of the total population, or an estimated 71 million snails. An additional 16% was estimated present in stratum 1S while all other strata contained between 2-10%. The total overall population estimated for the survey region was about 136 million snails.

Size composition, mean length and weight--N. heros collected during the survey ranged in shell length from 22-197 mm. Females generally were larger than males, averaging 102.5 mm compared to 96.2 mm for all strata combined (Figure VIII-109). Intermediately-sized (90-115 mm) males and females were the most abundant groups in nearly all strata (Table VIII-69) and represented over 60% of the overall apparent population. Small N. heros (< 90 mm) were the next most abundant size group and were found mostly in the northern and westernmost areas of the survey region in strata 1N, 1S, and 3W.

Table VIII-69.--Estimated population ($x10^6$) of Neptunea heros by stratum, sex and size group[1/] in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

	MALES				FEMALES				
Stratum	<90mm	90-115mm	>115mm	Total	<90mm	90-115mm	>115mm	Total	Sexes combined
Southeastern Chukchi Sea and Kotzebue Sound									
1N	3.4	18.3	2.3	24.1	2.6	12.5	7.4	22.5	46.5
1S	6.3	8.9	0.2	15.3	3.8	6.2	0.9	10.0	25.4
2Ø	0.4	1.0	0.1	1.5	T	0.3	0.8	1.1	2.7
2I	2.4	2.0	0.4	4.8	1.8	1.5	0.7	3.8	8.7
Norton Sound and northern Bering Sea									
3W	3.4	9.4	0.6	13.4	2.7	5.0	2.5	10.2	23.5
3E	1.3	4.5	0.2	6.0	0.3	3.0	1.0	4.3	10.3
4Ø	0.9	1.7	1.2	3.9	1.0	1.5	2.3	4.8	8.7
4I	1.8	4.8	0.5	7.1	1.2	3.1	2.0	6.3	13.4

1/ Shell length (mm).

Mean weight per individual was noticeably higher in all strata south of Bering Strait than to the north. Average weights of N. heros in strata 3W, 3E, 4Ø, and 4I were about 129 gm while in strata 1N, 1S, 2Ø, and 2I individual weights averaged 94 gm. The overall average weight of N. heros was about 108 gm.

Neptunea ventricosa

Distribution and abundance--Neptunea ventricosa was the second-most abundant snail species encountered, occurring at nearly 56% of all stations sampled (Table VIII-70) and comprising about 14% of the total snail biomass. Dense concentrations of this snail species were not encountered in the survey region, although highest average catch rates of about 0.6 kg/km occurred in the southern portion of the southern Chukchi Sea and the eastern part of the northern Bering Sea (strata 1S and 3E, respectively) (Figure VIII-110 and 111). Average catch rates dropped to between 0.2-0.4 kg/km in the remaining portion of the southeastern Chukchi and northern Bering seas and in Kotzebue Sound (strata 1N, 3E, 2Ø, and 2I) and further decreased to 0.1 kg/km in Norton Sound (strata 4Ø and 4I). The overall mean catch rate for the entire survey area was 0.3 kg/km trawled.

Table VIII-70.--Estimated biomass and population size of Neptunea ventricosa in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Strata	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population ($X10^3$)	Proportion of total estimated population	Mean weight per individual (kg)
Southeastern Chukchi Sea and Kotzekue Sound							
1N	55.2	0.424	717	.271	10,815	.319	.066
1S	53.3	0.599	453	.171	5,714	.168	.079
2Ø	26.3	0.274	118	.044	1,394	.041	.085
2I	100.0	0.252	76	.029	1,048	.031	.073
Norton Sound and Northern Bering Sea							
3W	75.0	0.340	741	.280	8,008	.236	.093
3E	85.7	0.576	353	.133	4,099	.121	.086
4Ø	39.7	0.083	111	.042	1,209	.036	.092
4I	64.7	0.148	79	.030	1,636	.048	.048
All strata combined:	55.72/	0.316	2,6483/		33,9233/		.078

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: biomass--1,811 - 3,485 mt; population--21,511,000 - 46,335,000.

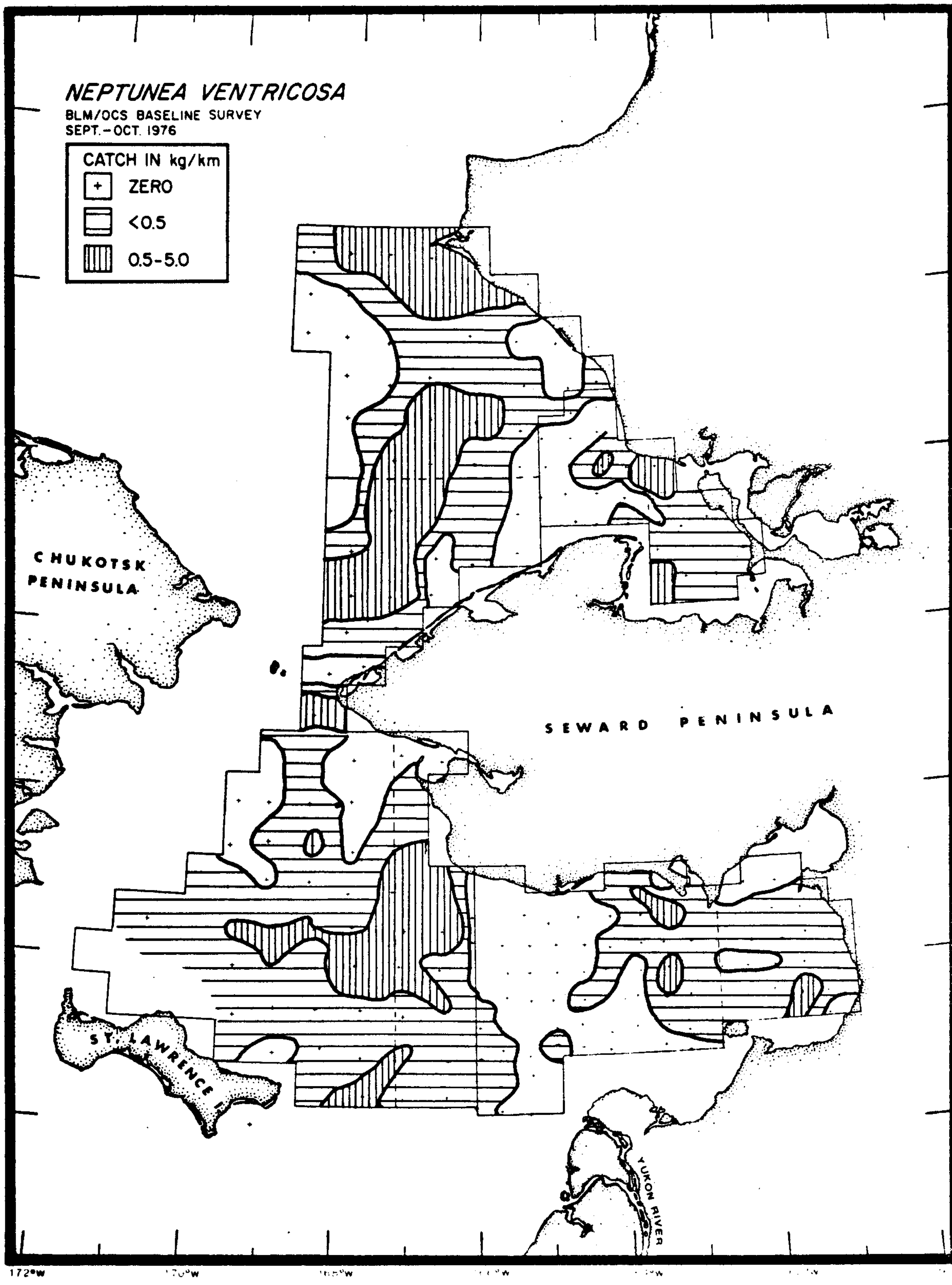


Figure VIII-110.--Distribution and relative abundance by weight of Neptunea ventricosa in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

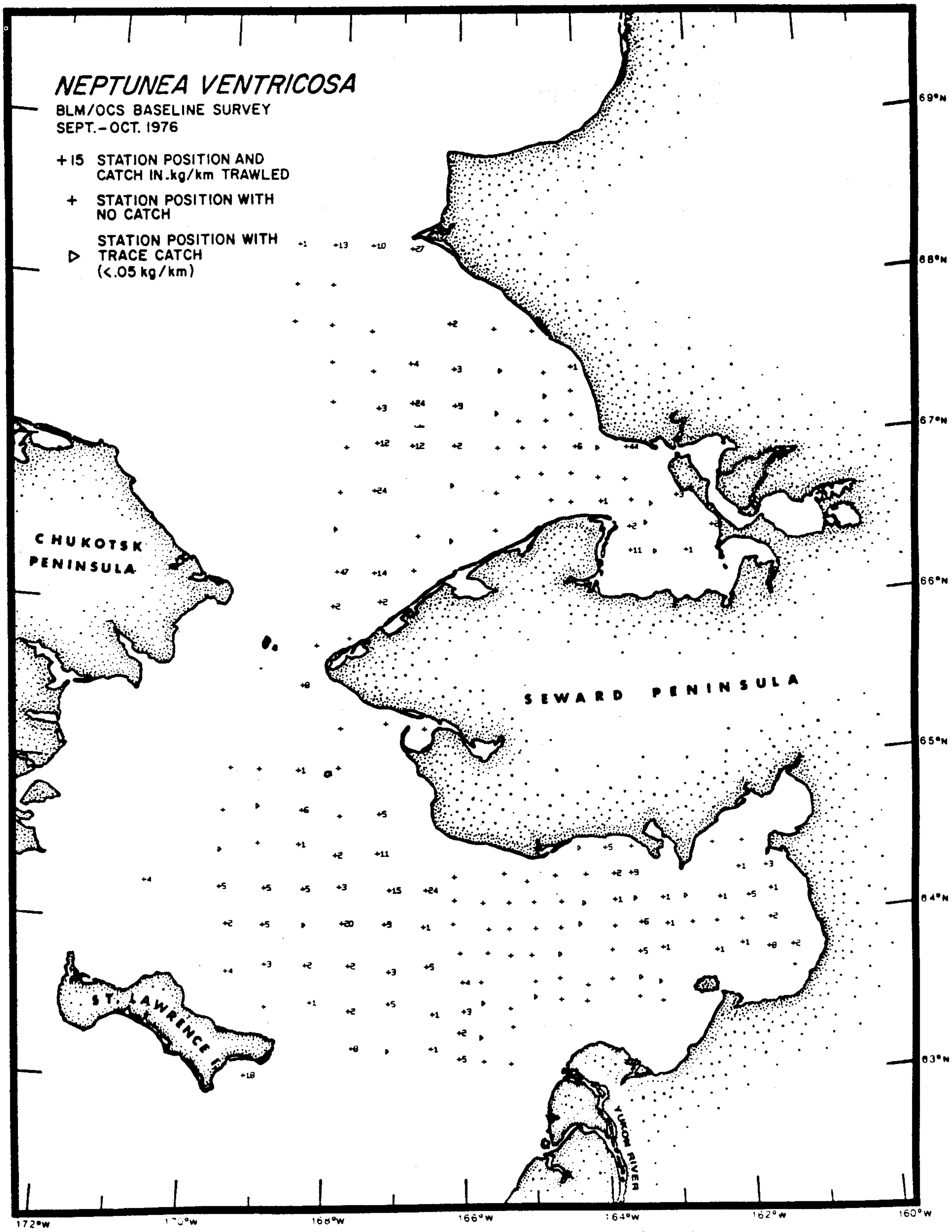


Figure VIII-111.--Distribution of catch rates by weight of Neptunea ventricosa in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

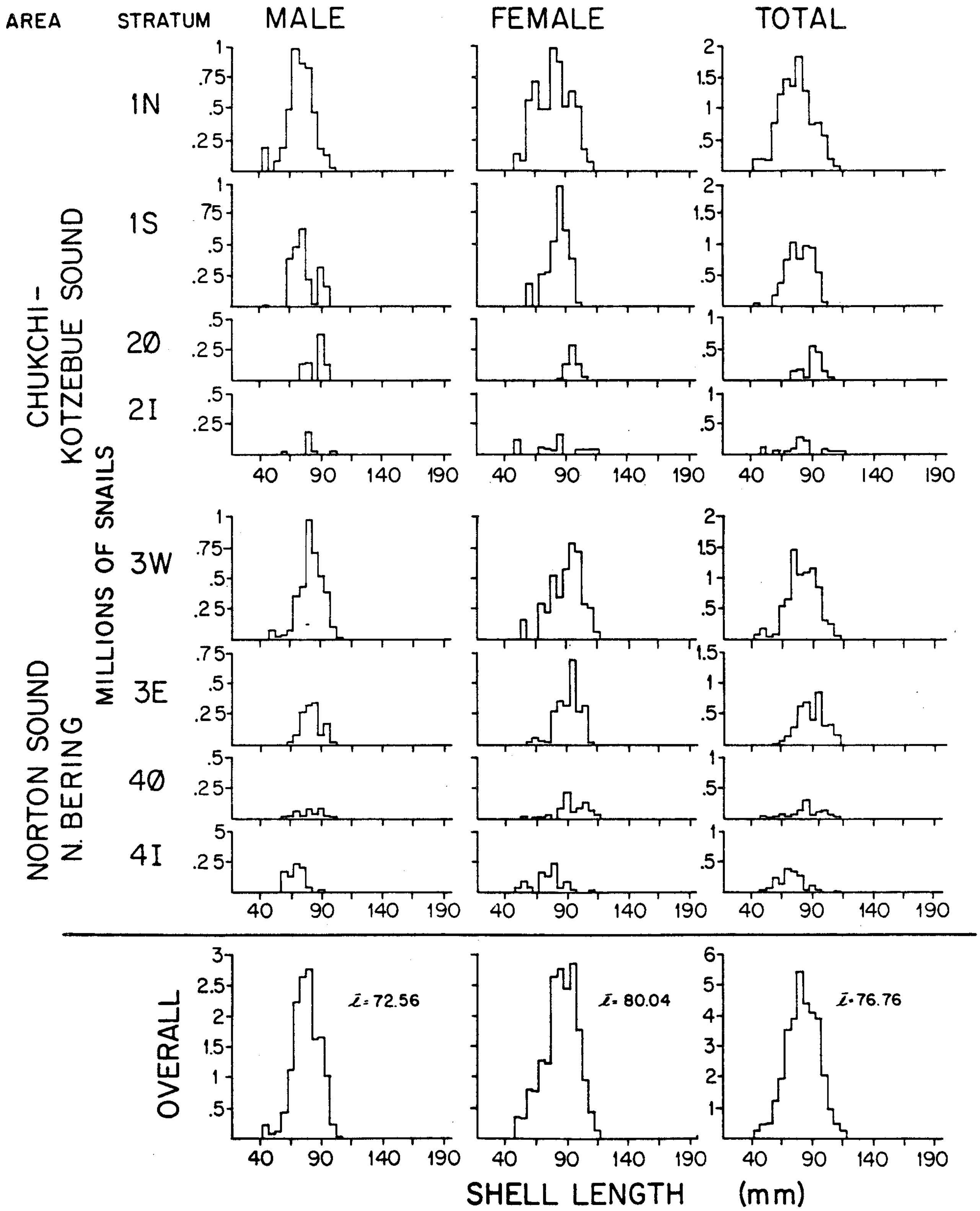


Figure VIII-112.--Size composition by sex and stratum for Neptunea ventricosa in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

The apparent biomass of N. ventricosa in the entire survey region was estimated at over 2,600 mt (95% confidence interval 1,811-3,485 mt). Nearly 86% of this amount was located in strata 1N, 1S, 3W, and 3E combined, where depths generally exceeded 25 m. The remaining portion of the estimated biomass was almost equally distributed among all other strata which were more inshore and had depths generally less than 25 m.

No substantial difference was observed between the distribution of apparent biomass and estimated numbers. Approximately 84% of the estimated population of N. ventricosa was found in strata 1N, 1S, 3E, and 3W. The total population estimated for the entire survey region was about 34 million snails.

Size composition, mean length and weight--N. ventricosa collected during the survey ranged from 47 to 117 mm in shell length (Figure VIII-112). Females usually were larger than males, averaging 80.0 mm compared to 72.6 mm. Nearly the entire observed population were small or intermediate-sized snails (< 115 mm). The largest portion of small individuals (< 90 mm) was found north of Bering Strait in strata 1N and 1S (Table VIII-71) while the greatest numbers of intermediate-sized individuals (90-115 mm) were located south of Bering Strait in strata 3W and 3E.

Mean weights per individual were fairly consistent throughout the survey region and averaged 78 gm.

Table VIII-71.--Estimated population ($x10^6$) of Neptunea ventricosa by stratum, sex and size group[1/] in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

	MALES				FEMALES				
Stratum	<90mm	90-115mm	>115mm	Total	<90mm	90-115mm	>115mm	Total	Sexes combined
Southeastern Chukchi Sea and Kotzebue Sound									
1N	4.1	0.4	—	4.5	4.3	1.9	—	6.2	10.7
1S	1.9	0.5	—	2.3	2.2	1.0	—	3.2	5.5
2Ø	0.3	0.5	—	0.8	T	0.6	—	0.6	1.4
2I	0.2	0.1	—	0.3	0.5	0.2	T	0.7	1.0
Norton Sound and northern Bering Sea									
3W	2.7	1.0	—	3.7	1.5	2.6	0.1	4.2	7.9
3E	1.1	0.3	—	1.4	0.8	1.6	—	2.4	3.7
4Ø	0.3	0.1	—	0.4	0.1	0.6	T	0.7	1.1
4I	0.8	T	—	0.8	0.7	0.2	—	0.8	1.7

1/ Shell length (mm).

Beringius beringii

Distribution and abundance--Beringius beringii was frequently encountered during the survey, occurring at nearly 47% of all stations (Table VII-72), but comprised less than 4% of the total apparent snail biomass. Moderate concentrations were found in small isolated locations throughout the survey area (Figures VIII-113 and 114) at depths usually less than 25 m. Largest catches occurred in inner Kotzebue Sound (stratum 2I) where catch rates averaged nearly 0.3 kg/km. Mean catch rates dropped to about 0.2 kg/km in outer Kotzebue Sound (stratum 2Ø) and further declined to 0.1 kg/km in the eastern portion of the northern Bering Sea (stratum 3E) and in Norton Sound (strata 4Ø and 4I). Only trace amounts were found in the remainder of the survey region. Overall, the mean catch rate for the entire survey area was about 0.1 kg/km trawled.

Table VIII-72.--Estimated biomass and population size of Beringius beringii in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Strata	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population ($X10^3$)	Proportion of total estimated population	Mean weight per individual (kg)
Southeastern Chukchi Sea and Kotzebue Sound							
1N	51.7	0.079	134	.183	1,399	.155	.096
1S	20.0	0.047	36	.049	354	.039	.102
2Ø	52.6	0.155	67	.092	829	.092	.081
2I	62.5	0.271	82	.113	1,113	.123	.074
Norton Sound and Northern Bering Sea							
3W	40.6	0.061	133	.182	2,093	.232	.064
3E	28.6	0.135	83	.114	830	.092	.100
4Ø	50.0	0.101	136	.185	1,465	.162	.093
4I	64.7	0.114	61	.083	938	.104	.065
All strata combined:	46.9 2/	0.087	732 3/		9,021 3/		.082

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence intervals: biomass--485 - 977 mt; population--6,183,000 - 11,863,000.

The apparent biomass of B. beringii for the entire survey region was estimated at about 730 mt (95% confidence interval 485-977 mt). This estimated biomass was fairly evenly distributed throughout most of the survey region. Of the estimated biomass, 18% was located in each of three strata, 1N, 3W, and 4Ø; 11% each in strata 2I and 3E; and 8-9% in strata 2Ø and 4I. Less than 5% of the total estimated biomass occurred in stratum 1S.

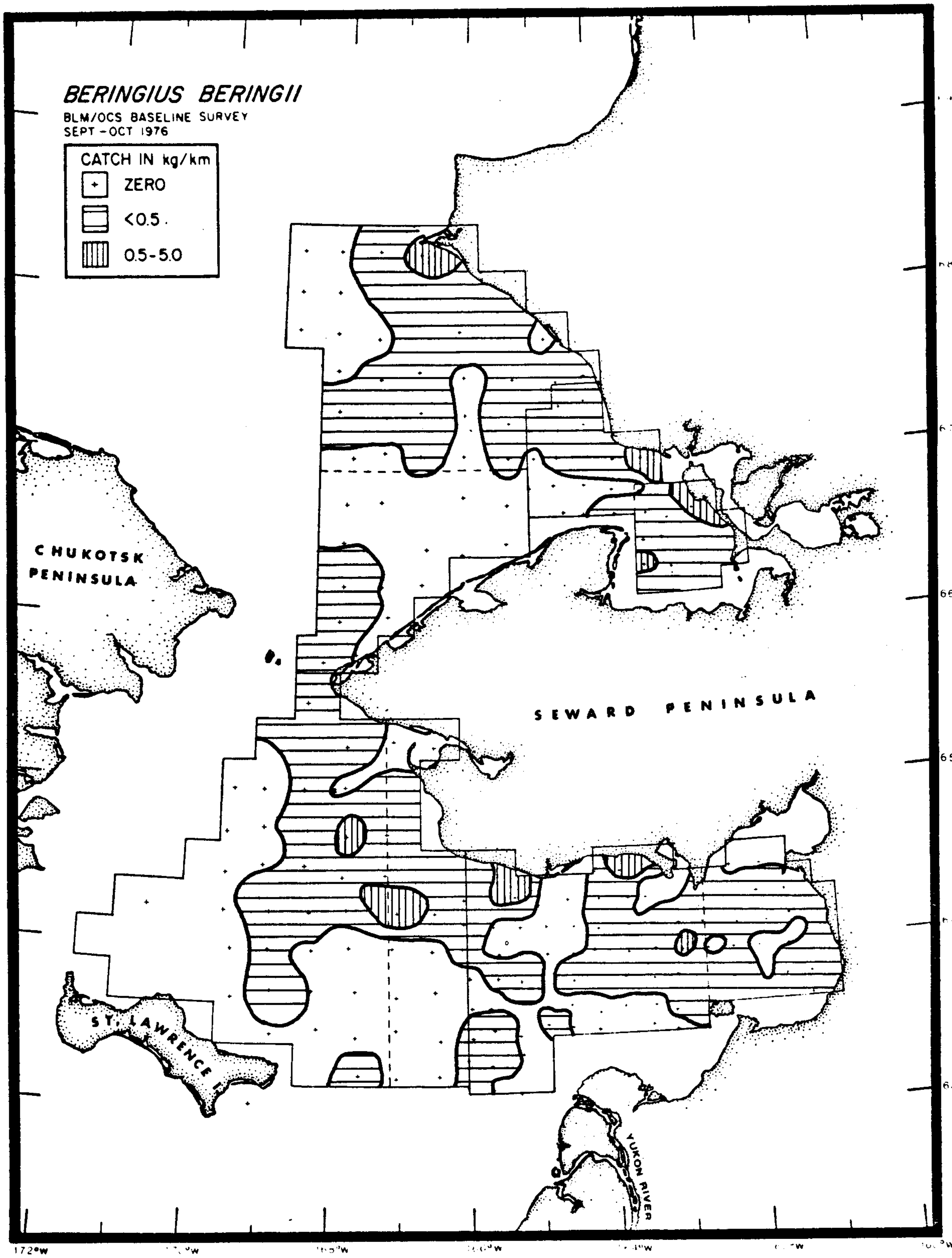


Figure VIII-113.--Distribution and relative abundance by weight of Beringius beringii in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

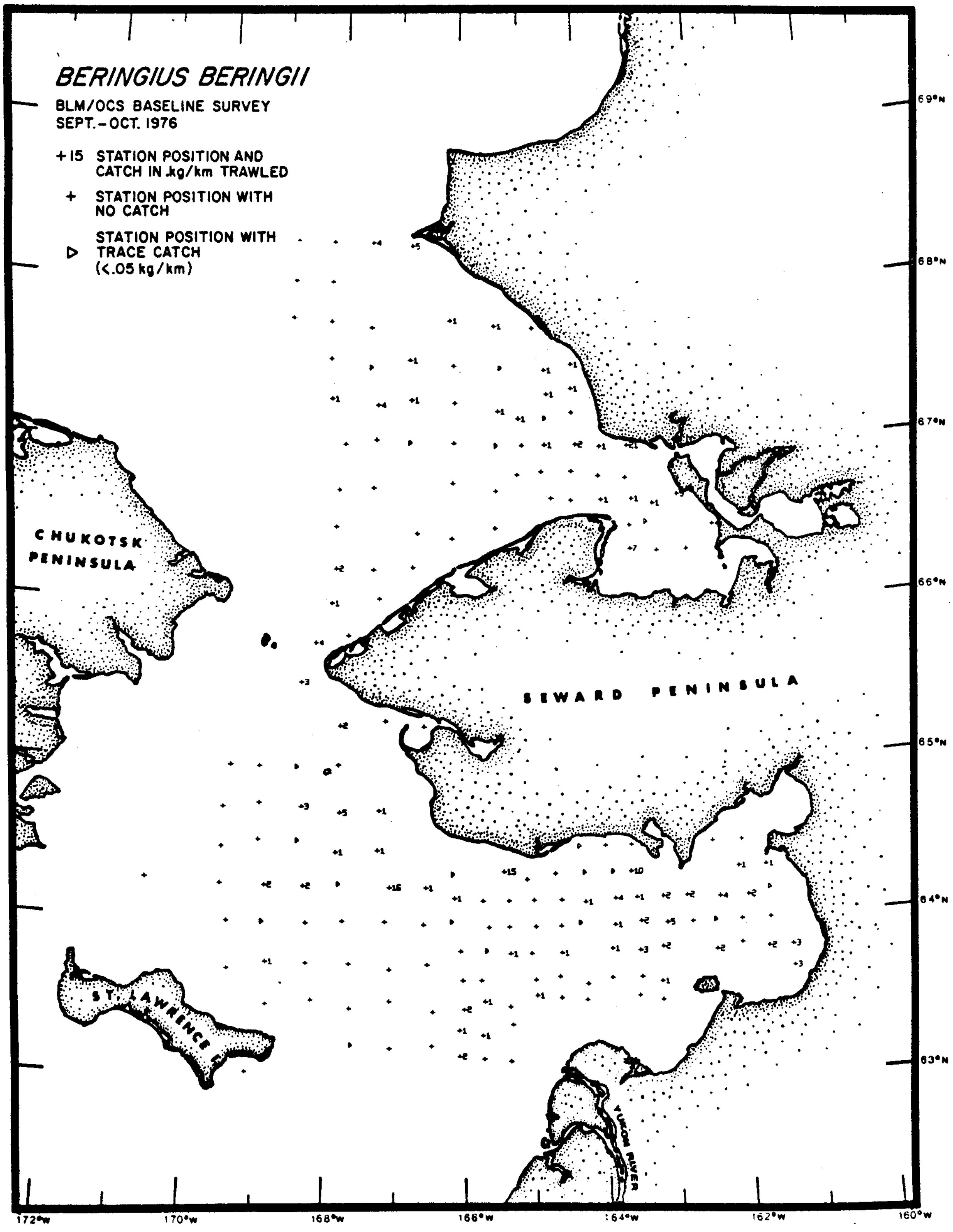


Figure VIII-114.--Distribution of catch rates by weight of <u>Beringius beringii</u> in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

The relative distribution of estimated numbers of B. beringii generally was similar to apparent biomass. The total population estimated for the entire survey region was 9 million snails.

Size composition, mean length and weight--B. beringii collected during the survey ranged in shell length from 47-147 mm. Females appeared to be larger than males, averaging 107.9 mm compared to 94.5 mm (Figure VIII-115). Intermediate-sized males and females (90-115 mm) were the most abundant groups in most strata (Table VIII-73). They represented nearly 60% of the overall apparent population. Small-sized (< 90 mm) and large (> 115 mm) snails comprised about equal proportions of the remaining number estimated. For all strata combined, small males outnumbered similar sized females and for the intermediate and large size groups, females were more numerous than males.

Overall, the average weight of B. beringii was 82 gm.

Table VIII-73.--Estimated population ($x10^5$) of *Beringius beringii* by stratum, sex and size group[1/] in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

	MALES				FEMALES				
Stratum	<90 mm	90-115mm	>115mm	Total	<90mm	90-115mm	>115mm	Total	Sexes combined
Southeastern Chukchi Sea and Kotzebue Sound									
1N	1.3	4.4	0.2	5.9	0.6	2.3	4.4	7.4	13.2
1S	0.1	1.7	0.3	2.0	—	0.7	0.7	1.4	3.4
2Ø	0.1	6.0	0.1	6.2	—	1.5	0.5	2.0	8.1
2I	1.2	2.3	—	3.5	1.7	6.1	3.5	8.7	12.3
Norton Sound and northern Bering Sea									
3W	5.2	1.8	0.4	7.4	2.7	9.7	1.8	14.2	21.6
3E	0.7	1.9	1.6	4.2	0.6	1.8	1.8	4.2	8.5
4Ø	1.6	3.8	0.1	5.4	1.0	5.0	2.7	8.7	14.1
4I	3.3	1.2	—	4.5	1.5	2.2	0.7	4.5	9.0

1/ Shell length (mm).

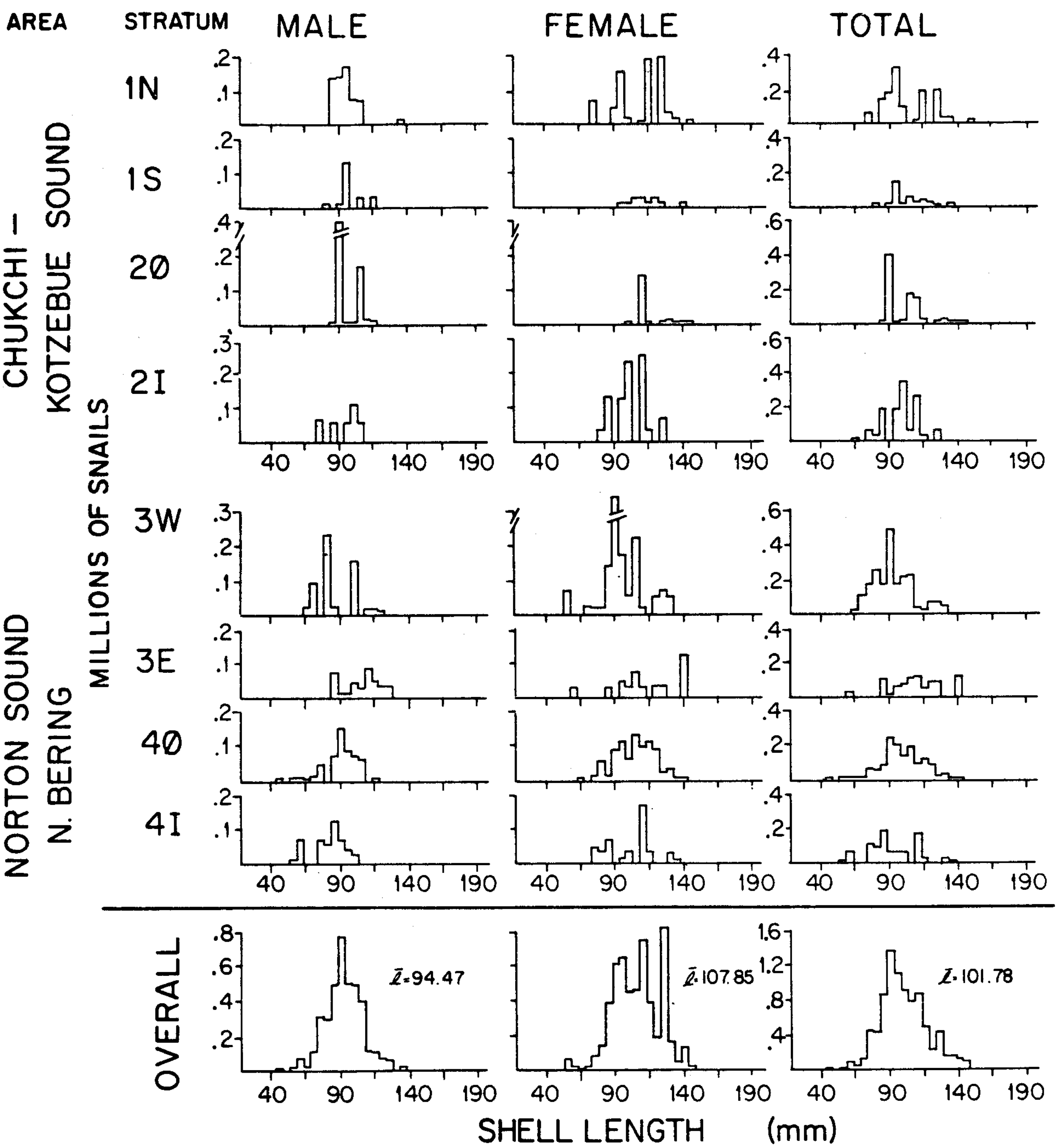


Figure VIII-115.--Size composition by sex and stratum for <u>Beringius beringii</u> in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Pyrulofusus deformis

Distribution and abundance--P. deformis was infrequently encountered during the survey, occurring at only 17% of the stations sampled (Table VIII-74) and accounting for less than 3% of the total snail biomass. Its distribution was fairly localized (Figures VIII-116 and 117) with highest catch rates occurring in the northern Bering Sea (strata 3E and 3W). Only trace amounts were encountered in most of the remaining survey area with no catches obtained in the southern portion of the Chukchi Sea (stratum 1S). Overall, the average catch rate for the entire survey area was less than 0.1 kg/km trawled.

The apparent biomass of P. deformis was estimated at 526 mt (95% confidence interval 211-913 mt) for the entire survey area. Most (70%) of this amount was located in strata 3W and 3E combined. These strata also contained the majority (65%) of the total population estimate of about 3.4 million snails.

Table VIII-74.--Estimated biomass and population size of Pyrulofusus deformis in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Strata	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population ($X10^3$)	Proportion of total estimated population	Mean weight per individual (kg)
Southeastern Chukchi Sea and Kotzebue Sound							
1N	6.9	0.048	82	.145	863	.164	.095
1S	--	--	--	--	--	--	--
2Ø	5.3	0.056	24	.043	427	.081	.057
2I	25.0	0.074	23	.040	287	.055	.078
Norton Sound and Northern Bering Sea							
3W	34.4	0.108	237	.422	2,255	.430	.105
3E	21.4	0.258	158	.282	1,141	.218	.139
4Ø	20.7	0.024	33	.059	238	.045	.139
4I	11.8	0.008	5	.008	33	.006	.145
All strata combined:	17.2 2/	0.067	562 3/		5,244 3/		.108

1/ Mean catch per unit effort, kg/km trawled
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: biomass--211 - 913 mt; population--2,115,000 - 8,373,000.

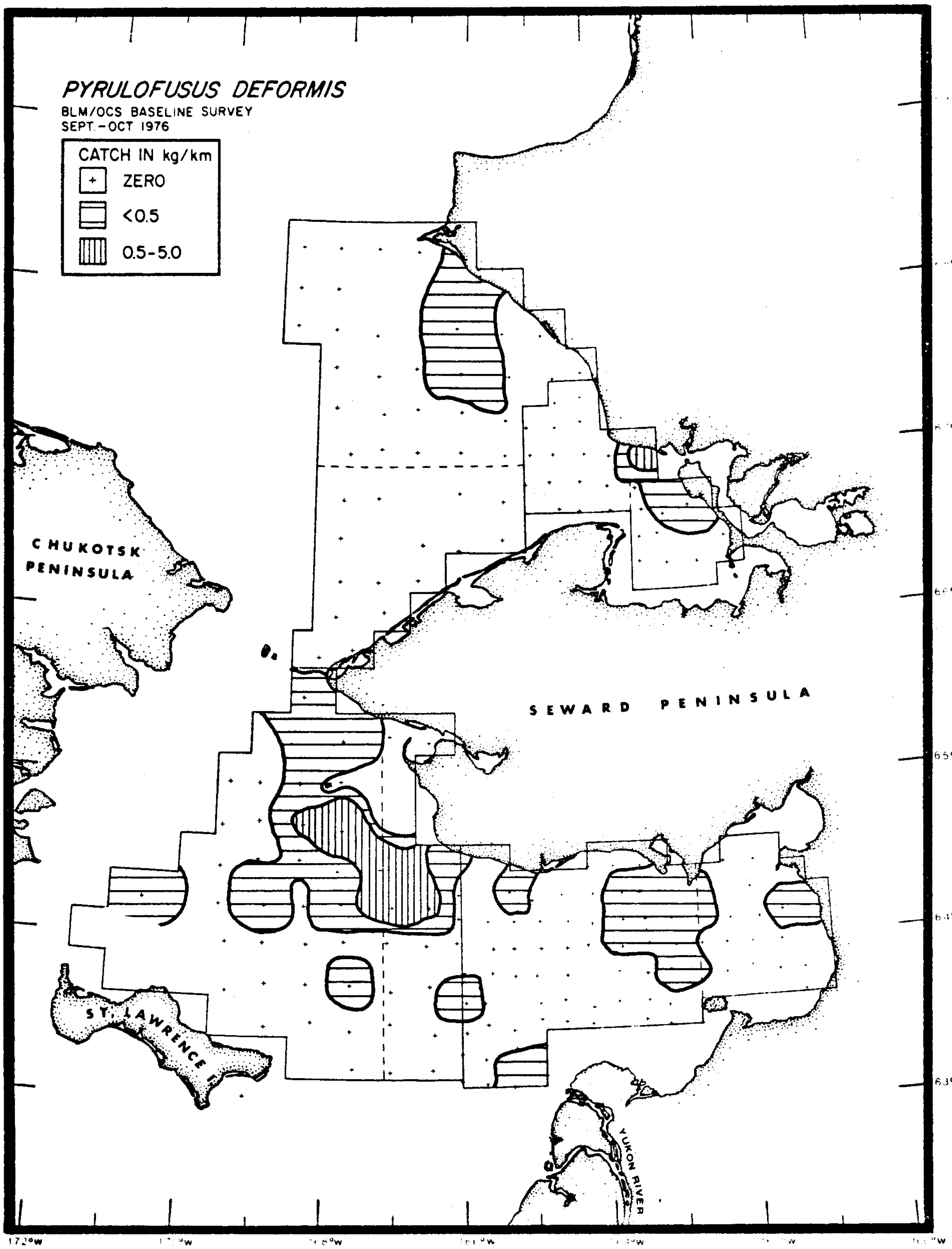


Figure VIII-116.--Distribution and relative abundance by weight of *Pyrulofusus deformis* in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

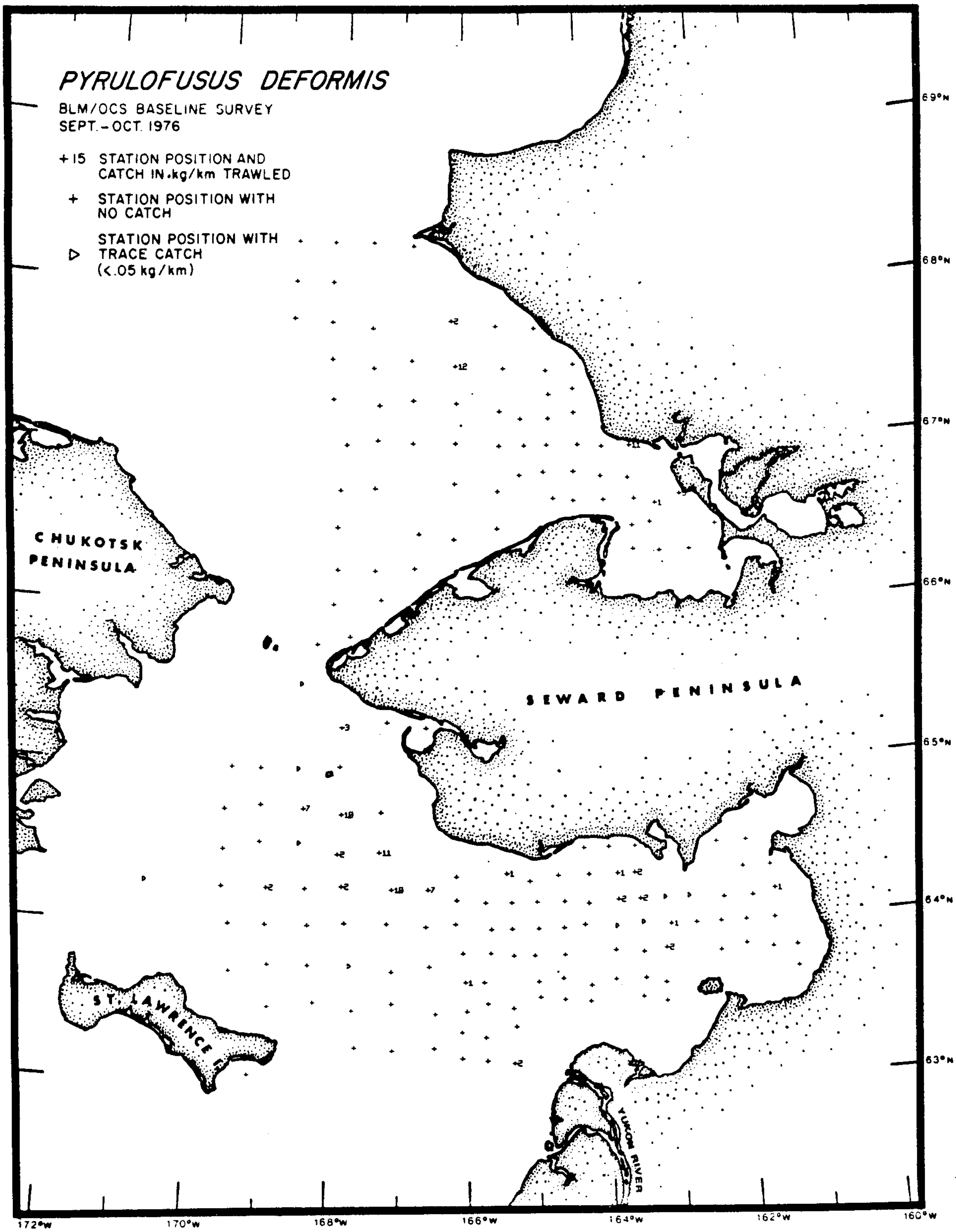


Figure VIII-117.--Distribution of catch rates by weight of Pyrulofusus deformis in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Size composition, mean length and weight--P. deformis collected during the survey ranged from 52-157 mm in shell length. Females were slightly larger than males, averaging 109.5 mm compared to 102.5 mm (Figure VIII-118). By size groups, intermediate - sized males and females (90-115 mm) were the most abundant groups in the survey area, together comprising 82% of the total estimated population (Table VIII-75).

The average size of P. deformis was markedly different north and south of Bering Strait. In strata 1N, 1S, 2I, and 2Ø, average shell length ranged from 78-98 mm and the average weight was about 77 gm. South of Bering Strait in strata 3W, 3E, 4Ø, and 4I, mean shell sizes ranged from 108-122 mm and individuals were much heavier, weighing an average of 132 gm.

Table VIII-75.--Estimated population ($x10^5$) of Pyrulofusus deformis by stratum, sex and size group[1/] in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

	MALES				FEMALES				
Stratum	<90mm	90-115mm	>115mm	Total	<90mm	90-115mm	>115mm	Total	Sexes combined
Southeastern Chukchi Sea and Kotzebue Sound									
1N	1.0	6.1	—	7.0	—	1.2	—	1.2	8.2
1S	—	—	—	—	—	—	—	—	—
2Ø	—	1.4	—	1.4	2.8	—	—	2.8	4.2
2I	2.7	—	—	2.7	1.6	1.4	0.5	3.4	6.1
Norton Sound and northern Bering Sea									
3W	0.9	7.9	0.2	9.0	0.2	6.1	4.8	11.0	20.1
3E	0.5	1.0	2.2	3.6	0.2	1.7	2.7	4.6	8.2
4Ø	0.3	0.6	0.1	1.0	—	0.3	0.5	0.9	1.9
4I	—	—	—	—	—	0.3	T	0.3	0.3

1/ Shell length (mm).

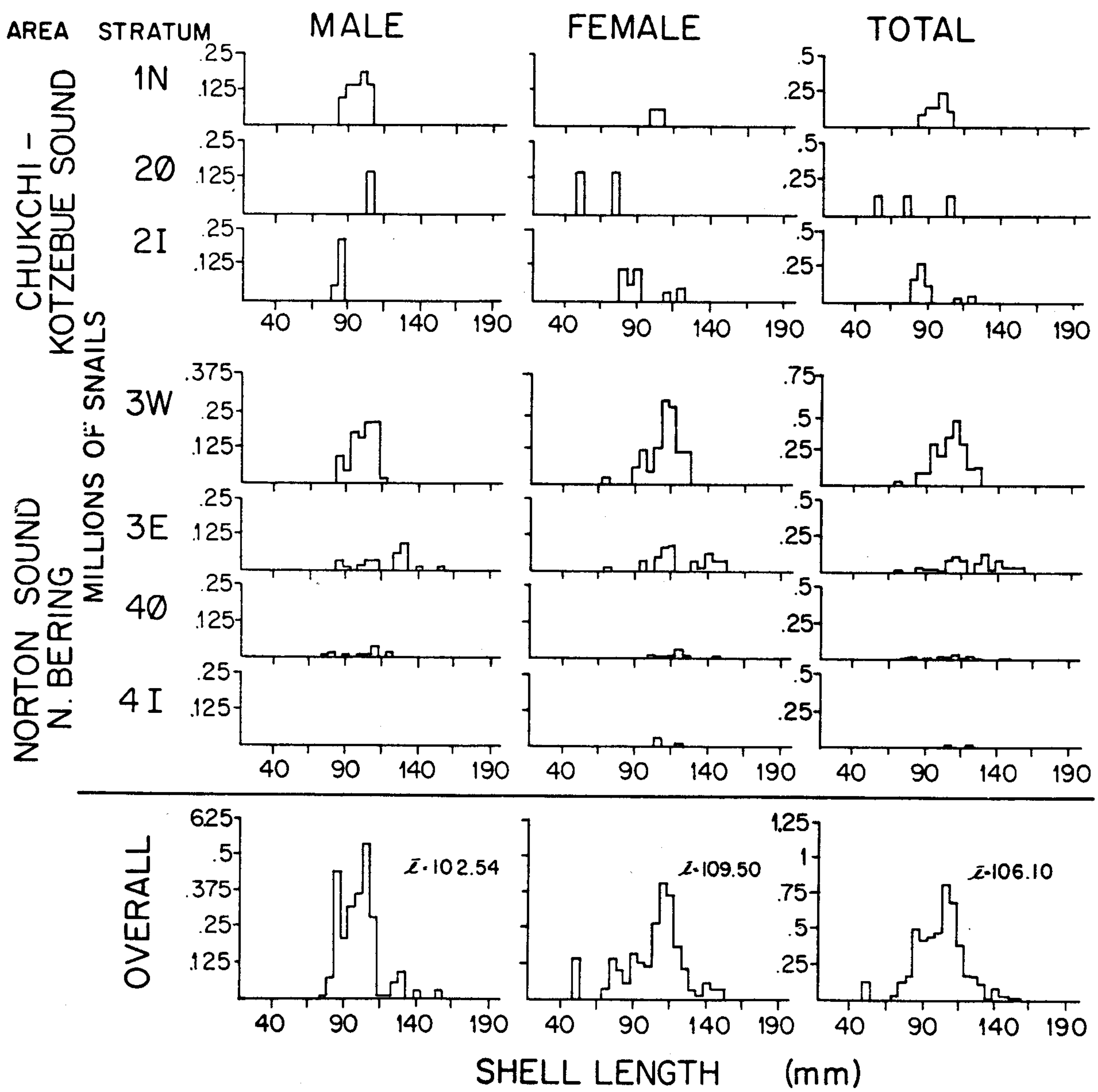


Figure VIII-118.--Size composition by sex and stratum for Pyrulofusus deformis in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

RESULTS OF THE GILLNET SURVEY

A total of 33 gillnet stations were completed during the survey. These included 22 stations located throughout the survey region (Figure VIII-119) to qualitatively determine the general distribution of common near-surface fish species. The remaining 11 were made in an attempt to determine the relative catchability of the gillnets by day and night as well as establish whether 2, 4, or 8 hour soak-times were the most effective means of obtaining (and retaining) fish.

Analysis of day-night and variable-time gillnet sets was not performed because extremely small catches were obtained during those sets.

All gillnet operations proved most unproductive. Catches were small, ranging from approximately 70 fish to no catch. Individual gillnet station catches are listed in Appendix C. Gillnet sets made in the shallower inshore areas of the survey region generally caught more fish than those made over deeper, offshore waters. All fish were taken in the smaller mesh sizes, i.e., 21-42 mm mesh. The 42 mm shackle caught the greatest amounts of all mesh sizes.

Of the 12 fish species obtained during gillnet operations (Table VIII-76), Pacific herring was by far the most abundant, occurring in 45% of all sets and comprising over 68% of all fish caught by gillnet. Largest catches occurred in Kotzebue Sound (Figure VIII-120).

Table VIII-76.--Numbers of fish by species taken by various mesh sizes during gillnet operations in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

SPECIES	STRETCHED MESH SIZE (mm)							Total
	21	35	42	64	83	114	113	
CLUPEIDAE								
Pacific herring	13	69	114					196
OSMERIDAE								
Toothed smelt	40	2	2					44
Pond smelt	1							1
SALMONIDAE								
King salmon		3	2					5
Chum salmon			1	1		2	2	6
Arctic char			8	1				9
Bering cisco					3			3
Pink salmon	1	6	1					8
PLEURONECTIDAE								
Starry flounder				1		1		2
COTTIDAE								
Arctic staghorn sculpin				1	1			2
Myoxocephalus spp.		2	2	1				5
GADIDAE								
Saffron cod		1	2	2				5
TOTAL	55	83	132	7	4	3	2	286

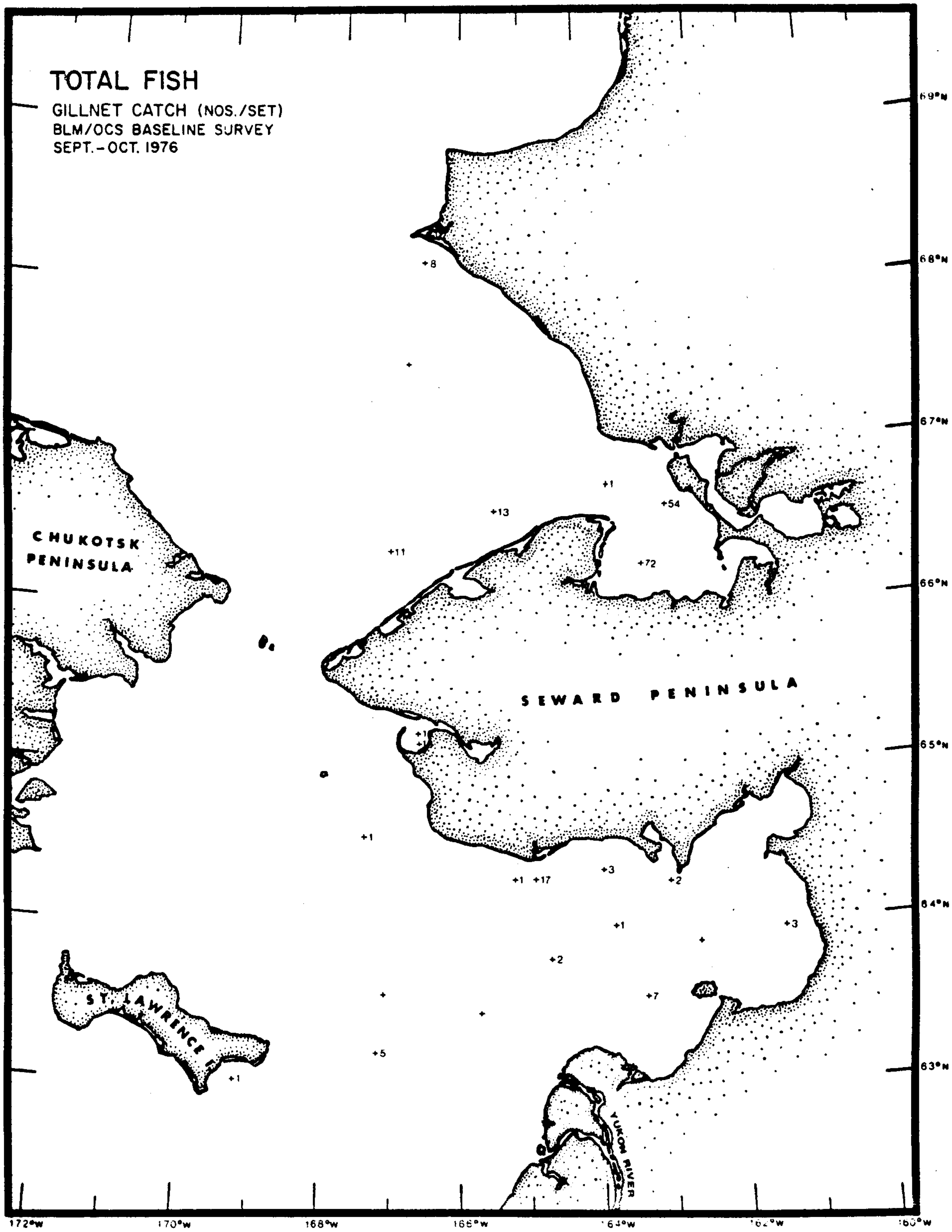


Figure VIII-119.--Gillnet sites (+) and total number of fish caught per site during 1976 BLM/OCS survey of Norton Sound, the southeastern Chukchi Sea and adjacent waters.

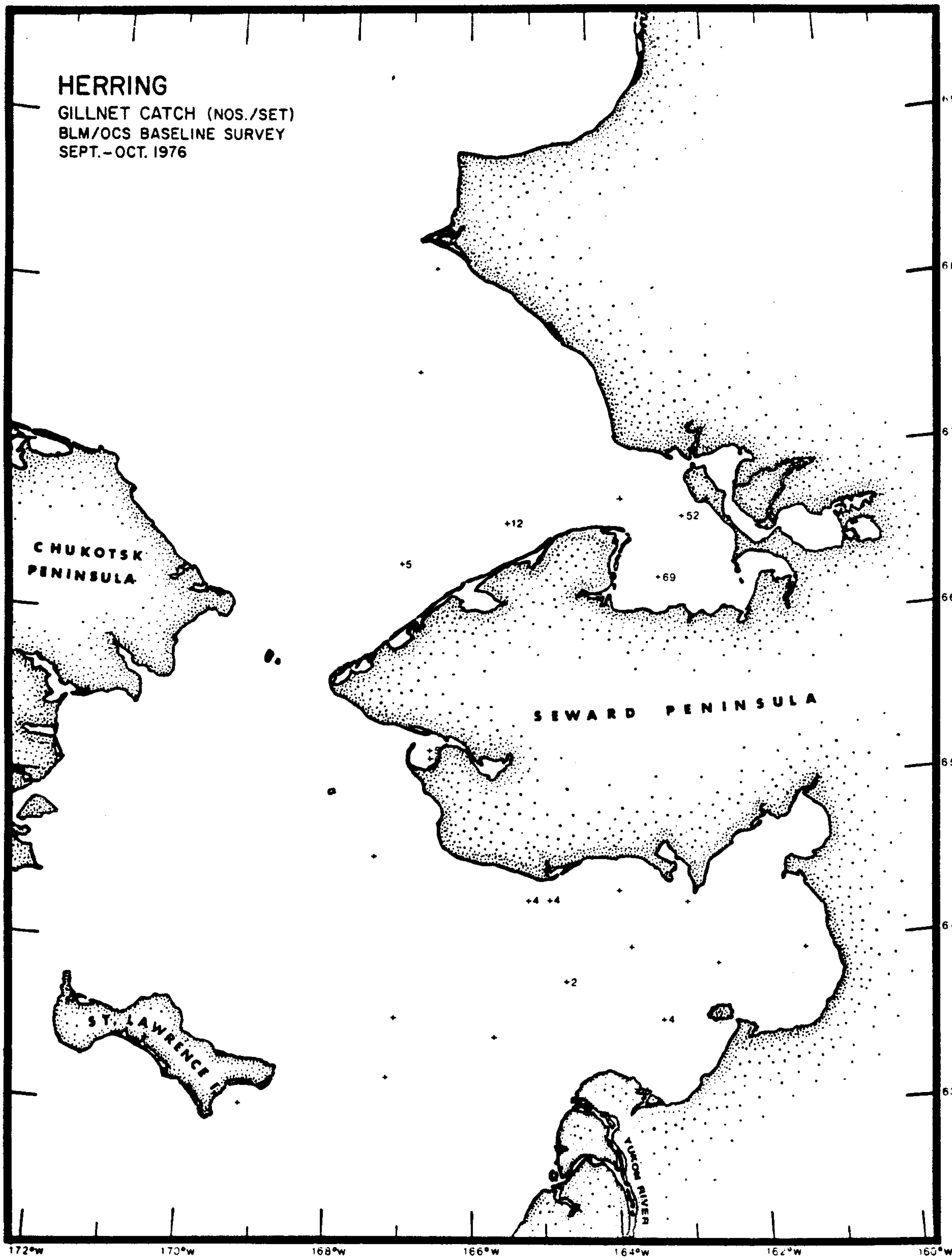


Figure VIII-120.--Numbers of Pacific herring caught at gillnet stations in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Size of Pacific herring captured varied, of course, by mesh size (Figure VIII-121). Pacific herring taken in the 21 mm shackle ranged in length from 9-18 cm and averaged about 13.8 cm. Fish caught with the 35 and 42 mm mesh nets had similar size ranges (15-24 cm and 16-24 cm, respectively), as well as average lengths (18.8 cm and 20.3 cm, respectively). Overall, the mean size of Pacific herring caught in the gillnets was about 19.4 cm, over 1.5 cm larger than the average size caught in the demersal trawls.

Toothed smelt was the second-most abundant species encountered in the gillnets. It occurred in 27% of the sets, mostly in more nearshore areas (Figure VIII-122), and accounted for about 15% of all fish caught. Again, all individuals were captured with the three smallest-sized meshes (Table VIII-76) with the 21 mm shackle accounting for over 90% of all fish caught. Overall, sizes ranged from 12 to 24 cm and averaged nearly 15.7 cm (Figure VIII-121), slightly more than trawl-caught fish.

Arctic char and pink, chum, and king salmon, four members of the family Salmonidae, were the third through sixth-most abundant species encountered during the gillnet operations. None of these species, however, had a total survey catch exceeding nine individuals. The length, weight, sex, and age (when available) for each salmonid caught during the survey are presented in Table VIII-77. Gillnet set catches are indicated in Figure VIII-123.

Other species caught during gillnetting included pond smelt, Bering cisco, starry flounder, Arctic staghorn sculpin, shorthorn sculpin, and saffron cod.

In general, Pacific herring appeared to be the most abundant fish species occurring near the sea-surface in the survey region. The relative abundance of salmon may have been low since nearly the entire adult population had already completed their spawning migration into the river systems around the survey region. Information from the gillnet commercial fishery (Louis Barton, ADF&G, personal communication) suggests that gillnet surveys performed earlier in the season probably would have encountered substantial numbers of adult salmon (and char).

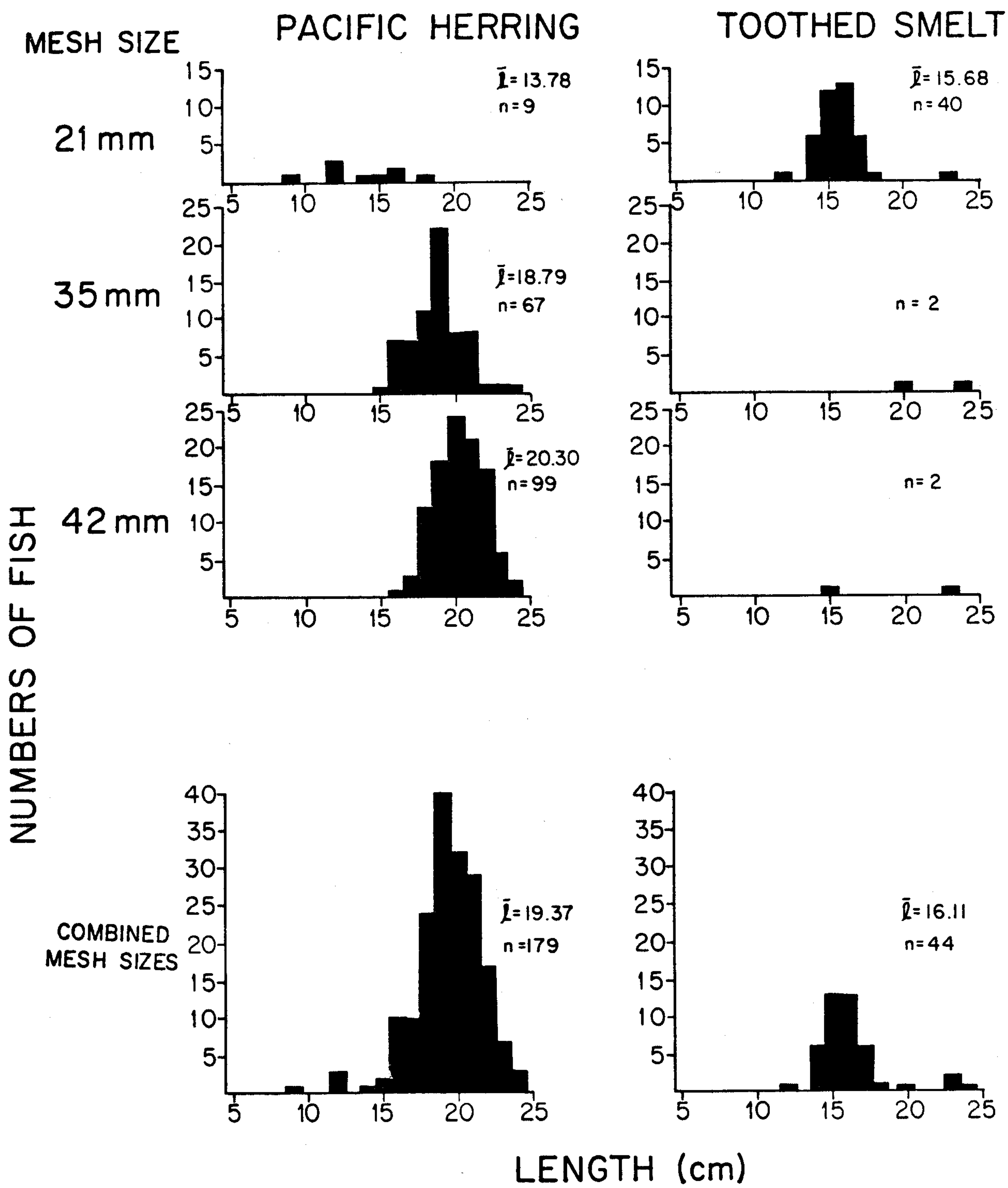


Figure VIII-121.--Size composition by mesh size for Pacific herring and toothed smelt caught by gillnets in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

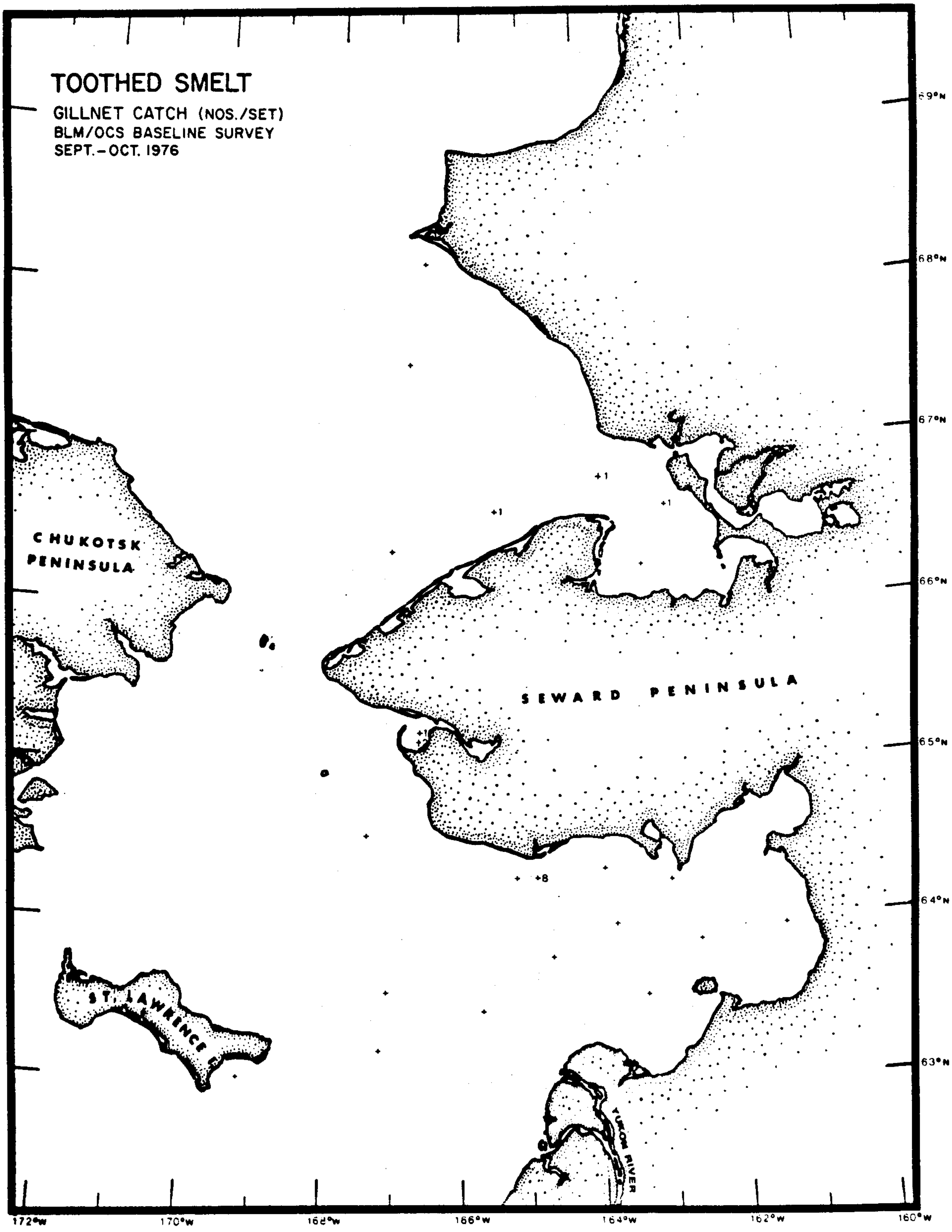


Figure VIII-122.--Numbers of toothed smelt caught at gillnet stations in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

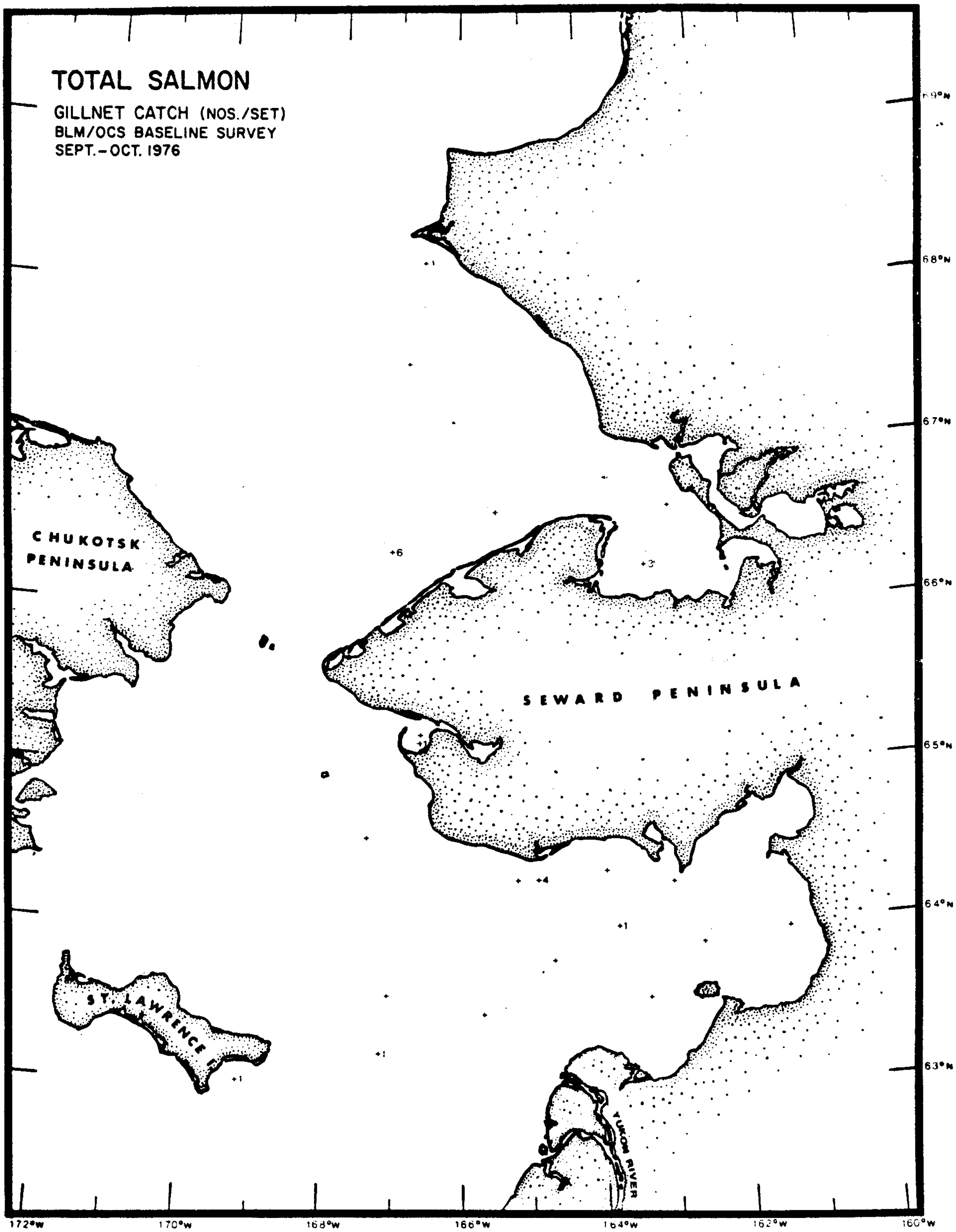


Figure VIII-123.--Numbers of salmon (all species combined) caught at gillnet stations in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Table VIII-77.--Age, length, and weight by sex of members of family Salmonidae captured by gillnets in Norton Sound and the southeastern Chukchi Sea (BLM/OCS survey, 1976).1/

Species	Sex	Length (cm)	Weight (kg)	Age
Chum salmon	Female	56.0	2.800	0.2 2/
"	"	60.5	3.550	0.3
"	"	61.0	3.600	0.3
"	Male	61.0	3.600	0.3
"	"	63.6	4.200	0.4
"	Juvenile	17.8	0.053	0.0
King salmon	Juvenile	22.1	0.133	1.0
"	"	18.3	0.053	1.0
"	"	22.6	0.121	2.0
"	Female 3/	77.9	6.700	1.3
Pink salmon	Juvenile	16.8	0.056	0.0
"	"	22.5	0.121	—
Bering cisco	Female	35.3	0.505	—
"	"	37.0	0.607	—
"	Male	34.6	0.531	—
Arctic char	Female	25.3	0.177	—
"	"	25.3	0.150	—
"	Male	24.2	0.116	—
"	"	24.2	0.116	—
"	"	25.9	0.180	—
"	"	24.5	0.157	—
"	"	24.6	0.155	—
"	"	25.9	0.185	—
"	"	25.5	0.163	—

1/ Small juveniles of some species were unmeasurable because they were damaged when removed from the gillnet.

2/ Freshwater annuli • Ocean annuli.

3/ Trawl caught.

RESULTS OF THE PELAGIC SURVEY

Hydroacoustical sounding revealed no extensive off-bottom fish concentrations. Time limitations and equipment malfunctions restricted pelagic trawl operations and resulted in only 8 sets (Figure VIII-124) for the entire survey.

Catches were extremely small and provided limited qualitative information. The largest pelagic trawl catch (15 fish) occurred near the entrance to Kotzebue Sound and included toothed smelt, saffron cod, Arctic char, and juvenile pink salmon.

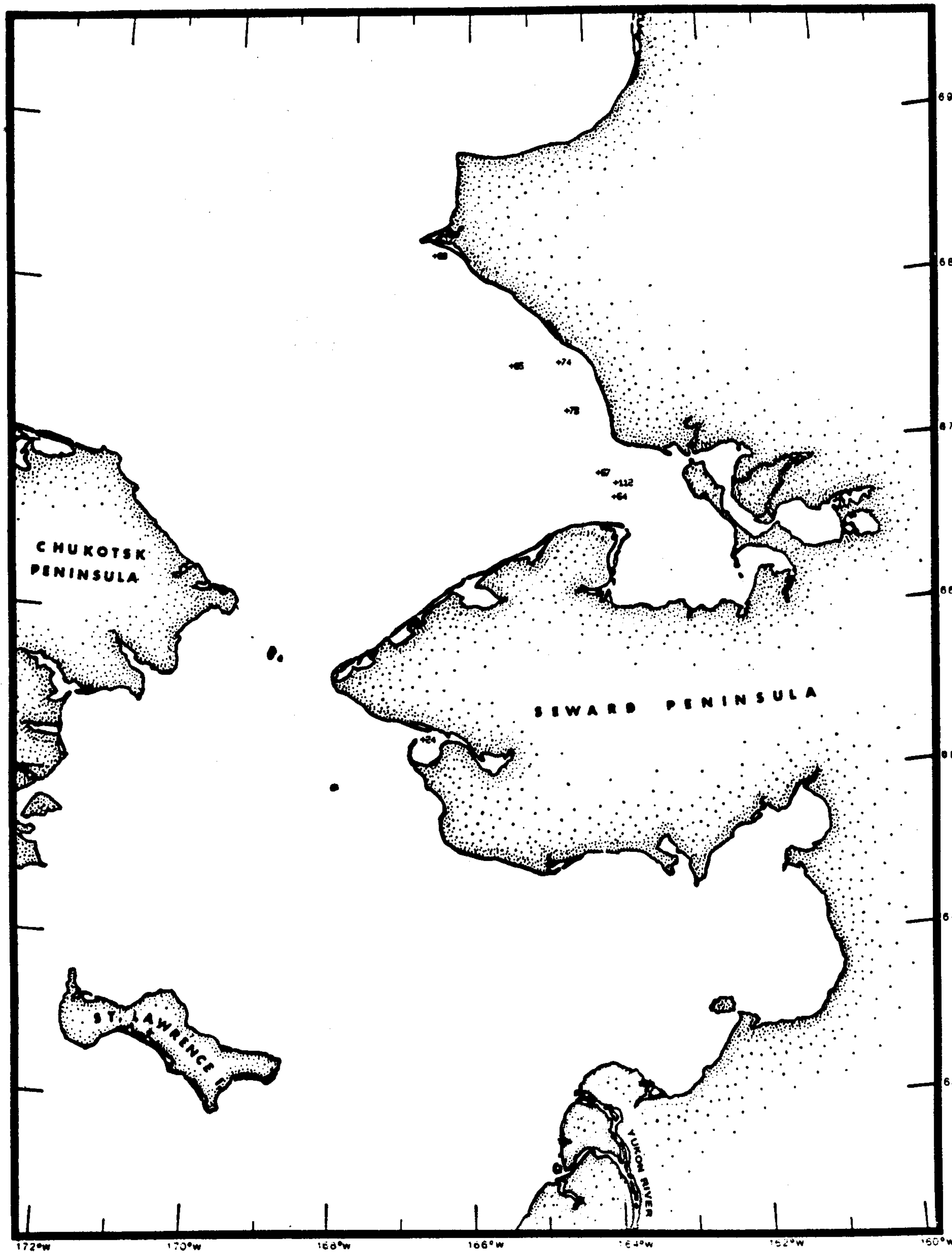


Figure VIII-124.--Pelagic trawl stations in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

IX

FISH AND SHELLFISH RESOURCE INFORMATION FROM HISTORICAL SURVEYS

Prior to the 1976 survey, only three investigations were made which provided information on the distribution and abundance of fish and/or shellfish in or near the 1976 BLM/OCS study area. These were: an exploratory fishing survey by the Soviet Union in Siberian waters of the Bering and Chukchi Seas in 1933-34 (Andriyashev, 1937); an exploratory fishing survey by the U.S. Fish and Wildlife Service in Norton Sound and north of St. Lawrence Island in 1948-49 (Ellson et al., 1950); and, AEC sponsored studies (Project Chariot) of the Cape Thompson region in 1959 (Wilimovsky, 1966). Data from the 1933-34 and 1948-49 investigations were too general to be of use as baseline material, while the AEC studies provided a considerable amount of earlier information on marine fish and invertebrates for Alaskan waters north of the Bering Sea. Sparks and Pereyra (1966) and Abbott (1966) described the invertebrate fauna from the AEC survey, and studies of the marine fish community were documented by Alverson and Wilimovsky (1966). Although the quantity of fish taken during the AEC study was quite limited (less than 200 kg), a relatively substantial amount of abundance, distribution, and size composition information was obtained. Unfortunately, little or no detailed abundance and size composition data were reported for the invertebrates. Additionally, much of the area examined during the AEC work was located north of our 1976 survey region. In as much as the AEC data provides about the only detailed assemblage of information on marine fish stocks of the far northern waters off Alaska, a review of these data should provide valuable comparisons with results from the 1976 BLM/OCS survey.

This section of our report presents a brief summary of information from the AEC Project Chariot studies on the distribution, abundance, and size and age composition for those fish species examined in detail during the 1976 survey.

Catches from the 1959 AEC work were recorded in numbers caught per trawl haul and very little age data were obtained. To provide some comparability between 1959 catch data and our study results, overall species catch rates were converted to kg/km trawled. This conversion to kg/km was performed by multiplying the overall average number caught by a mean weight per individual from the 1976 data and assuming a standard trawling distance of 2.5 nautical miles or 4.6 km/hr.

Approximations of the relative abundance of age groups were determined by applying age-length keys from the 1976 data to numbers of fish per size interval in the 1959 length-frequency samples. The assumptions used in converting the earlier data into a format comparable to the 1976 information are quite broad. It is felt however, that these conversions should provide reasonable estimates of general conditions observed during the AEC study.

Rank Order of Abundance of Fish and Invertebrates

Analysis of the demersal trawl and bottom dredge data from the AEC survey indicate that over 220 invertebrate and 40 marine fish species were encountered in the southeastern Chukchi Sea during July-August 1959.

Decapod crustaceans were the most abundant and frequently encountered invertebrate taxa in the region (Table IX-1). Representatives of this group were present in all but one of the demersal sites sampled and comprised an estimated 23% of all invertebrates captured. Dominant forms included crangonid and hippolytid shrimp and hermit and Tanner (C. opilio) crabs. Other components of the invertebrate community which were encountered at over half the stations sampled included: starfish, gastropod and pelecypod molluscs, amphipod crustaceans, ophiuroideans, annelid worms, anthozoan coelenterates, and ascidians. These other components accounted for an additional 58% of the total number of invertebrates caught.

Only three fish species, Arctic cod, Arctic staghorn sculpin, and Bering flounder were present in over half of the demersal trawl catches (Table IX-2). Other fish taxa encountered in several trawl catches (32 to 45%) included ribbed sculpin, unidentified eelpouts, and two cottid species from the genera Artidellus and Myoxocephalus. Of the twenty fish taxa most frequently encountered during the 1959 AEC study, seven were representatives of family Cottidae.

Distribution and Biological Features of Certain Fish Species

Arctic cod--Arctic cod was the most frequently encountered and by far the most abundant fish species captured during the 1959 trawl survey. It occurred in nearly 72% of the demersal trawl stations and comprised 59% of the total number of fish taken. Relatively high abundance (> 100 individuals/hour trawled) was found throughout a wide area from south of Pt. Hope to north of Cape Lisburne (Figures IX-1 and 2) with maximum catch rates approaching 2000 fish/hour. Relative abundance was fairly low with the southern portion of the area surveyed (Cape Thompson to the Seward Peninsula) having trawl catches never exceeding 50 fish/hour trawled. Overall, the average catch rate for the entire 1959 survey was slightly less than 59 fish/hour or, in terms of weight per distance, an estimated 0.20 kg/km trawled.

Size composition information from the AEC study indicated Arctic cod found in the southeastern Chukchi Sea during the summer of 1959 ranged in length from 9 to 31 cm and averaged 15.9 cm (Figure IX-3). Two modes were observed in the length frequency samples, at 10-13 cm and 15-20 cm. The latter mode included nearly 70% of all fish measured.

Comparisons of the 1959 size data with the 1976 survey north otolith area age-length key suggest that 1 to 6 year old Arctic cod were present in the AEC study area and age groups 2-4 were dominant. The dominant age groups comprised an estimated 87% of all individuals examined. Only 4% of the fish subsampled from the AEC catches appeared to be 1 year olds and no age group 0 Arctic cod were thought to be present.

Table IX-1.--Rank order by frequency of occurrence and relative abundance of the 20 most common invertebrate taxa in the southeastern Chukchi Sea (AEC survey, 1959). (Adapted from Sparks and Pereyra, 1966).

Rank	Taxon	Percent frequency of occurrence1/	Relative abundance index2/
1	Decapod crustaceans	98.6	5882.5
2	Starfish	77.0	2253.4
3	Gastropod molluscs	70.3	1064.5
4	Amphipod crustaceans	67.6	1039.0
5	Pelecypod molluscs	63.5	1422.5
6	Omphiuroidean echinoderms	62.2	2797.5
7	Annelid worms	56.8	2048.0
8	Anthozoan collenterates	56.8	1267.1
9	Ascidians	55.4	2715.0
10	Holothuroidean echinoderms	41.9	1354.0
11	Echinoidean echinoderms	32.4	922.5
12	Cirripedia crustaceans	32.4	625.0
13	Scyphozoa coelenterates	29.7	485.0
14	Bryzoans	27.0	377.7
15	Sponges	23.0	664.0
16	Hydrazoan coelentrates	21.6	286.4
17	Sipunculoidea (coelomate worms)	20.3	59.1
18	Nemertian worms	18.9	47.5
19	Isopod crustaceans	13.5	25.0
20	Amphineura molluscs	10.8	51.4

1/ Number of sampling stations (trawls or trawls and dredge): 74.

2/ Total number of animals present in all samples adapted from rank key presented by Sparks and Pereyra (1966).

Table IX-2.--Rank order by catch rate (numbers/trawl) and frequency of occurrence (percent) of the 20 most common fish taxa in the southeastern Chukchi Sea (AEC survey, 1959) (adapted from Alverson and Wilimovsky, 1966).

Rank	Taxon	CPUE 1/ (No./trawl)	Proportion of total CPUE 2/	Percent frequency of occurrence
1	Arctic cod	58.98	0.586	71.9
2	Arctic staghorn sculpin	10.58	0.105	68.4
3	Bering flounder	4.30	0.043	61.4
4	Capelin	4.04	0.040	22.8
5	*Artediellus* sp.	3.68	0.037	43.9
6	Ribbed sculpin	2.11	0.021	45.6
7	Toothed smelt	1.96	0.019	22.8
8	*Myoxocephalus* sp.	1.35	0.013	33.3
9	Saffron cod	1.32	0.013	24.6
10	Unidentified eelpouts	1.18	0.012	43.9
11	Unidentified snailfish	1.05	0.010	31.6
12	Sturgeon poacher	0.89	0.009	24.6
13	Leister sculpin	0.63	0.006	22.8
14	Slender eelblenny	0.60	0.006	24.6
15	Stout eelblenny	0.58	0.006	22.8
16	Yellowfin sole	0.54	0.005	14.0
17	*Triglops* sp.	0.53	0.005	14.0
18	Pacific herring	0.49	0.005	14.0
19	Unidentified sea poachers	0.46	0.005	28.1
20	Eyeshade sculpin	0.19	0.002	14.0

1/ Overall catch per unit effort, no./trawl. Total effort = 57 trawls.

2/ Proportion of total catch per unit effort, fish only. Total CPUE = 100.63 fish/1 hr. trawl haul.

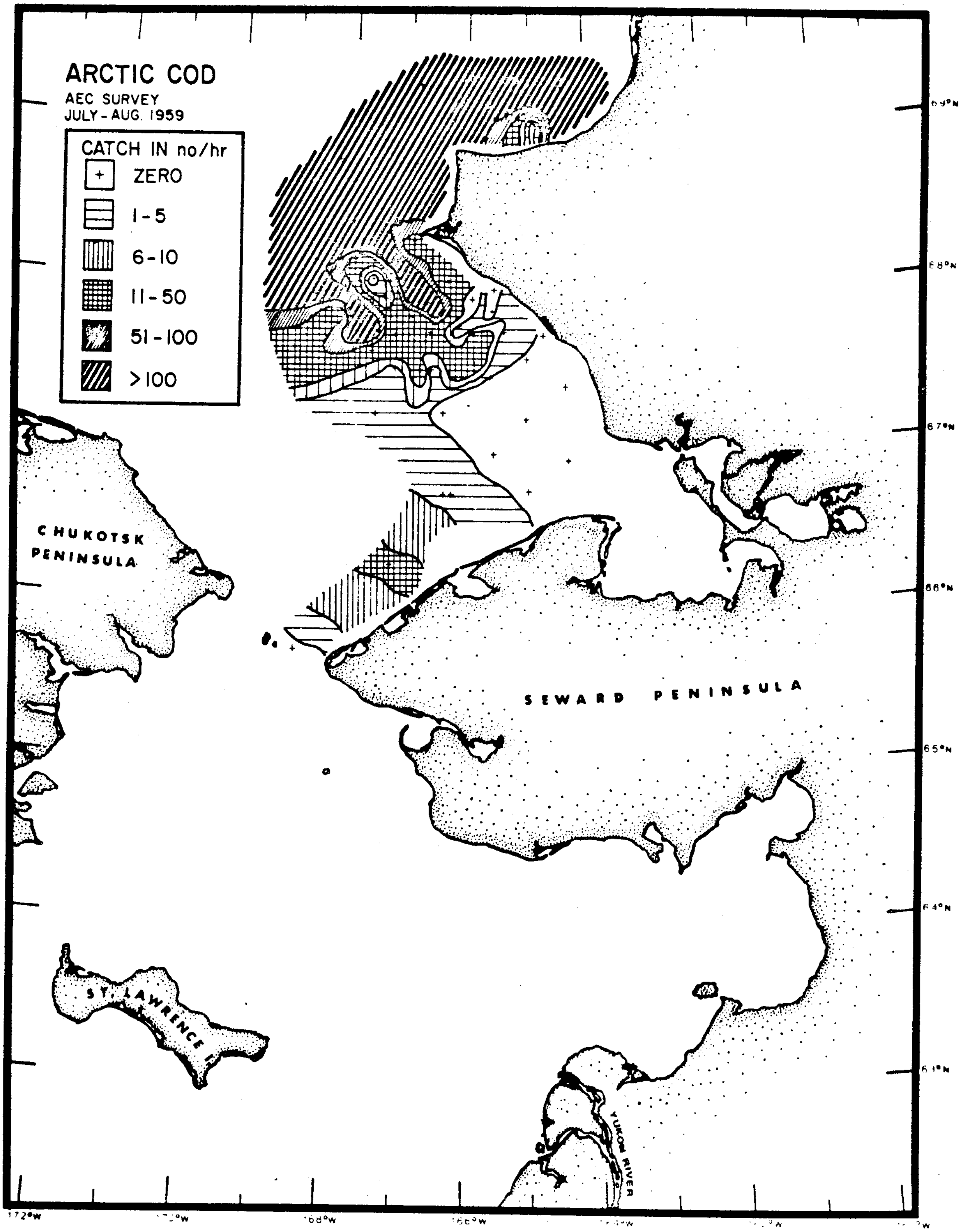


Figure IX-1.--Distribution and relative abundance by numbers of Arctic cod in the southeastern Chukchi Sea during 1959.

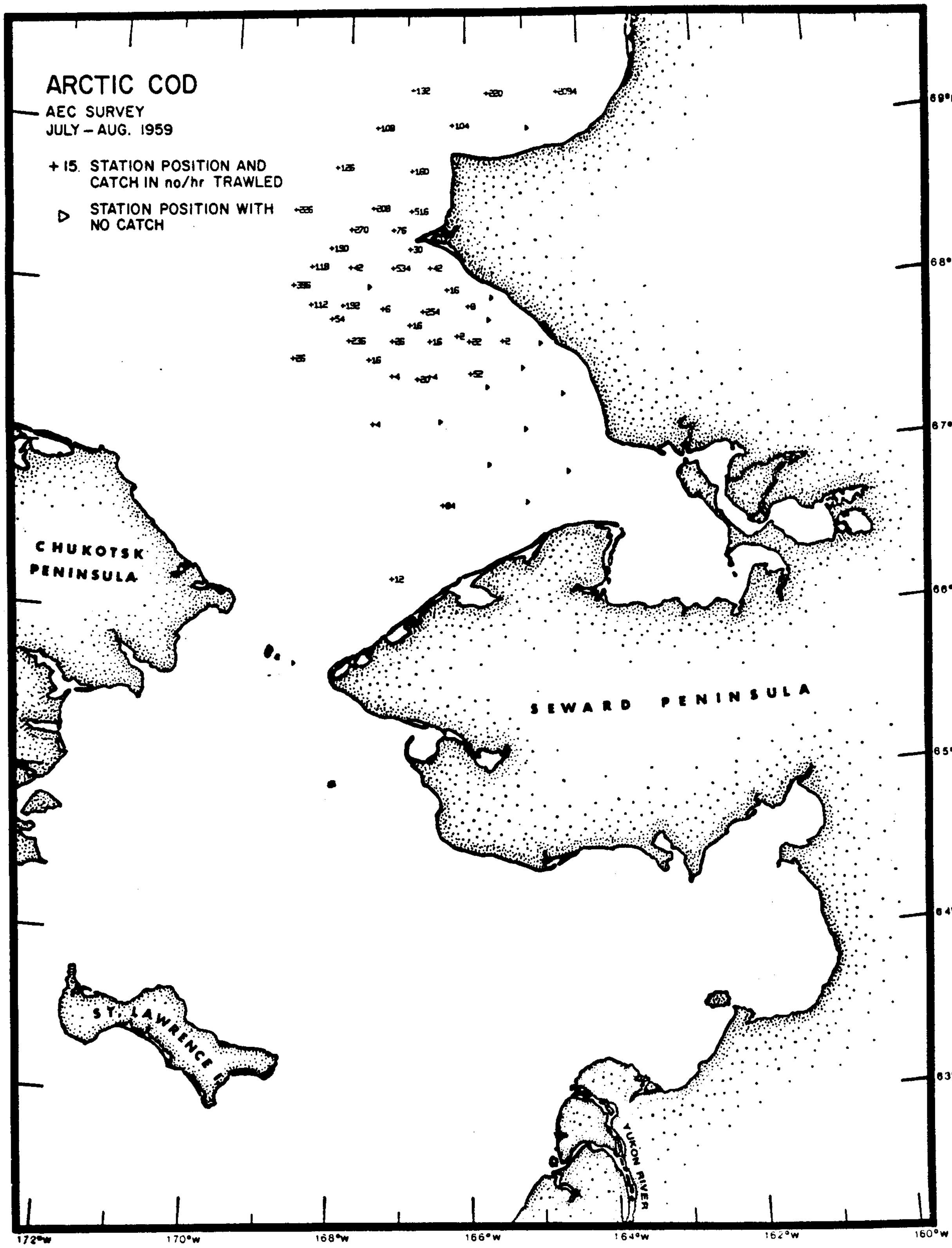


Figure IX-2.--Distribution of catch rates by numbers of Arctic cod in the southeastern Chukchi Sea during 1959.

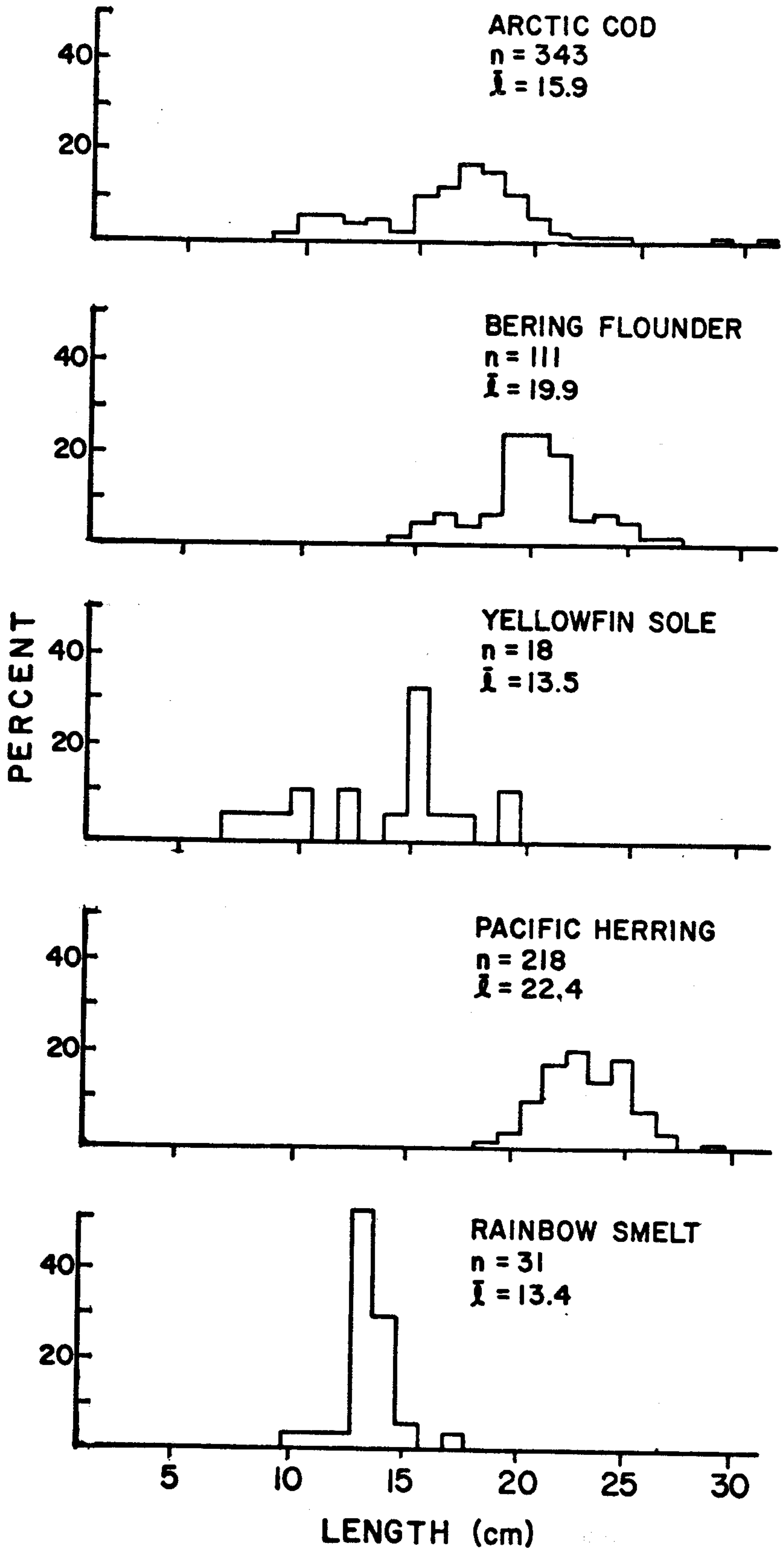


Figure IX-3.--Size composition and mean size for five fish species encountered during the 1959 AEC survey of the southeastern Chukchi Sea. (Adapted from Alverson and Wilimovsky, 1966).

Bering flounder--This pleuronectid was the third-most abundant fish species encountered in 1959, and occurred at over 61% of all stations sampled. Even though only two other species were captured in greater total numbers, the entire Bering flounder catch during the AEC survey was merely 252 fish, or 4% of the total number caught. Highest relative abundance was located off Pt. Hope (Figures IX-4 and 5). Overall, the average catch rate for this species was only 4.3 fish/hour trawled or, in terms of weight caught per distance, 0.08 kg/km. Pruter and Alverson (1962) indicated that during the 1959 study, most Bering flounder catches were associated with areas of relatively low temperature (2.6-3.6°C) and depths greater than 44 m.

Bering flounder measured during the 1959 survey of the southeastern Chukchi Sea ranged between 14 and 26 cm in length and averaged 19.9 cm (Figure IX-3). Most fish (64%) were in the 19-21 cm size range. Pruter and Alverson (1962) indicated an overall range in age of 6 to 13 years for Bering flounder in the AEC catches with individuals in the 19-21 cm size interval being mostly 8 and 9 year olds. Additionally, nearly all specimens were mature. This seems to contradict statements made earlier by Andriyashev (1937) regarding Bering flounder obtained during 1933-34 Soviet surveys of the Chukchi Sea. All specimens obtained during the Soviet studies were juveniles and ranged in length from 6 to 16 cm. Differences between the samples obtained during the AEC work and Soviet investigations probably were due to differing survey areas. The very early data described by Andriyashev (1937) came from Asian waters of the Chukchi Sea, a region known to possess colder water temperatures than those found off the coast of Alaska.

Toothed smelt--Very few toothed smelt were taken in the southeastern Chukchi Sea during the 1959 trawl survey. Of those fish encountered, all were found in the shallow nearshore stations and highest relative abundance occurred off the entrance to Kotzebue Sound (Figure IX-6). Size of toothed smelt in the AEC catches ranged only from 10-17 cm with an average length of 13.4 cm (Figure IX-3). Based on a comparison of the 1959 size data with 1976 age length keys, toothed smelt captured during the AEC study probably ranged in age from 3 to 7 years and an estimated 84% of all fish examined were age groups 4 and 5.

Saffron cod--Only 75 specimens of saffron cod were encountered during the entire AEC survey, and no size composition information was obtained. Of those fish taken, nearly all were found in shallow nearshore areas with highest concentrations located between Cape Lisburne and Pt. Hope, north of Kotzebue Sound (Figure IX-7). Fish were rarely encountered at trawl stations where depths exceeded 25 m. Since no length frequency data was obtained, no inference can be made regarding size and age composition.

Pacific herring--Very small catches of Pacific herring were encountered during the 1959 trawl survey. Highest relative abundance occurred nearshore, especially off Cape Thompson (Figure IX-8), but catch rates never exceeded 30 fish/hour trawled. Although demersal trawl catches were quite limited, a gillnet station, also near Cape Thompson, yielded an estimated 1000 herring, the largest catch taken by any of the survey gears.

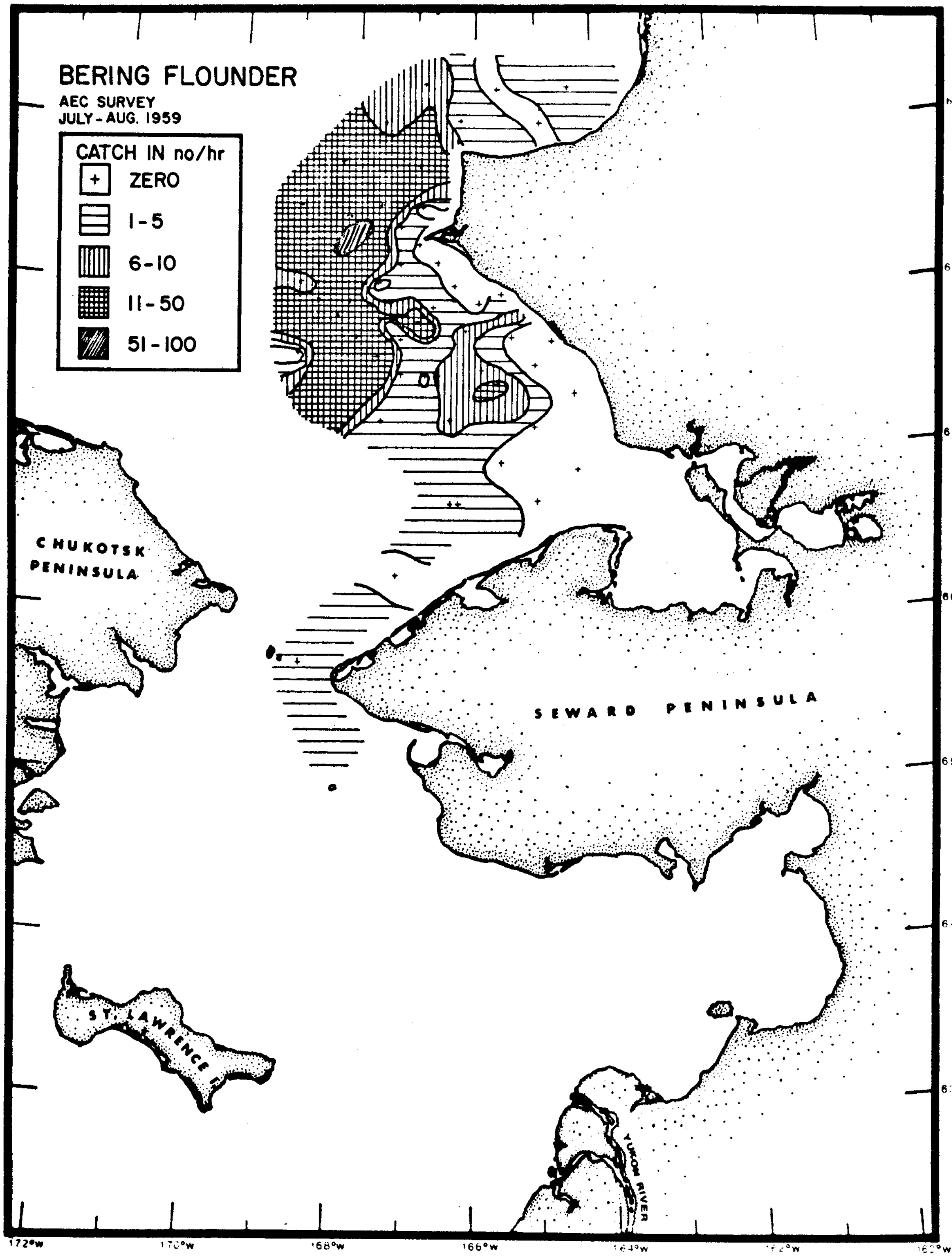


Figure IX-4.--Distribution and relative abundance by numbers of Bering flounder in the southeastern Chukchi Sea during 1959.

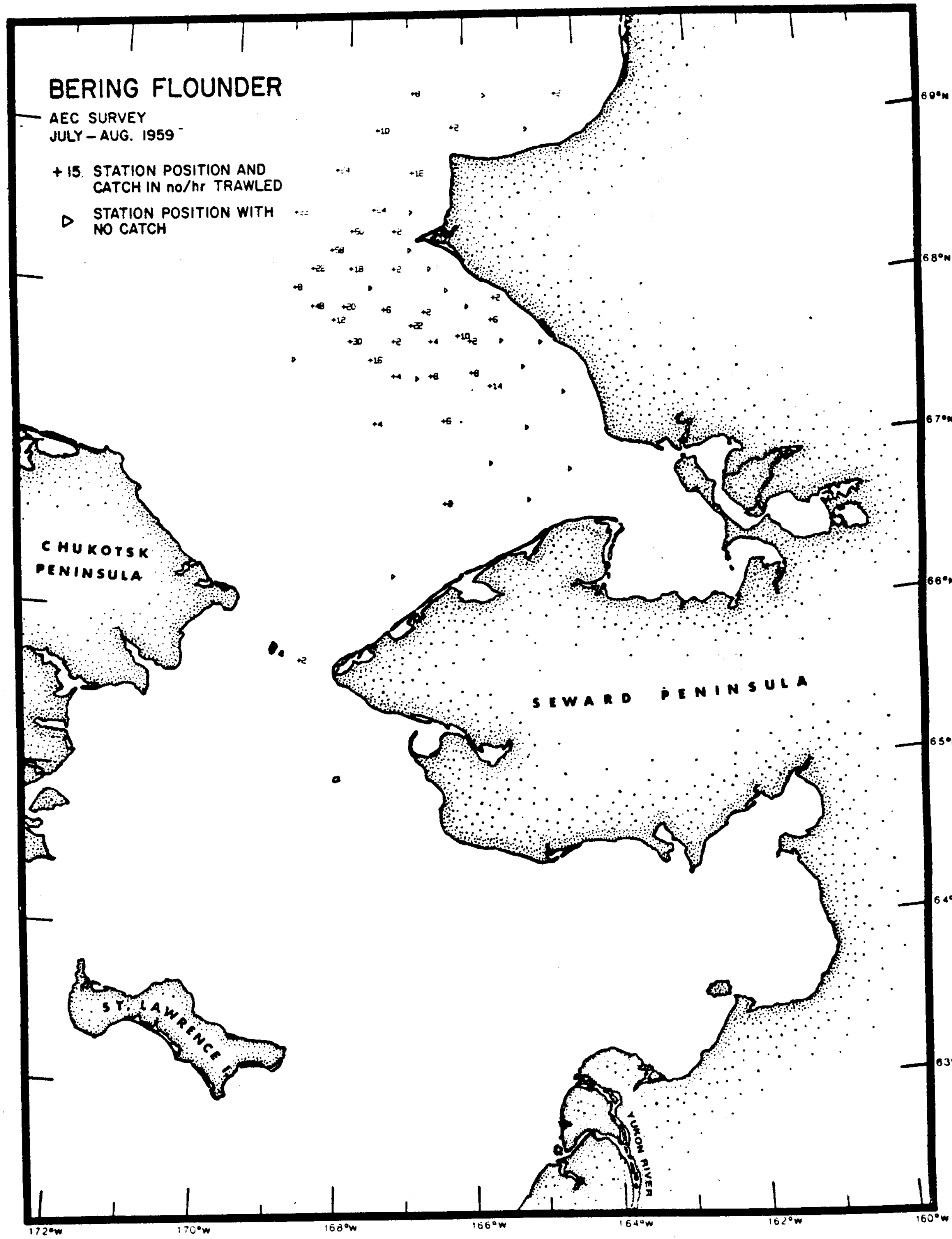


Figure IX-5.--Distribution of catch rates by numbers of Bering flounder in the southeastern Chukchi Sea during 1959.

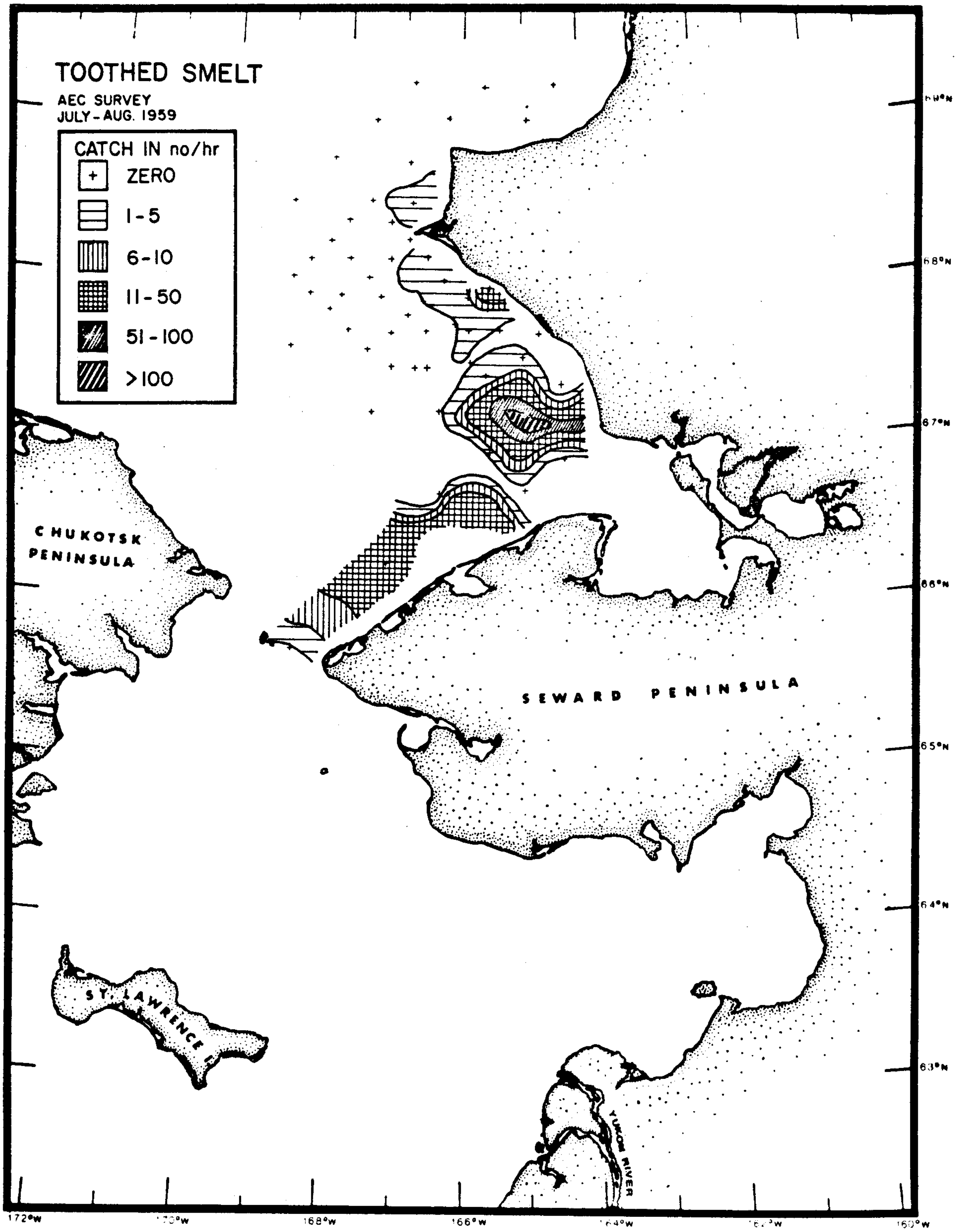


Figure IX-6.--Distribution and relative abundance by numbers of toothed smelt in the southeastern Chukchi Sea during 1959.

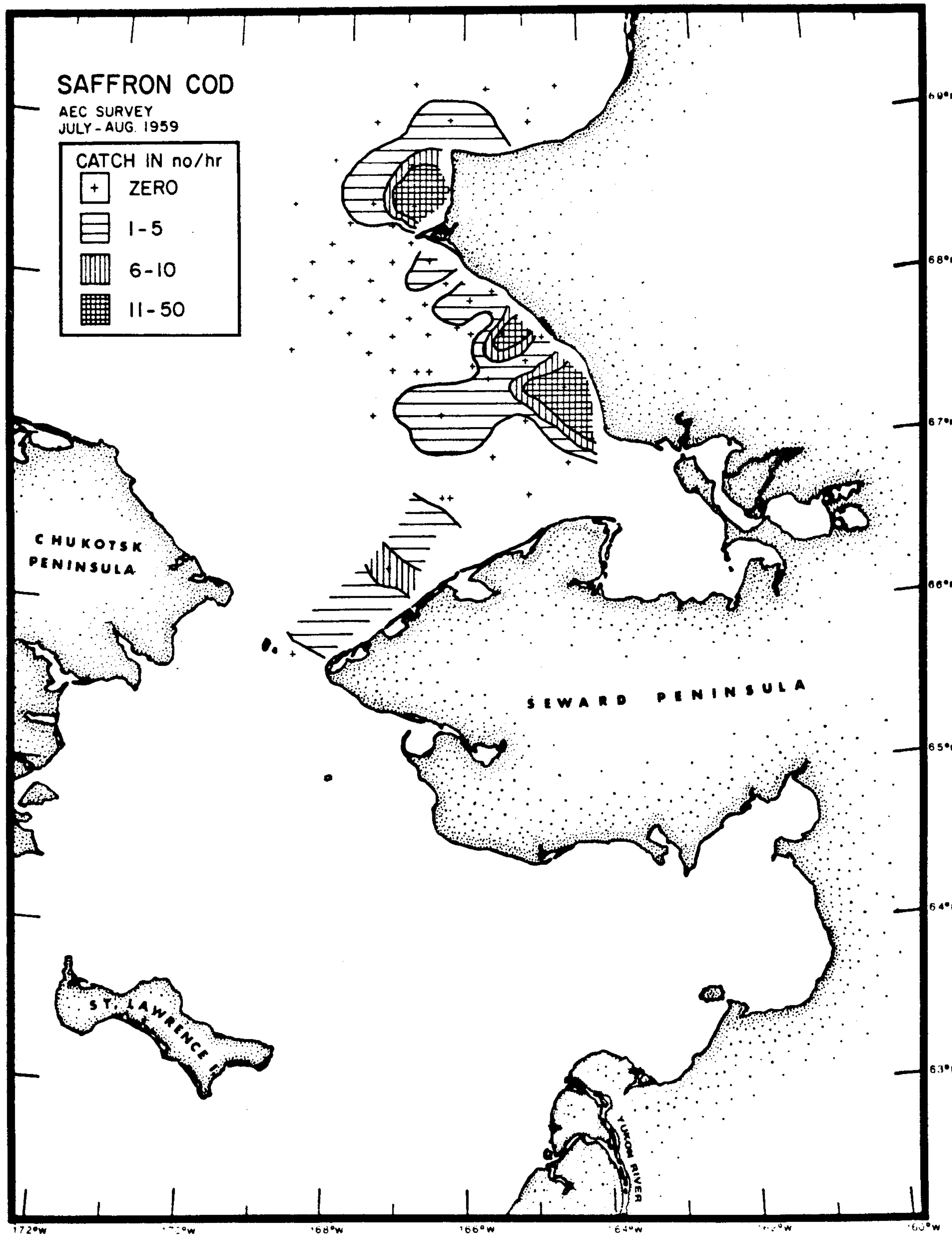


Figure IX-7.--Distribution and relative abundance by numbers of saffron cod in the southeastern Chukchi Sea during 1959.

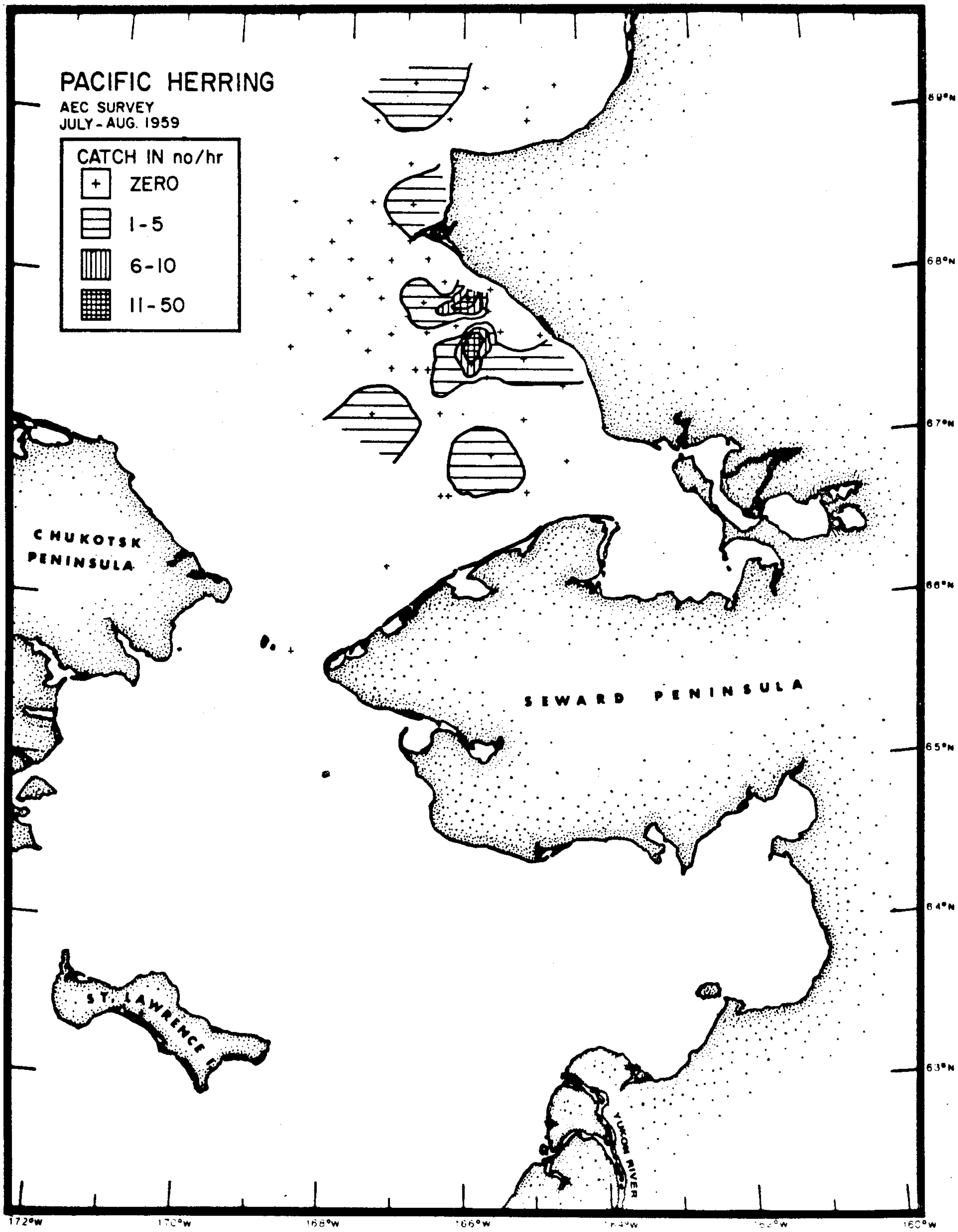


Figure IX-8.--Distribution and relative abundance by numbers of Pacific herring in the southeastern Chukchi Sea during 1959.

Sizes of trawl and gillnet caught fish, combined, ranged from 18 to 28 cm and averaged about 22 cm (Figure IX-3). A 1976 survey age-length key applied to the AEC samples suggests that ages ranged from 2 to 8 years with age groups 4-6 dominating.

Yellowfin sole--Only 31 individuals were taken during the AEC study. Most yellowfin sole were encountered in shallow, nearshore, warmer-water areas. Pruter and Alverson (1962) stated that during the 1959 study over 80% of all specimens were found at stations where depths ranged from 18 to 26 m and bottom temperatures exceeded 7°C.

Fish taken from the southeastern Chukchi Sea during 1959 were small, ranging from 7 to 19 cm in length and averaged about 13 cm (Figure IX-3). Age structures were obtained from 11 specimens and indicated a range in ages from 1 to 6 years.

X

SUMMARY

The 1976 BLM/OCS baseline demersal survey indicated a combined fish and invertebrate biomass of nearly 338,000 mt for the waters of Norton Sound, the southeastern Chukchi Sea, and adjacent areas. This amount seems quite substantial but in comparison to biomass estimates for other regions of the Alaska continental shelf, it is actually quite small. Results from the 1975 BLM/OCS survey of the eastern Bering Sea indicated a biomass approaching 5.9 million mt for that region (Kaimmer et. al., 1976). On a weight per area basis, the eastern Bering Sea demersal fish and invertebrate biomass averaged nearly 11.9 mt/km^2 while the biomass estimate for the Norton Sound-Chukchi Sea region averaged only 2.6 mt/km^2.

Biomass differences between our survey region and the eastern Bering Sea are even greater when specific components of the demersal community are compared. The primary purpose of both the 1975 and 1976 surveys was to intensively examine demersal fishes and shellfish of current or potential economic importance. These faunal elements comprised over 90% of the apparent biomass of the eastern Bering Sea (Figure X-1) but less than 25% of that estimated for our survey region, a nearly 60-fold difference in the magnitude of demersal fish and shellfish resources for the two continental shelf areas.

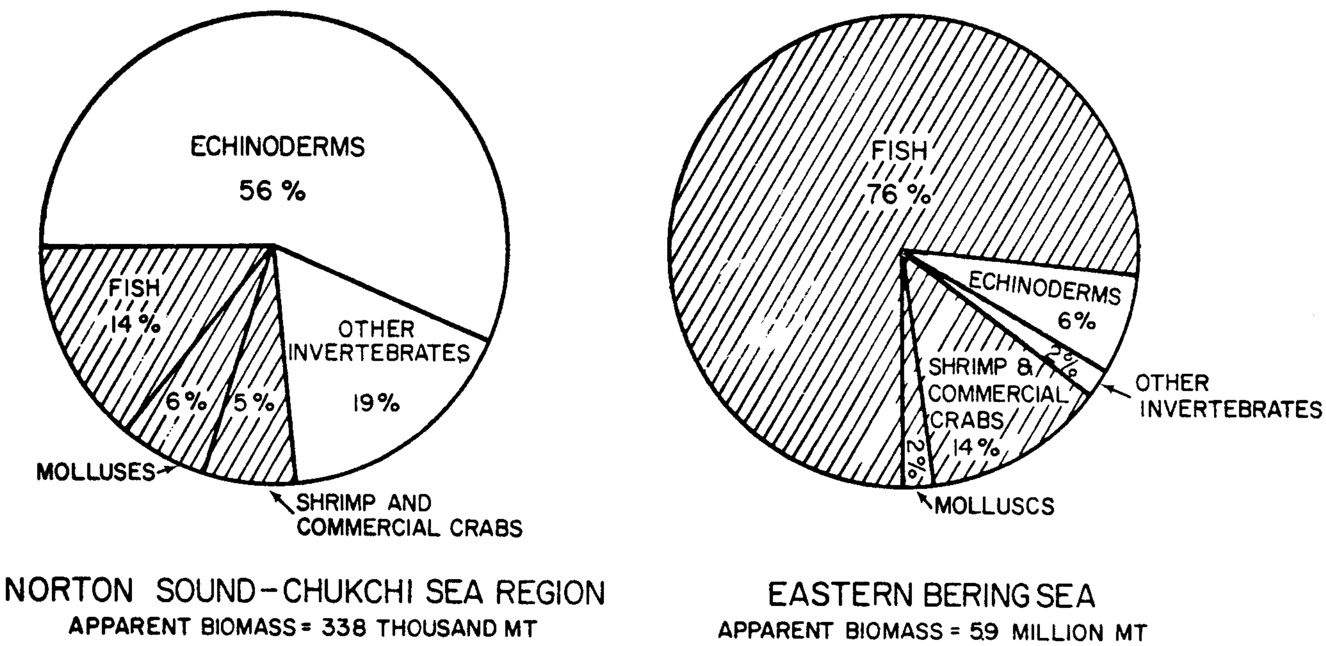


Figure X-1.--Relative importance of demersal species groups in the Norton Sound-Chukchi Sea and eastern Bering Sea regions in terms of apparent biomass. Biomass estimates are from results of the 1976 BLM/OCS baseline survey of Norton Sound and the southeastern Chukchi Sea and from Alton (1976).

Even though the demersal resources present in the Norton Sound-Chukchi Sea region do not approach quantities present elsewhere, information concerning these northern stocks is essential to enlarge our knowledge of the biota in all areas of the Alaska continental shelf. A summary of the major findings from the survey follows:

1) Results of the 1976 BLM/OCS demersal survey of Norton Sound, the southeastern Chukchi Sea, and adjacent waters indicate that highest relative abundance for nearly all fish and invertebrates occurred south of Bering Strait, especially in Norton Sound.

2) Starfish and other invertebrates of little or no potential economic importance had an estimated biomass of over 250,000 mt. This amount comprised of 74% of the entire biomass estimated for the survey region.

3) Gadidae and Pleuronectidae were the dominant fish families encountered during the survey and had a combined estimated biomass of over 33,000 mt. This amount accounted for 70% of the total fish biomass estimated for the survey area. Cottidae, Osmeridae, and Clupeidae accounted for an additional 25% of the total fish biomass.

4) The eight most abundant fish species in the survey region, by rank order of estimated biomass were: saffron cod, starry flounder, shorthorn sculpin, Pacific herring, toothed smelt, Alaska plaice, yellowfin sole, and Arctic cod.

5) Most of the dominant fish species were found in highest relative abundance in areas south of Bering Strait and where bottom waters were warmer than 4°C and shallower than 30 m (Figure X-2).

6) Arctic cod was an exception to relative abundance trends for the dominant fish species. Relatively high abundance of this species occurred at nearly all bottom temperatures and at depths greater than 20 m.

7) Almost no fish species was encountered in either sufficient size of quantity to be considered as potential for commercial harvest. Pacific herring is the only non-salmonid species presently taken in a commercial fishery in the survey region. Recent harvests have been very small and attempts to greatly expand harvest levels do not appear likely.

8) Survey information on age-length and length-weight relationships indicate age and growth differences north and south of Bering Strait for several fish species. Pacific herring, toothed smelt, yellowfin sole, and Alaska plaice all displayed greater lengths-at-age and maximum sizes south of Bering Strait than to the north, while saffron cod data suggested the opposite--largest size and lengths-at-age in the north. Definite reasons for growth differences by area are not provided by our data; however, differences were identified and seem to suggest some stock segregation within the survey region.

9) Little is known about spawning and nursery areas in the survey region. An examination of catch rates by stratum for the youngest two age groups

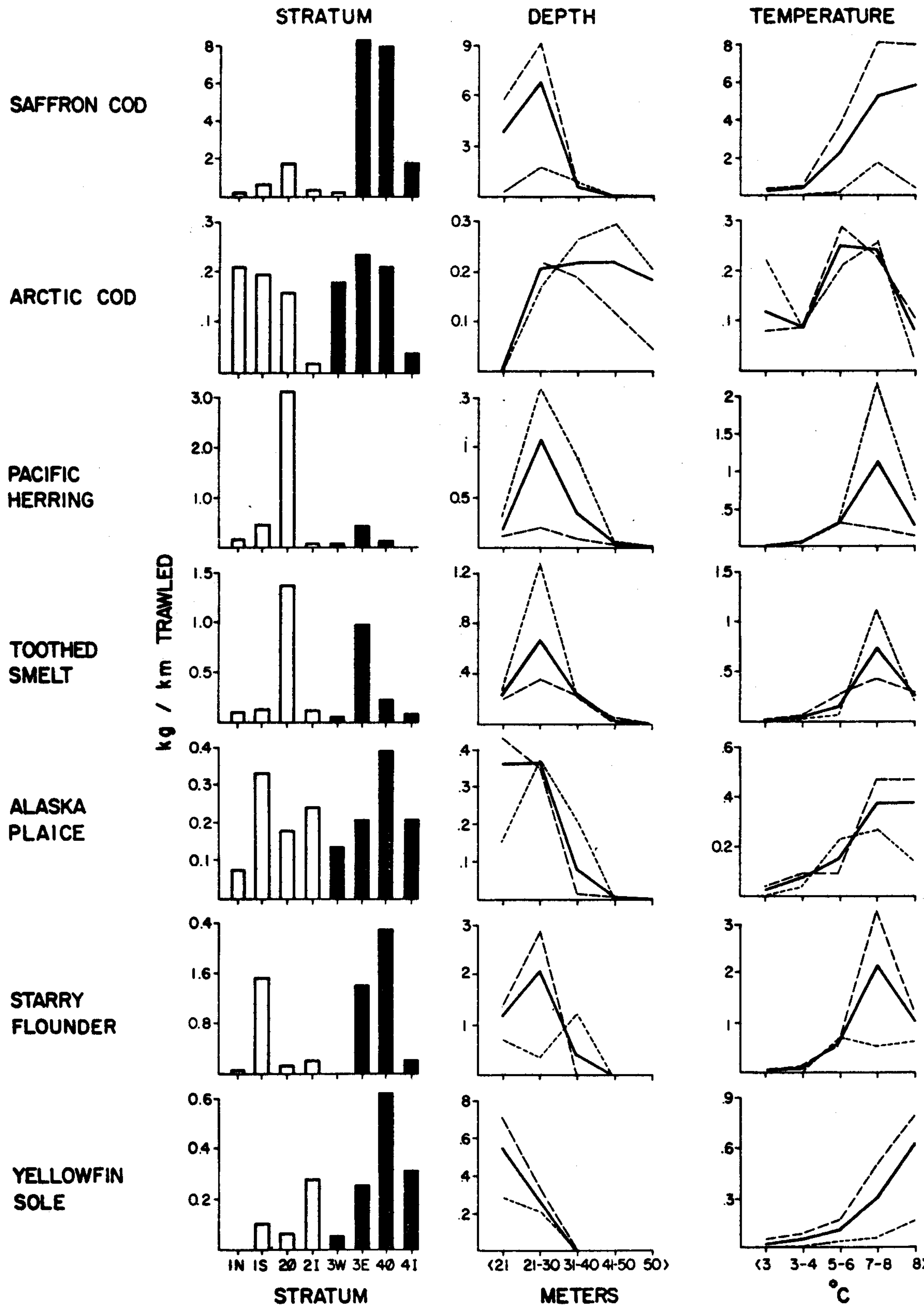


Figure X-2.--Average catch rates for dominant fish species by stratum, depth, and temperature, BLM/OCS survey, 1976. (Shaded bars and broken lines represent strata south of Bering Strait. Unshaded bars and dotted lines represent strata north of Bering Strait).

of each dominant fish species provides some insight as to possible locations of spawning areas and nursery grounds. Highest relative abundance for young saffron cod, Pacific herring, starry founder, Alaska plaice, and yellowfin sole was found in Norton Sound (Figure X-3). For species with more arctic distributions, Arctic cod and toothed smelt, either cold-deep waters or regions north of Bering Strait provided the areas of highest density of young fish.

10) About 2/3 of the area surveyed during the 1959 AEC work in the southeastern Chukchi Sea coincided with portions of our 1976 survey region (primarily stratum 1N). A general comparison of species composition and relative species abundances between the 1959 and 1976 data for this overlapping region suggests that no major changes have occurred in the fish community of the southeastern Chukchi Sea since that earlier study.

11) Three crab species of economic importance in other Alaskan waters, red and blue king crabs and Tanner crab (C. opilio), were encountered in the study region during the 1976 survey. Biomass estimates for all three species were quite low and all individuals encountered were very small.

12) Less than 1% of the estimated population of 5 million red king crabs were larger than the minimum size (135 mm carapace length) for commercial harvests in any region of Alaska. None of the blue king crabs or Tanner crabs were of sufficient size to be harvested under present size restrictions in any king or Tanner crab fishery.

13) A moderate snail biomass of 19,000 mt was estimated present in the survey region. Shell sizes of several species are similar to those taken in the Japanese harvest of snails in the eastern Bering Sea.

14) The clam population in the survey region appears to be large. One species, the greenland cockle, was encountered in almost half of our demersal catches. A trawl is a very ineffective means of sampling infauna; however, catches of this pelecypod species occasionally approached 150 individuals per trawl haul.

15) The gillnet and pelagic trawling portions of the 1976 survey offered little information on mid-water or near-surface fish populations in the study area. Pacific herring was the most commonly encountered fish species in the very sparse off-bottom sampling.

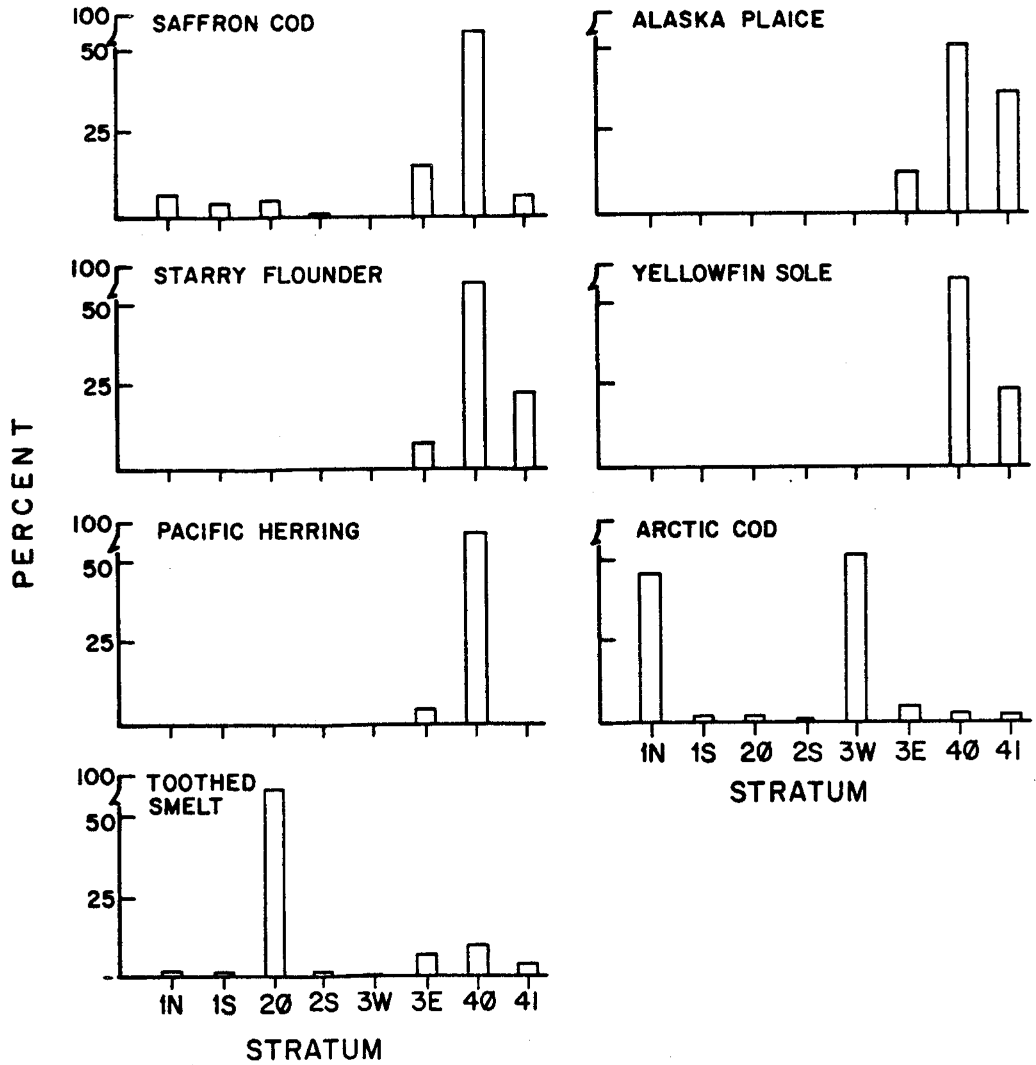


Figure X-3.--The proportion of total average catch rate by stratum of the youngest two age groups of each dominant fish species taken during the 1976 BLM/OCS survey of Norton Sound, the southeastern Chukchi Sea, and adjacent waters. (Numbers in parentheses indicate the age groups for which a catch rate was determined).

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FINAL REPORT OF BEAUFORT SEA ACTIVITIES

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Trophic Relationships Among Ice Inhabiting Phocid Seals and Functionally Related Marine Mammals

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1 April 1979

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Appendix I. Common and scientific names of species included in this report.

I. Summary

A total of 203 ringed seal and 20 bearded seal stomachs containing food collected in the Beaufort Sea were analyzed. These specimens were collected primarily in two areas: the vicinity of Point Barrow and off Prudhoe Bay. Samples were collected at several times of year in order to assess seasonal changes in feeding patterns. Due to the nature of available logistics, the poorest sample coverage was obtained in spring and summer.

The diet of ringed seals in the Beaufort Sea shows pronounced seasonal variation. In late winter and early spring crustaceans are the primary food. The species eaten are primarily benthic forms such as shrimps and gammarid amphipods. In summer crustaceans are still the primary food. However, nektonic forms such as euphausiids and hyperiid amphipods are most commonly eaten. Benthic forms are eaten where nektonic forms are not available. In most of the seals collected in fall, winter and early spring, arctic cod were the main food. The main exception to this pattern was a collection of seals made just off shore from the barrier islands within the proposed lease area in November 1978. These seals had eaten almost entirely crustaceans, mostly mysids and gammarid amphipods. Ringed seals are able to consume largest quantities of food where prey are concentrated. Arctic cod and nektonic crustaceans appear to be particularly suitable foods because they are sometimes present in dense concentrations. These concentrations appear to occur only in localized areas.

Small sample sizes precluded detailed analysis of the foods of bearded seals in the Beaufort Sea. The most commonly eaten foods were crabs and shrimps. Some seasonality in the diet appears to occur. Clams were eaten only in summer months. Arctic cod were eaten in substantial quantities only in November and February.

Bearded seals are not abundant in the Beaufort Sea. They are tied predominantly to a benthic food web and feed on a large number of species. For these reasons, OCS activities in the Beaufort Sea will probably have little effect on bearded seals.

Ringed seals are abundant in the Beaufort Sea and are present throughout the year. Shorefast ice is their preferred breeding habitat. They compete for food with seabirds, bowhead whales and some fishes, and provide food for polar bears and arctic foxes. They are obviously a very important species in the trophic structure of the area.

Ringed seals are tied to a primarily pelagic food web. Relatively little is known of the biology of their major prey species. Eggs, larvae and adults of arctic cod occur primarily in areas where contact with spilled oil appears likely. The patchy distribution of arctic cod, euphausiids and hyperiid amphipods suggests that hydrocarbon releases in certain areas could have disastrous effects. Unfortunately, neither the sensitivity to hydrocarbons nor the temporal and spatial distribution of

the patches is known for the major prey species. Until such information becomes available we can only conclude that a detrimental effect of OCS development on ringed seals is likely, but the probability and magnitude cannot be quantified. Changes in ringed seal populations will likely affect other species such as bowhead whales and polar bears.

II. Introduction

Nearshore waters of a portion of the Beaufort Sea are scheduled to be leased for oil development in December 1979. Preparation of the environmental impact statement for the lease sale is underway. As a part of the Alaskan Outer Continental Shelf Energy Assessment Program, this research unit has been investigating trophic relationships of Beaufort Sea marine mammals, primarily ice-inhabiting seals, since 1975. This final report is an effort to synthesize the information collected since that time and make it available to resource managers for consideration during EIS preparation and policy formulation.

The State-Federal Beaufort Sea lease sale was originally scheduled to take place in October 1977. Two and one-half years ago, at the request of OCSEAP administrators, this research unit terminated work in the Beaufort Sea, synthesized information available at that time and on 30 September 1976 submitted a Final Report of the Beaufort Sea Activities (Lowry et al. 1976). Shortly thereafter, the lease sale was postponed and OCSEAP redirected research to the Beaufort Sea. Since that time the primary emphasis of this project has been in the Beaufort Sea. The recent work has been of a markedly different nature than that conducted before 1977. In 1975 and 1976 logistics support was generally extremely limited and available only on an opportunistic basis. Many of the pre-1977 specimens were collected prior to OCSEAP in conjunction with polar bear research, or from the NARL animal facility which procured seals for polar bear food. Our attempts at collecting specimens were generally unsuccessful. A May collection trip utilizing a fixed-wing airplane failed due to weather. A multidisciplinary icebreaker cruise in August of the same year proved unsatisfactory and largely unsuccessful.

When Beaufort Sea work was re-initiated in 1977, a much more intense field program was designed to fill those data gaps identified in the 1976 Final Report. Dedicated helicopter support since that time has been excellent for fall and winter months. Summer logistics have been less available and less satisfactory, and as a result the summer period is now the major temporal data gap.

The Beaufort Sea is an area of extremes where biological processes are regulated by great seasonal fluctuations in light, nutrients and ice cover. Sea ice exerts a profound effect on the marine flora and fauna. Ice usually covers the nearshore area from late October through June. In some years the ice moves off shore more than 200 kilometers during August-September and the nearshore areas remain ice free for several months. In other years the ice never moves far off shore.

Several species of marine mammals regularly occur in the Beaufort Sea. From April to June, bowhead whales pass Point Barrow on their way from a poorly known wintering area in the Bering Sea to their summer feeding grounds in the eastern Beaufort Sea. These whales leave the Beaufort Sea when ice reforms in September and October. The smaller belukha or white whales accompany the bowheads north. These small whales often bear their young in coastal lagoons and estuarine systems. They too usually leave in autumn as the ice forms. Belukhas are occasionally trapped in polynyi where they overwinter or perish as the ice cover becomes complete.

As the pack ice disintegrates and recedes north in the spring, most of the Pacific walrus population leaves its wintering grounds in the Bering Sea and moves north. The majority of these animals summer in the northern Chukchi Sea and off the coast of northeast Siberia. Some walrus penetrate the western and central Beaufort Sea. They move south in the early fall, passing through the Bering Strait mainly in the months of October, November and December.

In summer, a few spotted seals are found along the western Beaufort Sea coast. However, this species is no more suited to a winter existence in this area than are those mentioned above.

Only three species of marine mammals can be considered year-round residents of the Beaufort Sea. These are ringed seals, bearded seals and polar bears. Although the arctic fox ranges widely over all types of sea ice in the Beaufort Sea, it is debatable whether it can be considered a truly marine species.

Polar bears are distributed throughout ice-covered arctic waters. In summer they are found on the pack ice, with greatest densities along the edge. They are primarily found in areas of high abundance and availability of ringed and bearded seals which are their primary prey.

The remaining two species, ringed seals and bearded seals, are the two with which this report is primarily concerned.

Bearded seals, although year-round residents of the Beaufort Sea, occur in very low densities in winter. They are able to maintain breathing holes in ice, but appear to do so only rarely, and are thus largely excluded from the fast ice zone. Rather, they are most common in the transition zone and offshore pack ice (Burns 1967, Burns and Harbo 1972, Stirling et al. 1975). The western Beaufort Sea unlike the Chukchi Sea and northern Bering Sea has a relatively narrow continental shelf with the 100-m contour occurring mostly within 40 km of shore. As 100 m is probably close to the maximum feeding depth for bearded seals, the western Beaufort Sea does not offer a very large foraging area. This is especially true in the winter when landfast ice extends 20 to 40 km off shore, resulting in a very narrow band of proper ice type and water depth.

Our recent studies have shown that in winter months bearded seals are more common in the Barrow area where shore ice is not extensive and the pack ice moves more regularly than in the less dynamic ice of the central Beaufort. During summer months there is an influx of bearded seals from the south as the ice in those areas melts and recedes north. However, the majority of animals appear to stay over the shallow Chukchi platform rather than moving into the Beaufort Sea. Few bearded seals are present in the summer pack ice of the Beaufort Sea when the southern edge is over deep water. For these reasons bearded seals were not the prime focus of this study. Instead emphasis was placed on the widely distributed and abundant ringed seal.

Ringed seals are found almost throughout ice-covered seas of the northern hemisphere, and they are the most common species of seal in the Beaufort Sea. Their density in any given area and at any given time is closely related to ice conditions. In late March and early April, ringed seal pups are born in lairs excavated in snow-covered ice (McLaren 1958, Burns 1970, Smith and Stirling 1975). Although stable landfast ice is the preferred area for pupping, and the greatest density of seals occurs there, pups are also born on drifting ice. Ringed seals of the drifting ice probably constitute most of the total population because of the vast areas of drifting ice habitat. There are some indications that older, more experienced females may occupy the preferred breeding habitat (McLaren 1958, Burns, 1970). Subadult animals are often found congregated along transient lead systems (Stirling et al. 1975; Burns, unpubl.).

Subsequent to pupping and breeding, ringed seals undergo a period of molting during which they spend a large amount of time hauled out on the ice and are relatively easy to observe and count. During this period feeding intensity is quite low (McLaren 1958, Johnson et al. 1966). The overwintering population of ringed seals in the western Beaufort Sea is and may have for many years been relatively low. Burns and Harbo (1972) estimated the minimum population on the shorefast ice in June 1970 to be 8,717 animals. In summer, the population size increases with the seasonal influx of animals from the south. During the summer season ringed seals are found throughout the restricted ice-covered waters. With the onset of winter and increase in ice cover, the area occupied by ringed seals expands accordingly. Specific details of these movements are largely unknown.

Ringed seals and bearded seals, as well as many other species of marine mammals, are of cultural and economic importance to Alaskan Eskimos and non-Eskimo residents of this region. They are hunted for human and dog food, and for the skins which have traditionally been used for clothing, equipment and crafts. National interest in these animals and the habitats they utilize is high. This interest is perhaps best exemplified by the Marine Mammal Protection Act of 1972 (Public Law 92-522) passed by the Congress of the United States which states that "marine mammals have proven themselves to be resources of great international significance, esthetic and recreational as well as economic, and it is the sense of the Congress that they should be protected and encouraged to develop to the greatest extent feasible commensurate with sound policies of resource management."

These factors and others make it imperative that the potential effects of oil and gas exploration and development in the Beaufort Sea on ice-inhabiting marine mammals be anticipated and minimized to whatever degree possible. Such an evaluation requires an understanding of the biology of the species involved, as well as how these species affect and are affected by their environment. This study of the trophic relationships of ice-inhabiting phocid seals of the Beaufort Sea will contribute to such an understanding. We have dealt primarily with the two resident and most abundant species of seals, ringed seals and bearded seals, but it is not enough to look only at the highly visible or economically important species or to examine discrete parts of the system as separate entities. One must also consider the inconspicuous species upon which the more visible ones depend, and study the connections and dependencies among different system components. It is well understood that all animals act as part of a system in which radiant energy from the sun is captured by plants, passed on to animals and ultimately recycled in the form of organic compounds. We will attempt to deal with ringed seals and bearded seals as part of such a system.

The intricacy of biological systems is such that even gross simplifications are difficult to render verbally and/or graphically. However, through this study of trophic relationships of marine mammals we have attempted to identify key species, those organisms which are the most tightly woven into the web of trophic interdependencies. Is is our hope that identification of these key species and important species interdependencies will provide a focus of attention among the many hundreds of species present in the Beaufort Sea and contribute to the assessment of anticipated ecological effects. When integrated with other OCSEAP research it should be possible to identify potential differential sensitivity of parts of the system and to evaluate which times, places or species appear to be most or least vulnerable.

III. Current State of Knowledge

There are no accounts of the food habits of marine mammals in the Alaskan Beaufort Sea published prior to this OCSEAP study. Some preliminary results of this study were published by Lowry et al. (1978a) in which the food habits of a small number of ringed seals and bowhead whales from Barrow, Alaska, were discussed, as was the possibility for interspecies competition.

Published accounts of the food habits of ice-inhabiting phocid seals in other parts of the world have been reviewed in the 1978 and 1979 annual reports for this research unit (Lowry et al. 1978b, Lowry et al. 1979.

IV. Study Area

The study area is shown in Figure 1. It includes the Alaskan Beaufort Sea from Point Barrow in the west to Demarcation Point in the east. The proposed Joint Federal-State lease area is indicated in this figure as are the general locations from which samples were obtained.

V. Sources, Methods and Rationale of Data Collection

Field Collections

Because the formation and breakup of sea ice is a dynamic process which varies from year to year, it was impossible to establish predetermined sampling locations and to collect seals repeatedly at those same locations. However, we did try to restrict our sampling to two geographical areas (Barrow and Prudhoe Bay), realizing that within each area there may be considerable variation in water depth, prey availability, ice topography, etc. At Prudhoe Bay we attempted to collect seals inside the actual lease area, but due to ice conditions specimens were usually taken somewhat offshore.

Specific locations at which seals were collected were determined by the presence of leads and open water polynyi. During winter months the shorefast ice is a solid, unbroken sheet and seals living under this sheet are inaccessible. Only at the outer edge of the fast ice, and in leads and polynyi in the pack ice, is it possible to locate and collect seals in an efficient manner. For this reason, seals collected by this project in winter months are representative only of lead-pack ice conditions. They may not be representative of seals found in shallower nearshore water under the fast ice.

Pre-OCSEAP specimen material was collected on an opportunistic basis in conjunction with other research projects. Some specimen material was provided by Mr. Jack W. Lentfer, then with the U. S. Fish and Wildlife Service. These specimens were obtained in conjunction with Mr. Lentfer's polar bear research. The material consisted of the remains of seals killed by bears, and sometimes included stomachs containing food.

Other specimens were provided by Alaska Department of Fish and Game personnel stationed in Barrow, by the Naval Arctic Research Lab from seals obtained as polar bear food and by Bob Everitt of the National Marine Fisheries Service.

OCSEAP collection efforts began in late 1975 and intensified in 1977-1979. In other areas of the state most specimens have been acquired from subsistence hunters in coastal villages. In the Beaufort Sea there are only three coastal settlements, none of which depends on seals as a primary source of food or income, and it was impossible to obtain adequate specimen material by this means. Most specimens were necessarily collected by project personnel. In May 1976, four ADF&G personnel utilizing a Beaver aircraft equipped with wheel skis were stationed at the Oliktok Point DEW line site with the intention of flying to offshore leads and

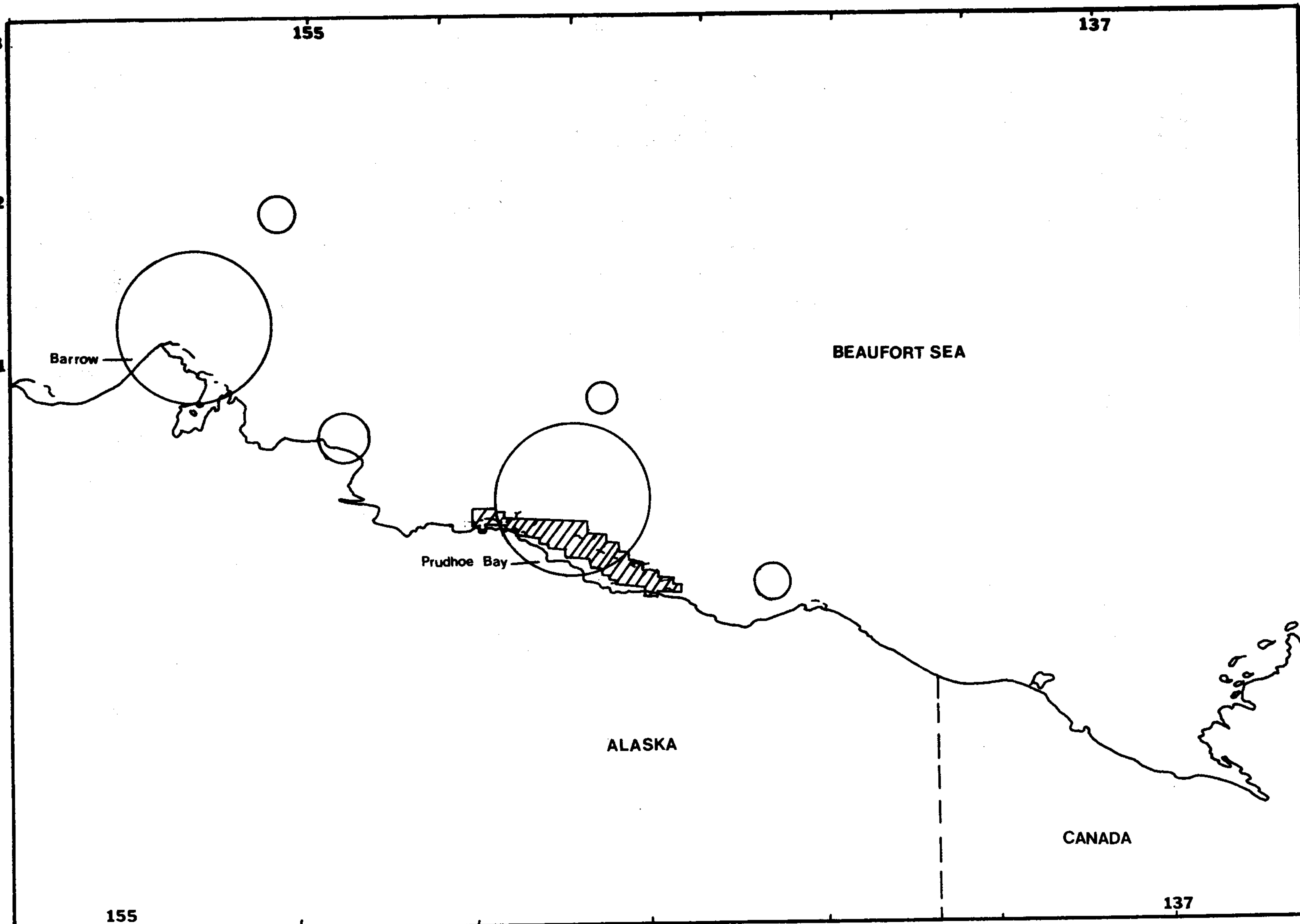

Figure 1. Map of the Beaufort Sea showing general locations of specimen collections. The proposed Beaufort Sea lease area is crosshatched.

collecting seals. Inclement weather and the limitations of fixed-wing aircraft rendered this attempt futile. Two ADF&G personnel were aboard the USCGC GLACIER during August 1976 Beaufort Sea operations. Inclement weather and the multidisciplinary nature of this cruise made it largely unsuccessful. A final attempt in 1976 in the Beaufort Sea was made by two ADF&G personnel aboard the NARL R/V NATCHIK. No animals were collected due to poor weather and limitations of the vessel.

In 1977, with the rescheduled lease sale and redirection of OCSEAP effort to the Beaufort Sea, this project reinitiated collection efforts in that area. In the ensuing 2-1/2 years, winter logistics support by OCSEAP was excellent and collection attempts were in all cases successful. Sampling was done with the aid of Bell 206 and UH1H helicopters. Animals were shot in the water, retrieved from the helicopter and taken to the lab for processing.

Summer logistics were less adequate and less successful. Shipboard sampling from icebreakers was conducted during August-September of 1977 and 1978. Some seals were collected but the multidisciplinary nature of both cruises greatly restricted the mobility of the ship and the time available for marine mammal work. A scheduled cruise in fall 1977 on the NARL R/V NATCHIK was canceled due to mechanical failures.

Whenever possible seals from which specimen material was taken were weighed and a series of standard measurements were made for use in this and other ongoing studies on ice-inhabiting seals. Sex was determined, and teeth and claws were collected for age determination. Tissue and blood samples were collected in some cases to be made available to other investigators for hydrocarbon, heavy metal, PCB and pathogen analyses. However, to our knowledge, none of these samples have been analyzed due to lack of funding. (See methods section in RU#230 annual reports for detailed description of standard measurements and collection of additional specimen material.)

Most seals collected in the Beaufort Sea were processed at NARL or in the ADF&G lab in Fairbanks. During processing, stomachs were removed and either opened immediately and the contents preserved in 10 percent formalin, or frozen and shipped to the lab in Fairbanks where they were opened and preserved. For those stomachs containing large numbers of small otoliths, which degrade rapidly in formalin, the otoliths were immediately sorted out and stored in 95 percent ethanol.

During the 1977 icebreaker cruise, in addition to collecting seal specimen material, we also conducted bottom sampling for fishes and invertebrates with 16- and 19-foot (4.9 and 5.8 m) Marinovich otter trawls (1-3/8-inch (3.2 cm) stretch mesh body, 1/4-inch (0.6 cm) mesh cod end liner). Trawls were of 5-10 minutes duration at a ship speed of 3-5 knots. Contents of each trawl were identified, enumerated and weighed. The otoliths of fishes were removed, measured to determine the correlation of otolith size to fish size and the annular rings counted. Stomach contents of fishes were examined and reproductive status noted. When appropriate, invertebrates were measured and reproductive status of females was noted. Identification of all fishes and decapod crustaceans (crabs and shrimps) was done by ADF&G personnel (Frost and Lowry). All other invertebrates were identified by personnel at the University of Alaska Marine Museum/Sorting Center. (For a complete report of this trawl series see OCSEAP RU#232 1978 Annual Report, Appendix I, Offshore Demersal Fishes and Epibenthic Invertebrates of the Northeastern Chukchi and Western Beaufort Seas (Lowry et al. 1978b)).

Laboratory Procedures and Identification

The preserved contents of stomachs were washed onto a 1.0-mm mesh screen. When very small otoliths were noted in the contents, a 0.355-mm mesh screen was used beneath the larger mesh. Contents were sorted and identified to the lowest taxonomic level permitted by their condition, using appropriate taxonomic keys and reference specimens. In the majority of cases identifications entailed the sorting and recognition of small bits and pieces of organisms. Crustaceans were frequently identified by claws, carapaces or abdomens. Fishes were identified on the basis of otoliths and bone fragments. The volume and number of each type of prey item were determined by water displacement and counts of individuals or otoliths. Size ranges of various prey items were determined when possible.

Virtually all identifications were made by project personnel. Necessary taxonomic keys and references both published and unpublished have been accumulated. Much use was made of the Marine Museum/Sorting Center reference collection and of the expertise of Sorting Center personnel. A reference and voucher collection of invertebrates and fishes has been established at ADF&G. In addition, an otolith collection has also been compiled. Considerable interchange of specimen material and ideas occurred among personnel of this project, Dr. James Morrow, OCSEAP RU#285, and John Fitch, California Department of Fish and Game.

VI. Results

The results of field collections are shown in Table 1. General locations of these collections are shown in Figure 1. A total of 203 ringed seal and 20 bearded seal stomachs containing food were analyzed. Of those, 17 ringed seals and 7 bearded seals were collected prior to OCSEAP, 20 ringed seals and 2 bearded seals in 1975 and 1976, and 166 ringed seals and 11 bearded seals since the redirection of OCSEAP effort in 1977. Figures 2 through 5 show locations for ringed seal samples collected in 1976-1979. Results of ringed seal stomach contents analyses are shown in Tables 2-6.

We have analyzed ringed seal samples from the Barrow area collected in all months except January. Our best collections are from February-April and November. In the general area of the scheduled lease sale we have made collections during February-March, August-September and November. In both of these areas data from summer months are the most limited.

The diet of ringed seals in the Beaufort Sea shows pronounced seasonal variation. Near Barrow in late winter and early spring (March-June) gammarid amphipods, mysids and shrimps were the main food items.

Table 1. Schedule of field work in the Beaufort Sea and summary of specimens obtained. Only stomachs with food are listed.

Location	Dates	Specimens Obtained: Ringed Seals	Specimens Obtained: Bearded Seals
Barrow	July-August 1969	6	0
Barrow	1-25 October 1970	3	0
Barrow	22 December 1971	2	0
Barrow	20 April-15 May 1972	3	0
Barrow	1-2 September 1973	0	7
Northeast of Point Barrow[1]	29 April-1 May 1974 and 26 April 1975	3	0
Barrow[2]	Spring-summer 1975	10	0
Barrow	3 September 1975	1	0
Northeast of Point Barrow	23 March 1976	1	0
Oliktok Point	10-19 May 1976	0	0
Barrow[3]	11-25 May 1976	3	0
Barrow	13 June 1976	1	0
Barter Island	20 July-3 August 1976	1	0
Barrow	2-10 August 1976	2	1
USCGC GLACIER	17 August-3 September 1976	1	0
R/V NATCHIK	27-30 September 1976	0	0
Barrow[4]	15 November 1976	0	1
Barrow	1 February 1977	1	0
Barrow	4-14 April 1977	3	2
USCGC GLACIER	31 July-6 September 1977	16	2
Barrow	21 July 1977	0	1
Barrow	14-17 November 1977	14	1
Prudhoe Bay	6-10 November 1977	19	2
Barrow	26 March-4 April 1978	16	0
Prudhoe Bay	27-28 March 1978	12	0
USCGC NORTHWIND	20-21 August 1978	3	0
Prudhoe Bay	5-11 November 1978	22	0
Barrow	13-16 November 1978	18	1
Prudhoe Bay	20-23 February 1979	24	0
Barrow	24-27 February 1979	18	2
	Total	203	20

[1] Specimens provided by Mr. Jack W. Lentfer, then with the U.S. Fish and Wildlife Service, now with the Alaska Department of Fish and Game.
[2] Nine of the 10 specimens were obtained from seals purchased by the Naval Arctic Research Lab for polar bear food--time of collection was estimated from physical and reproductive condition of the animals.
[3] Specimens provided by Mr. R. Everitt, National Marine Fisheries Service.
[4] Specimen provided by Dr. A. Blix, University of Alaska.

Table 2. Summary of stomach contents of ringed seals collected at Barrow prior to 1976. Numbers in parentheses following the dates denote sample size.

July-August 1969 (6)	-	Fish - 91%, all Boreogadus Mysid - 9% (all identified were Neomysis) Mean Volume = 5.3
1-25 October 1970 (3)	-	Fish - 100%, all Boreogadus Mean Volume = 3.7
22 December 1971 (2)	-	Fish - 100%, all Boreogadus Mean Volume = 110.0
20 April-15 May 1972 (3)	-	Fish - 98%, 133 Boreogadus, 1 Lycodes Neomysis - 2% Mean Volume = 15.3
29 April-1 May 1974 (2)	-	Shrimp (Pandalus sp.) - 91% Gammarid amphipod - 9% Mean Volume = 11.0
26 April 1975 (1)	-	Crustacean (shrimp and amphipod) - 75% Fish - 25%, all Boreogadus Mean Volume = 22.8
Late spring-summer 1975 (10)	-	Euphausiid - 70% Gammarid amphipod - 23% Fish - 6%, Boreogadus 90% of fishes Mean Volume = 18.0
3 September 1975 (1)	-	Fish - 100%, all Boreogadus Mean Volume = 7.0

Table 3. Ringed seal stomach contents data from the Beaufort Sea, 1976. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:	1	2	3	4	5
Dates:	23 March	11-25 May	13 June	7 August	20 August
Sample Size:	1	3	1	2	1
Mean Volume (ml)	9.8	47.1	212.6	361.5	81.0
Food Items 1	Shrimp 94	Euphausiid 90	Isopod 94	Euphausiid 100	Euphausiid 78
Food Items 2	Mysid 6	Gammarid Amphipod 5	Gammarid Amphipod 6		Mysid 11
Food Items 3		Squid 3			Gammarid Amphipod 6
Food Items 4		Hyperiid Amphipod 1			Shrimp 4
Food Items 5					

Table 3. cont. Ringed seal stomach contents data from the Beaufort Sea, 1976. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		6				
Dates:		29 July				
Sample Size:		1				
Mean Volume (ml)		23.3				
Food Items	1	Gammarid Amphipod 91				
	2	Shrimp 9				
	3					
	4					
	5					

Table 4. Ringed seal stomach contents data from the Beaufort Sea, 1977. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		1	1	2	2	3
Dates:		1 February	8-9 April	10 April	7 August	9 August
Sample Size:		1	2	1	1	1
Mean Volume (ml)		14.0	254.6	8.2	32.8	22.5
Food Items	1	Fish 50 Arctic Cod 98 Sculpins 2	Gammarid Amphipod 55	Fish (unidentified) 50	Shrimp 70	Fish 80 Boreogadus 100
	2	Gammarid Amphipod 43	Mysid 45	Gammarid Amphipod 22	Fish 27 Arctic Cod 74 Polar Cod 14 Pricklebacks 12	Hyperiid Amphipod 18
	3	Shrimp 7		Mysid 20	Gammarid Amphipod 1	Gammarid Amphipod 2
	4			Hyperiid Amphipod 9	Euphausiid 1	
	5					

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Table 4 cont. Ringed seal stomach contents data from the Beaufort Sea, 1977. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		4	5	6	7	
Dates:		1-2 September	17 August	7-10 November	14-17 November	
Sample Size:		13	1	19	14	
Mean Volume (ml)		216.0	18.7	167.9	369.0	
Food Items	1	Hyperiid Amphipod 92	Mysid 78	Fish 87 Arctic Cod 99	Fish 94 Arctic Cod 96 Polar Cod 3	
	2	Mysid 4	Gammarid Amphipod 12	Hyperiid Amphipod 12	Hyperiid Amphipod 5	
	3	Fish 2 Arctic Cod 91 Sea Snails 5 Saffron Cod 3 Sculpins 1	Shrimp 10			
	4	Gammarid Amphipod 1				
	5					

Table 5. Ringed seal stomach contents data from the Beaufort Sea, 1978. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		1	2	3	4	
Dates:		25 March-4 April	27-28 March	20 August	21 August	
Sample Size:		16	12	1	2	
Mean Volume (ml)		50.7	80.9	31.5	118.1	
Food Items	1	Fish 77 Arctic Cod 98 Sea Snails 1 Sculpins 1	Fish 90 Arctic Cod 100	Fish 89 Arctic Cod 100	Mysid 86	
	2	Hyperiid Amphipod 17	Hyperiid Amphipod 6	Shrimp 11	Hyperiid Amphipod 7	
	3	Shrimp 3	Gammarid Amphipod 3		Fish 4 Arctic Cod 100	
	4	Gammarid Amphipod 1			Shrimp 2	
	5					

Table 5. Ringed seal stomach contents data from the Beaufort Sea, 1978. Numbers in
cont. parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		5	6			
Dates:		5-11 November	14-16 November			
Sample Size:		22	18			
Mean Volume (ml)		147.6	171.7			
Food Items	1	Mysid 45	Fish 93 Arctic Cod 100			
	2	Gammarid Amphipod 30	Hyperiid Amphipod 4			
	3	Polychaete Worm 9	Echiuroid Worm 3			
	4	Hyperiid Amphipod 7				
	5	Fish 6 Arctic Cod 95 Sea Snail 3 Sand Lance 2				

Table 6. Ringed seal stomach contents data from the Beaufort Sea, 1979. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		1	2			
Dates:		22-26 February	20-23 February			
Sample Size:		18	24			
Mean Volume (ml)		224.3	247.8			
Food Items	1	Fish 98 Arctic Cod 100	Fish 97 Arctic Cod 99			
	2	Mysids 1	Euphausiids 2			
	3					
	4					
	5					

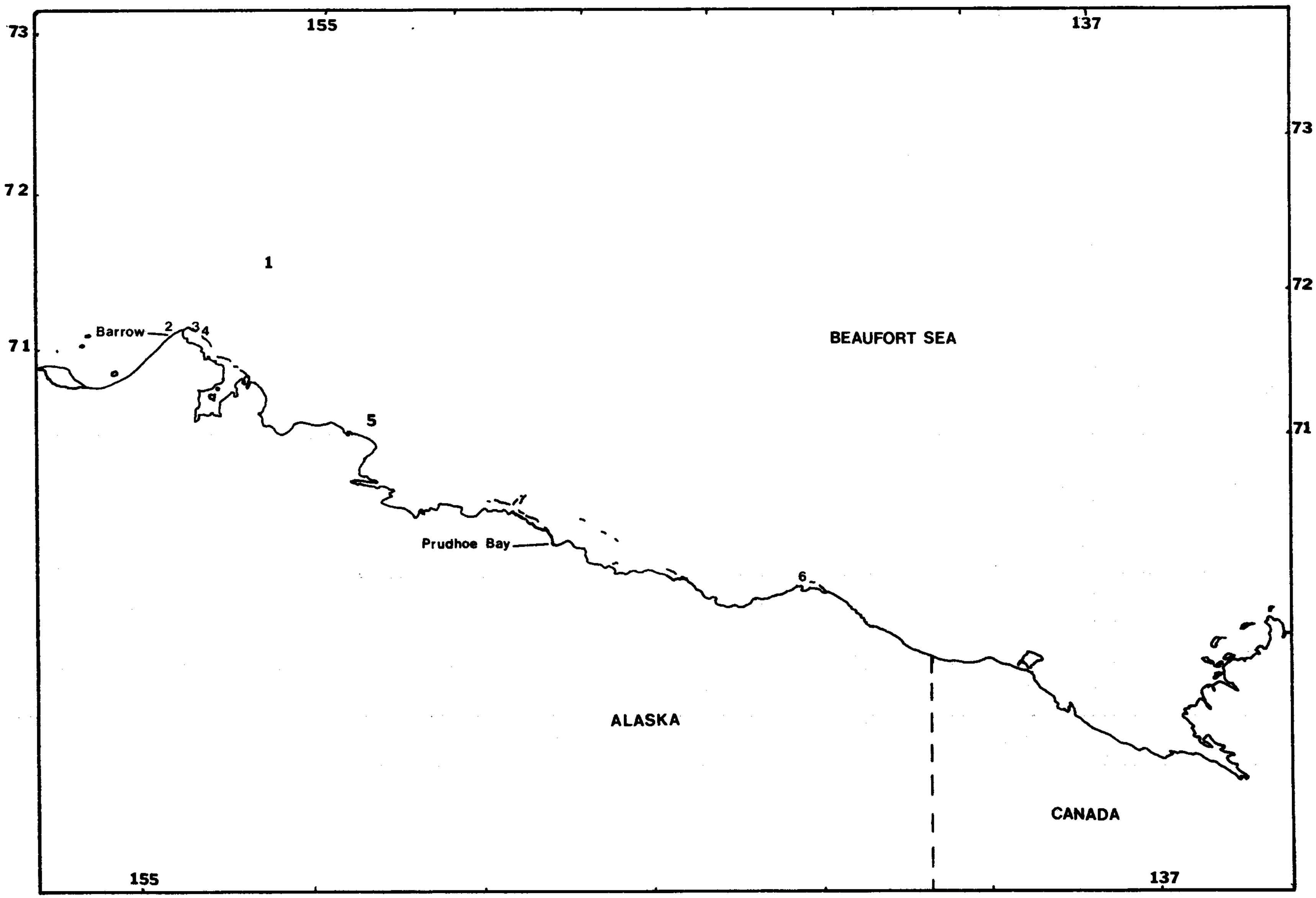

Figure 2. Map of the Beaufort Sea showing locations of 1976 ringed seal collections. Numbers correspond to samples shown in Table 3.

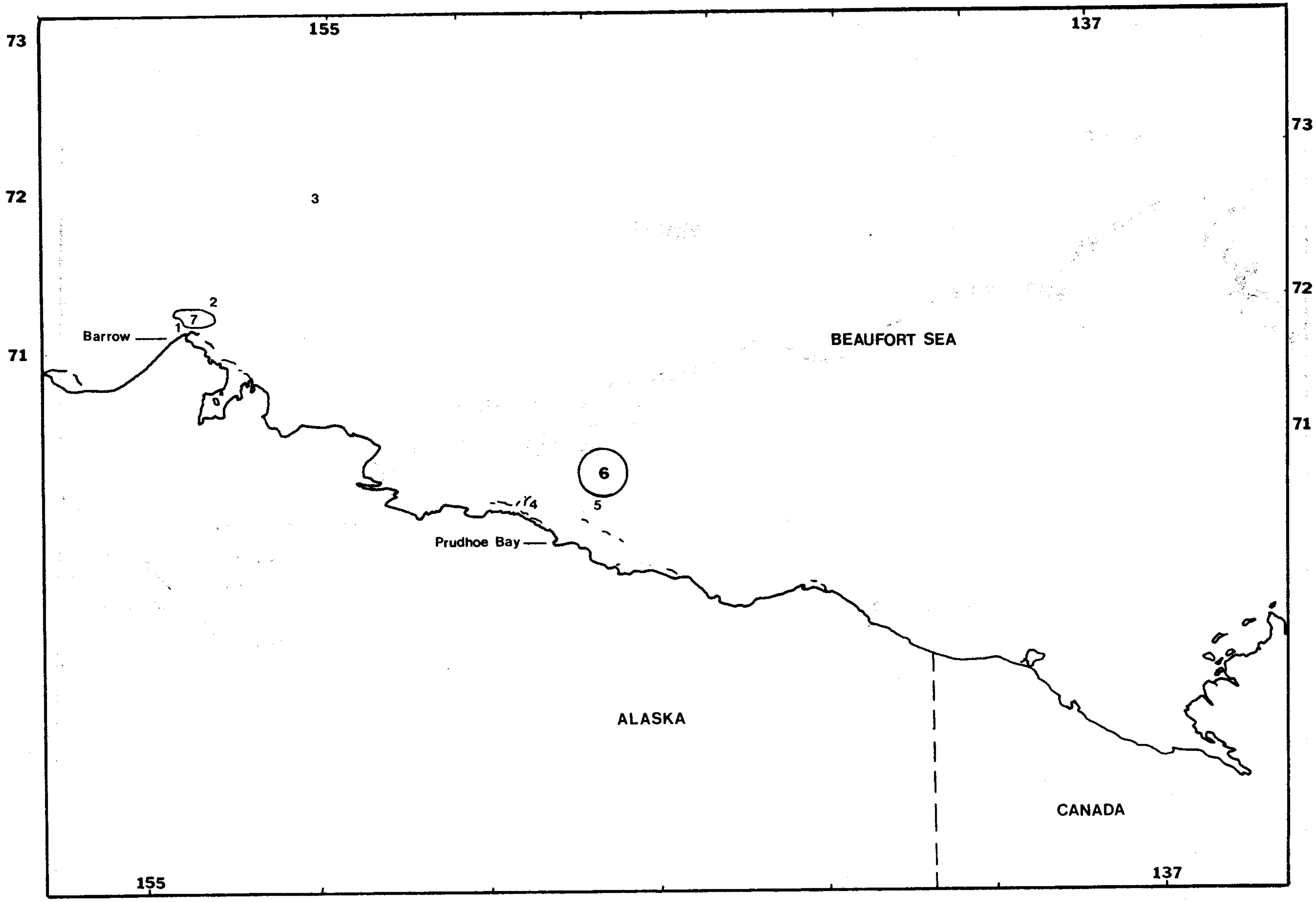

Figure 3. Map of the Beaufort Sea showing locations of 1977 ringed seal collections. Numbers correspond to samples shown in Table 4.

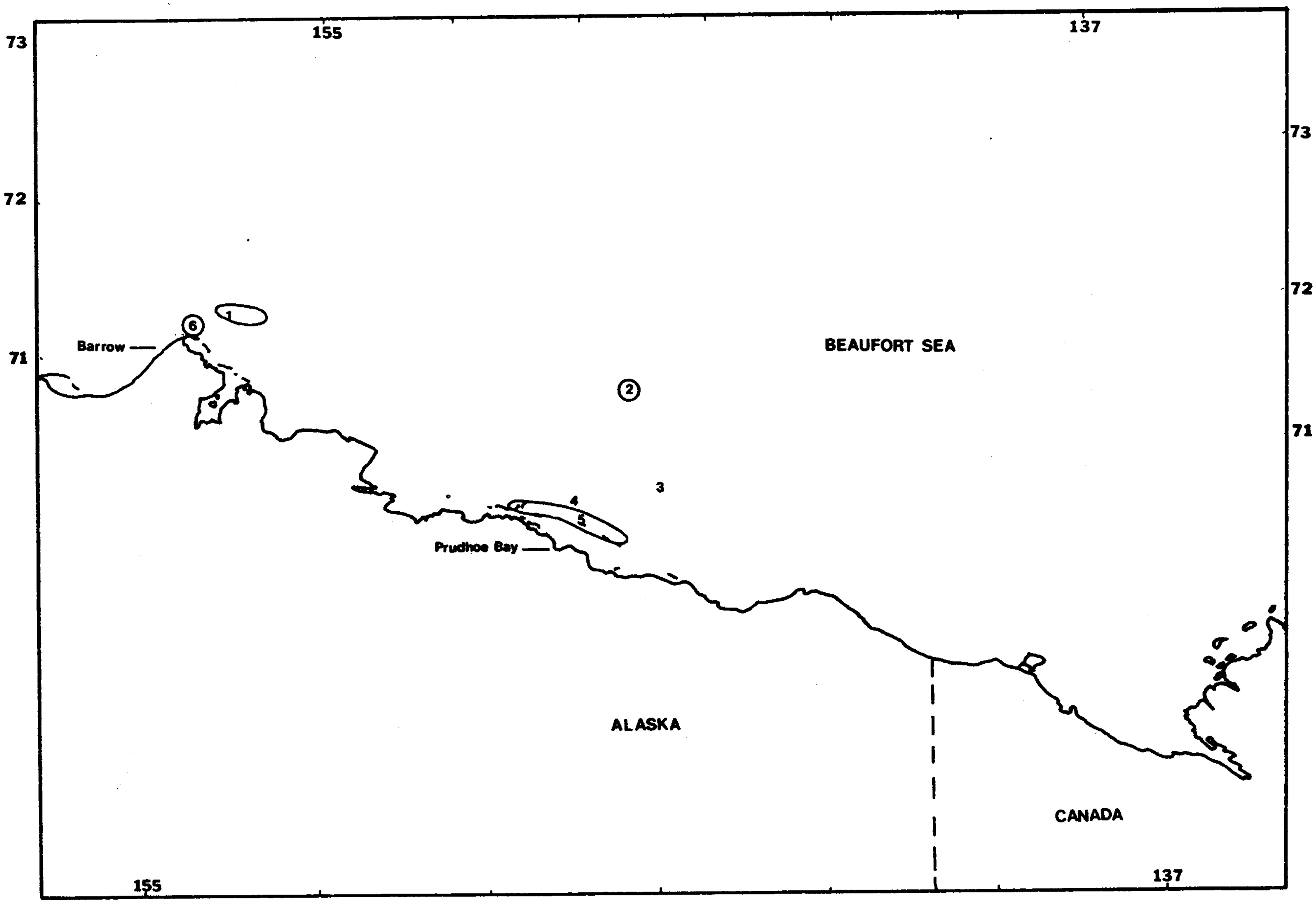

Figure 4. Map of the Beaufort Sea showing locations of 1978 ringed seal collections. Numbers correspond to samples shown in Table 5.

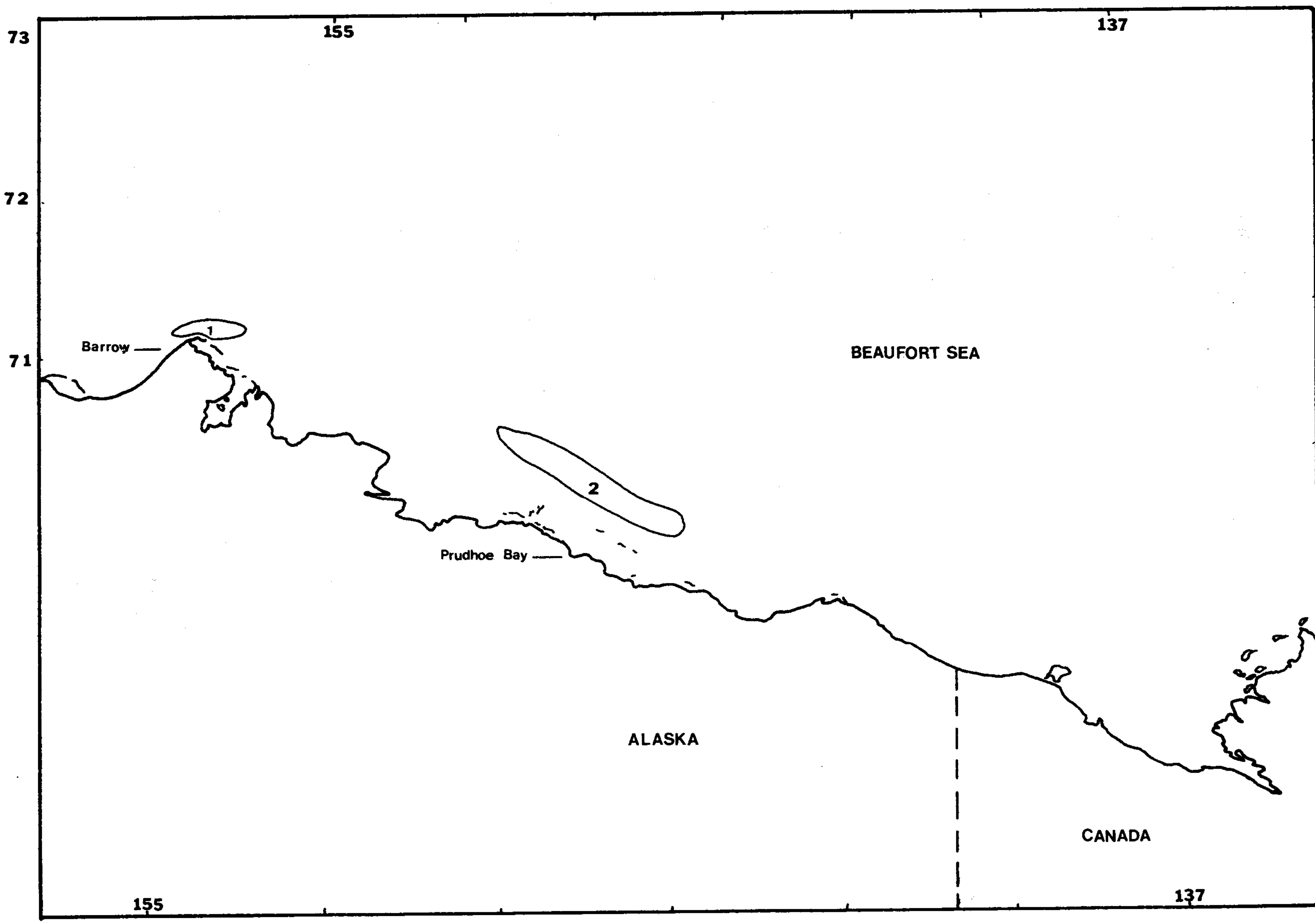

Figure 5. Map of the Beaufort Sea showing locations of 1979 ringed seal collections. Numbers correspond to samples shown in Table 6.

Arctic cod were also eaten, primarily during the early part of this period. In May and June euphausiids appeared in the diet and were eaten regularly in small amounts. Gammarid amphipods and isopods were also eaten at this time. Three seals taken near Barrow and off Pitt Point in August 1976 had eaten large quantities of euphausiids. All seals taken near Barrow between September and February (1970, 1971, 1975-1979) had eaten primarily arctic cod. November samples contained large volumes of arctic cod and small amounts of hyperiid amphipods. The relative proportion of cod to hyperiids was almost identical in 1977 and 1978. Seals collected in late February 1979 had eaten almost entirely arctic cod.

Thirteen seals taken north of Prudhoe Bay in early September had fed extensively on hyperiid amphipods. Two seals taken east of Prudhoe in summer had eaten very small amounts of crustaceans (mysids, amphipods and shrimps) as had two seals collected directly north of Prudhoe in August. Seals collected 72 km north of Prudhoe in November 1977 had eaten arctic cod and some hyperiid amphipods. Seals collected in November 1978 just off shore from the barrier islands had eaten almost entirely crustaceans, primarily mysids and gammarid amphipods. Twenty-four seals taken 54-90 km off Prudhoe in late February 1979 and 12 seals taken 126-162 km off Prudhoe in late March 1978 had eaten arctic cod and small amounts of crustaceans.

We have collected relatively few bearded seal specimens, reflecting the low abundance of this species in the Beaufort Sea. However, our sample size has increased from 3 to 20 since our 1976 report. All but four of those seals were collected in the Barrow region. Figure 6 shows the location of bearded seal collections for all years. Results of specimen analysis are presented in Tables 7 and 8.

As at other locations throughout Alaska, bearded seals collected in the Beaufort Sea had fed primarily on decapod crustaceans (shrimps and spider crabs). Clams, hermit crabs, octopus, gammarid amphipods, isopods and fish were also eaten. Clams were found only in August. Arctic cod were a major component of the diet at Barrow in November and February.

VII. Discussion

A. Bearded Seals

Very small sample sizes preclude detailed analysis of geographical and seasonal differences in the diet of bearded seals in the Beaufort Sea. However, because bearded seal diets are very similar throughout their range, it is possible to examine Beaufort Sea data in light of patterns established elsewhere. In general these seals feed on a wide variety of benthic organisms (Kenyon 1962, Johnson et al. 1966, Kosygin 1966, Burns 1967, Lowry et al. 1978b). Although the diet is diverse, relatively few types of organisms comprise the bulk of the food; these are bivalve molluscs, crabs, shrimps, sculpins and sometimes arctic or saffron cod. Beaufort Sea bearded seals follow the same pattern.

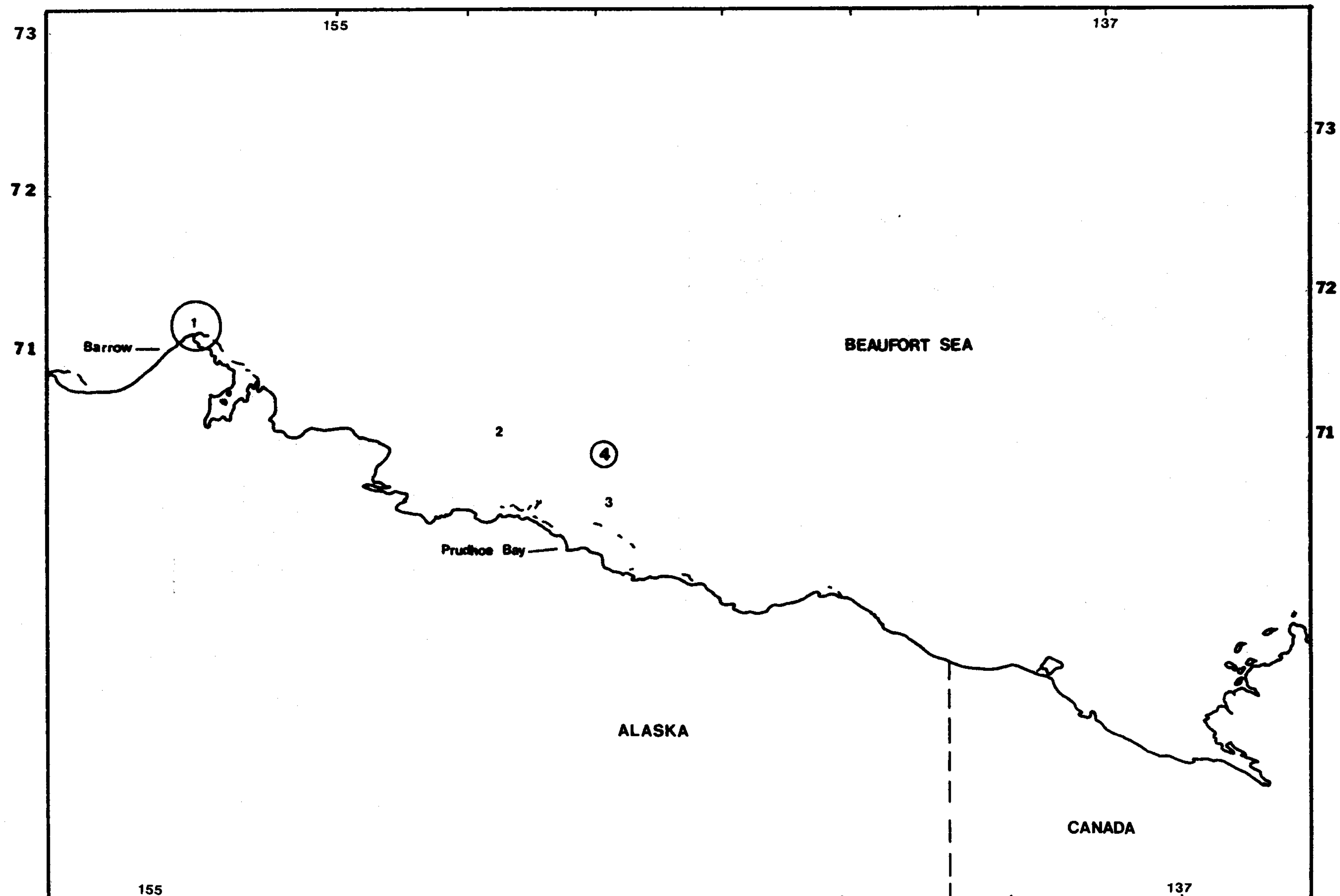

Figure 6. Map of the Beaufort Sea showing locations of 1975-1979 bearded seal collections. Numbers correspond to samples shown in Tables 7 and 8.

Table 7. Bearded seal stomach contents data from the western Beaufort Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:	1	1	1	1	1
Dates:	February 1979	12-13 April 1977	August 1976 & 1977	1-2 September 1973	November 1976,1977 1978
Sample Size:	2	2	2	7	3
Mean Volume (ml)	985.6	139.7	841.3	94.6	473.9
Food Items 1	Fish 58 Arctic Cod 95 Eelpout 3 Sculpins 2	Hermit Crab 37	Clams 65	Shrimp 50	Shrimp 33
Food Items 2	Spider Crabs 19	Spider Crabs 29	Isopods 29	Spider Crabs 31	Spider Crabs 28
Food Items 3	Shrimp 11	Octopus 19	Fish 5 Arctic Cod 56 Sculpins 38	Sponge 11	Fish 23 Arctic Cod 82 Sculpins 15 Saffron Cod 2
Food Items 4	Priapulids 10	Gammarid Amphipod 7		Fish 2 Arctic Cod 96 Eelpout 3	Gammarid Amphipod 14
Food Items 5		Shrimp 4			

Table 8. Bearded seal stomach contents data from the central Beaufort Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		2	3	4		
Dates:		14 August 1977	17 August 1977	6-7 November 1977		
Sample Size:		1	1	2 PRUE-1,2-77		
Mean Volume (ml)		708.1	649.4	594.8		
Food Items	1	Shrimp 57	Spider Crab 77	Shrimp 66		
	2	Spider Crab 18	Shrimp 18	Gammarid Amphipod 16		
	3	Sea Cucumber 8	Gammarid Amphipod 5	Octopus 8		
	4	Priapulid 8		Fish 3 Sculpins 54 Arctic Cod 41 Eelpout 4		
	5	Octopus 4		Spider Crab 2		

At Barrow two species of crabs and one species of shrimp were the most important prey on a year-round basis. The crabs, Chionocetes opilio and Hyas coarctatus, and the shrimp, Sclerocrangon boreas, are also primary prey species of bearded seals in the Bering and Chukchi Seas. MacGinitie (1955) in his samples of invertebrates from near Barrow noted that Hyas was the most abundant of the true crabs and was found in nearly every trawl. Carey (1976) reported Hyas from 10 stations. Lowry et al. (1978b) encountered Hyas in 28 of 33 trawls. Chionocetes is generally much less abundant in the Beaufort east of Barrow (MacGinitie 1955, Squires 1969, Lowry et al. 1978b).

Sclerocrangon is most abundant west of Barrow on rocky bottom areas (Lowry et al. 1978b), although it has also been reported from the western Canadian Arctic (Squires 1969).

In the Prudhoe Bay area spider crabs and shrimps were also the most important components of the diet, but the species changed from those eaten at Barrow. Chionocetes, which occurs only rarely east of Barrow, was replaced entirely by Hyas. Sclerocrangon was replaced by Sabinea septemcarinata, another large crangonid shrimp which is one of the two most abundant shrimps east of Barrow.

In spring and summer months at both areas invertebrates, primarily crabs and shrimps, comprised over 95 percent of the stomach contents. Clams were an important component in August at Barrow, where large clam beds are known to occur off shore. This same phenomenon occurs elsewhere in Alaska. At Nome and Wainwright, from which we have examined numerous bearded seals, clams are eaten in large quantities but only in summer months. This apparent seasonal preference may be related to seasonal availability of clams which may be less active and buried deeper in the substrate during winter months.

In November and February samples from Barrow, fish assumed much greater importance. Although invertebrates (shrimps and crabs) were still major prey, arctic cod were eaten in substantial quantities. Such an increase in the importance of arctic cod during winter months has also been noted at Point Hope (Johnson et al. 1966). Figure 7 shows graphically the seasonal variation in the diet of bearded seals collected at Barrow.

In general, demersal fish were less important in the diet of bearded seals in the Beaufort Sea than elsewhere in Alaska. In those stomachs containing fish remains, arctic cod, sculpins and eelpout were the most numerous. Although arctic cod have been found in samples from other localities, demersal fishes were always much more common. The reverse appears true in the Beaufort Sea. The importance of arctic cod is probably a result of the abundance of this species in this area, and its appearance in the winter diet may coincide with an onshore spawning migration by arctic cod in the fall. Sculpins are the fishes most commonly eaten by bearded seals at other locations in Alaska. They are common benthic forms which would most likely be encountered during foraging along the bottom. In the Beaufort Sea, however, sculpins are

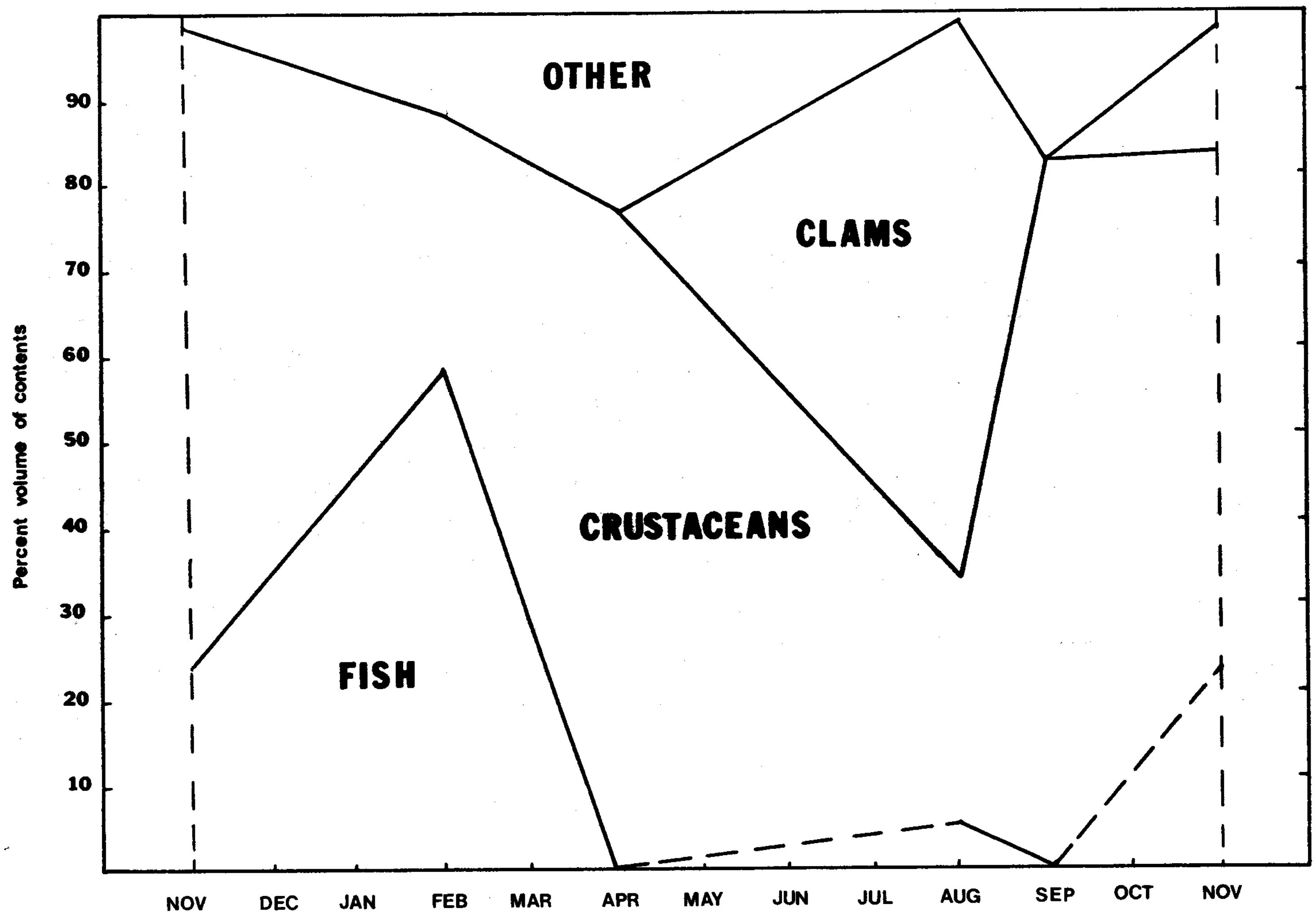

Figure 7. Seasonality in the foods of bearded seals taken in the vicinity of Barrow, 1975-1979.

less abundant than in the Bering or Chukchi Seas (Lowry et al. 1978b). The most common offshore Beaufort Sea genera, Icelus and Artediellus, appear to be considerably smaller than the sculpins generally eaten by bearded seals elsewhere. Eelpout were the second most common fish in the trawls conducted by this project in the Beaufort Sea. They appeared to be most numerous in the Barrow area.

B. Ringed Seals

At the time our 1976 Beaufort Sea Final Report was submitted, no ringed seal data were available from fall/winter months and little data existed for any area except Barrow. In the ensuing 2 years we obtained November, February and March collections of ringed seals and have expanded our collecting program to include the central Beaufort Sea around Prudhoe Bay. At this time we consider ringed seal data available for the Beaufort Sea in fall and winter adequate to characterize the food habits and trophic dependencies of seals during those months. The data for spring and summer months is much less adequate, especially for the central Beaufort Sea in the area of the proposed lease sale. Given appropriate logistics, as have been available for winter operations, an adequate collection of material could almost certainly be made.

Our investigations as well as results of previous work (Dunbar 1941, Pikharev 1946, McLaren 1958, Johnson et al. 1966) have shown that ringed seals eat primarily nektonic crustaceans (euphausiids, mysids and hyperiid amphipods), small benthic crustaceans (shrimps, isopods and gammarid amphipods), and small- to medium-size, schooling pelagic fishes (arctic cod, smelt, capelin and herring). Benthic fishes (sculpins and flatfishes) play a relatively minor role in the diet.

In the Beaufort Sea nektonic crustaceans and arctic cod comprise the bulk of the food. Diet varies markedly with the time of year (see Figures 8 and 9). Arctic cod are the primary, and often the only, food eaten during winter months. During spring and summer the importance of arctic cod in the diet diminishes and nektonic crustaceans become the main food. Whether fish or crustacean, the particular species consumed at any time of year is probably a function of seasonal abundance and local distribution of that prey species. It appears that certain areas have concentrations of appropriate food items while food is more scarce in other areas.

Those species which swarm or aggregate facilitate feeding by making it easier for seals to fill their stomachs. The largest mean volumes of contents are found in seals feeding on arctic cod in winter and nekton during summer. Large aggregations of prey species are not always available to seals, and at any time of year one may find stomachs containing generally low volumes of small benthic crustaceans such as amphipods and shrimps. The importance of aggregations of prey species has been discussed in more detail in Lowry et al. (in prep.). (See Section XI.B of RU #232 Annual Report, 1 April 1979.)

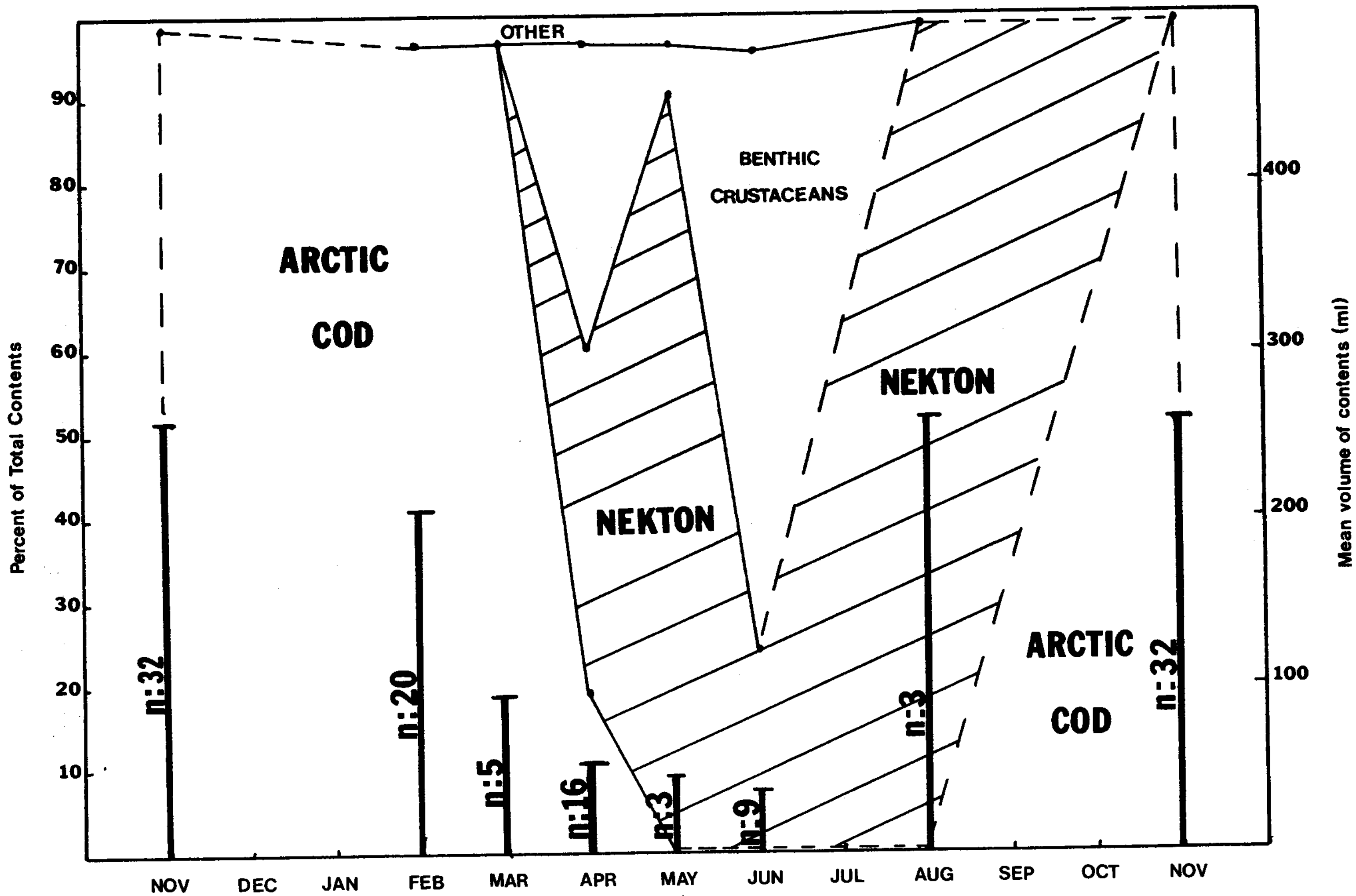

Figure 8. Seasonality in the foods of ringed seals taken in the vicinity of Barrow, 1975-1979. Vertical bars indicate mean volume of contents in each sample.

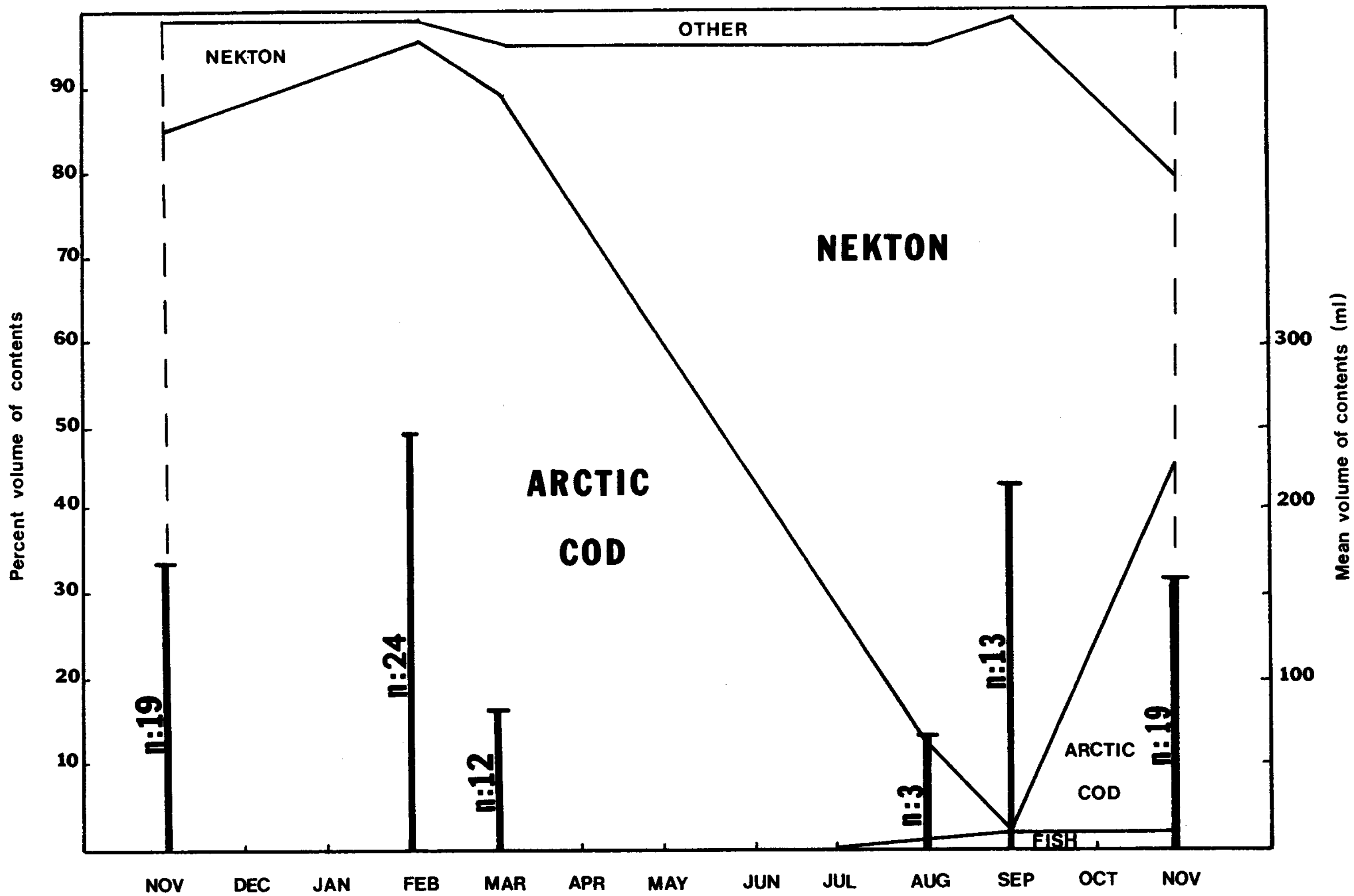

Figure 9. Seasonality in the foods of ringed seals taken offshore from Prudhoe Bay, 1977-1979. Vertical bars indicate mean volume of contents in each sample.

Although published information on winter distribution and abundance of arctic cod in Alaska is nonexistent, literature for other parts of the world suggest that an onshore spawning movement occurs in the fall. At this time fish are probably aggregated and thus more easily available to ringed seals. The nearshore area presumed to be spawning grounds for arctic cod is also the area with most stable ice conditions, and thus prime habitat for breeding ringed seals.

Arctic cod are not a major food in summer although they are the most abundant offshore fish at that time (Lowry et al. 1978b). In areas where seal collecting and trawling were conducted simultaneously, seals were found to be feeding only on nekton, although arctic cod were also present. This may be because arctic cod are dispersed during non-spawning summer months and are less efficient to feed on than swarming nektonic crustaceans.

Three types of nekton comprise the bulk of the summer diet: euphausiids, hyperiid amphipods and mysids. Which group predominates is probably a function of geographic location and time of year. Reproductive chronology and resultant peaks in abundance are quite different for the three groups, as are required hydrographic regimes. For example, euphausiids are more common in relatively warm waters than are the hyperiid amphipods which are characteristic of the high arctic (Dunbar 1957). The areas around Barrow in which euphausiids are a major component in the diet of seals coincide with areas that are influenced by an influx of warmer Bering Sea waters (Aagaard 1978).

Even at times of year and in general areas where prey is abundant, distribution of prey sometimes appears to be very patchy. Figures 10 and 11 and Tables 9 and 10 present data from seals collected off Prudhoe Bay in November 1977 and February 1979. Mean volumes and percent of stomach contents comprised by arctic cod for the collections as a whole reflect the general winter pattern, i.e. relatively high volumes of primarily arctic cod. When collection locations of individual seals are plotted and individual stomach contents data reviewed, it is evident that mean volumes and percent arctic cod are not uniform. Seals from some localized areas contained very high volumes of almost exclusively arctic cod. Seals from other areas had much lower stomach contents volumes comprised of proportionately less arctic cod. For example, seal specimens 13-19 taken in November 1977 were all taken from the same lead, and had a mean volume of 324 ml, 98.6 percent of which was arctic cod. Seals collected in adjacent areas had a mean volume of only 45 ml, comprised of 44.5 percent arctic cod. It appears that arctic cod are not uniformly distributed, but instead occur in localized patches. Seals feeding in these patches are able to consume large quantities of food in a short time. During August-September 1977 a similar situation occurred in seals eating hyperiid amphipods. The stomachs of 13 seals collected off the Prudhoe Bay area where seal densities were quite high contained uniformly high volumes of hyperiid amphipods. Stomachs collected from areas of low seal density contained very low volumes of a variety of benthic crustaceans.

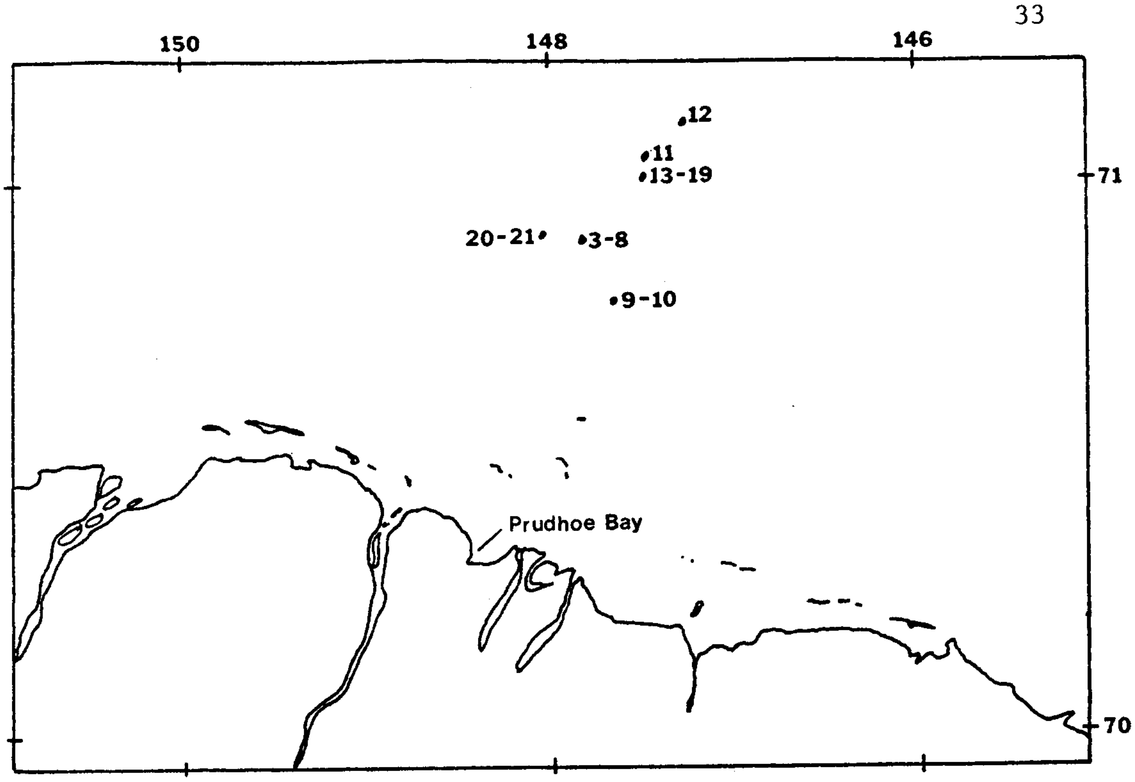

Figure 10. Map of the area off Prudhoe Bay showing locations of ringed seal specimen collections in November 1977.

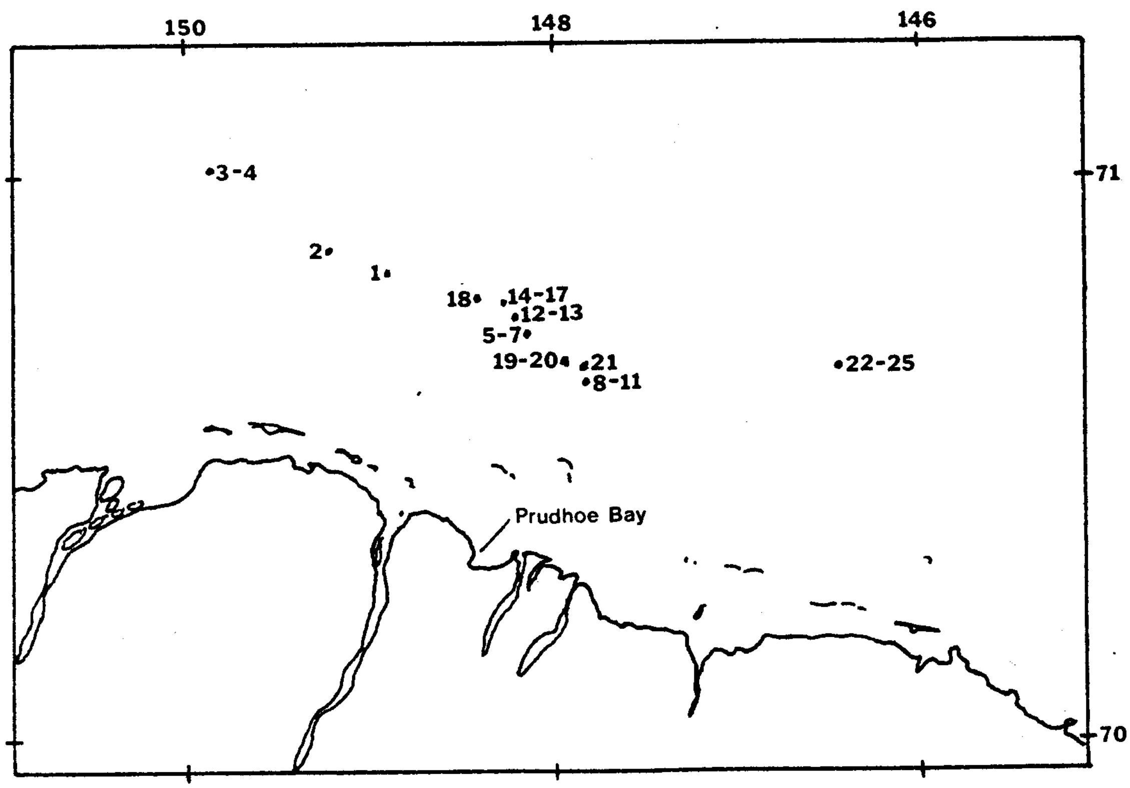

Figure 11. Map of the area off Prudhoe Bay showing locations of ringed seal specimen collections in February 1979.

Table 9. Stomach contents of ringed seals collected off Prudhoe Bay 6-9 November 1977. Specimen numbers refer to locations shown in Figure 9.

Specimen No.	Volume of Contents (ml)	Percent Arctic Cod
3	69.7	86.1
4	128.3	24.9
5	136.2	66.5
6	15.4	97.4
7	123.0	82.9
8	180.6	65.8
9	5.1	0
10	46.6	19.3
11	58.6	1.0
12	58.0	70.7
13	360.0	98.6
14	263.4	96.8
15	160.8	97.6
16	471.7	99.6
17	406.7	98.3
18	363.0	99.2
19	242.5	99.0
20	50.2	87.6
21	50.0	50.0
Specimens 3-8	Mean = 108.9	Mean = 64.1
Specimens 13-19	324.0	98.6
Others	44.8	44.5
All Specimens Combined	167.9	87.0

Table 10. Stomach contents of ringed seals collected off Prudhoe Bay 20-23 February 1979. Specimen numbers refer to locations shown in Figure 10.

Specimen No.	Volume of Contents (ml)	Percent Arctic Cod
1	440.0	100.0
2	6.9	14.5
3	81.8	95.4
4	39.9	90.2
5	430.0	100.0
6	790.0	100.0
7	448.0	100.0
8	62.1	0.2
9	70.0	42.9
10	16.7	3.6
11	1.0	100.0
12	86.0	100.0
13	Empty	--
14	1200.0	100.0
15	370.0	99.5
16	690.0	100.0
17	455.0	100.0
18	675.0	100.0
19	2.6	38.5
20	2.0	100.0
21	17.2	0
22	20.8	48.1
23	2.6	100.0
24	4.7	0
25	36.2	96.7
Specimens 5-7	Mean = 556.0	Mean = 100.0
Specimens 14-18	678.0	100.0
Others	52.4	81.2
All Specimens Combined	224.3	98.0

C. Biology of Major Prey Species of Ringed Seals

Thysanoessa raschii was the most abundant food item in the stomachs of ringed seals collected near Barrow in summer. The two most abundant species of euphausiids in the nearshore area of the Beaufort Sea are *Thysanoessa raschii* and *T. inermis* (Geiger et al. 1968). Redburn (1974), in a sampling of the plankton in the Chukchi Sea off Barrow, found a maximum concentration of 93 *T. raschii* (mostly juveniles)/100 cubic m of water on June 22, during the ice-covered period. This species had largely disappeared from his samples by the end of August. *Thysanoessa raschii* was less common in our stomach samples than was *T. inermis*. According to Nemoto (1966), *T. inermis* is believed to spawn in shallow waters along the continental shelf. The finding of several thousand individuals of this species in stomachs of ringed seals taken in August indicates presence of high concentrations which might perhaps be associated with spawning. MacDonald (1928) working in the Firth of Clyde (Scotland) found two spawning periods for *T. raschii*, the first from February to mid-May and a second from mid-August to mid-September. The frequency and period of spawning of *Thysanoessa* spp. in the Beaufort Sea are unknown. However, considering the cold temperatures and short "summer" season in the arctic waters, a single spawning in summer seems most likely (see Dunbar 1957). Redburn noted two periods during which larvae of euphausiids were abundant; the first from the middle until the end of June and the second in late July and early August. Perhaps these two peaks correspond to the spawning periods of the two species. Nemoto (1966) states that the main stocks of *T. raschii* winter in ice-covered waters. Mohr and Geiger (1968) found the abundance of *Thysanoessa* spp. to be considerably lower under the central polar ice pack than near shore. Although we found euphausiids to be present in seal stomachs in minute quantities in February 1979, they did not appear in any other winter collections. It seems likely that even if present in winter they are not found in large concentrations and arctic cod are preferred prey. *Thysanoessa* spp. feed largely on algae and microcrustaceans (Berkes 1976), and on detritus (Mauchline 1966).

Mysids (*Mysis littoralis* and *Neomysis rayii*) occurred as a major prey species in our samples from April and August and also in the November 1978 sample. They appear to be most important in the nearshore central Beaufort Sea samples, although they were also present in Barrow seals. Mysids have also been found in substantial quantities in our samples from other localities (e.g. Mekoryuk and Savoonga). Redburn (1974) encountered mysids only rarely in his collections from the Chukchi Sea near Point Barrow. MacGinitie (1955) noted that *Mysis relicta* was at times found washed up in rows on the beaches of Elson Lagoon (Barrow area). Crane (1974) encountered high concentrations of *Mysis oculata* in samples from the Beaufort Sea off Simpson Lagoon. He estimated a standing stock of 28 milligrams carbon/square meter. The food habits of mysids have been little studied. It seems likely that they consume both animal and plant material.

The hyperiid amphipod (*Parathemisto libellula*) occurred frequently in our samples throughout the year. It was most abundant in August-

September collections off Prudhoe, and generally more abundant at Prudhoe than Barrow. Dunbar (1941) found Parathemisto to be the most important food item in the diet of ringed seals from the Baffin Island area of the eastern Canadian Arctic. He later stated (Dunbar 1957) that P. libellula "forms the most important link in the food chain between the copepods and other smaller planktonic forms on the one hand, and the vertebrates on the other, and in fact it takes the place, in cold water, of the euphausiids in this respect." While this may be the case in the eastern Canadian Arctic and central Beaufort Sea, our samples indicate that it is less the case in nearshore waters of the western Beaufort Sea. This demonstrates the need for information specific to the locality under consideration. MacGinitie (1955) noted that P. libellula was extremely abundant at Barrow, while Redburn (1974) found them to be less common than gammarid amphipods, reaching maximum concentrations under the ice in spring and early summer. Mohr and Geiger (1968) consider Parathemisto an important food source for whales in waters north of Alaska.

Gammarid amphipods are a conspicuous and diverse element of the Beaufort Sea fauna (MacGinitie 1955, Shoemaker 1955). They are the predominant food of many demersal fishes, and regular prey items of seabirds, arctic cod, ringed and bearded seals, and bowhead whales. Although primarily benthic, several species make use of the inverted substrate provided by the undersides of ice floes in arctic waters (Barnard 1959, George and Paul 1970, Tencati and Leung 1970). In most of the ringed seal stomachs we examined, gammarids were found in small quantities in stomachs containing very little food. In only two samples were gammarids a major food item and stomach contents volume high. Gammarids are probably eaten at times when little else is available, or when they are locally very abundant. Redburn (1974) found gammarids to be most common during the early summer, with decreasing density during the seasonal transition to open water. Gammarid amphipods are typically considered scavengers and predators on small benthic organisms.

Arctic cod are the most common and most important forage fish in the Beaufort Sea (MacGinitie 1955, McAllister 1962, Milne and Smiley 1976, Lowry et al. 1978b). In spite of this, the basic biology of this species is poorly known. The distribution of arctic cod is closely related to the presence of ice, with the majority of the population believed to stay under or near the edge of compact ice (Svetovidov 1948, Andriyashev 1954, Ponomarenko 1968). Andriyashev (1954) indicates that in fall large schools are found near shore, especially in warm relatively fresh water near river mouths. Not surprisingly, arctic cod are the fish most commonly eaten by the ringed seals in the Beaufort Sea. They are the major and often the only prey species during winter months. Arctic cod feed mostly on zooplankton and amphipods and to a lesser extent on benthic crustaceans (Svetovidov 1948, Barnard 1959, Lowry et al. 1978b).

D. Food Webs

The main objective of this project has been to develop an understanding of the trophic relationships of marine mammals, primarily ringed seals, in the Beaufort Sea, and to assess the potential effects on seals of changes in the trophic structure of the Beaufort Sea caused by offshore oil and gas exploration and development. The following discussion is a synthesis of what we know about Beaufort Sea food webs and trophic interactions. This information has been simplified and shown diagrammatically in Figures 12 and 13. Emphasis will be placed on the pelagic food web since that subsystem is best understood, of greatest importance to marine mammals and perhaps most likely to be affected by OCS activities. This discussion relies heavily on material compiled by one of the principal investigators for the 1978 Beaufort Sea Synthesis Report. For further details please refer to that report (Frost 1978).

The offshore pelagic food web during winter months is a relatively simple one. Primary production apparently does not occur. Herbivorous zooplankton species, abundant during the phytoplankton bloom, are much reduced in number (Grainger 1959). Zooplankton consists mostly of a variety of copepods, gammarid and hyperiid amphipods, many of which are detritivores or carnivores. Stored energy reserves may be crucial for overwinter survival of some species (Dunbar 1953, Mauchline 1966).

The offshore pelagic fish fauna in winter is comprised almost entirely of two genera of cods, Boreogadus (arctic cod) and Arctogadus (polar cod). Arctic cod are by far the most abundant. Movement in winter into shallower onshore water for spawning has been reported for arctic cod in other parts of the arctic (Ponomarenko 1968). Subsistence fishers on the Beaufort Sea coast jig for arctic cod during the winter in apparent response to an increased winter abundance. Foods of arctic cod in winter months are poorly known but probably include copepods, mysids and hyperiid amphipods.

Arctic cod are of direct and major importance to two of the four top-level consumers (ringed seals and people) present in the Beaufort Sea during winter months, and of indirect importance to the other two, polar bears and arctic foxes. The relationship between polar bears and ringed seals is simple and direct: polar bears eat ringed seals (Stirling and Archibald 1977). Arctic foxes also utilize ringed seals, sometimes through direct predation on pups and sometimes through scavenging remains of kills made by polar bears (Smith 1976).

The complexity of this relatively simple winter system increases dramatically with the onset of spring and the open water period. As the amount of daylight increases, ice algae (also referred to as epontic algae) begin to grow and multiply. Although algae are present in brine pockets within the ice as early as March (Meguro et al. 1966), the peak of this bloom takes place in late May. Ice algae have been estimated to contribute 25-30 percent of the total annual phytoplankton production in northern coastal waters (Alexander 1974). The ice algal bloom lengthens the productive season by about 2 months, providing food for herbivores long before the phytoplankton are available. The ice algae largely disappear with decreasing ice cover and increasing light intensity (Horner and Alexander 1972, Alexander 1974, Mansfield 1975).

Pelagic Offshore

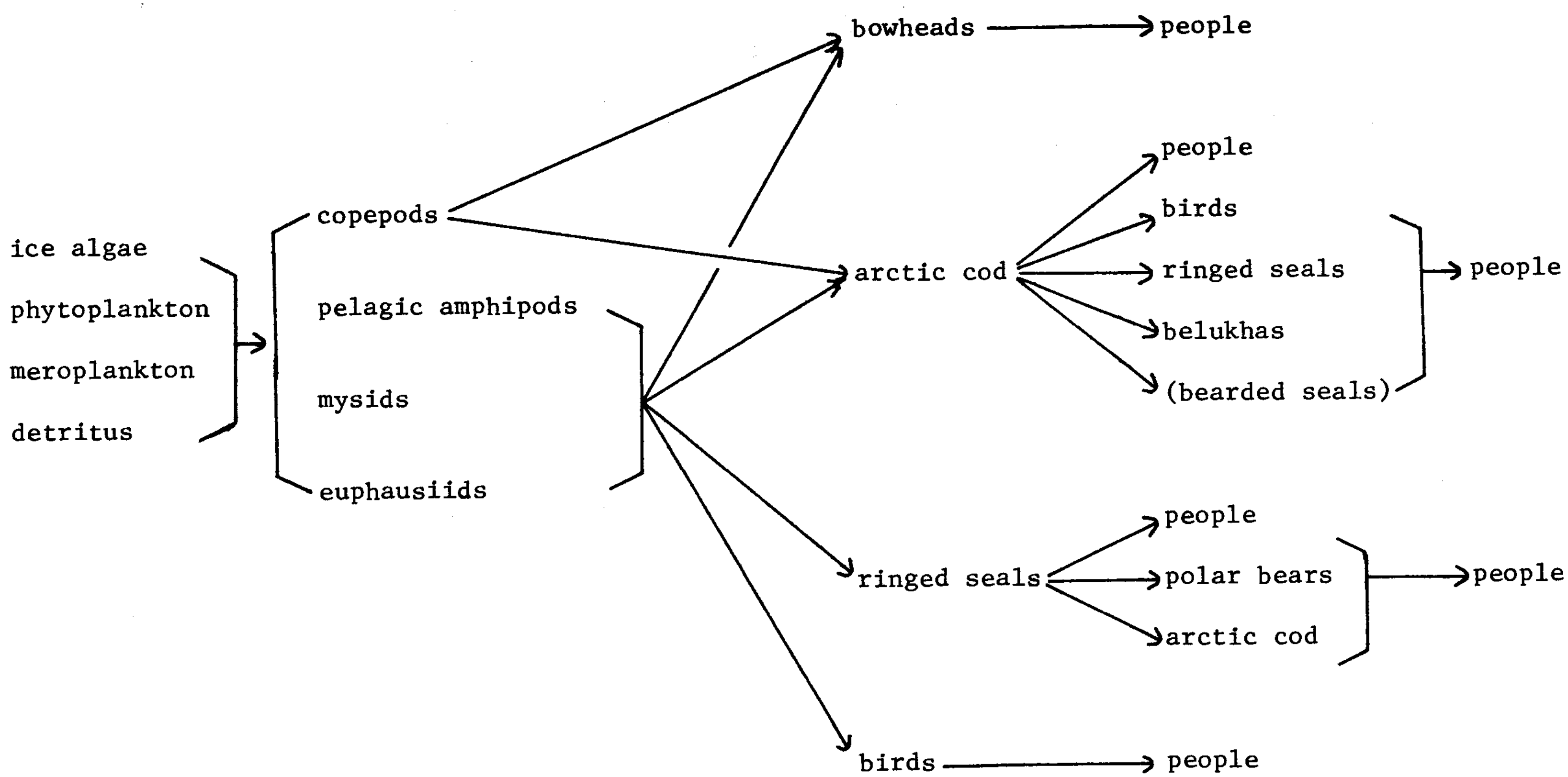

Figure 12. Diagrammatic representation of major trophic connections in the offshore pelagic food web of the Beaufort Sea.

Benthic Offshore

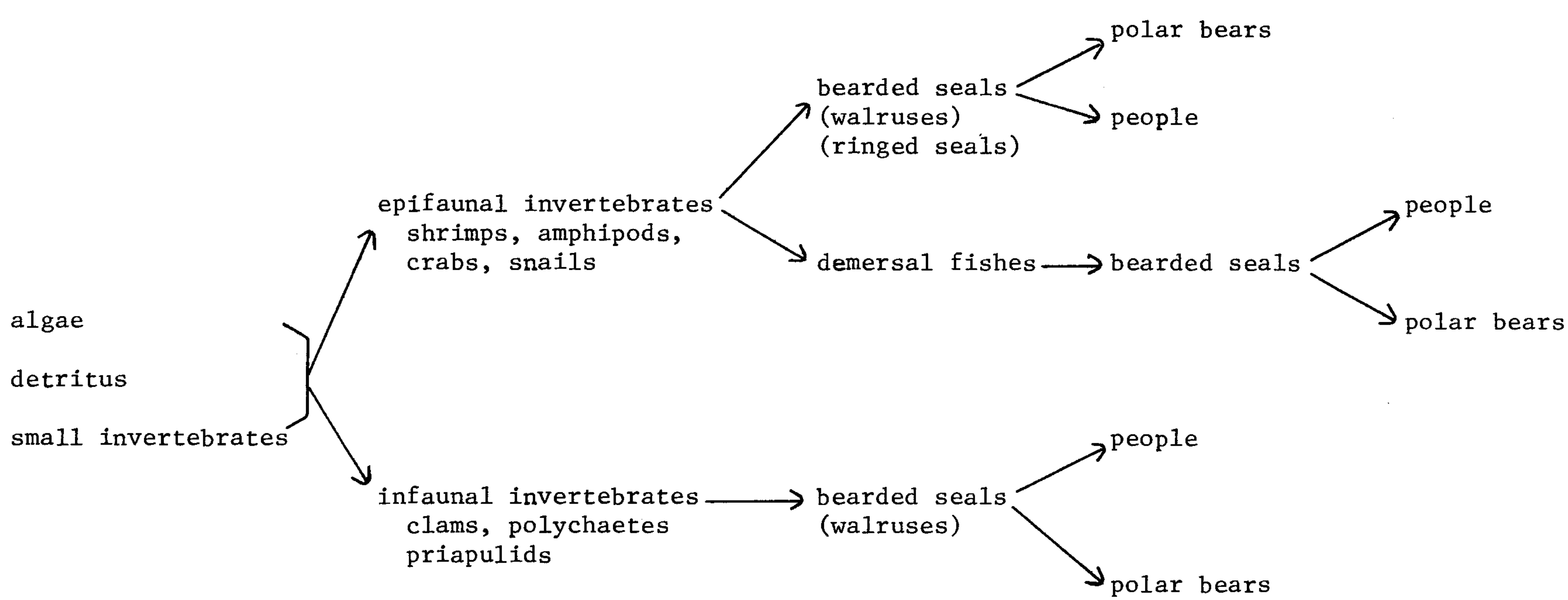

Figure 13. Diagrammatic representation of major trophic connections in the offshore benthic food web of the Beaufort Sea.

The phytoplankton bloom in the water column begins in June and July. Primary production in the water column is restricted to the months of open water, and is highest at about the time of ice breakup when nutrient levels, especially nitrogen, are high and sufficient light is available. In years of extensive summer ice cover carbon fixation by phytoplankton in the water column may be reduced by as much as 50 percent (Grainger, cited in Mansfield 1975). Diatoms are usually the most abundant components of the phytoplankton bloom, although small, non-photosynthetic flagellates may also be common (English and Horner 1977).

Reproduction of some key zooplankton species, notably copepods, occurs when the phytoplankton are available as food (Dunbar 1968). Those benthic invertebrates that have pelagic larvae also spawn during the phytoplankton bloom (Thorson 1950).

During early spring ringed seals are the only abundant marine mammals in the area. Arctic cod are apparently either less abundant or more dispersed at this time, since they are not important in ringed seal diets.

In May and early June offshore leads open. Bowhead and belukha whales move into and through the area on their eastward migrations. There is a mass influx of migrating seabirds, which are also concentrated along these leads. Shortly thereafter bearded seals move north from the Bering and Chukchi Seas and some of these enter the Beaufort Sea. Additional numbers of ringed seals enter the Beaufort Sea as ice in the southern portion of their range disappears. Few Pacific walrus enter the area. Bearded seals and walrus are benthic feeders, but all others rely primarily on a pelagic food web.

Although detailed food habit studies of bowhead whales have not been done, it is known that they feed on zooplankton such as copepods, euphausiids, mysids and amphipods (MacGinitie 1955, Mitchell 1975, Lowry et al. 1978a). Food habits of belukha whales in the offshore Alaskan Beaufort Sea are entirely unknown. As they are eaters of fish, shrimps and cephalopods in other areas, they probably feed in a similar manner in the Beaufort Sea and eat arctic cod, shrimps and squid or octopus.

By July, phytoplankton and zooplankton are abundant in the water column. Herbivorous species have a ready food supply of diatoms. Herbivores, as well as their reproductive products, provide a rich food supply for carnivorous zooplankton such as *Parathemisto*. Arctic cod collected in offshore areas in August fed extensively on copepods, particularly *Calanus glacialis*, *C. hyperboreas*, and *Euchaeta glacialis*, and on the amphipod *Parathemisto libellula* (Lowry et al. 1978b).

Large numbers of seabirds breed, raise their young and molt along the Beaufort Sea coast during summer months. Major species of birds in offshore waters include gulls (Sabine's and glaucous), arctic terns, jaegers and black guillemots, among others. These birds feed on zooplankton in nearshore areas and overwhelmingly on small arctic cod in areas more than 2 km offshore (Divoky 1978).

Ringed seals remain the most abundant marine mammals in the Beaufort Sea in summer. During this time they feed almost exclusively on nektonic crustaceans. The late summer/early fall foraging period is extremely important to ringed seals as this is the time in which they regain weight lost during the spring molt. During the molt seals may lose as much as 30 percent of their body weight.

At this time of year bowhead whales are thought to forage mostly in the eastern Beaufort Sea and Amundsen Gulf (Fraker et al. 1978).

During the fall phytoplankton populations decrease due to low light and low nutrient concentrations. Zooplankton may also become less abundant as a result of reduced food and post-spawning die-offs. Some species, including hyperiid amphipods, probably remain abundant and produce eggs and breed during the fall and early winter. Dunbar (1957) reported <u>Parathemisto libellula</u> carrying hatched young in brood pouches in December.

As food availability declines and sea ice cover increases, those species of birds and mammals not adapted to overwintering in the Beaufort Sea migrate from the area. Seabirds, bowhead and belukha whales, walruses and most bearded seals all move west and south.

Many ringed seals remain in the Beaufort Sea. At this time their diet shifts from primarily nektonic crustaceans to arctic cod. This shift is probably due to the combined effects of a decrease in availability of nekton and an increase in availability of arctic cod.

Although our knowledge of the pelagic food web is far from complete, it does provide us with focal points in the form of key species and species interactions. The relationship of primary productivity to copepods and nektonic crustaceans is basic to the system. Copepods, euphausiids, mysids and hyperiid amphipods are important prey species of arctic cod, ringed seals, birds and bowhead whales. Arctic cod are important to virtually all seabirds feeding off shore in summer months and to ringed seals and people in the winter. Ringed seals are the primary food source of polar bears and a major food source of arctic foxes in winter. Ringed seals, polar bears, arctic foxes and bowhead whales have been traditionally utilized by coastal Eskimo residents for food and income.

E. <u>Trophic Interactions of Major Vertebrate Consumers</u>

Most species of truly marine fishes in the Beaufort Sea are part of a benthic food web. They feed primarily on polychaete worms and gammarid amphipods. As such, they compete to only a limited degree with ringed seals which seem to eat benthic amphipods only when other more aggregated prey are not available. Arctic cod are linked primarily to the pelagic food web. They consume mostly copepods, hyperiid amphipods, mysids and euphausiids. All of these groups are also eaten by bowhead whales, thus placing arctic cod and bowheads, for at least part of the year, in direct competition for the same resources. All groups except copepods are important prey species of ringed seals. The competition for food between seals and cod may be reduced by seasonal dietary differences. During the months when ringed seals are eating nektonic crustaceans, arctic cod in offshore waters seem to depend primarily on copepods. During the winter months when cod feed on nekton competition is reduced by the fact that ringed seals eat primarily arctic cod.

The many seabirds that feed outside the barrier islands in summer eat almost exclusively arctic cod (Divoky 1978). Because of seasonal changes in ringed seal diet, direct competition between these groups is probably slight. During the months in which seabirds are abundant and eat arctic cod, ringed seals eat mostly nektonic crustaceans. However, even without temporal overlap in utilization, predation at one time of year will affect availability at other times. This effect would probably be compounded if arctic cod abundance was low during a particular year.

No data on food habits of spotted seals or belukha whales taken in the western Beaufort Sea are available in the literature. Data from specimens taken at other localities indicate that both species feed largely on fish, shrimp and cephalopods (Gol'tsev 1971, Sergeant and Hoek 1974, Mansfield et al. 1975, Lowry et al. 1979). In the Beaufort Sea arctic cod, anadromous fishes, shrimps and octopus are potential foods. Some of the same foods are also used by ringed seals.

Off the north coast of Alaska both spotted seals and belukhas are present only in late spring through fall and tend to stay near shore, often at or in the mouths of rivers. Ringed seals during summer and early fall are usually farther off shore associated with the pack ice. The foraging of belukhas and spotted seals is therefore somewhat geographically and temporally separated from that of ringed seals, although some of the prey species may be similar.

Perhaps the most significant trophic competitor of ringed seals is the bowhead whale. During the months when bowheads are in the Beaufort Sea, they feed at least in part on the same nektonic crustaceans that ringed seals eat (Lowry et al. 1978a). Tremendous quantities of nekton must be present to meet the energy requirements of these whales. Although the present population of bowhead whales is fairly small, probably numbering between fifteen hundred and three thousand animals, the size of the animals is so great that the daily consumption of a single medium-sized whale would exceed that of 500 ringed seals. One wonders what effect the decimation of the bowhead whale population has had on the trophic structure of the Beaufort Sea, especially on ringed seals and arctic cod which eat the same foods. It is perhaps significant that in our investigations the Beaufort Sea is the only area where nektonic crustaceans figure prominently in the diet of ringed seals.

As discussed earlier, relatively few bearded seals occur in the Alaskan Beaufort Sea, probably because of the limited areas of shallow water habitat. The same is true for walruses. In the Bering Sea in spring, walruses feed largely on bivalve molluscs (Fay et al. 1977). A casual examination of the stomach of a walrus taken northeast of Point

Barrow revealed mostly sea cucumbers and lesser amounts of priapulids, gastropods and bivalves. Although bearded seals in the Beaufort Sea also eat these foods, the bulk of their diet is comprised of shrimps and crabs. Trophic interaction between bearded seals and walruses in the Beaufort Sea is probably not significant.

The trophic interactions between polar bears and seals are quite simple. Where they both occur, polar bears kill and eat seals. The seal most available to polar bears is the ringed seal (Lentfer 1972). Bearded seals are taken much less frequently. There are several reported instances of polar bears attacking and eating belukha whales (Freeman 1973, Heyland and Hay 1976). This apparently happens most frequently when belukhas have become trapped in small polynyi by the formation of new ice. Bears frequently scavenge on carcasses of bowhead whales and walruses. It is possible for them to occasionally kill a walrus. It is unlikely that bears often encounter spotted seals as their distributions hardly overlap.

Arctic foxes frequently scavenge the remains of polar bear kills, as well as any other carcasses of marine mammals. They also kill and eat ringed seal pups which are restricted to subnivian lairs (Smith and Stirling 1975, Smith 1976). Because of their small size, it is unlikely that arctic foxes ever kill healthy, weaned seals.

Humans, as high-level consumers, interact trophically with all marine mammals. They are predators of seals, whales, walruses, bears and foxes. They compete with polar bears for seals and with seals for fish. Perhaps more important than these direct interactions are existing or potential "indirect" interactions such as displacement of seals by noise disturbance or contamination of the ocean with pollutants causing alterations in prey availability.

F. Potential Effects of Oil Development

The main objective of this project has been to develop an understanding of the trophic relationships of marine mammals and to assess the potential effects on marine mammals of changes in the trophic structure of the Beaufort Sea which may result from OCS exploration and development. If the magnitude and kinds of changes to be expected were known, our task would be relatively easy. However, such work as has been done on the fate and effects of hydrocarbons in marine systems merely emphasizes the complexity of the problem and, as yet, has yielded little of predictive value.

In order to assess the impact of oil in the environment in a quantitative sense, two sorts of information must be available. First, the quantities and kinds of petrochemicals expected to be released into the environment must be estimated. In addition, the probable vertical and horizontal distribution and persistence of these compounds must be known. From this, the duration and concentration of the various chemicals in various habitats (i.e. under ice, water column, sediments) must be predicted. These tests are not within the realm of this project. However, a general discussion of these considerations can be found in Ross et al. (1977).

The second kind of information required is an evaluation of the effects of expected levels of petrochemical pollution on representative organisms. Consideration must be given to effects on all life history stages as well as to sublethal effects which may significantly alter long-term population levels. This information coupled with knowledge of basic biological parameters (e.g. seasonal movements, reproductive rates, growth rates) of the species under consideration might allow a prediction of the expected effects on population levels of the species tested. If the species tested were well chosen and a sufficient knowledge of ecological interactions such as food dependencies and competition existed, an evaulation of effects at the ecosystem level might be attempted.

Numerous ongoing projects presently deal with lethal and sublethal effects of petrochemicals on marine organisms. Unfortunately, few of the organisms being tested appear important in the food webs of marine mammals in the Beaufort Sea.

Organisms of key trophic importance in the Beaufort Sea pelagic food web are arctic cod, euphausiids, hyperiid amphipods and mysids. Other major groups are copepods, gammarid amphipods and spider crabs. A brief discussion of the results of contamination studies on these groups follows.

Arctic cod are probably the single most important species, from a trophic standpoint, in the Beaufort Sea. Essentially nothing is known about the effects of hydrocarbon pollution on this species. However, acute toxicity tests have been done on other species of cods in Alaska. DeVries (1977) in reporting results of preliminary tests stated that Alaska pollock and Pacific cod died within 2 hours of exposure to 4 ppm naphthalene at +1°C. At 3 ppm they lost equilibrium after 3 hours and ceased to ventilate after 13 hours, with no recovery upon return to clean sea water. In contrast, sculpins and flatfish tested at 4 ppm lived 20 hours, and at 3 ppm suffered only 10 percent mortality after 48 hours.

Grose (1977, cited in Clark and Finley 1977) reported that 70 percent of the Atlantic pollock eggs (Pollachius virens) within the Argo Merchant slick area were moribund and had adhering oil globules. In adjacent areas a greater percent of the eggs were viable but 64 percent showed evidence of oil contamination. Cytogenetic studies indicated a high incidence of abnormal development.

Kuhnhold (1970), working with another cod species, Gadus morhua, found water extracts of crude oils to be highly toxic to eggs tested 5-30 hours after fertilization. Mortality was lower in older eggs, but many of the hatched larvae were abnormal and died within a few days. Mironov (1967) also working on cod found that crude oil killed all eggs within 2 days at 100 ppm and within 3 days at 10 ppm.

Arctic cod in the Beaufort Sea probably spawn near shore under the fast ice in January and February. Their eggs develop in surface waters under the ice (Rass 1968). The egg stage lasts 1.5-3.0 months, and the larval stage, which is also present in surface waters, lasts about 2 months. For these reasons, arctic cod are potentially very vulnerable to impact from petroleum development activities. Because the eggs and larvae are in the upper water column, they are likely to be exposed to surface spills, emulsions and dispersions. In other species eggs and larvae appear to be the stages most sensitive to contamination (Eldridge et al. 1978), and this sensitivity may be compounded in arctic cod by the long egg and larval stages.

The schooling of the adult arctic cod at spawning time in nearshore areas, particularly near narrow cracks in the ice, places them in the areas most likely to be contaminated by winter oil spills. It also suggests that in the event of a catastrophic spill or blowout a large proportion of the breeding segment of the population might be affected.

To our knowledge the effects of hydrocarbons on the other three key species groups, euphausiids, mysids and hyperiid amphipods, are completely unknown. Some tests have been run on arctic copepods, gammarid amphipods and spider crabs. Corner (1976, cited in Eldridge et al. 1978) found the copepod Calanus helgolandicus to accumulate hydrocarbons through its diet. Accumulation and depuration were slower when the hydrocarbon source was from contaminated food rather than in solution in the water. Percy and Mullin (1975) found the copepod Calanus hyperboreas, a prey species of arctic cod and bowheads, to be "remarkably resistant." On the other hand, they found the amphipod Onisimus glacialis to be the most sensitive of all invertebrates tested to oil-contaminated sediments and dispersions of oil in water. Onisimus is known to clean rocks of asphaltics (Atlas, pers. comm.). To our knowledge asphaltics do not transform and their fate once ingested by amphipods is unknown. Busdosh and Atlas (1977) reported that, in Beaufort Sea gammarid amphipods, gravid females subjected to the parafinic fraction of Prudhoe Bay crude oil lost their eggs.

The susceptibility of crabs to petrochemicals is suggested by the work of Karinen and Rice (1974) and Parker and Menzel (1974). Karinen and Rice found that oil emulsions at 1 ml/l and less caused autonomizing of limbs in newly molted tanner crabs. They also found a delay of molt and lower rates of molt success. Parker and Menzel, working on crab larvae (hermit, spider and stone), found them sensitive to No. 2 fuel oil. Concentrations of 0.5 ppm retarded growth and inhibited molting in hermit and spider crab larvae. Smith (1976) found that exposure to Gulf of Alaska crude oil caused alteration of gill ultrastructure in Alaska king crabs. Mironov (1970) states that crabs which have highly resistant adult forms often have sensitive larvae. Rice et al. (1976) did acute toxicity tests on tanner crab larvae with Prudhoe Bay and Cook Inlet crude oils and found that, although actual death occurred quite slowly and at relatively high concentrations, moribundity happened at concentrations as low as 1-2 ppm.

In predicting or assessing the effects of petroleum exploration and development on trophic interactions among species, one must consider a multitude of questions. Not only is it important to know the direct effects of hydrocarbons on critical prey species, but one must also evaluate temporal variations in prey sensitivity, critical times or areas for particular prey species and critical feeding periods for predator species. Two examples follow.

1. Ringed seals in the Beaufort Sea feed extensively in late summer on nektonic crustaceans. This feeding period may be disproportionately important to the general well-being of the seals throughout the year. Food reserves accumulated during this time may enable animals to survive through ice-covered winter months. They may also be important to pregnant females with newly implanted fetuses. An event affecting nekton availability at this time might have far greater ramifications than if it occurred at another time.

2. Arctic cod spawn in nearshore areas under the ice. Eggs, larvae, juveniles and adults at some times of year are localized in areas where oil contamination is likely to occur. Because egg and larval development is so slow, these sensitive stages could be exposed to pollutants for long periods of time.

Pollutant levels high enough to cause large-scale die-offs of individuals will probably occur only on a very localized basis (except where oil or pollutants are trapped under the ice and transported long distances in a relatively unweathered state). The greatest concern may not be with these local catastrophic events but with long-term sublethal effects of pollutants. Individuals may not be killed directly, but very low concentrations of pollutants may affect locomotion, metabolism or reproduction and lead to substantial reduction of populations over several generations (Percy and Mullin 1975). These long-term reductions are of special concern in considering food availability to consumers. Figure 14 presents a diagrammatic representation of the possible pathways of spilled oil in the Beaufort Sea marine environment.

VIII. Conclusions

Bearded seals are relatively uncommon in the Beaufort Sea. They eat mostly crabs, shrimps, clams and other benthic organisms. Arctic cod are eaten during late fall and winter. It appears unlikely that OCS activities in the proposed Beaufort Sea lease area will have a measureable impact on bearded seals.

Ringed seals are abundant in the Beaufort Sea and compete with and provide food for other marine species. They feed mostly on a relatively few species which are primarily pelagic. These species are: *Boreogadus saida* (arctic cod), *Parathemisto libellula* (hyperiid amphipod), *Thysanoessa* spp. (euphausiid) and *Mysis littoralis* (mysid). Seasonal changes in prey are evident. Indirect evidence suggests that optimum feeding conditions occur when prey are present in dense concentrations.

Available information on the distribution, abundance and natural history of the major prey species is inadequate. Information on hydrocarbon sensitivity of these species is totally lacking. Until such information becomes available, the potential effects of OCS development

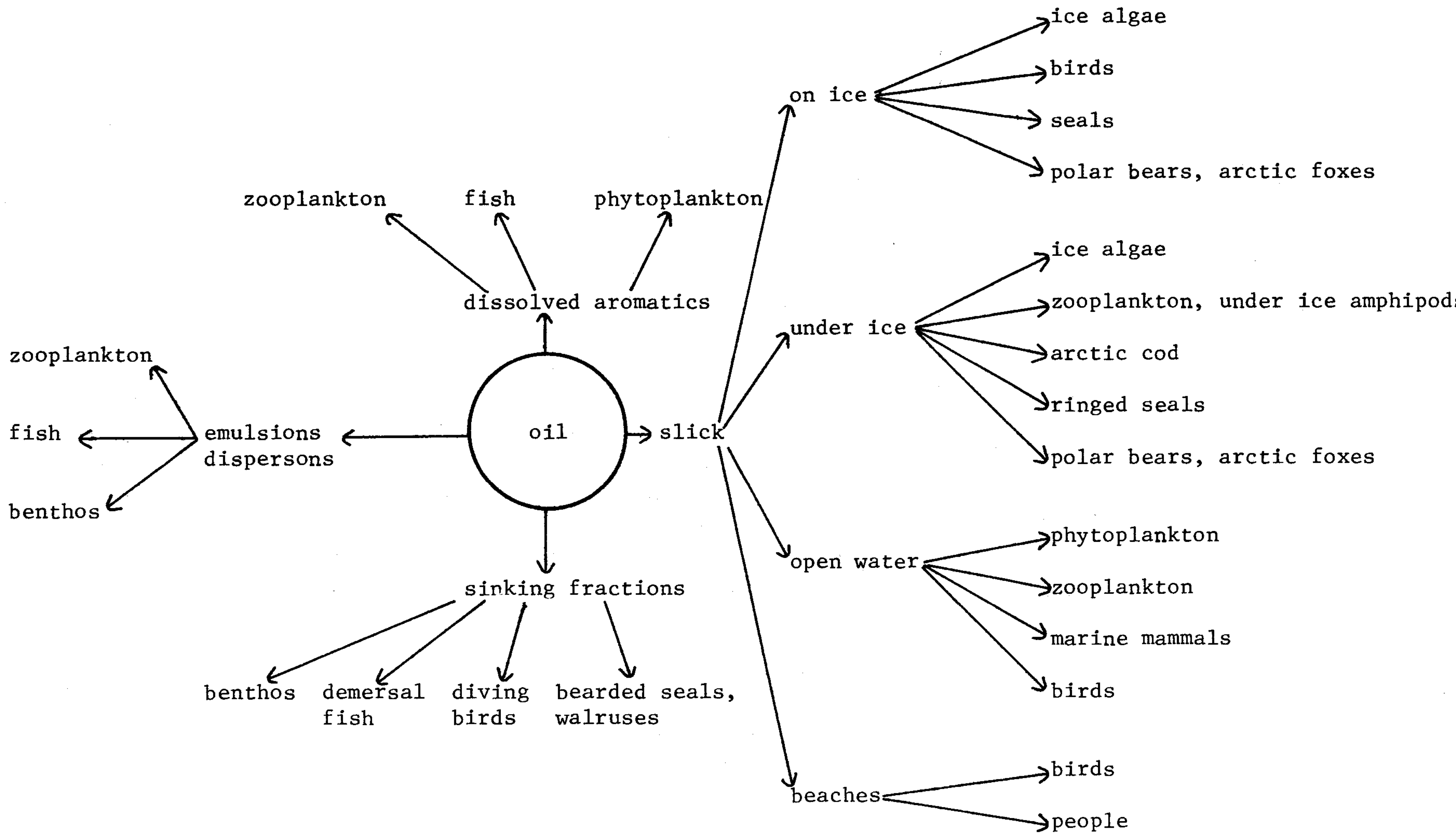

Figure 14. Diagrammatic representation of possible pathways of spilled oil in the Beaufort Sea.

in the Beaufort Sea on ringed seals cannot be quantified. However, based on the scanty information available, a real potential for a detrimental effect does exist. Changes in abundance of ringed seals in the Beaufort Sea can be expected to influence populations of other marine vertebrates.

IX. Needs for Further Study

Distribution and abundance of arctic cod are virtually unknown in the Beaufort Sea. Spawning time and locations are unknown. Very limited data are available on feeding. Prey specificity, seasonal variation in prey, availability of alternate prey items and sensitivity of prey to hydrocarbons should be examined. With this information it would be possible to evaluate the sensitivity of this link. Arctic cod are one of the most important forage species in the Beaufort Sea. Research should be undertaken immediately to fill in these data gaps.

Data are needed on a seasonal basis on the distribution and abundance of key invertebrate prey species, the factors determining their presence or absence and the timing of important life history events in the Beaufort Sea.

These species are:

Pelagic amphipods	- *Parathemisto libellula*
Mysids	- *Mysis littoralis*
Euphausiids	- *Thysanoessa raschii* and *T. inermis*

Some information on these species is available in the literature. It should be compiled and analyzed in light of questions pertaining to petroleum development. If critical feeding areas for high-level consumers exist in the Beaufort Sea, they will be determined in part by the distribution of these organisms.

There is a need for an assessment of the sources and rates of production, as related to ice, oceanographic and meteorologic conditions. Magnitude and causes of natural variation, relative rates of production in open water versus under sea ice, contribution of ice algae and the possible effects of heavy or light ice years on total production should be explored. With this information one should be able to delineate areas and/or times in which oil spills would be most detrimental to production, i.e. under the ice or in open water, during winter or summer months.

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Appendix I. List of common and scientific names of the marine mammals and prey organisms included in this report.

A. Marine Mammals

Bearded seal	*Erignathus barbatus*
Ringed seal	*Phoca hispida*
Spotted seal	*Phoca largha*
Walrus	*Odobenus rosmarus divergens*
Belukha whale	*Delphinapterus leucas*
Bowhead whale	*Balaena mysticetus*
Arctic fox	*Alopex lagopus*
Polar bear	*Ursus maritimus*

B. Fishes

Arctic cod	*Boreogadus saida*
Sculpins	F. Cottidae
Eelpout	*Lycodes* spp.

C. Invertebrates

Mysids	*Mysis* spp., *Neomysis* spp.
Euphausiids	*Thysanoessa inermis*, *T. raschii*
Isopods	*Saduria entomon*
Hyperiid amphipods	*Parathemisto libellula*, *P. abysorrum*
Shrimps	*Eualus gaimardii*, *Sclerocrangon boreas*, *Sabinea septemcarinata*
Spider crabs	*Hyas coarctatus*, *Chionocetes opilio*
Clams	*Mya* sp.
Hermit crabs	*Pagurus* spp.

FINAL REPORT

Research Units 338/341/343

The following was submitted as the final report for these research units:

Sowls, Arthur L., Scott A. Hatch, and Calvin J. Lensink (October 1978). Catalog of Alaskan Seabird Colonies, Fish and Wildlife Service, U.S. Department of the Interior, FWS/OBS - 78/78, 32 pp. + 153 maps + Appendixes A,B&C.

FINAL REPORT

April 1979

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Reporting Period: January 1, 1976 to

31 October, 1977

A SURVEY OF CETACEANS OF PRINCE WILLIAM SOUND AND ADJACENT VICINITY - THEIR NUMBERS AND SEASONAL MOVEMENTS

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I. Summary of Objectives, Conclusions, and Implications with Respect to OCS Oil and Gas Development

Basic objectives of this project were to document the relative numbers and seasonal distribution of cetaceans in Prince William Sound, Alaska and to determine major foraging and accumulation areas for principal species.

With regard to peak numbers, Odontocete (toothed) cetaceans are far more numerous in Prince William Sound than are Mysticete cetaceans. Based on aerial surveys conducted in 1977, it is estimated that more than 8,500 Odontocete whales inhabit Prince William Sound during the summer months. Mysticete whales probably do not number over 100 animals during the peak of the summer season, but many more pass through the area on migrations to or from feeding grounds in teh Bering Sea. It is estimated that almost the entire population of gray whales, *Eschrichtius robustus*, passes through the Northeast Gulf of Alaska twice yearly. Surveys conducted at Cape Sarichef on Unimak Island indicate that over 10,000 gray whales passed into the Bering Sea by mid-June in 1977.

Within Prince William Sound major foraging by whales and porpoises occurs in the area between Naked Is., Perry Is. and Eleanor Is. during May and June, and then is especially concentrated in the southwest area of the Sound for the remainder of the forage season which lasts through October. Additional feeding by both porpoise and whales was observed in both Hinchinbrook Entrance and Montague Strait from May through October.

It is presumed that oil and gas development impact on cetaceans will arise from two sources. The first will be disturbance due to human activity associated with exploration and development, and is expected to be minor since significant vessel activity occurs in the study area at present.

The second potential impact on cetaceans will be caused by oil spills. Either a spill from a drilling rig in the Northeast Gulf of Alaska or a spill by a loaded tanker outside Prince William Sound could impact cetaceans. Direct impact would include oiling of the animals themselves, while secondary impact would affect the food chain upon which the whales are dependent. No estimate of severity of impact from spilled oil is available, but it is assumed to be potentially serious.

II. INTRODUCTION

Between May 1976 and October 1977, periodic field surveys were conducted in Prince William Sound and the adjacent northern Gulf of Alaska. These surveys were designed to identify and enumerate the various whales and porpoise found in these areas. The results presented here represent part of the effort by the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the Alaska Department of Fish and Game to obtain baseline resource data from outer continental shelf areas in Alaska. These data will be used by the Bureau of Land Management to evaluate the probable impacts on natural resources from development of petroleum reserves in Alaskan waters.

The objectives of this study were to:

1. Determine relative numbers and seasonal distribution
2. Determine major foraging and accumulation areas.

While marine scientists feel confident that an oil spill in an area inhabited by sea otters, *Enhydra lutris*, will be extremely damaging to those otters actually oiled by the spill, there is much less concurrence about the effects of oil spills on cetaceans. Kooyman, et al. (1975) found that gray whales, *E. robustus*, actively take surface water into the upper sacs of the respiratory system. Should these findings apply to most, or all, cetaceans, it would indicate a much higher vulnerability to oil spills by these animals than originally suspected. Another area of concern is the likelihood of disturbance to cetacean populations by exploratory and development activity in the lease areas and from or by marine petroleum transport corridors, such as Hinchinbrook Entrance and the port of Valdez. The Marine Mammal Protection Act of 1972 states that it is illegal to harass marine mammals without a permit, and the House report (supra note 22, at 4155) defines harass to include "the operation of motor vessels in waters in which these animals are found" (Coggins, 1975). The National Marine Fisheries Service, however, has promulgated regulations which make only intentional harassment of cetaceans illegal.

III. CURRENT STATE OF KNOWLEDGE

Apparently no previous studies of cetaceans in Prince William Sound have been conducted. The U.S. Fish and Wildlife Service, the Alaska Department of Fish and Game, the National Park Service, the U.S. Forest Service, personnel of the National Marine Fisheries Service as well as numerous commercial fishermen have reported incidental sightings of cetaceans in Prince William Sound during the course of other activities. A list of cetaceans known to occur in the Sound is included in Table 1.

We know, from conversations with people and organizations familiar with Prince William Sound, that certain species of large whales occur on a semi-regular seasonal basis, and that at least two species of porpoise occur in the Sound year-round. However, until now, we have had no knowledge of numbers of animals in the area. Brochures produced by the Forest Service and the National Park Service provided information on cetaceans those groups had seen; and Karl Schneider, Ken Pitcher and Don Caulkins of Alaska Department of Fish and Game provided records of their previous and current cetacean sightings. Jim Johnson of the National Marine Fisheries Service mentioned sighting numerous humpback whales, _Megaptera novaeangliae_, in Prince William Sound during the early 1950's; while Jim King of the Fish and Wildlife Service mentioned that he saw no humbacks in the Sound in the late 1950's. Pete Isleib of Cordova saw very few humpbacks in the mid to late 1960's, but noted that they were becoming more numerous in the early 1970's. These observations of numerous humpback whales present in the early 1950's, few in the late 50's and 60's and increasing sightings in the 1970's coincides well with the timing of pelagic whaling by the Japanese and Soviets in the Gulf of Alaska. Major effort by these two nations began in the mid 1950's, peaked by about 1965, and dropped to nothing with the granting of protection to humpback whales in 1966. Fin whales, _Balaenoptera physalus_, have been reported in the Sound by the Forest Service and the National Park Service, but I considered this species a casual visitor until many were sighted during a Fish and Wildlife Service aerial survey over the area in 1975. All sources reported minke whales, _Balaenoptera acutorostrata_, to be common visitors, perhaps even residents of the Sound. Both commonly sighted species of small cetaceans, Dall porpoise, _Phocoenoides dalli_, and the harbor porpoise, _Phocoena phocoena_, were reported to occur in varying numbers throughout the year by most sources. Gray whales have been sighted passing through the northern Gulf of Alaska on their annual migration by Richard MacIntosh of the Kodiak laboratory of the National Marine Fisheries Service. Gray whales have also been sighted in the Kodiak area by other NMFS observers (Rice and Wolman, 1971), and by Fish and Wildlife Service observers aboard OCSEAP vessels near Montague Strait in Prince William Sound.

Thus it was clear, before this project started, that investigators from various agencies had seen whales and porpoise in and near Prince William Sound.

It was also clear that no systematic effort had been made to quantify the numbers and distribution of cetaceans in the Sound, even though sizeable populations of whales and porpoises were thought to inhabit the area.

IV. STUDY AREA

Prince William Sound is located in southcentral Alaska at the northernmost point of the Gulf of Alaska (Figure 1). Central latitude and longitude of the area is approximately 60°30' North latitude by 147°00' West longitude, though the study included an area of over 6,500 Nautical mile^2 (10,000 km^2). The area was created during the Pleistocene by repeated advance and retreat of glaciers (Coulter, et al, 1973), and is characterized by a series of deep fjords located around the perimeter while several large barrier islands form the southern boundary. Because of its protected nature and oceanic accessability through two major entrances, Hinchinbrook Entrance to the east and Montague Strait to the west, the Sound has recently been described as a potential petroleum cesspool due to the wind and current patterns in the Gulf of Alaska (NEGOA Synthesis Meeting, December 1976). While it has the potential of becoming a cesspool in the future, at present Prince William Sound is a relatively untouched marine gem with extensive natural resources. Marine mammals, birds, fish and invertebrates abound, and the macrophytic growth is luxurious. Today these resources undergo relatively light utilization by man, with the exception of salmon, herring, crab and some macrophytes.

The climate in Prince William Sound is decidely northern maritime with rain and clouds common in spring, summer and fall, and snow and rain common in winter. Temperatures are mild with highs in the summer generally less than 18° C and lows in the winter normally above 0° C. Wind is a common feature with two general patterns visible. Winds tend to be light and variable in the summer, but change to strong southwest to southeast blows in the fall, winter and spring when associated with the passage of frontal lows. Throughout the year, but especially during high pressure periods in the winter, the winds change more to north to northeast and blow down canyons and fjords with velocities of 70 knots or greater.

During the passage of occluded lows, the entire area may be blanketed by fog and low clouds for several days, but during periods of high pressure, visibility may exceed 100 kilometers. Marine water temperatures (surface) range from 11° C to 13° C in the summer to 1° C to 4° C in the winter.

Because of the abundance of forage fish in Prince William Sound, high trophic level consumers, such as marine mammals and birds, find this area a nearly ideal seasonal niche. Commonly utilized forage fish include herring, *Clupea harengus pallasi*, capelin, *Mallotus villosus*, pollock, *Theragra chalcogramma*, and sand lance, *Ammodytes hexapterus*.

V. METHODS

The study has utilized semi-standarized marine mammal survey techniques (Leatherwood and Platten, 1975). These have included strip census techniques from fixed-wing aircraft and surface vessels, streamer tag deployment for mark-recapture studies, and natural mark identification for unique individuals.

Strip census techniques as utilized in marine mammal studies vary considerably from one study to the next because of the different characteristics of various orders of marine mammals. For the aerial survey portion of this study, predetermined fixed transects were flown at fixed altitudes and speeds (Figure 2).

A measurement of the right angle distance of each animal sighted was made by measuring the declination angle of the animal relative to the aircraft with a standard inclinometer. Using the computation:

$$B=a/\mathrm{Tan}B \quad \underline{\text{or}} \quad b=a\ \mathrm{Cot}A$$

the horizontal distance between the survey aircraft and the target was determined. This distance clearly varies as a function of observer experience, weather and sea conditions, and platform speed and altitude (Caughley, 1976). In order to minimize the effects of these variables, a standard platform, the McKinnon Turbo-Goose, was utilized. This converted Grumman Goose is equipped with a navigation suite including a VLF band position locator. This instrument, model GNS-500, provided a continuous digital readout of the platform's position in longitude and latitude measured to 1/10 nautical mile. All animal sightings were voice recorded on magnetic tape by the observer. Each sighting included the following information:

Species identification

Number sighted

Time of sighting

Position of sighting

Platform speed

Platform altitude

Clinometer reading

Comments on animal behavior observed

Upon return to Anchorage, the magnetic tapes were manually stripped of information and resulting data was coded on Environmental Data Service approved marine mammal sighting records and batch submitted for processing (Appendix 1).

Vessel surveys differed significantly from aircraft surveys in that several activities in addition to marine mammal observations were conducted. These included remote tagging of both large and small cetaceans; and the collection of certain environmental data such as surface water temperature, water depth, weather pattern, wind speed and direction, sea state, air temperature, and barometric pressure. These data, along with the sighting data, were recorded on approved record sheets. Submission of data records to the keypuncher occured on a regular basis. Final data submission was in December 1977. During vessel surveys, a marine mammal watch was posted continuously during daylight hours.

The track design of the vessel surveys was different from those described above for the aircraft. Because we were interested in describing areas of extensive utilization, we attempted to traverse areas that had been noted in the past to have large populations of cetaceans. As time allowed the vessel surveys also covered as much as possible of the rest of Prince William Sound.

VI. RESULTS

The data presented here represent those collected during the study, as well as migratory data for the gray whale, *E. robustus*.

During the study five aerial surveys representing 2144 nautical miles (3281 km) of survey trackline and ten vessel surveys covering 3094 N. mi. (4735 km) were completed. Combined trackline totals represent 5238 N. mi. (7986 km) of survey effort (Table 2). During the surveys 2945 cetaceans were actually sighted. This represents .562 cetaceans/N. mi. (.368 cetaceans/km). Statistical data relating to cetacean sightings is shown in Table 3. Corresponding figures showing sightings by species and as a function of effort are shown in Appendix 2.

In general cetaceans became increasingly obvious and abundant starting about late April or early May and peaked in numbers during the late summer. By late fall (October) the numbers appeared to be declining, and by January the area appeared almost devoid of cetaceans, especially the larger whales. Both Dall and harbor porpoise were present throughout the year, though centers of distribution varied seasonally. Dall porpoise were most abundant well inside the Sound, while harbor porpoise were concentrated in the Hinchinbrook Entrance area during fall and winter.

Annotated Species Accounts

Dall porpoise - *Phocoenoides dalli*

This typically pelagic porpoise occurs in the North Pacific Ocean from Baja California to the northern Bering Sea. It is clearly the numerically dominant cetacean in Prince William Sound. Dall porpoise were sighted throughout the year. During the study Dall porpoise were observed on 419 occasions. These sightings represented a counted population of 1,762 individuals. Average group size was 4.70 porpoise/group, and group sized ranged from 1 to 35 individuals per group. Larger groups have been sighted in the Sound in winter by the Alaska Department of Fish and Game (Hall and Tillman, 1977).

Sightings of Dall porpoise accompanied by calves have been limited to spring (March-April) and late summer (August-September). Newborn Dall porpoise in Prince William Sound frequently have light gray pigmentation on the dorsal surface of the head, and are thus distinct from adults by coloration as well as size. As the young porpoise grow the gray pigmentation fades to a "skullcap" surrounding the blowhole. By mid-summer these young animals are indistinguishable from older Dall porpoise by coloration, though they still are smaller in size. Observation of the gray area is difficult due to light reflection and refraction near the surface of the water. Reliable observation of this gray coloration in young Dall porpoise could only be accomplished by standing directly over the animal as it rode the bow wave of the tagging vessel. This was accomplished by mounting a one meter long bow pulpit to the foredeck of the tagging vessel, thus allowing observations from almost one meter ahead of the cutwater. Previous reference to this color pattern phenomena in young Dall porpoise has not been mentioned in the literature. It is unknown whether or not this color pattern is present in stocks of Dall porpoise from the western Pacific.

During the study a total of 23 Dall porpoise were marked with modified FH-69 Floy porpoise tags. Thus far one reliable resight of a tagged animal has been made. A Dall porpoise tagged in Chatham Strait (57°55' North by 135°00' West) on May 12, 1977 was resighted by an Alaska Department of Fish and Game enforcement vessel in the same general area of Chatham Strait (58°05' N. by 135°00' W.) on August 12, 1977. During the 90 day interval between tagging and resight the porpoise covered only a net of 10 nautical miles. This apparently restricted home range is very similar to the findings of Mororejohn for the same species in Monterey, California (unpublished ms.).

A uniformly gray Dall porpoise was sighted twice in 1976 in the Sound and was sighted three times in 1977 from the vessel, but not at all from the aircraft. An additional sighting of a uniformly gray Dall porpoise was reported by C.S. Harrison from near the Barren Is. in 1975. A total of 6 sightings of uniquely pigmented adult Dall porpoises from in and near Prince William Sound have been made. In 1976 these animals were accompanied by 50 and 2 other Dall porpoises respectively. In 1977, gray Dall porpoises were accompanied by 10 Dall porpoise on two occasions and by 7 Dall porpoise on the third occasion. Capture of this uniquely marked animal was attempted in August of 1977, and though the animal was netted while bow riding, it managed to escape from the head net before it could be examined. As soon as it escaped, the entire group of accompanying Dall porpoise sounded and surfaced very quietly several hundred yards away from the capture boat. Although the gray Dall porpoise was extremely visible when near the vessel due to its light gray color, after the aborted capture attempt it was almost impossible to identify the gray animal when it surfaced in a group of normally pigmented animals. Only by using binoculars could the gray animal be identified at over 100 yards distance. It is unlikely that other investigators would recognize this (these) animal(s) unless the investigator were actively checking every Dall porpoise sighted.

I believe that the 5 sightings of these uniquely marked animals inside Prince William Sound over a 24 month period represent home range records for the summer season. If this hypothesis is correct, it adds further data to that of Moorejohn for Monterey Bay and the tag resight from Chatham Strait, and indicates that these animals, at least in the eastern North Pacific, may be quite restricted in individual movements, especially on a seasonal basis.

In 1977 an inappropriate population estimator was used to estimate the population of P. dalli in Prince William Sound (Hall and Tillman, 1977). More recently the estimator developed by Eberhardt (1968) has been utilized since the data meet the assumptions required that estimator (See Crain, B.R. et al, 1978 for a more complete review of the modified Beta distribution analysis). The technique developed by Eberhardt involves catagorizing the data by cells of increasing sighting distances. The resulting product of the equation:

$$D = \frac{n\,(k+1)^2}{4\,L\,\bar{x}\,k\,(k+2)}$$

is an estimate of the density of animals per transect length unit, where

D= density per survey length unit

n= number of sightings

L= length of transect

$\bar{x}$= average sighting distance

k= the shape of the curve describing the sighting rate as a function of sighting distance (where k=1 the curve is linear, where $k > 1$ the curve is convex and if $k < 1$ the curve is concave).

The Dall porpoise population, based on the summer (6/6/77) aerial survey, is estimated to be 7,328 animals with 95% confidence limits (based on right angle sighting distance) of 5,406 and 9,972 animals. This population estimate is based on 4,866 nautical mi^2 of Dall porpoise habitat inside the Sound and 6,109 N. mi^2 outside Prince William Sound, but within the overall study area (total habitat= 10,975 N. mi^2). These habitat figures were developed using a Numonics 1224 Graphics Computer on Landsat MSS Band 4+5 imagery and NOAA chart No. 16700. The inshore limit of Dall porpoise habitat was defined as the 10 fathom isobath because Dall propoise were only rarely seen in water less than 10 fathoms deep. The offshore limit was 59°30' N. latitude to the south, 149°30' W. longitude to the west and 146°00' W. longitude to the east.

Using the same estimator described above, an estimate for the within Prince William Sound Dall porpoise population was calculated from the fall (9/12/77) aerial survey data. The results are listed on the following page.

DATE	POPULATION ESTIMATE	95% CONFIDENCE LIMITS
9/12/77	6,756	5,137 - 9,785

This estimate is based on a habitat area of 4,866 N. mi^2. Although aerial surveys were conducted during January and March in 1977, insufficient numbers of P. dalli were sighted during the flights to allow development of population estimates for winter and spring, though the populations are clearly lower than during summer or fall.

Harbor porpoise - Phocoena phocoena

This small odontocete cetacean is world wide in distribution, and in the Eastern Pacific the animal ranges from about Pt. Conception in California to the Arctic Ocean near Pt. Barrow, Alaska. In the study area harbor porpoise were infrequently encountered anytime between June and September, however, a large population of this species occupies the area in and near Hinchinbrook Entrance from mid-summer until late April. Eighty-four harbor porpoise were sighted in and near Hinchinbrook Entrance during a 6 mile long segment of an aerial survey completed in September 1977. These porpoise, when near Hinchinbrook Entrance, are always associated with the plume of turbid water from the Copper River. As soon as the aircraft left the area of turbid water, sightings of this species declined to almost zero. I presume that the animals are feeding in the more turbid water from the Copper River, perhaps on forage species concentrated by the edge effect and mixing of the Copper River plume with the Gulf of Alaska waters in Hinchinbrook Entrance. During the study 315 harbor porpoise were sighted on 136 occasions. One hundred seventeen of the sightings were made during aerial surveys and the majority of vessel sightings were made in May 1977 during the nearshore Gulf of Alaska cruise of the tagging vessel.

Using the density estimator described in the section on Dall porpoise, I calculated the population of *P. phocoens* for winter (1/26/77), spring (3/12/77) and late summer (9/12/77) aerial surveys. The results are presented below and in Table 3.

DATE	POPULATION ESTIMATE	95% CONFIDENCE LIMITS
1/26/77	590	347 - 743
3/12/77	909	789 - 1,063
9/12/77	946	820 - 1,109

Because sightings of *P. phocoena* were almost entirely limited to the turbid water of Hinchinbrook Entrance, the habitat area denoted as suitable for harbor porpoise was determined using the graphics computer and Landsat MSS Band 4+5 imagery which shows the turbid glacial plume clearly (Figure 3). Habitat areas were calculated from September 2, 1973 and February 28, 1976 images in order to compare periods of maximum and minimum terrestrial export from the Copper River. However, only a 5% difference in turbid water habitat was detected between the fall and spring images. Therefore the late summer area (266 N. mi^2) was utilized to represent the *P. phocoena* habitat for population level analysis.

Pacific White Sided Porpoise - *Lagenorhynchus obliquidens*

No sightings of this transient porpoise were made in the study area during the surveys, however, Fish and Wildlife Service observers noted several hundred of these gregarious animals about 30 miles south of Cape Cleare (59°26' N. latitude by 147°08' W. longitude) in early October, 1976 (G. Sanger, pers. comm.).

Killer Whale - _Orcinus orca_

Though circumpolar in distribution and found in tropical as well as temperate and arctic seas, in the Eastern North Pacific killer whales tend to be more abundant from Puget Sound north. Five hundred and ninty six of these spectacularly marked animals were observed on 34 occasions during the study. While this species was observed throughout the year in 1977, they were much more abundant from May through October. It appears that a large feeding group (70+ animals) takes up station in the south of Knight Island Passage (Figure 4) in June and is in the general area until at least September. This timing coincides with the seasonal migration of pink salmon into Prince William Sound via Montague Strait and the passages between the islands in the southwest corner of the Sound. In 1977, this feeding group of killer whales was observed five times during a 75 day period (late June through early October), and were never more than 10 miles from the initial sighting location. I believe that these sightings represent seasonal home range records for killer whales in Prince William Sound, and substantiate the results home range studies by K. C. Balcomb of the National Marine Fisheries Service in the Puget Sound area.

In May of 1977 a group of over 55 _O. orca_ was sighted in Knight Passage near La Touche Island (Figure 5). As much as 20% (12 animals) of the group appeared to be newborn calves. These calves stayed very close to adult animals assumed to be their mothers, blew more frequently than large animals in the group and appeared to have an almost orange pigemntation in the eye patch area. K.C. Balcomb (pers. comm.) has also noted this orange tint in newborn _O. orca_ calves in Puget Sound.

Minke whale - Balaenoptera acutorostrata

This species, the smallest of North Pacific baleen whales, was frequently sighted in Prince William Sound from May through October. Ninty-eight minke whales were sighted on 55 occasions during the study.

Minke whales were easy to approach if care was taken not to vary engine speed during the approach. In June 1977, 3 out of a group of 12 whales were tagged with the Floy tag. This group of 12 whales was located in the area between Naked Is., Perry Is. and Eleanor Is. This area is utilized by minke whales each year during late May and June. These whales appear to be quite curious and frequently approached the tagging vessel if it was not underway. No obvious minke whale calves were spotted in the Sound during the study. Most of the minke whales sighted during the study appeared to be about 6 to 8 meters in length, but no obvious pair bonding was evident.

While minke whales were sighted throughout the Sound and were concentrated in the north-central area during May and June, one or more were always present in Hinchinbrook Entrance near Montague Pt. Whether these animals were entering or leaving the Sound is unclear.

California Gray Whale - Eschrichtius robustus

These whales, the most primitive of the Mysticeti, pass through the northern Gulf of Alaska twice each year on their migration to and from the polar seas. In spring (March-May) and fall (Nov.-Jan.) gray whales closely follow the coast around the Gulf of Alaska, frequently passing through both Hinchinbrook Entrance and Montague Strait.

Aerial surveys conducted on April 13-14, 1977 from the Elizabeth Is. (59°10' N. latitude by 151°50' W. longitude) to Cape Suckling (60°00' N. latitude by 143°54' W. longitude) revealed the presence of 44 gray whales (Figure 6). Most of the whales were less than one quarter mile from the coast, often almost in the heavy surf. Three gray whales were sighted milling in a small cove just off Montague Strait, and another three were sighted milling in Hinchenbrook Entrance.

The land based census at Cape Sarichef sighted over 2,100 gray whales passing into the Bering Sea from early April until early June in 1977. Using a polynomial regression technique based on daily counts of whales passing Cape Sarichef, a calculated population of over 10,000 gray whales entered the Bering Sea in 1977 (Figure 7). Very few gray whale calves were sighted entering the Bering Sea and it is probable that calves and their mothers either are late migrants or do not enter the Bering Sea.

Humpback Whale - _Megaptera_ _novaeangliae_

Found in oceans of both the Northern and Southern Hemishperes, humpback whales display both coastal and pelagiv characteristics. During the summer they are found in the high latitudes feeding in protected coastal waters, while in the winter they migrate to the tropics where calving takes place. Many of the migrations to and from the feeding grounds involve travel across expanses of open ocean. In this manner these whales are exposed to both advantages and disadvantages of coastal and pelagic habitats.

In the North Pacific humpbacks were lightly harvested prior to the early 1950's (Rice, 1974). About 1955 though, the pelagic harvest of humpback whales increased rapidly. By 1966 when international protection was declared for humpback whales, the North Pacific population had declined drastically to just a few hundred animals. Humpbacks today appear to utilize Alaskan waters extensively as feeding grounds during the summer.

During the present study 257 humpback whales were sighted on 59 occasions. This species occurs in two distinct areas of Prince William Sound during two separate periods. During the late spring (May to late June) humpbacks were sighted in the northwestern area of the Sound. Sightings were especially frequent in the area of Station 13 (Damkaer, 1977). This area is between Naked Is., Perry Is. and Eleanor Is. and is characterized by very high primary and secondary productivity during the spring of the year (Lawrrance, 1977; Damkaer, 1977). By early July the whales moved south to the area of Icy and Whale Bays near Chenega Is. They remain there until late fall (Oct-Nov) when most begin moving out of the Sound toward the tropical winter grounds.

Eight humpback whales were marked with the Floy tag during the study, but none were resighted more than a few days after tagging. High tag shedding and tag mechanical failure is suspected.

Because humpback whales display distinctivly marked ventral surfaces of the flukes when diving (Perkins and Whitehead, 1977), photographs of humpback flukes from Prince William Sound were cataloged and are provided as Appendix 3. The catalog contains fluke photos of 30 different humpback whales sighted in the Sound during 1976 and 1977. Five of the 30 were sighted two or more times in 1977. Non-OCSEAP investigators sighted 3 of the cataloged animals during the period of June-August 1978 (W. Watkins, WHOI, pers. comm.), indicating that at least some humpbacks may utilize Prince William Sound habitually.

Finback Whale - Balaenoptera physalus

Finback whales, the largest whales sighted in Prince William Sound, were seen on 11 occasions. These sightings represented a counted population of 55 animals This species appears to limit its use of the Sound to April, May and June. The animals appear to be spending a few days in the Sound during their summer migration into Soviet waters in the western Bering Sea (Berzin and Rovenin, 1966). Though finbacks are probably transients, during May and June thay are normally quite abundant and very visible. Twelve were observed in Hinchinbrook Entrance on June 6, 1977, and 7 of the 12 were marked with the Floy tag. No resightings of tagged animals have been reported to date. While investigators in the Western Atlantic have found finbacks difficult to approach for marking purposes (R. Maiefski, pers. comm.), finbacks in Prince William Sound were found to be unusually docile and frequently paid little attention to the approach of the tagging vessel.

VII. DISCUSSION AND CONCLUSIONS

These data represent the better part of two years of field effort, yet really only allow a glimpse of the cetacean community of Prince William Sound. Effort during the period December through April was limited to aerial surveys because of inclement sea surface weather, and as noted in the tables and figures, the great whales (M. novaeangliae, B. physalus, B. acutorostrata, and E. robustus) are under represented. I believe this is because great whale use of the Sound is limited in time and space. For example, humpback whales were sighted in the area of Station 13, with very few observations from anywhere else, during May and June. The presence of whales in this area is probably closely related to the high primary and secondary productivity for the same area during those months.

As the secondary production declined, humpbacks then moved to the area of Whale and Icy Bays. They remained in this vicinity throughout the remainder of the summer and fall. The only humpback sighted in the Sound in winter was sighted in this general area in February 1977 by the Alaska Department of Fish and Game. This indicated that at least one humpback whale overwintered in the Sound rather than migrating to the tropics with the rest of the population. Since the aerial survey transects did not include either the area of Station 13 or the area near Whale and Icy Bays, the only humpback whale sightings from the aircraft were those entering Prince William Sound through Hinchinbrook Entrance or enroute to either of the above mentioned two areas.

While this geographically limited distribution of *M. novaeangliae* in Prince William Sound produced an under representation of humpback whales in the aerial survey results, it facilitated relocation of the population during surface surveys.

I suspect that several groups of humpbacks may utilize the Sound during spring, summer and fall. It is possible that each group is in residence from a few days to a few weeks and then moves on to another area. On October 3, 1977 several humpbacks were observed near Chenega Is., some of which had been sighted previously. Later in the cruise, October 5, 1977, a group of 15 humpbacks was sighted, apparently just entering the Sound through Hinchinbrook Entrance. Flukes of 12 of the 15 animals were photographed, however later examination of the photographs indicated that this group had not been sighted previously in Prince William Sound in 1977. It is unlikely that we would have overlooked such a large group of balaenopterid whales on our previous cruises in 1977.

Finback whales, B. physalus, also tended to be limited in distribution to the Hinchinbrook Entrance corridor and the general vicinity of Station 13. However, finbacks were not sighted in the Sound after late June, indicating that their departure may be related to the decline in secondary productivity.

Killer whales, O. orca, also displayed a limited distribution from mid-June until at least early October. In 1977, when both aerial and surface effort was most intense, a large group (70+) of killer whales was sighted five times during a 75 day period between mid-June and early September. Throughout this 75 day period the whales were never sighted more than ten miles from the original sighting position. This limited distribution, in the area of Pt. Helen on Knight Island is, I believe, related to the presence of large numbers of migrating pink salmon, Oncorhynchus gorbusha, entering Prince William Sound through Montague Strait and nearby interisland passages.

While killer whales have a popularized reputation for agression, at no time during the study was agression by the whales toward humans or other mammals noted. Quite the contrary was true. If the animals were actively pursued to obtain photographic records and reliable estimates of group size and composition, the whales became very elusive. By matching the vessel speed and direction to that of the whales though, it was frequently possible to approach within 10 meters of the whales.

On one occasion in August 1977, two killer whales left the main group, approached the tagging vessel and rode the bow and stern wakes for a few moments before rejoing the herd. The whales were generally quite curious and frequently approached the boat and swam under and around it, apparently examining the vessel visually.

In the 1976 annual report I mentioned observing a large male killer whale with a distinctive curve in the trailing edge of the dorsal fin. Through 1977 this characteristic was noted in the dorsal fin of every large killer whale (assumed to be adult males) in Prince William Sound. The group in residence near Knight Is. Passage was composed of at least five large animals with the dorsal fin curve characteristic. It is possible that the peculiar dorsal fin curve observed in large male killer whales in Prince William Sound represents a ~~six~~ sex- linked genetic trait, raising the possibility of a seasonally resident and genetically isolated population of killer whales in the Sound. Disturbance or exploitation of a genetically isolated population of killer whales would be more deleterious than disturbance or exploitation of a genetically hererogeneous population.

While humpback and finback whales were extremely limited in their distribution in Prince William Sound, minke whales, <u>B</u>. <u>acutorostrata</u>, were sighted throughout the study area. In June they tended to congregate in the area of Station 13, much like the other balaenopterids. In June 1977 a scattered group of twelve minke whales was sighted in this general area. Later in the summer minke whales were frequently encountered near Montague Pt. in Hinchinbrook Entrance. An additional sighting of seventeen minke whales scattered between the Needle and Little Green Is. was made during a non-OCSEAP sponsered aerial survey in August 1976. While the minke whale distribution in the Sound appears less constricted than that of humpback whales, minke whales also responded to miscellaneous ship noises by approaching the motionless vessel and apparently the whales made a cursory examination of the submerged portion of the vessel before swimming away. This curiosity displayed by both humpback and minke whales was especially prevalent during June, but was noted throughout the summer occasionally. Should this approach behavior be generalized and not site specific, it is possible that both minke and humpback whales will be attracted to surface generated noises of drilling rigs and support vessels in the open waters of the Gulf of Alaska. Should this behavior coincide with an oil spill, these curious whales would be exposed to potential hazards on a much more frequent basis than whales which actively avoid human activities.

Based on the sighting per effort figures in Appendix 2, it appears that a shift in peak abundance by season occured in 1977, when maximum numbers sighted per survey mile, for both mysticetes and odontocetes, occured in the third quarter compared to a peak in sightings per effort during the second quarter in 1976. These changes may be related to a shift in the timing of high secondary productivity, unfortunately no information on productivity at Station 13 in Prince William Sound is available for 1977.

Even with a definate seasonal shift in peak populations of cetaceans from 1976 to 1977, it is clear that cetaceans represent a significant biomass in Prince William Sound from May through October, and this pattern is probably evident even with interannual seasonal shifts.

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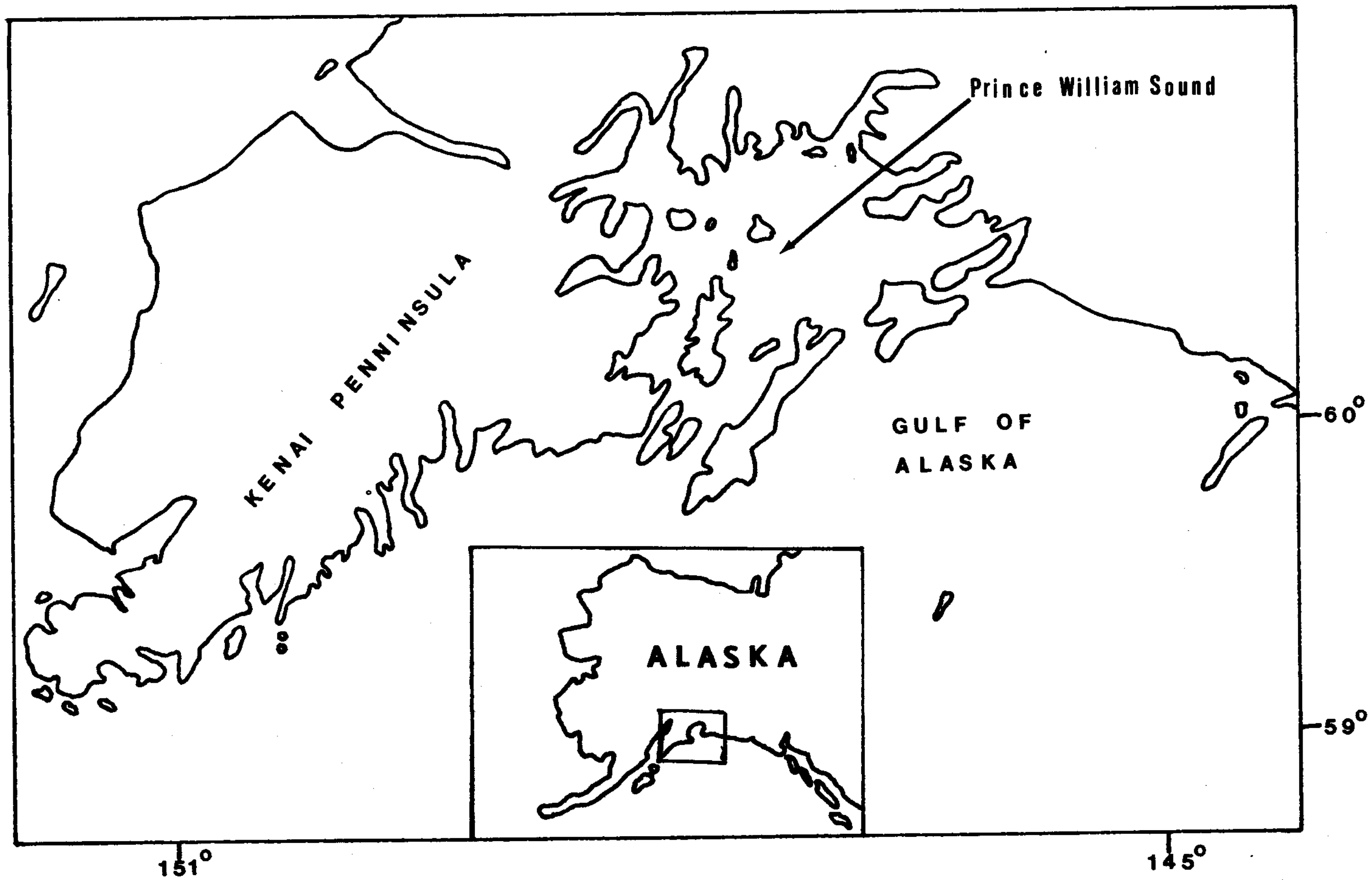
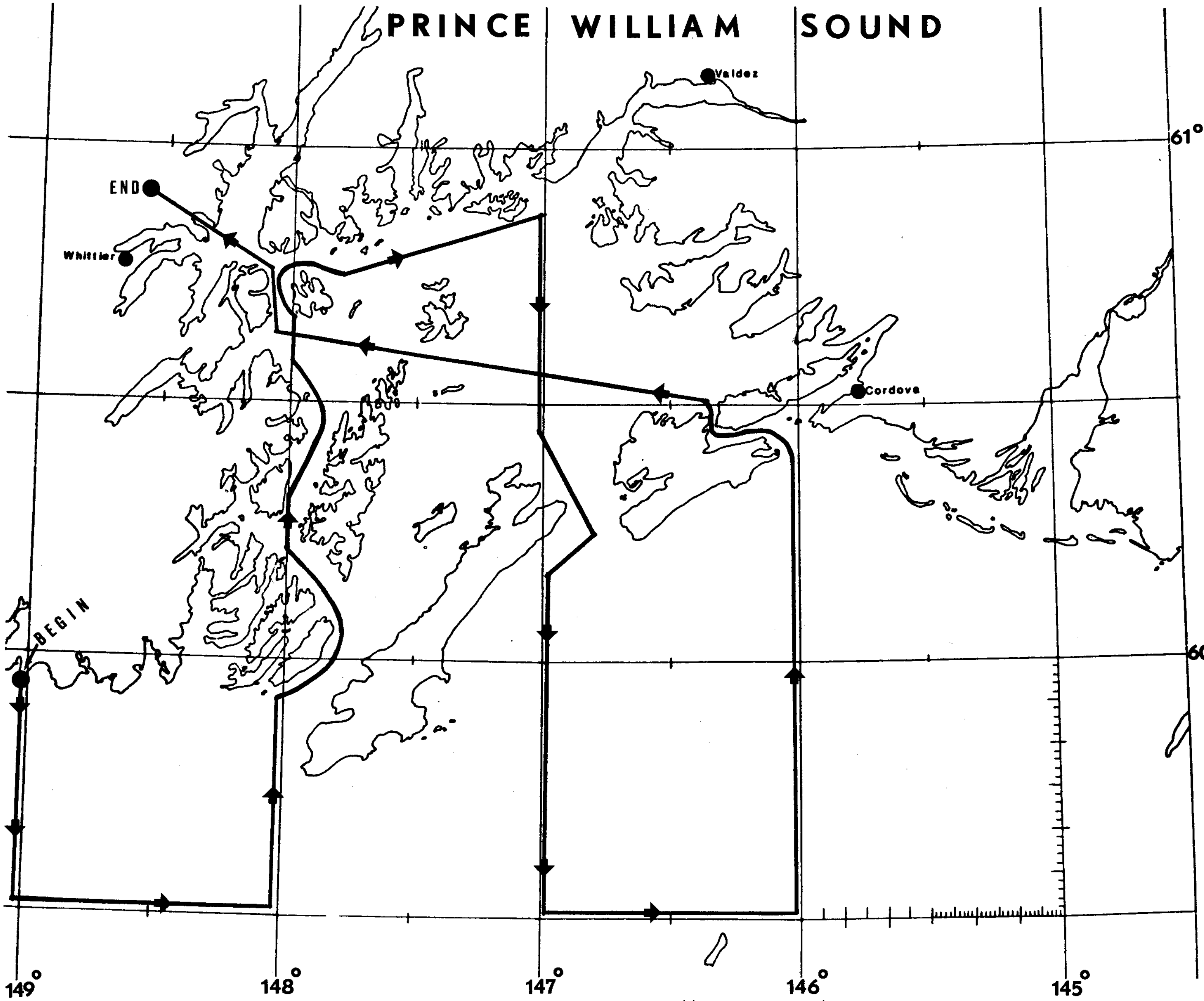


Figure 1- Overall study area (state of Alaska inset)



AERIAL SURVEY TRANSECTS (470 N. Mi.)

Figure 2

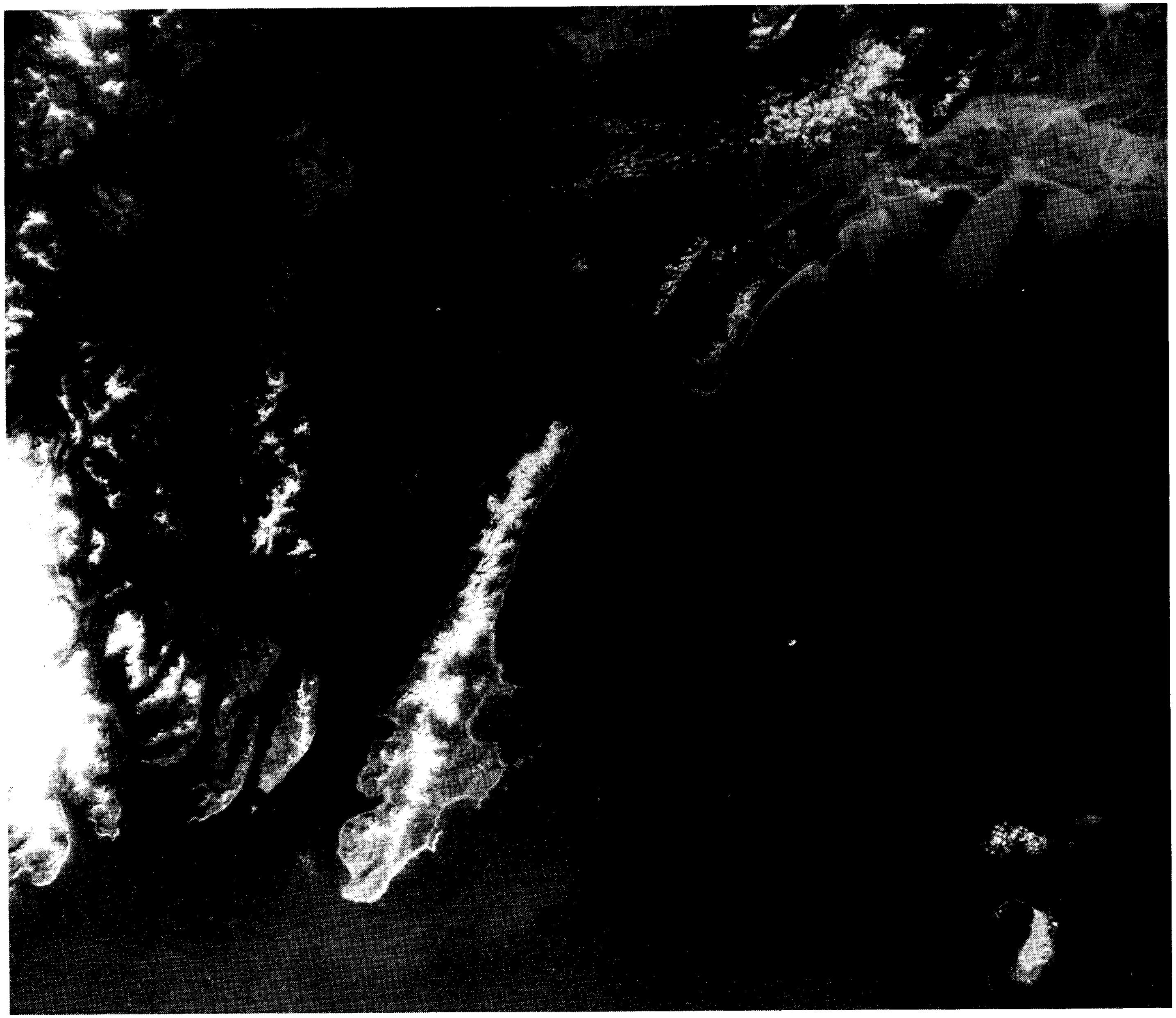


Figure 3- Landsat Image (9/12/73) MSS Band 4+5. Note Glacial Plume.

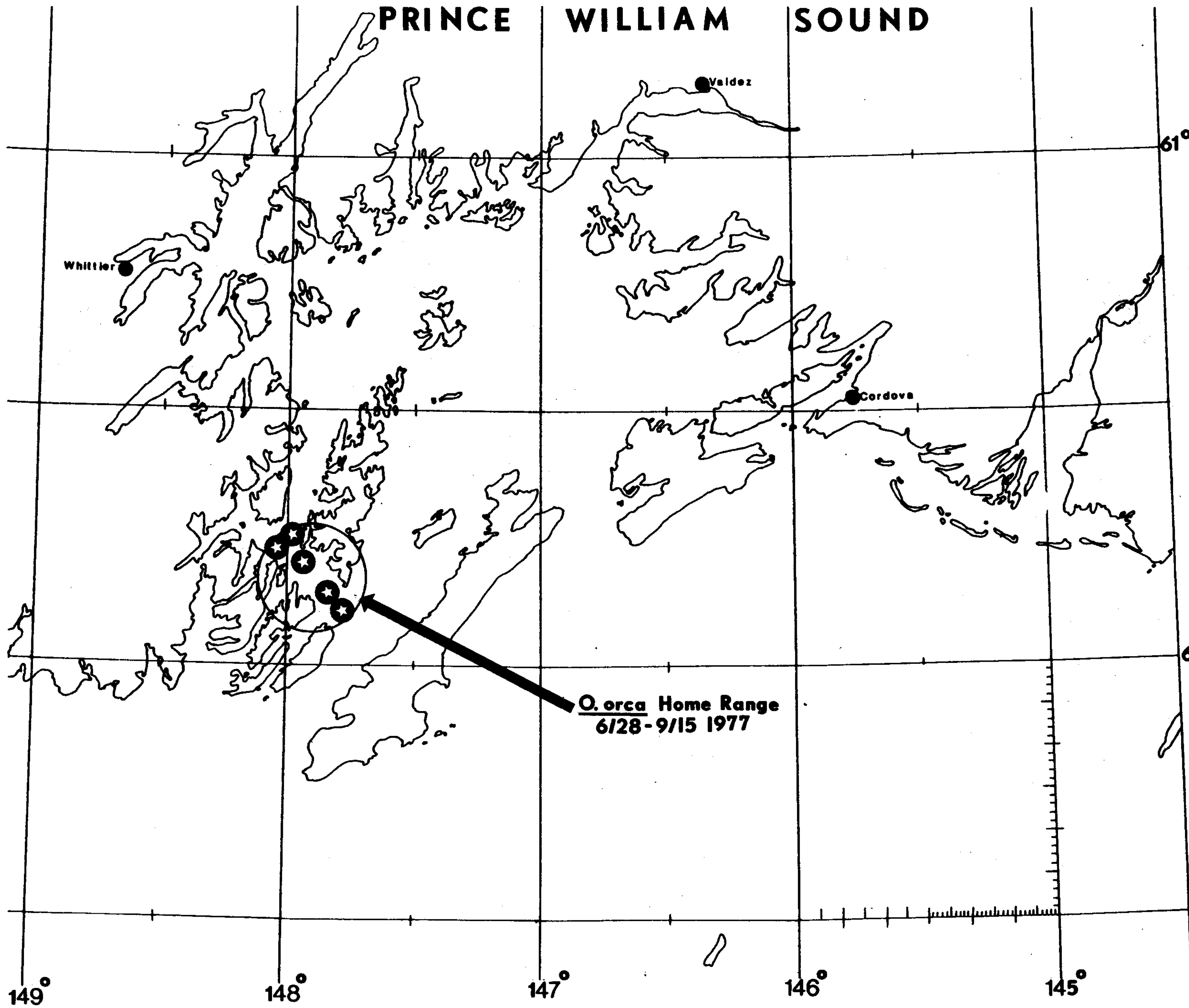


Figure 4- Killer Whale Summer Range in PWS

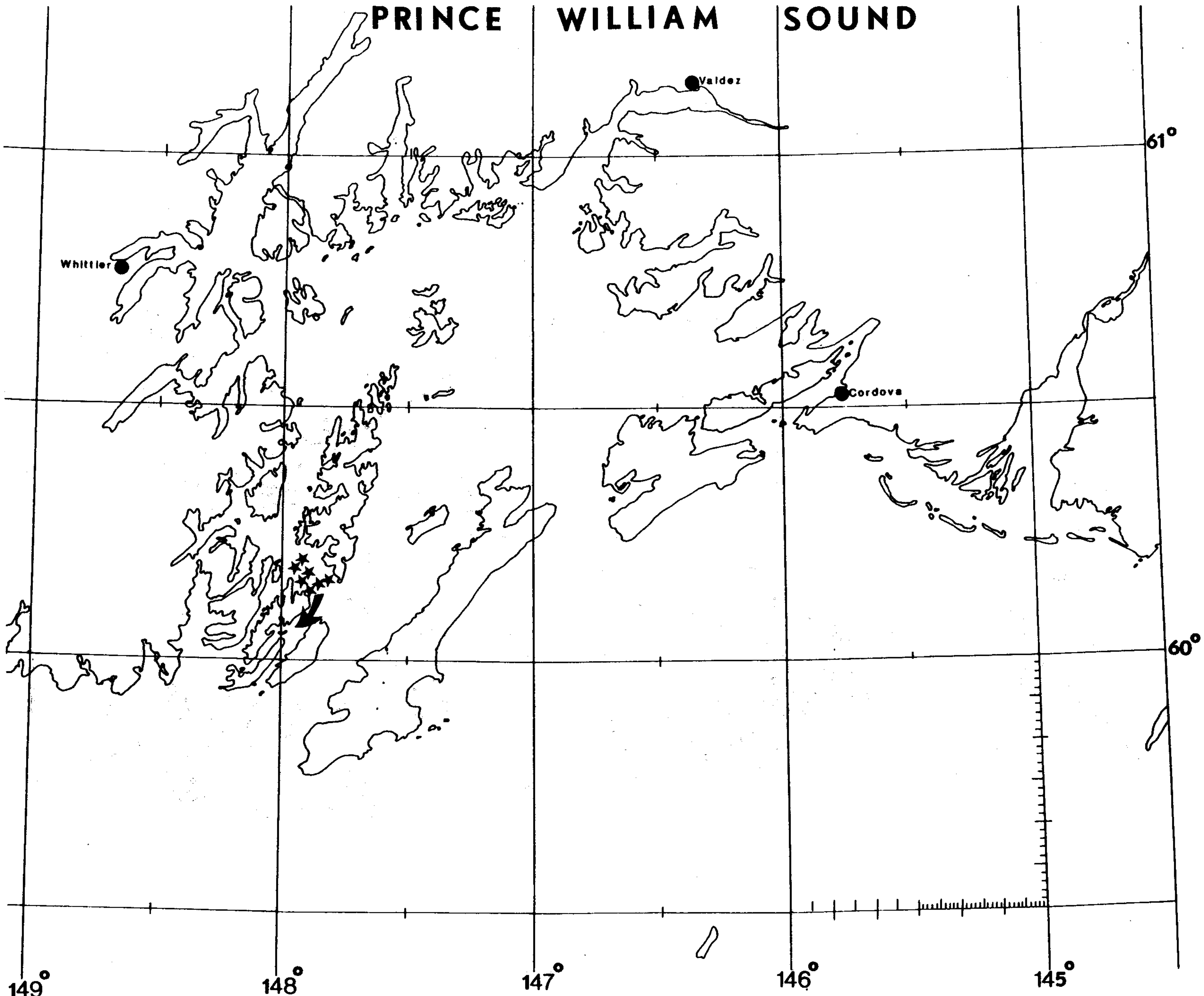


Figure 5- May 1977 Sighting of a Large Group of O. orca with Many Calves

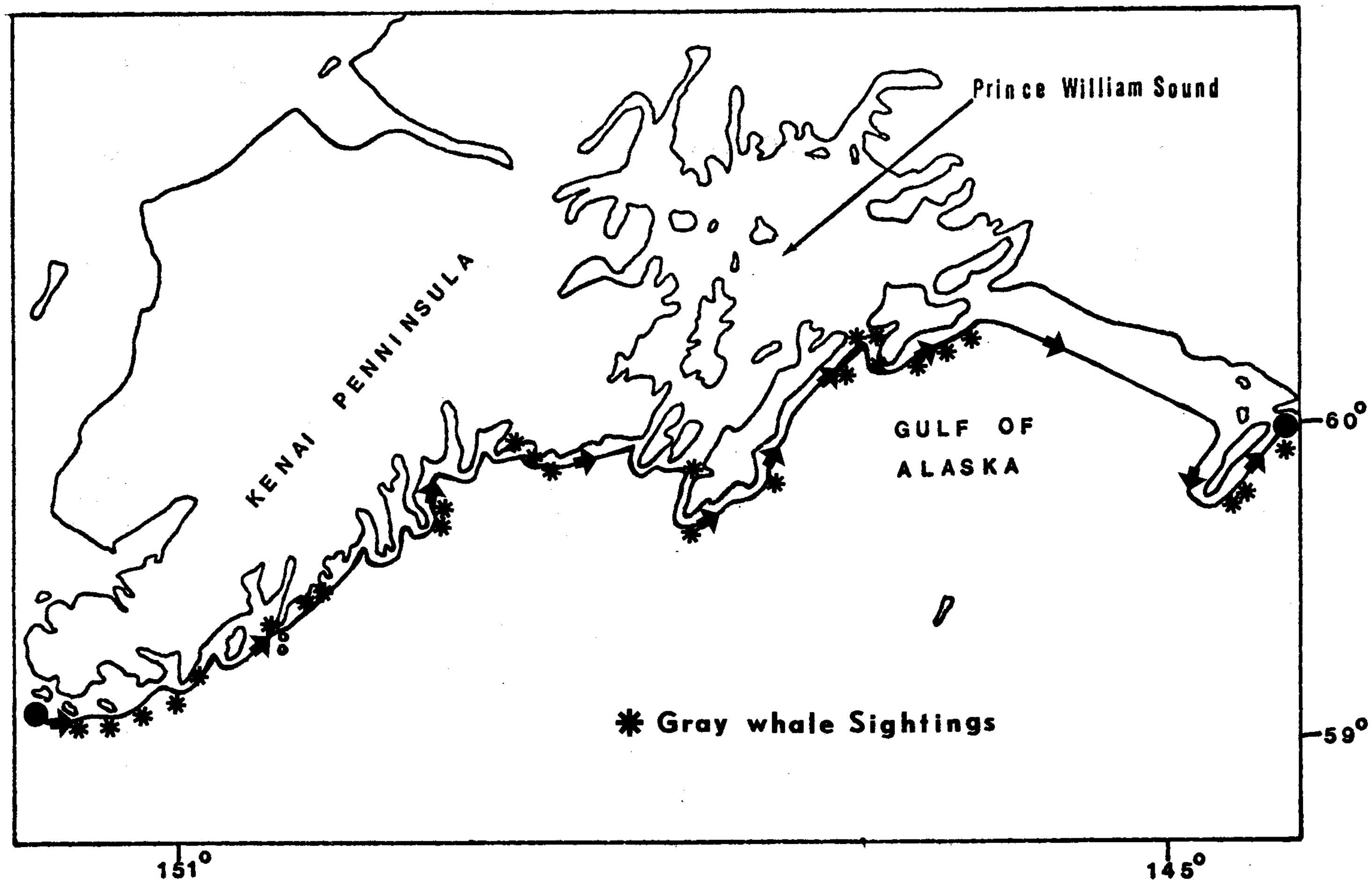


Figure 6- Gray Whale Aerial Survey (April 13/14, 1977)

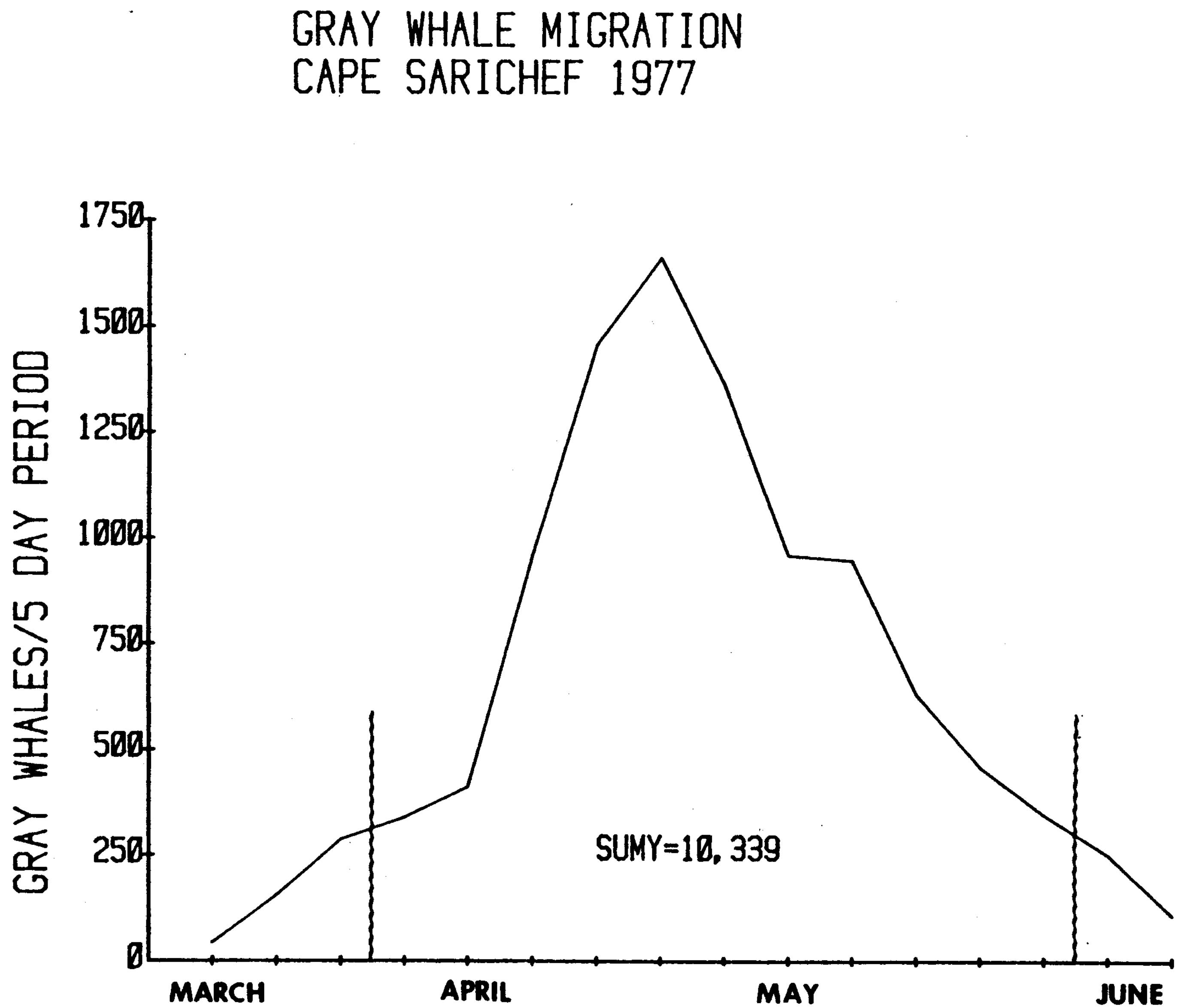


Figure 7- Polynomial Regression Yielding The Total Estimated Gray Whale Population Entering The Bering Sea By 6/15/77. (Vertical wavy lines denote arrival and departure of observers)

CETACEANS REPORTED FROM PRINCE WILLIAM SOUND

Table 1.

Order Cetacea

Suborder Mysticeti

Family Eschrichtiidae

Eschrichtius robustus - Gray whale

Family Balaenopteridae

Balaenoptera physalus - Finback whale

Balaenoptera borealis - Sei whale

Balaenoptera acutorostrata - Minke whale

Megaptera novaeangliae - Humpback whale

Family Monodontidae

Delphinapterus leucas - Beluga

Family Ziphiidae

Ziphius cavirostris - Cuvier's beaked whale

Family Delphinidae

Orcinus orca - Killer whale

Lagenorhynchus obliquidens - Pacific white sided porpoise

Family Phocoenidae

Phocoena phocoena - Harbor porpoise

Phocoenoides dalli - Dall's porpoise

Table 2

RU-481
FIELD ACTIVITY SCHEDULE

Survey No.	Date	Technique	Platform	Survey Coverage
FW6079	5/17-/9 1976	Surface	Nordic Prince	230 N. mi.
FW6079	6/14-18 1976	Surface	Nordic Prince	380
FW6079	7/23 1976	Aerial	Super Wigeon	210
FW6079	8/1-6 1976	Surface	Nordic Prince	397
Non-OCSEAP	8/13 1976	Aerial	Beech Baron	234
FW6079	11/18-23 1976	Surface	Surf Scoter	145
FW7001	1/27 1977	Aerial	Super Goose	295
FW7002	3/12 1977	Aerial	Super Goose	470
FW7003	4/13-14 1977	Aerial	Super Goose	350
FW7005	5/8-13 1977	Surface	Shelby D	780
FW7006	5/29-6/4 1977	Surface	Shelby D	370
FW7007	6/6 1977	Aerial	Super Goose	480
FW7008	6/19-24 1977	Surface	Shelby D	370
FW7009	6/28-30 1977	Surface	Shelby D	300
FW7010	8/22-30 1977	Surface	Shelby D	680
FW7011	9/12 1977	Aerial	Super Beaver	520
FW7012	9/30-10/6 1977	Surface	Shelby D	310
FW7013	4/7-6/7 1977	Field Camp	Cape Sarichef	(Gray whale census)

Table 3a

SIGHTING AND EFFORT DATA

1976

Species	Surface Sightings by Quarter				Surface Survey Effort by Qtr. (N.Mi.)				Aerial Sightings by Quarter				Aerial Survey Effort by Qtr. (N.Mi.)				Surface Sightings/ Effort				Aerial Sightings/ Effort			
	J-M	A-J	J-S	O-D	J-M	A-J	J=S	O-D	J-M	A-J	J-S	O-D	J-M	A-J	J-S	O-D	J-M	A-J	J-S	O-D	J-M	A-J	J-S	O-D
Dall porpoise	82	233	299	16	300	320	480	135	/	/	65	/	/	/	235	/	.273	.728	.623	.118	/	/	.276	/
Harbor porpoise	3	87	6	0	300	320	480	135	/	/	0	/	/	/	235	/	.001	.271	.012	0	/	/	0	/
Killer whale	0	73	85	0	/	320	480	135	/	/	0	/	/	/	235	/	0	.228	.177	0	/	/	0	/
Humpback whale	0	30	93	0	/	320	480	135	/	/	0	/	/	/	235	/	0	.093	.193	.007	/	/	0	/
Minke whale	0	11	14	0	/	320	480	135	/	/	29	/	/	/	235	/	0	.034	.029	0	/	/	.129	/
Finback whale	0	13	6	0	/	320	480	135	/	/	0	/	/	/	235	/	0	.040	.012	0	/	/	0	/
Totals	85	437	503	17	935				/	0	94	/	235				1.10				.400			

RU-481
SIGHTING AND EFFORT DATA
1977

Table 3b

Species	Surface Sightings by Quarter				Surface Survey Effort by Qtr. (N.Mi.)				Aerial Sightings by Quarter				Aerial Survey Effort by Qtr. (N.Mi.)				Surface Sightings/ Effort				Aerial Sightings/ Effort			
	J-M	A-J	J-S	O-D	J-M	A-M	J-S	O-D	J-M	A-J	J-S	O-D	J-M	A-J	J-S	O-D	J-M	A-J	J-S	O-D	J-M	A-J	J-S	O-D
Dall porpoise	/	477	166	169	0	1240	620	300	55	125	75	/	740	860	310	0	/	.384	.267	.563	.074	.145	.241	/
Harbor porpoise	/	55	10	0	0	1240	620	300	49	19	84	/	740	860	310	0	/	.044	.014	/	.066	.022	.270	/
Killer whale	/	103	119	20	0	1240	620	300	1	0	69	/	740	860	310	0	/	.083	.192	.066	.001	0	.222	/
Humpback whale	1	50	20	53	300	1240	620	300	0	1	8	/	1040	860	310	0	.009	.040	.032	.176	0	.001	.025	/
Minke whale	/	28	7	1	0	1240	620	300	0	5	3	/	740	860	310	0	/	.022	.011	.003	0	.006	.009	/
Finback whale	/	20	0	0	0	1240	620	300	0	16	0	/	740	860	310	0	/	.016	0	0	0	.018	0	/
Totals	1	733	322	243	2160				105	166	239	/	1910				.601				.267			

APPENDIX 1

FISH AND WILDLIFE SERVICE
MARINE MAMMAL SIGHTING

FILE TYPE			FIELD OPERATION NUMBER						RT	TRANSECT NUMBER										SEQ. NO.				DATE YR		MO		DAY		TIME GMT			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
0	2	7	F	W					1	0	0	0	0	0				7	4														

RT	UNIT	SIGHT DIST. (yds)		
10	71	72	73	74
4	2			

RT	POSITION LATITUDE							LONGITUDE							E/W	PLATFORM TYPE	NAME			HDG. (Deg)			ALTIT. (meters)			SPEED (kts)			ICE COVER TYPE	OCTAS THIN	MOD	THICK	Char SEC	FIRST	DEFORM	WIDTH
10	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	72	73	74	75	76	77	78	79
2					0	0	N						0	0																							

RT	IDR	GLARE	DEBRIS	PAC. OCS ZONE			OBS.		SPECIES			
10	35	36	37	38	39	40	41	42	43	44	45	46
6												

671

RT	WIND SPD. (kts)		WIND DIR. (deg)			VIS	WEATHER		AIR TEMP. (degC)			SS	SEA TEMP. (degC)				BARO. Press. (mb)				INC ANG deg		WATER DEPTH (meters)			
10	50	51	52	53	54	55	58	59	60	61	62	63	64	65	66	67	71	72	73	74	75	76	77	78	79	80
3																										

RT	TAXONOMY CODE											BEHAVIOR		NO. SIGHTED				MARK TYPE
10	26	27	28	29	30	31	32	33	34	35	36	37	38	40	41	42	43	75
5																		

COMMENT

U. S. FISH AND WILDLIFE SERVICE

CETACEAN SPECIMEN

HEADER CARD

File Type			Field Operation Number						Transect Number					RT	Specimen Number				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0	2	5	F	W	6									2					

LOCATION CARD

CN	Position Lat.				N/S	Long.					E/W	Time GMT				Date day/mo/yr						Sp.		Sex	Whole Wt. (lbs)				Photo	Coll.		Dispo
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
1																																

MEASUREMENT CARD 1

CN	Total Length (cm)					Std. Length (cm)					Rost. to BH				Rost. to Eye				Rost. to D. Fin				D. Fin Len.			Dor. Fin Ht.			Dorsal Fin to Notch				Gape to Eye			BH Len.			BH Width			Pect. Fin Len.				Pect. Fin Wid.			Fluke Width				Fluke Depth			Max. Girth			
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
2																																																											

MEASUREMENT CARD 2

CN	Tooth Count U/L				Tooth Count L/L				Baleen Count U/L				Throat Groove Count				Naval to Notch				Anus to Notch				Genital to Notch				Mamm. Len.			Comment
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
3																																

U. S. FISH AND WILDLIFE SERVICE

MARINE MAMMAL FOOD HABITS

HEADER CARD

File Type			Field Operation Number						Transect Number					R T	Specimen Number				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0	2	5	F	W	6									3					

FOOD QUANTITY CARD

Position: Lat			N/S	Long.						E/W	Stomach Wt. Full (gm)						Food Wt. (gm)							Food Vol. (ml)						Unid. Food Wt. (gm)						Unid. Food Vol. (ml)				
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61

FOOD TYPE CARD

R T	Species I.D.										Number of Indiv.				Max. Length (cm)					Min. Length (cm)					Otoliths: Number				Otoliths: Len. (cm)			Otoliths: Width (cm)			Number Squid Beaks				Seq. No.		
5	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	78	79	80
4																																									
4																																									
4																																									
4																																									
4																																									
4																																									
4																																									
4																																									

U.S. Fish and Wildlife Service

Unimak Pass Census

DATE Yr Mo Day	TIME BEGIN	TIME END	OBSERVER	CENSUS SITE	SPECIES	TOTAL NO SIGHTED	CALVES SIGHTED	WEATHER	WIND SPEED	SEA STATE
77										
MARKED or TAGGED										

674

COMMENT

MARINE MAMMAL CODES

Weather Code

00-Clear
03-Cloudy
41-Fog
61-Rain
94-Hail
71-Snow
51-Drizzle

Water Color

01-21- Forel-Ule

Glare Code

0-None
1-1 to10%
2-11 to25%
3-26 to50%
4-51 to75%
5-76 to100%

Visibility Code

0- Under 50m
1-51-200m
2-201-500m
3-501-1000m
4-1001-2km
5-2-4km
6-4 - 10km
7-10 - 20km
8-20 - 50km
9-Over 50km

Debris Code

9-None present
1-Floatsam
8-Ship trash
A-Oil slick
2-Kelp
4-Foam

Sea State Code

0-Calm
1-Rippled
2-Wavelet
3-Slight(2-4')
4-Moderate(4-8')
5-Rough(8-13')
6-Very rough(13-20')
7-High(20-30') Over 30'-c

MARKED ANIMAL/TAG TYPE

0-Unmarked
1-Streamer
2-Disc tag
3-Discovery tag
4-Brand
5-Roto tag
6-Metal crimp tag
7-Telemetry tag
8-Natural mark

Platform Activity

1-Stationary
2-Drifting
3-Underway
5-Fishing
6-Ice ramming
7-Surveying
8-Transiting

Platform Type

1-Ship
5-Aircraft
B-Shore
G-Ice

I.D. Reliability

0-Unsure
1-Probable
2-Sure

Bottom Topography Code

00-Unsure
01-Seamount
02-Escarpment
03-Canyon
04-Guyot
05-Bank
06-Trench
07-Sound
08-Basin
09-Con. Shelf
10-Con slope
11-Bay
12-Pass
13-Strait

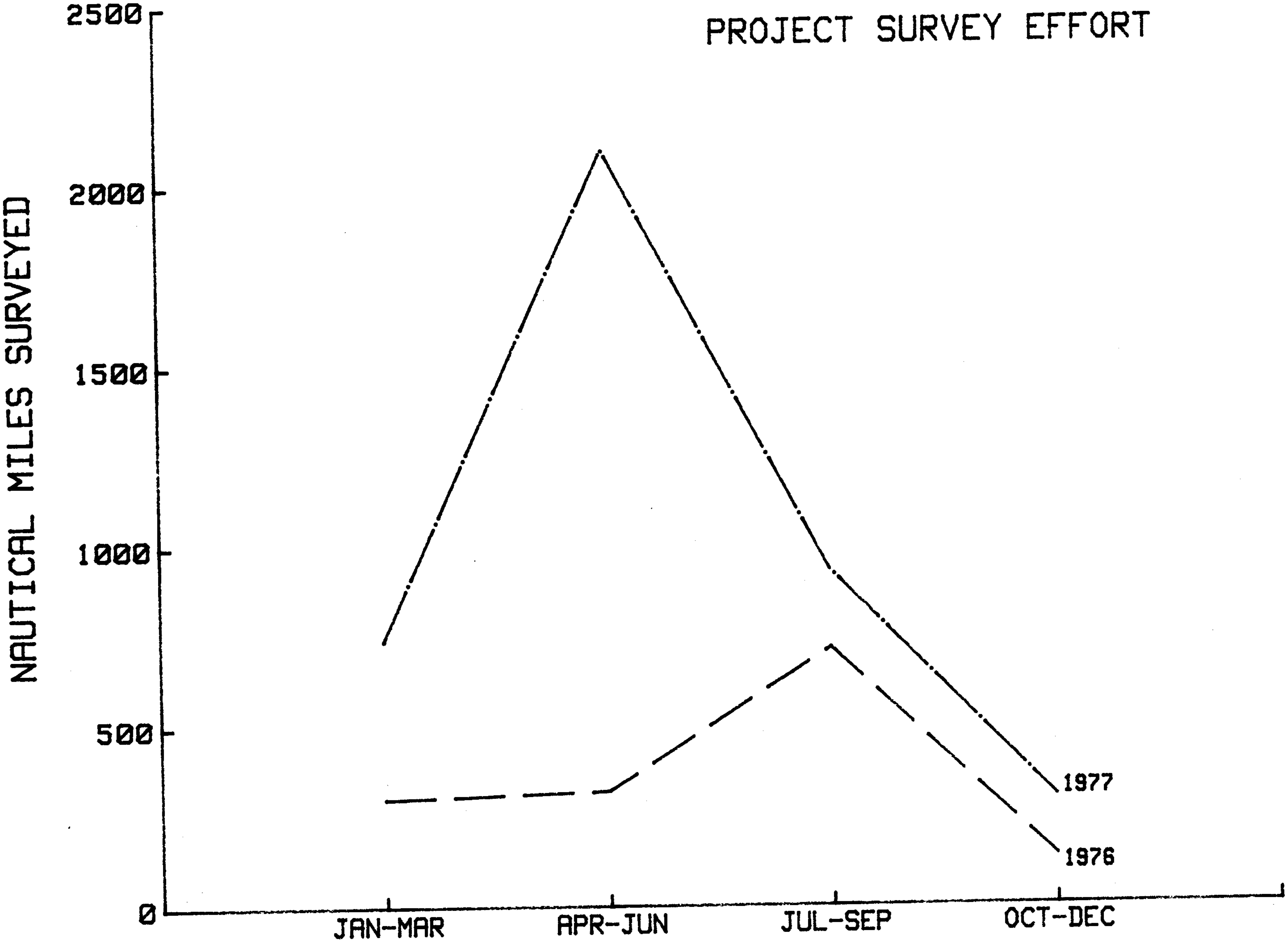
SPECIES CODE

Gray whale- Gray
Minke whale- Mink
Sei whale- Sei
Fin whale- Fin
Blue whale- Blue
Humpback whale- Hump
Bowhead whale- Bow
Right whale- Rite
White sided porp.- Lag
Right whale porp.- Liso
Risso's porp.- Riso
False killer whale- FKWh
Pilot whale- PiWh
Killer whale- Orca
Harbor porp.- HarP
Dall porp.- Dall
Belukha- Belu
Narwhal-Narw
Sperm whale- Sprm
Beaked whale- BkWh
Polar bear- Polr
Sea Otter- SeaO
Steller sea lion- Stel
Northern fur seal- FurS
Walrus- Walr
Largha seal- LarS
Harbor seal- HarS
Ring seal- Ring
Ribbon seal- RibS
Bearded seal- BrdS
Other- Othr
Largha or Ring- LarR
Unid. whale- UnWh
Unid. seal- UnSe

BEHAVIOR CODE

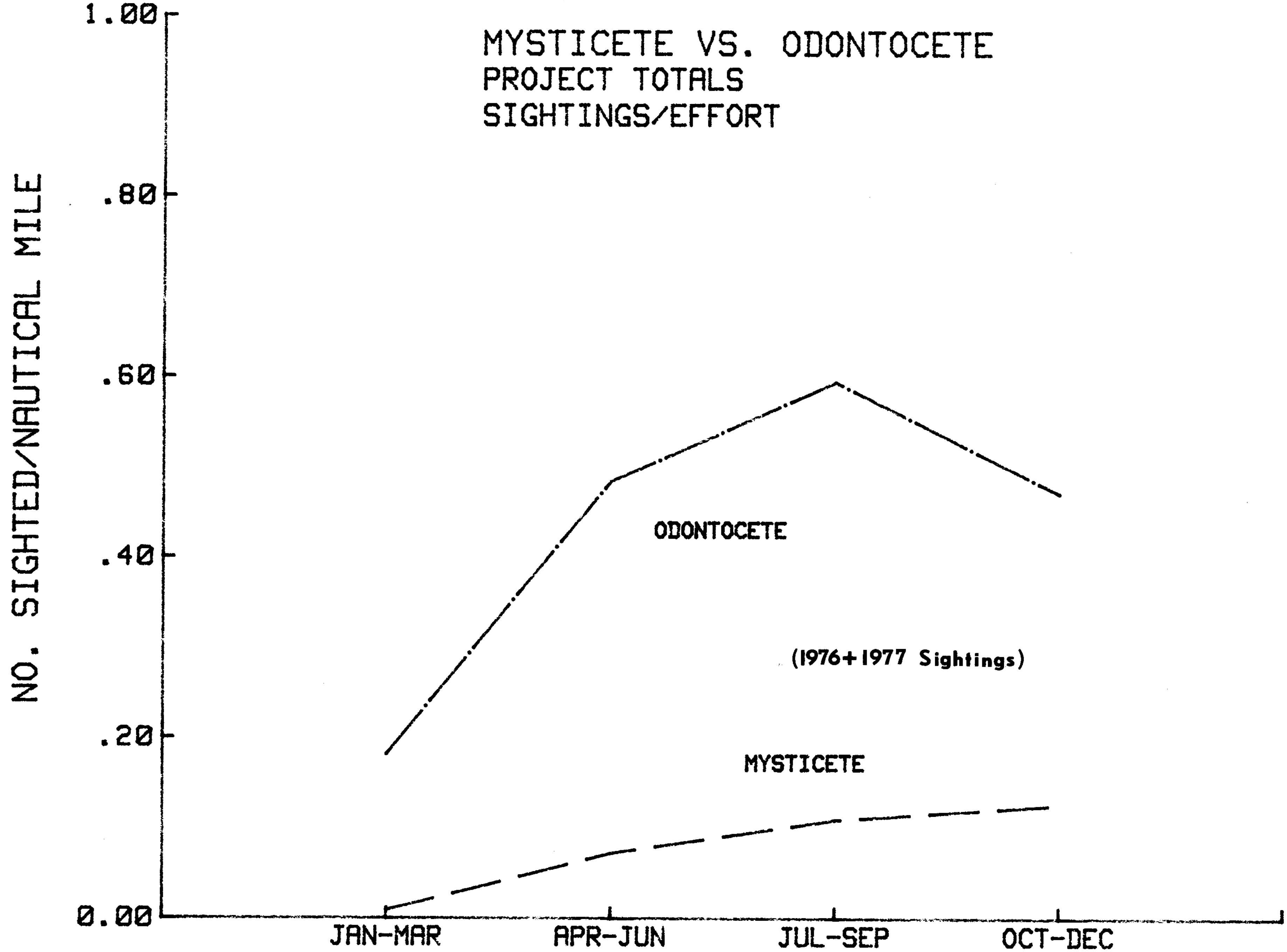
01- No behavior observed
02- Sleeping
03- Breeding/Copulation
04- Feeding
05- Mother/young
06- Aggressive
07- Play/Contact
08- Bow ride
09- Porpoising
10- Curious/Following
15- Cetacea/Birds
16- Pinniped/Birds
17- Cetacea/Pinniped
26- Synchronous Diving
27- Moribund/Dead
28- Leaping
29- Avoidance
30- Tail Lobing
31- Hauled Out

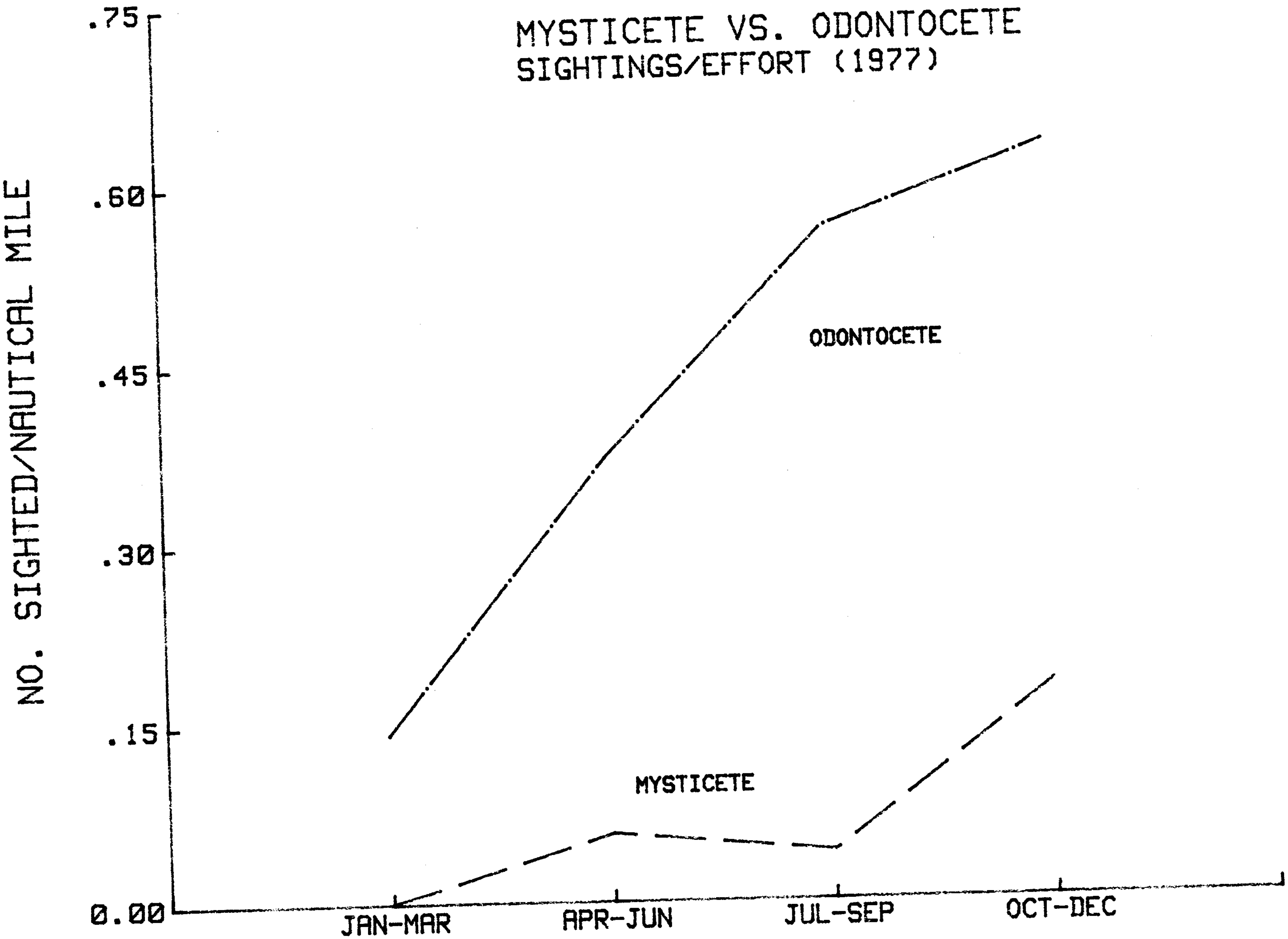
APPENDIX 2

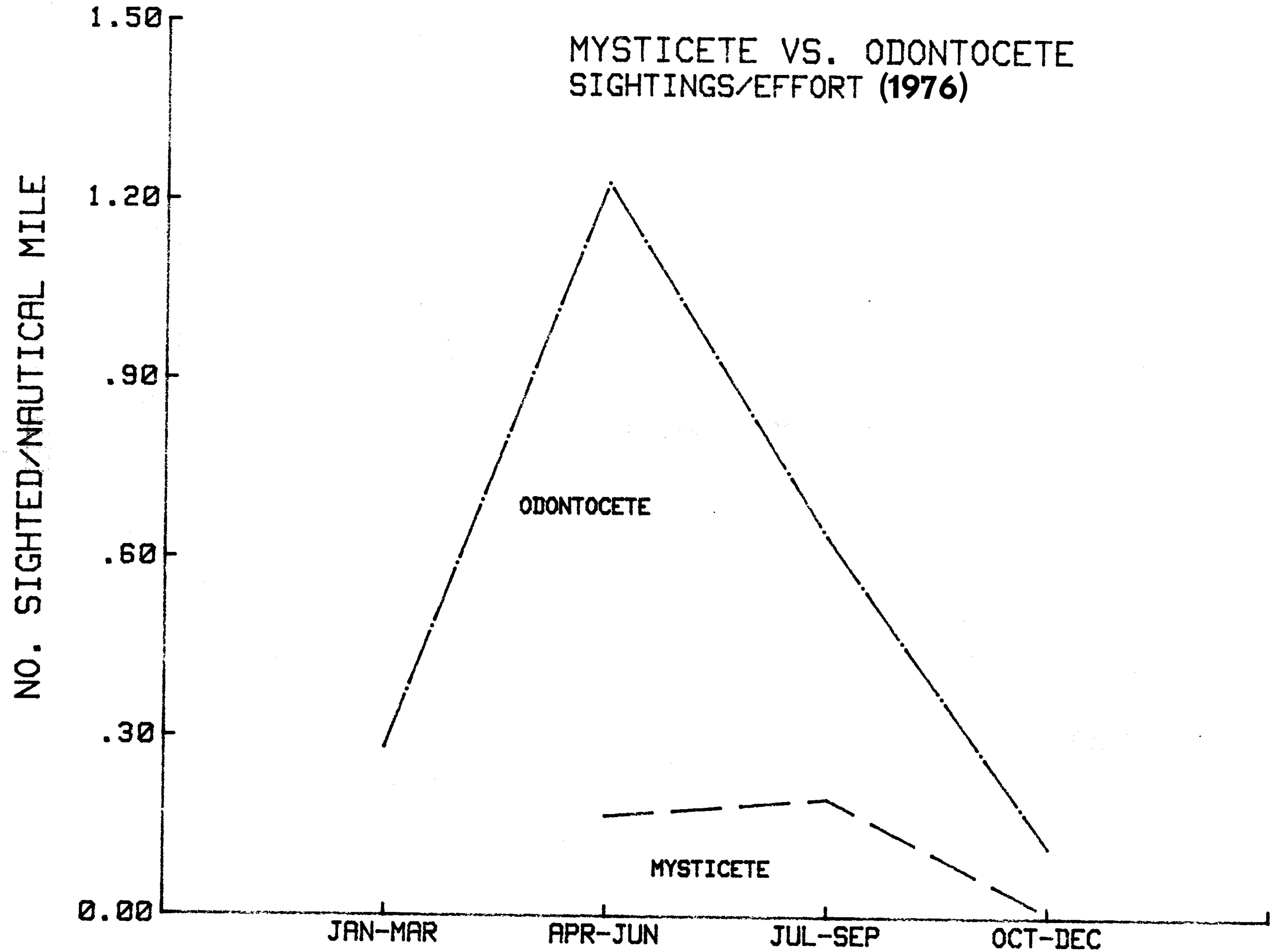


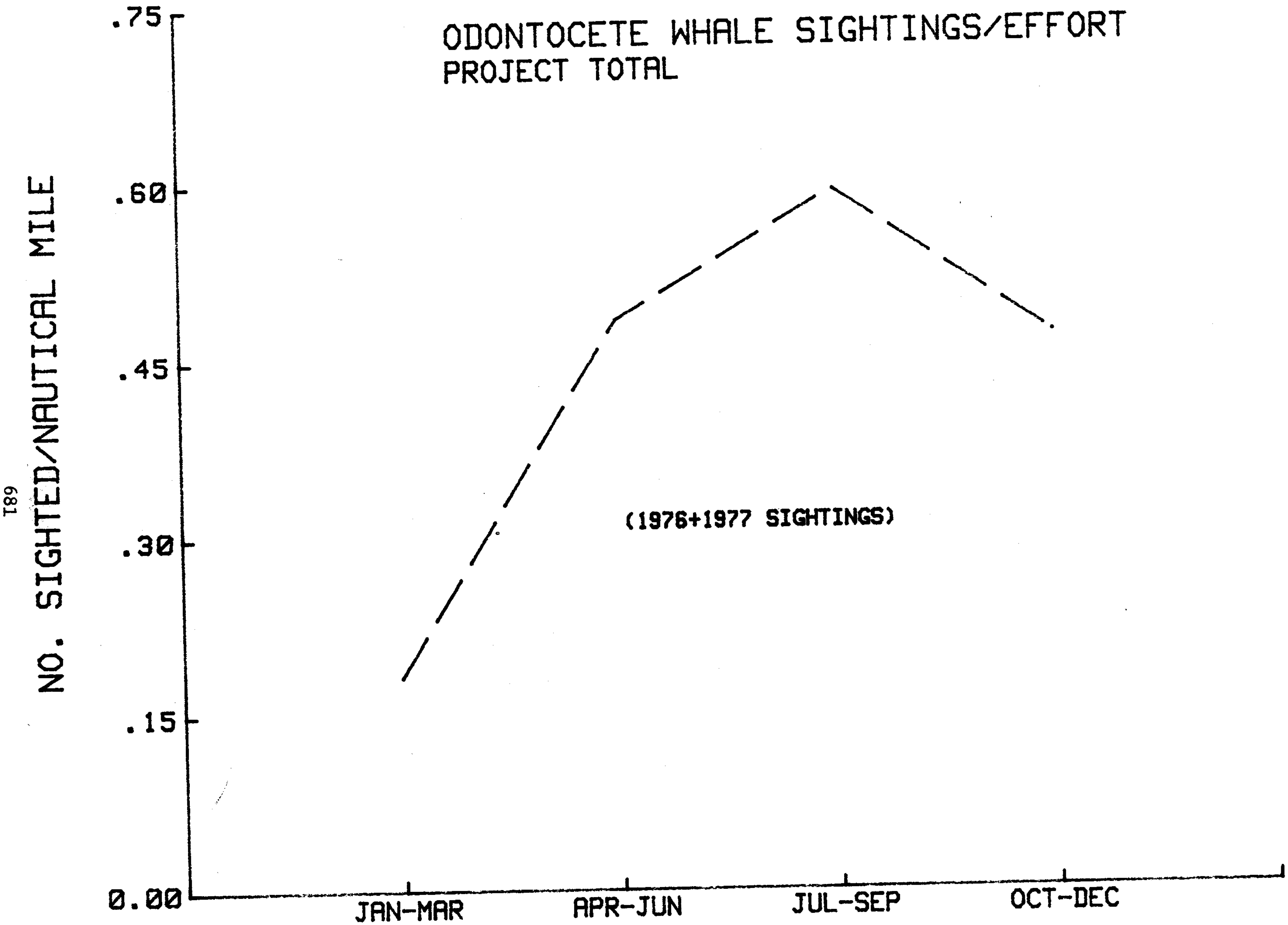
PROJECT SURVEY EFFORT
NAUTICAL MILES SURVEYED
2500
2000
1500
1000
500
0
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC
1977
1976

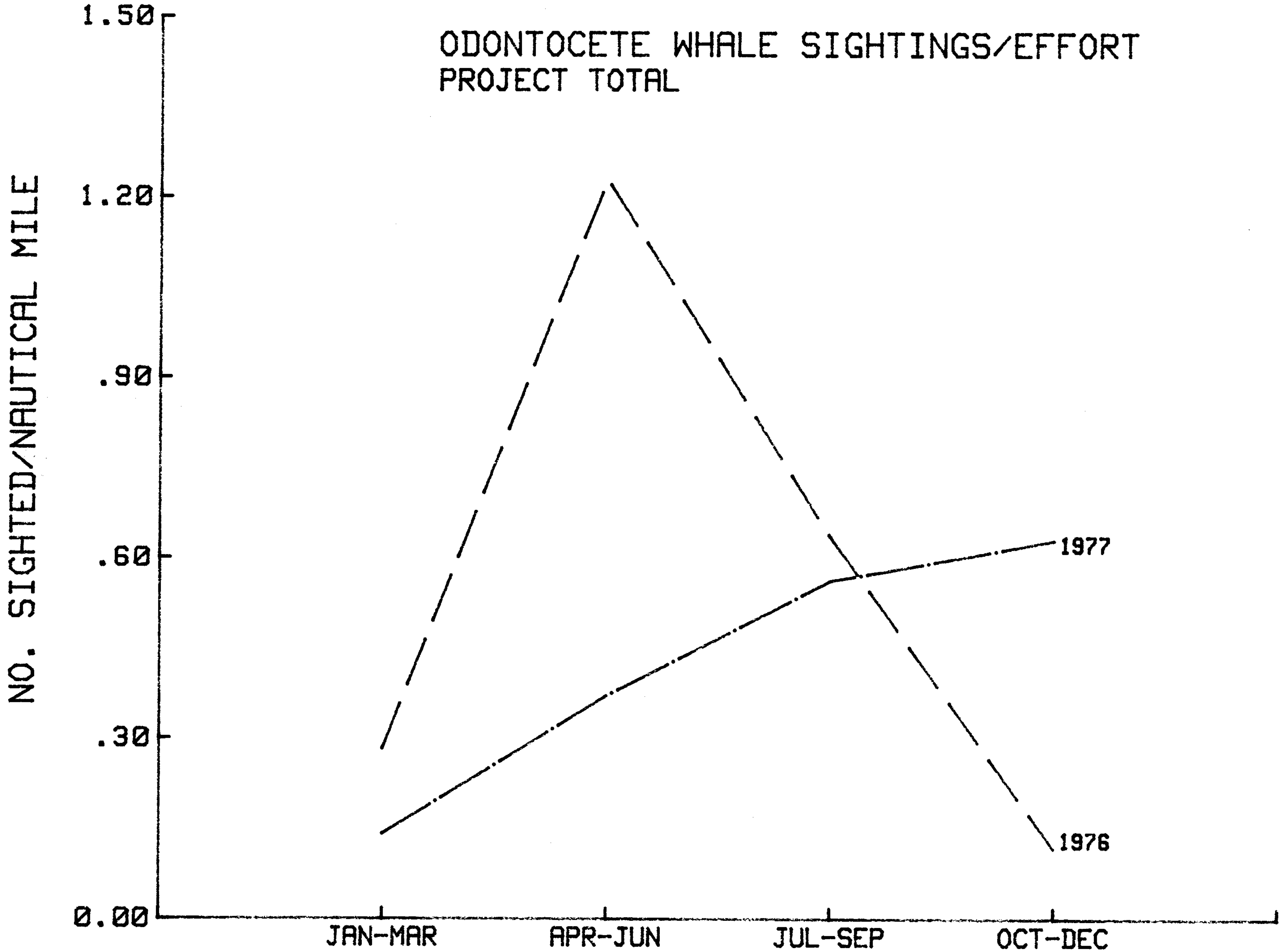
677


MYSTICETE VS. ODONTOCETE
PROJECT TOTALS
SIGHTINGS/EFFORT
NO. SIGHTED/NAUTICAL MILE
1.00
.80
.60
.40
.20
0.00
ODONTOCETE
(1976+1977 Sightings)
MYSTICETE
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC

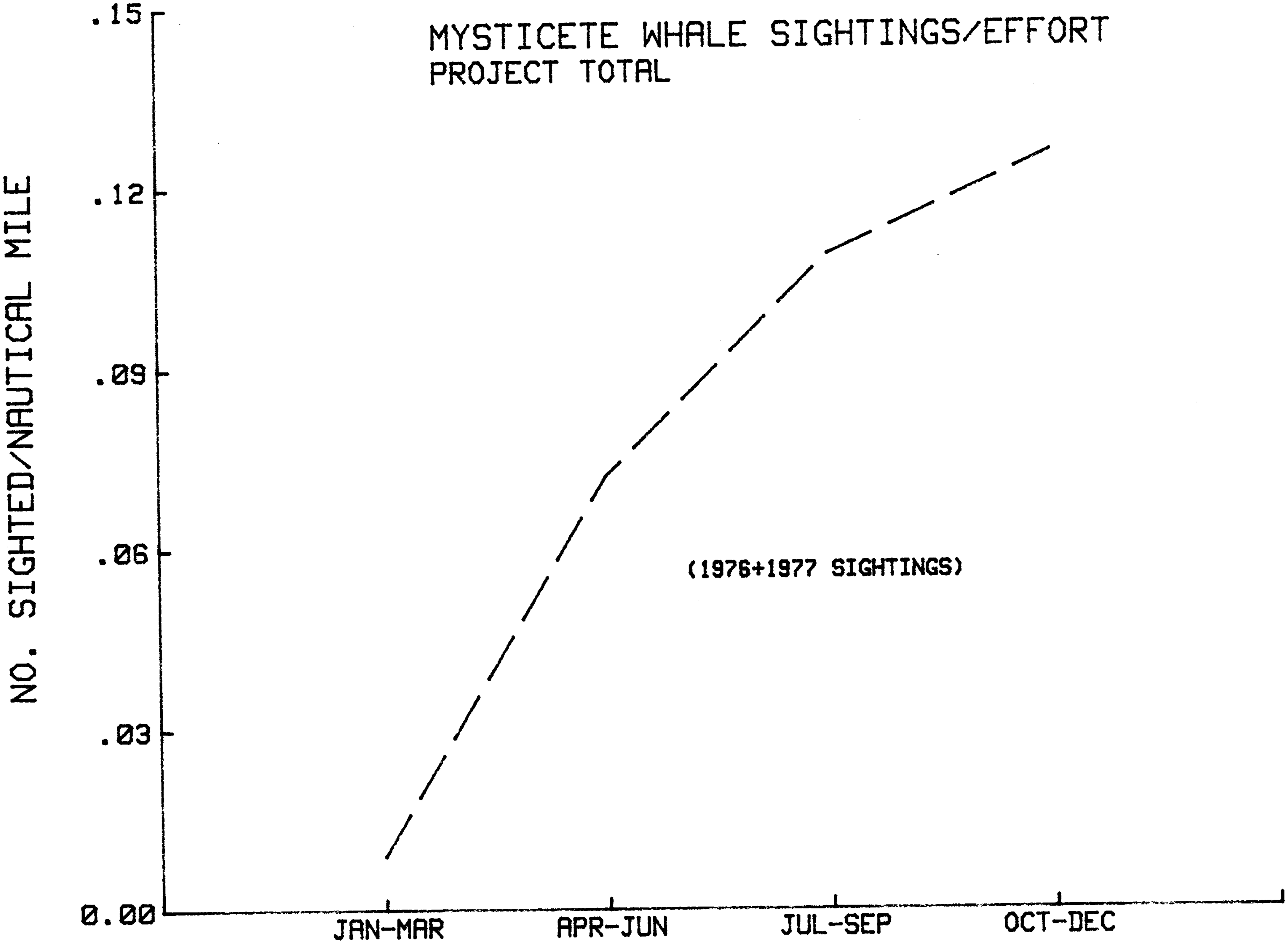

MYSTICETE VS. ODONTOCETE
SIGHTINGS/EFFORT (1977)
NO. SIGHTED/NAUTICAL MILE
.75
.60
.45
.30
.15
0.00
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC
ODONTOCETE
MYSTICETE

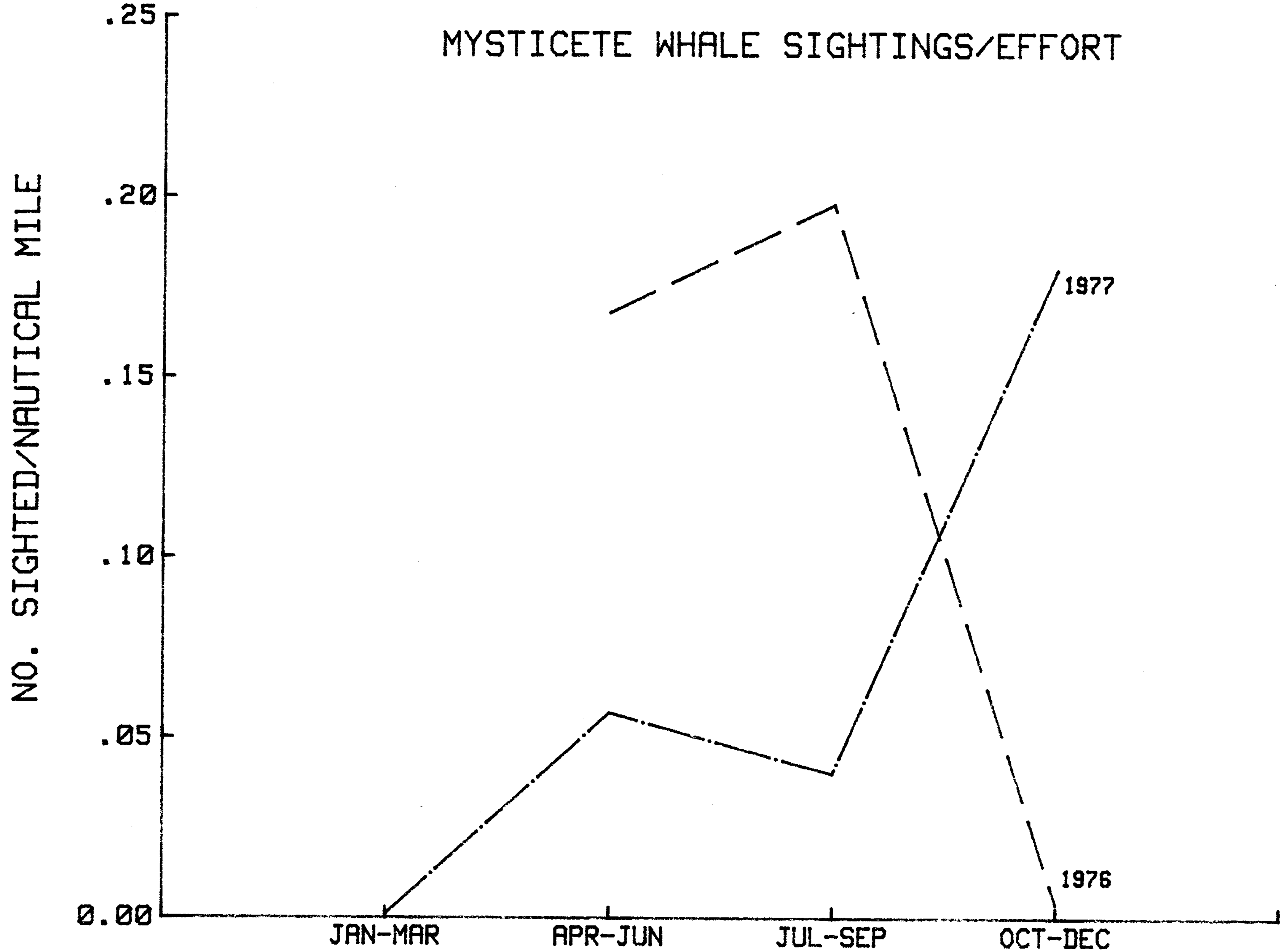

MYSTICETE VS. ODONTOCETE
SIGHTINGS/EFFORT (1976)
NO. SIGHTED/NAUTICAL MILE
1.50
1.20
.90
.60
.30
0.00
ODONTOCETE
MYSTICETE
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC

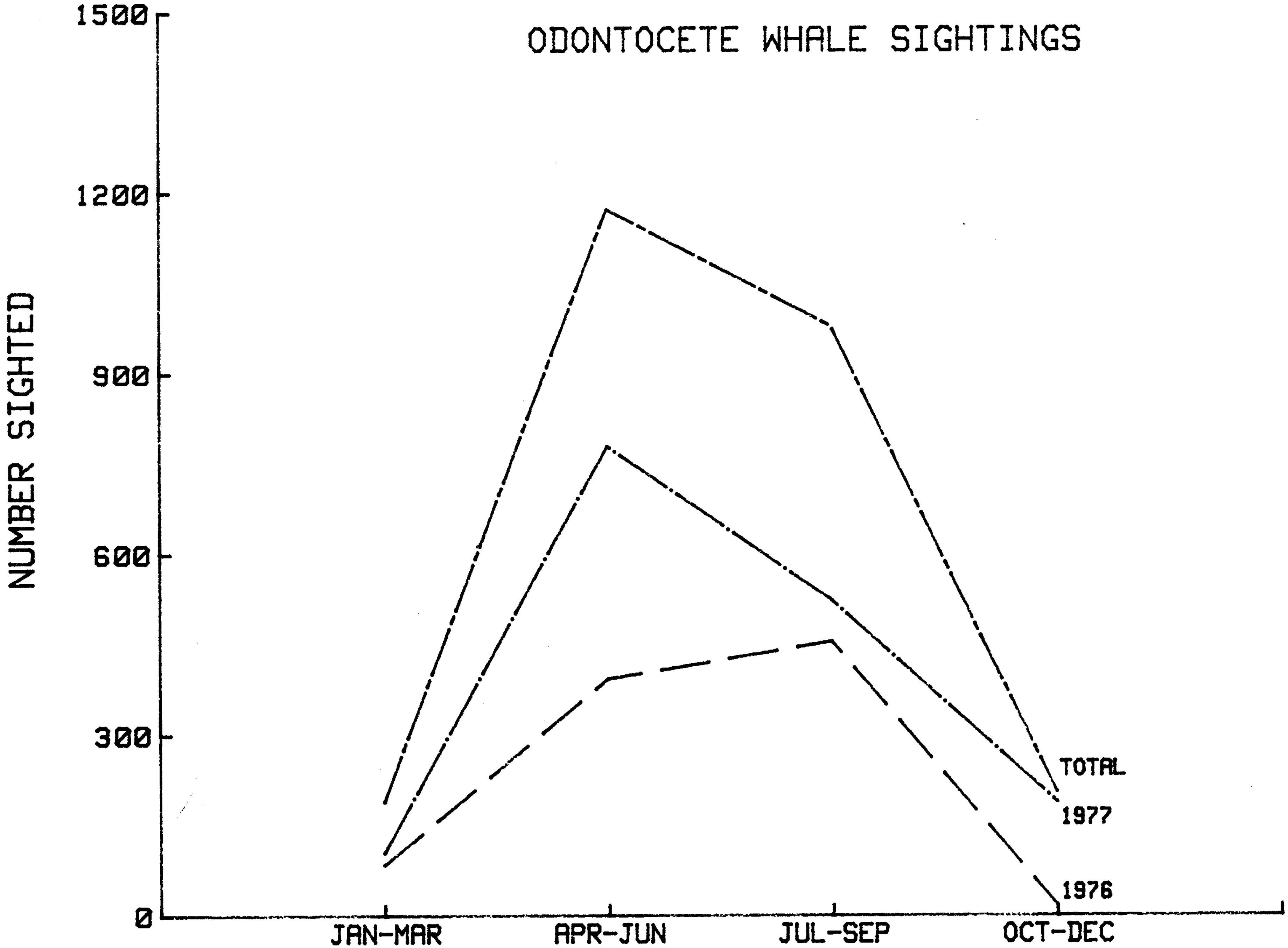

ODONTOCETE WHALE SIGHTINGS/EFFORT
PROJECT TOTAL
NO. SIGHTED/NAUTICAL MILE
.75
.60
.45
.30
.15
0.00
(1976+1977 SIGHTINGS)
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC



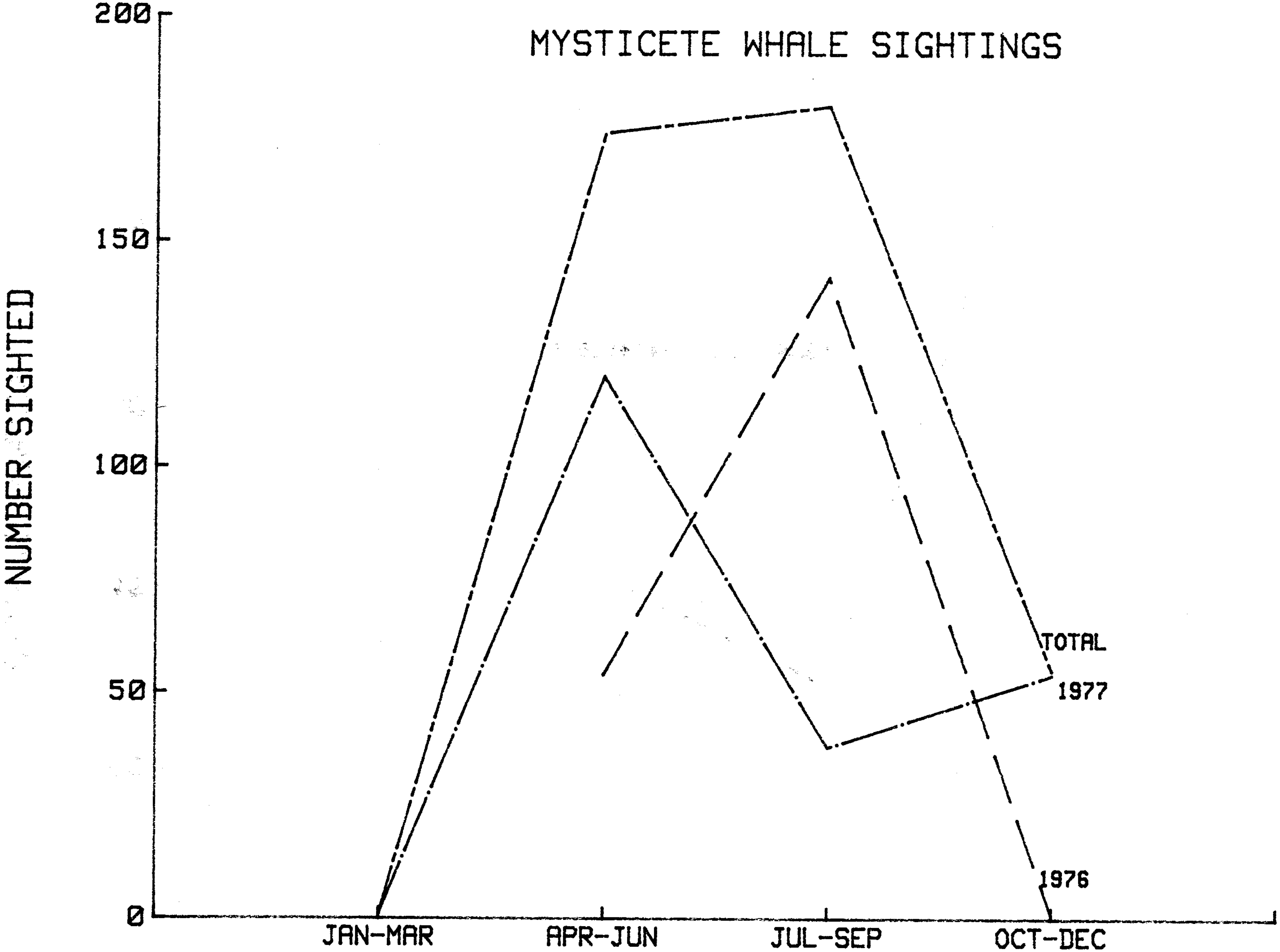
ODONTOCETE WHALE SIGHTINGS/EFFORT
PROJECT TOTAL
NO. SIGHTED/NAUTICAL MILE
1.50
1.20
.90
.60
.30
0.00
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC
1977
1976

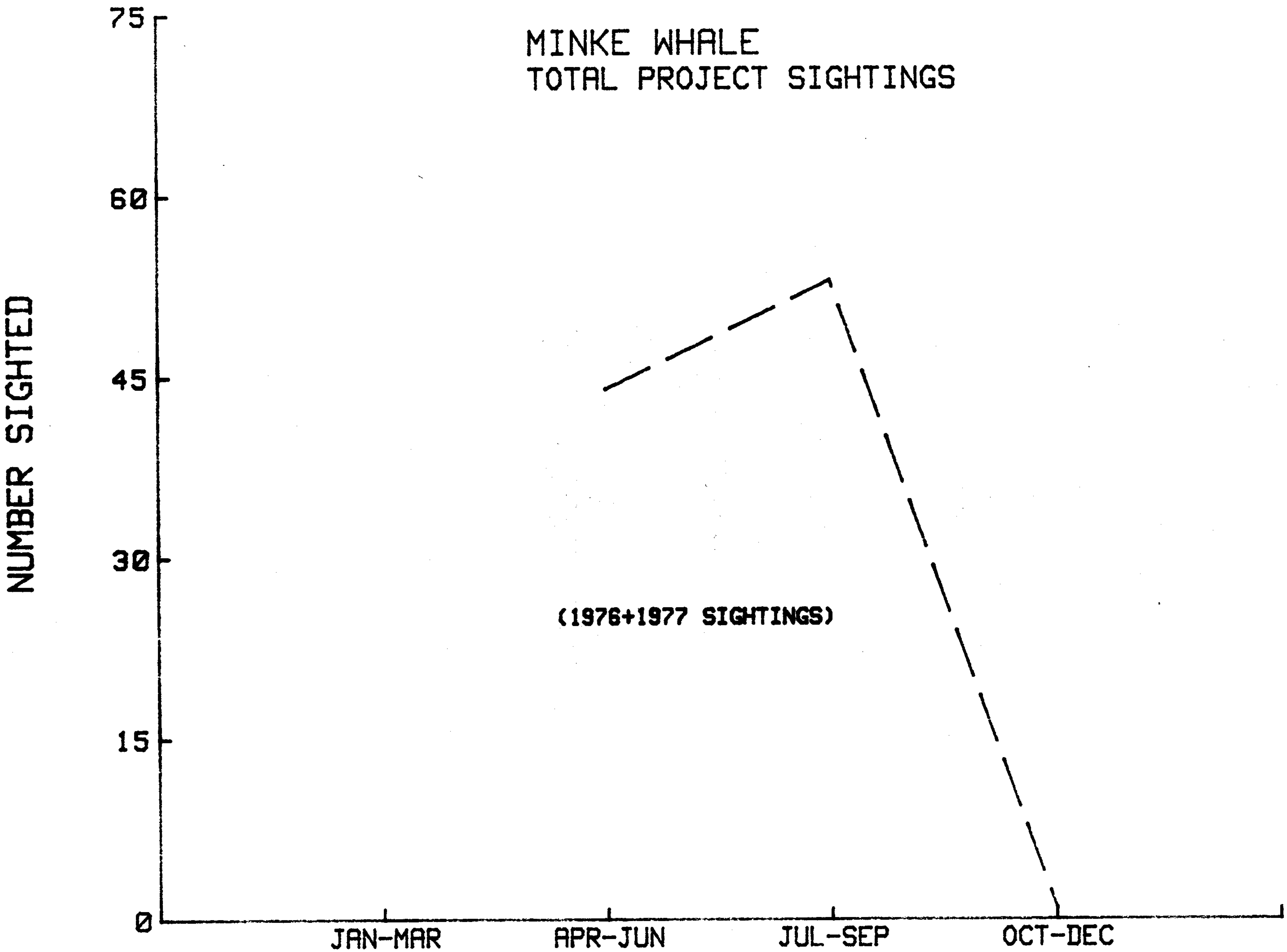

MYSTICETE WHALE SIGHTINGS/EFFORT
PROJECT TOTAL
(1976+1977 SIGHTINGS)
NO. SIGHTED/NAUTICAL MILE
.15
.12
.09
.06
.03
0.00
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC

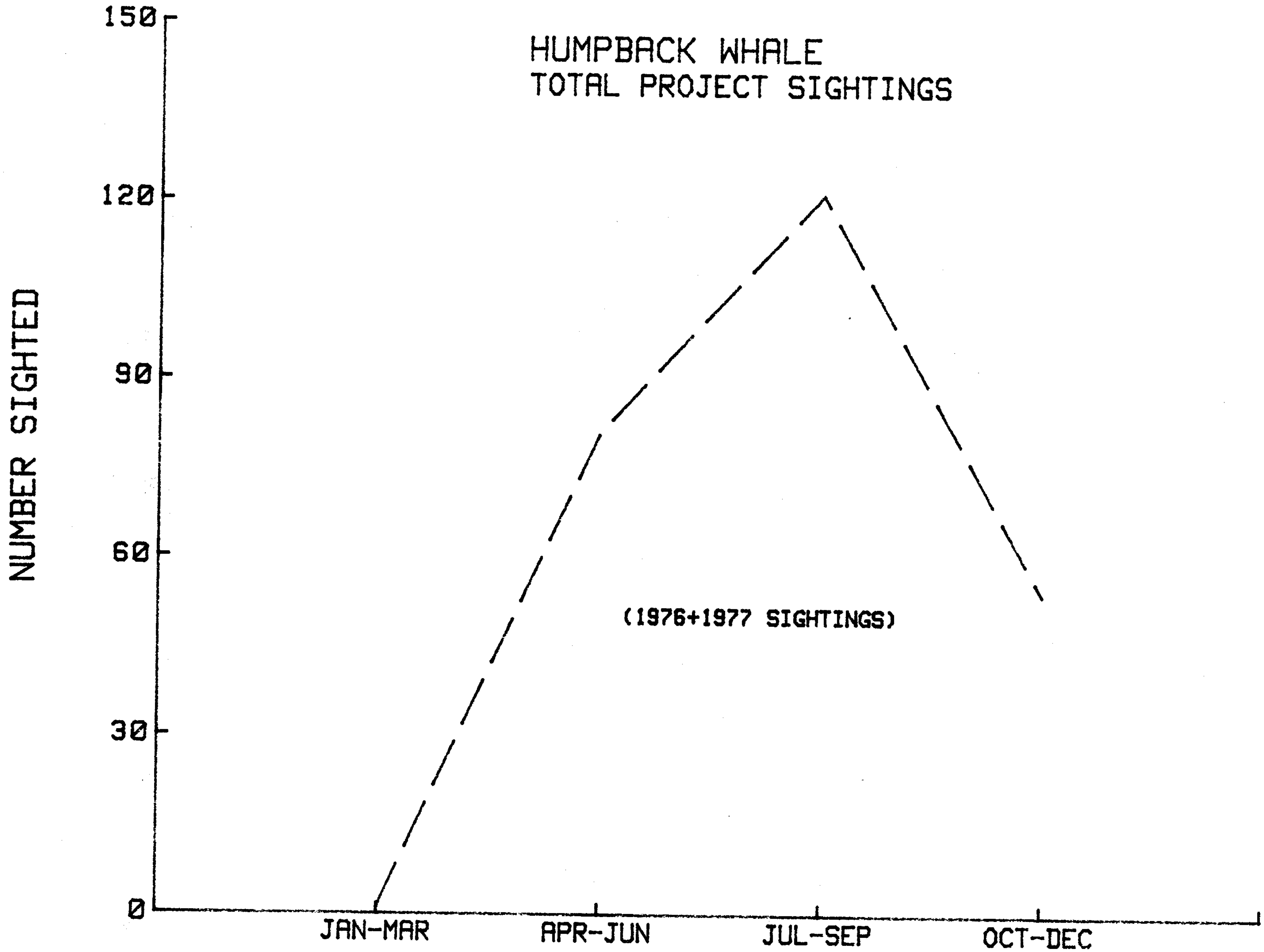

MYSTICETE WHALE SIGHTINGS/EFFORT
NO. SIGHTED/NAUTICAL MILE
.25
.20
.15
.10
.05
0.00
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC
1977
1976



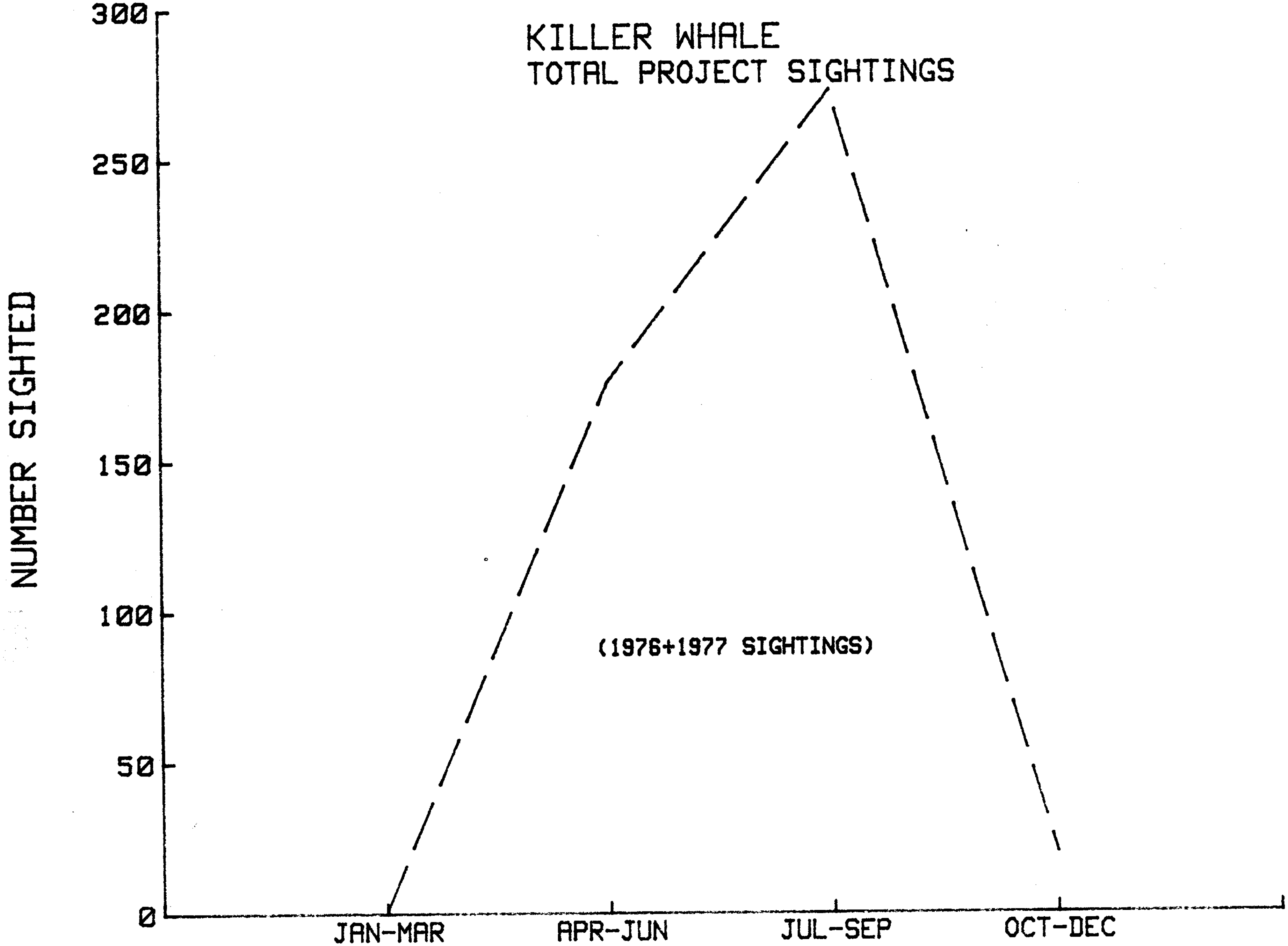
ODONTOCETE WHALE SIGHTINGS
NUMBER SIGHTED
1500
1200
900
600
300
0
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC
TOTAL
1977
1976

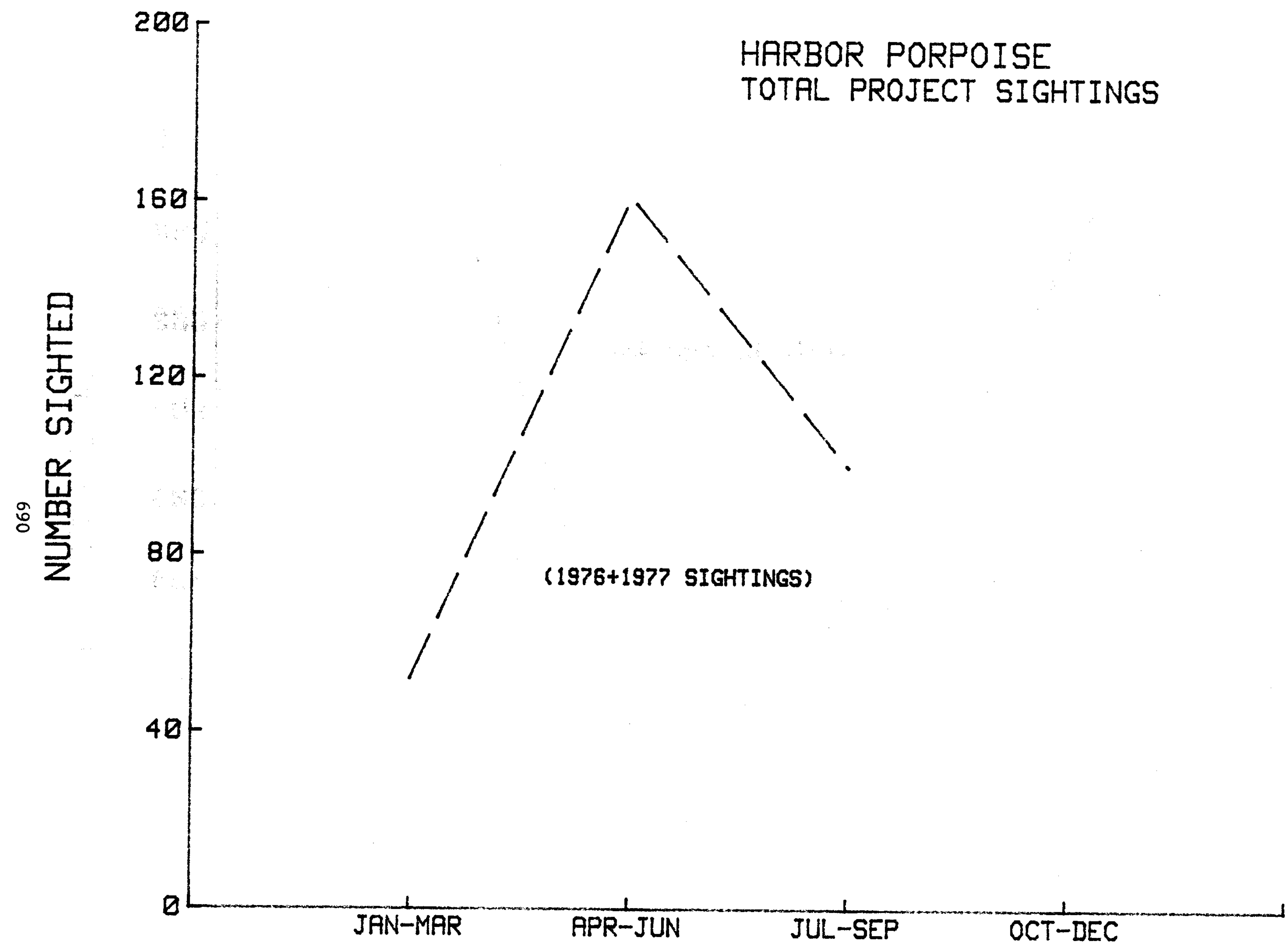

MYSTICETE WHALE SIGHTINGS
NUMBER SIGHTED
200
150
100
50
0
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC
TOTAL
1977
1976


MINKE WHALE
TOTAL PROJECT SIGHTINGS
(1976+1977 SIGHTINGS)
NUMBER SIGHTED
75
60
45
30
15
0
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC

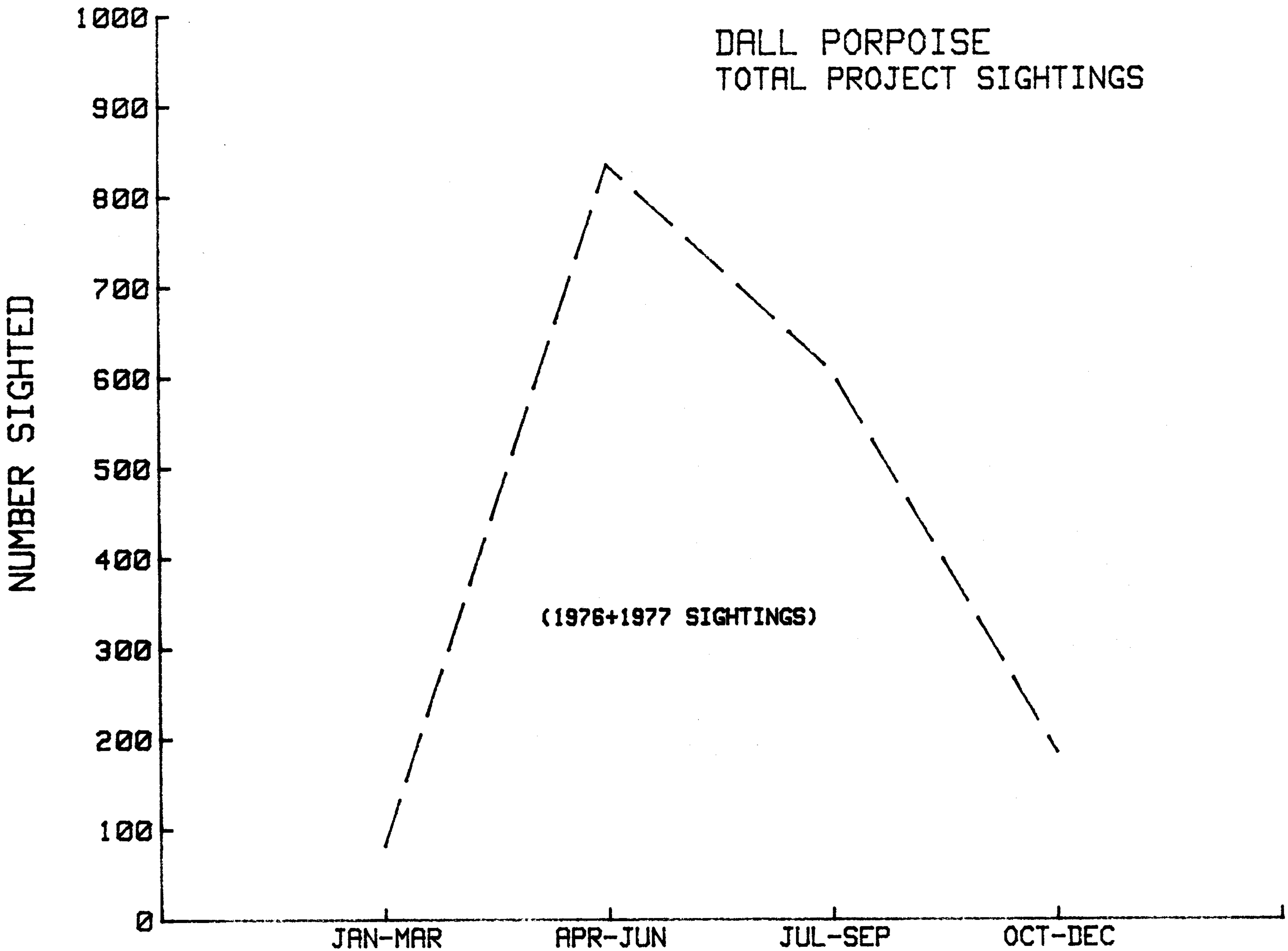

HUMPBACK WHALE
TOTAL PROJECT SIGHTINGS
(1976+1977 SIGHTINGS)
NUMBER SIGHTED
150
120
90
60
30
0
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC

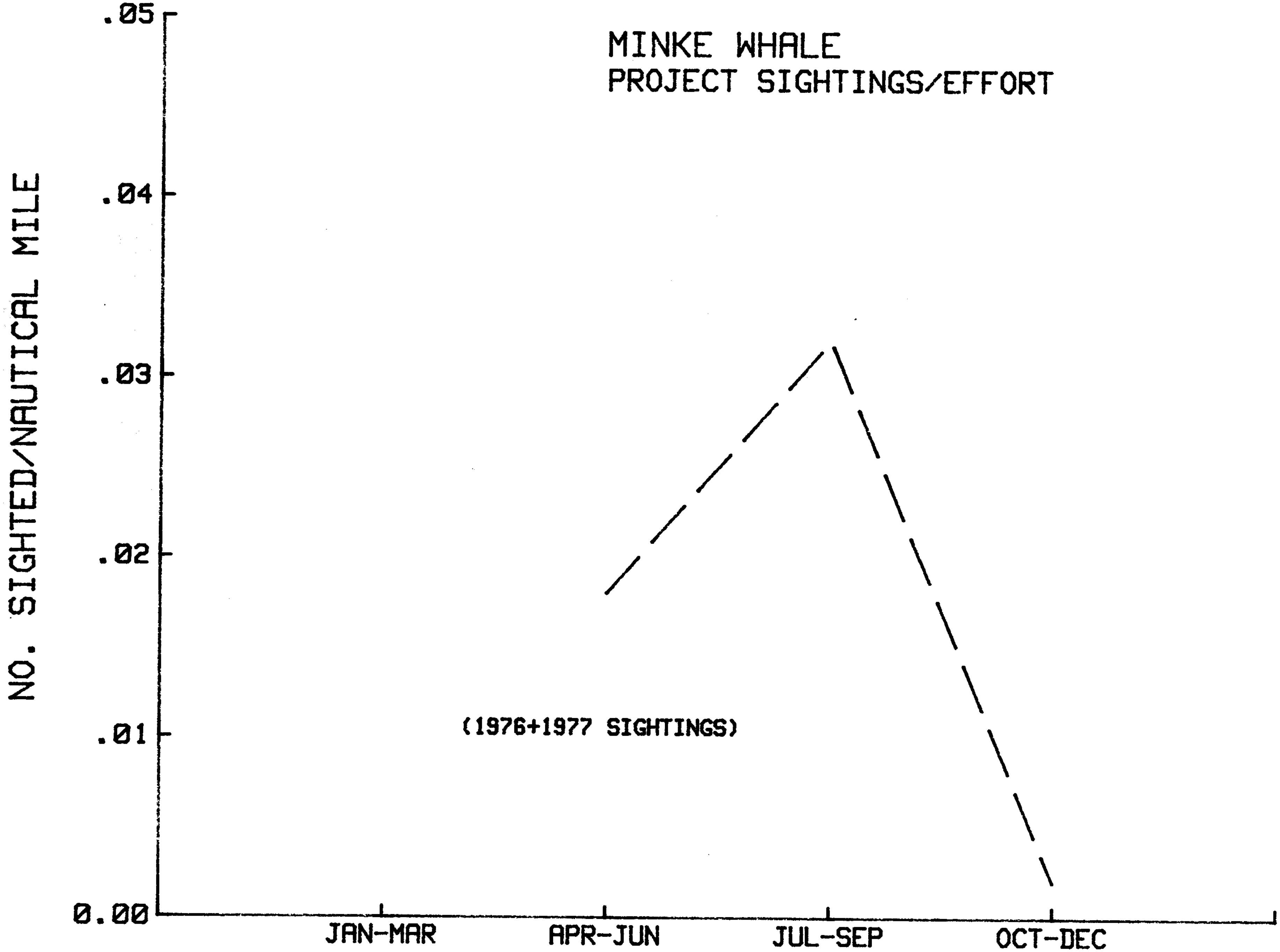
689

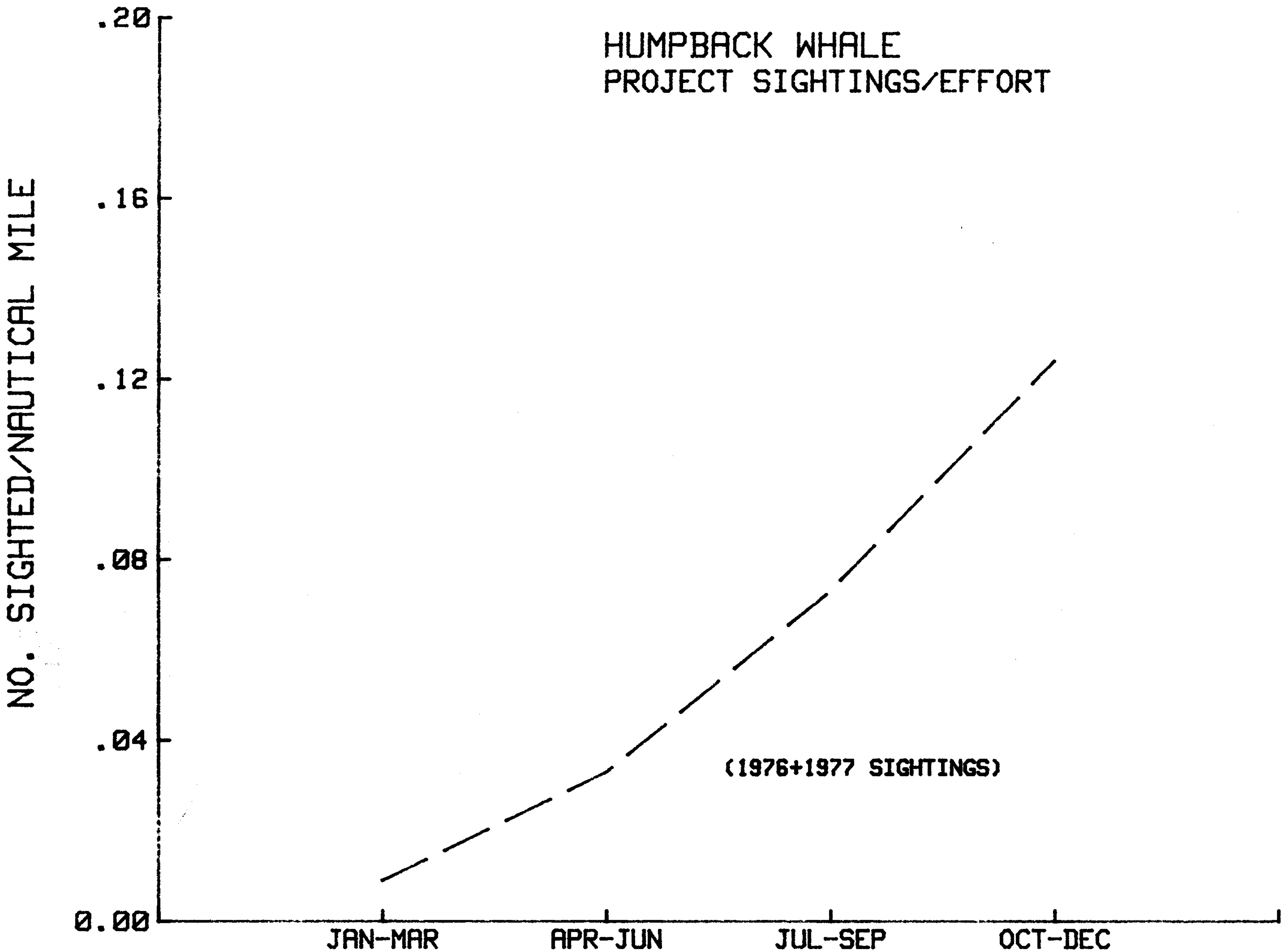

KILLER WHALE
TOTAL PROJECT SIGHTINGS
(1976+1977 SIGHTINGS)
NUMBER SIGHTED
300
250
200
150
100
50
0
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC



HARBOR PORPOISE
TOTAL PROJECT SIGHTINGS
NUMBER SIGHTED
200
160
120
80
40
0
(1976+1977 SIGHTINGS)
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC


DALL PORPOISE
TOTAL PROJECT SIGHTINGS
(1976+1977 SIGHTINGS)
NUMBER SIGHTED
1000
900
800
700
600
500
400
300
200
100
0
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC


MINKE WHALE
PROJECT SIGHTINGS/EFFORT
(1976+1977 SIGHTINGS)
NO. SIGHTED/NAUTICAL MILE
.05
.04
.03
.02
.01
0.00
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC


HUMPBACK WHALE
PROJECT SIGHTINGS/EFFORT
NO. SIGHTED/NAUTICAL MILE
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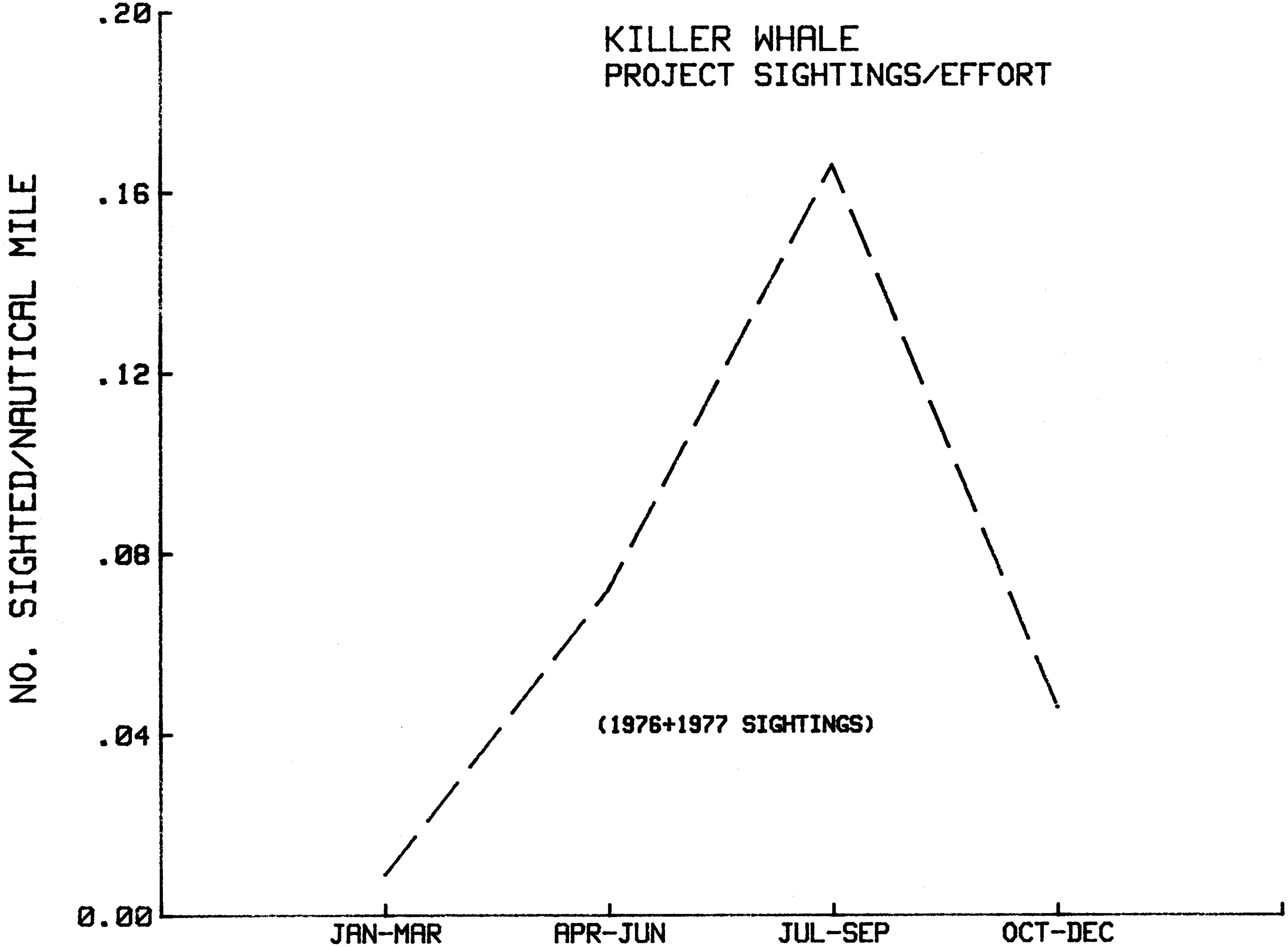
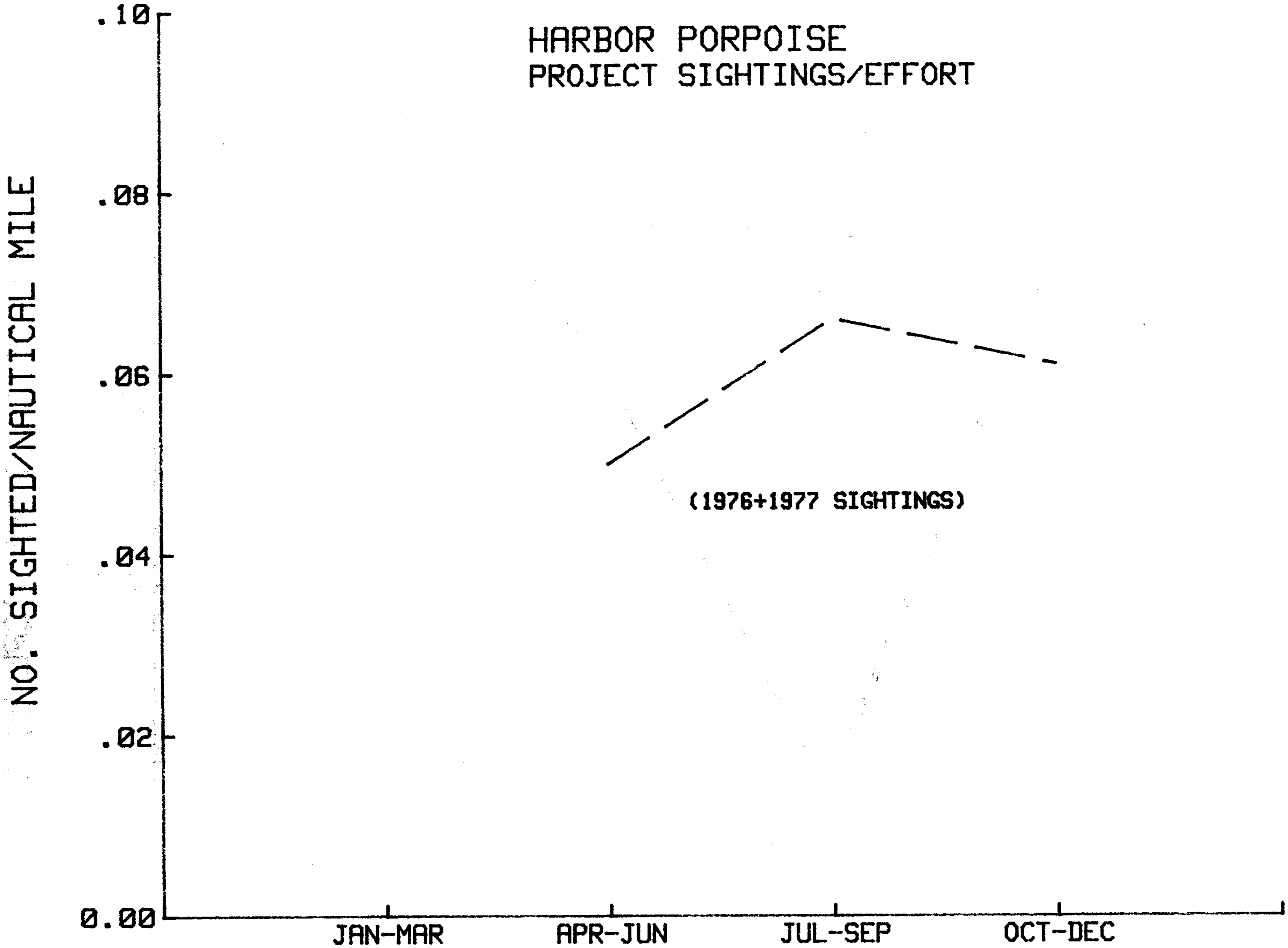
.16
.12
.08
.04
0.00
(1976+1977 SIGHTINGS)
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC


KILLER WHALE
PROJECT SIGHTINGS/EFFORT
(1976+1977 SIGHTINGS)
NO. SIGHTED/NAUTICAL MILE
.20
.16
.12
.08
.04
0.00
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC


HARBOR PORPOISE
PROJECT SIGHTINGS/EFFORT
(1976+1977 SIGHTINGS)
NO. SIGHTED/NAUTICAL MILE
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.08
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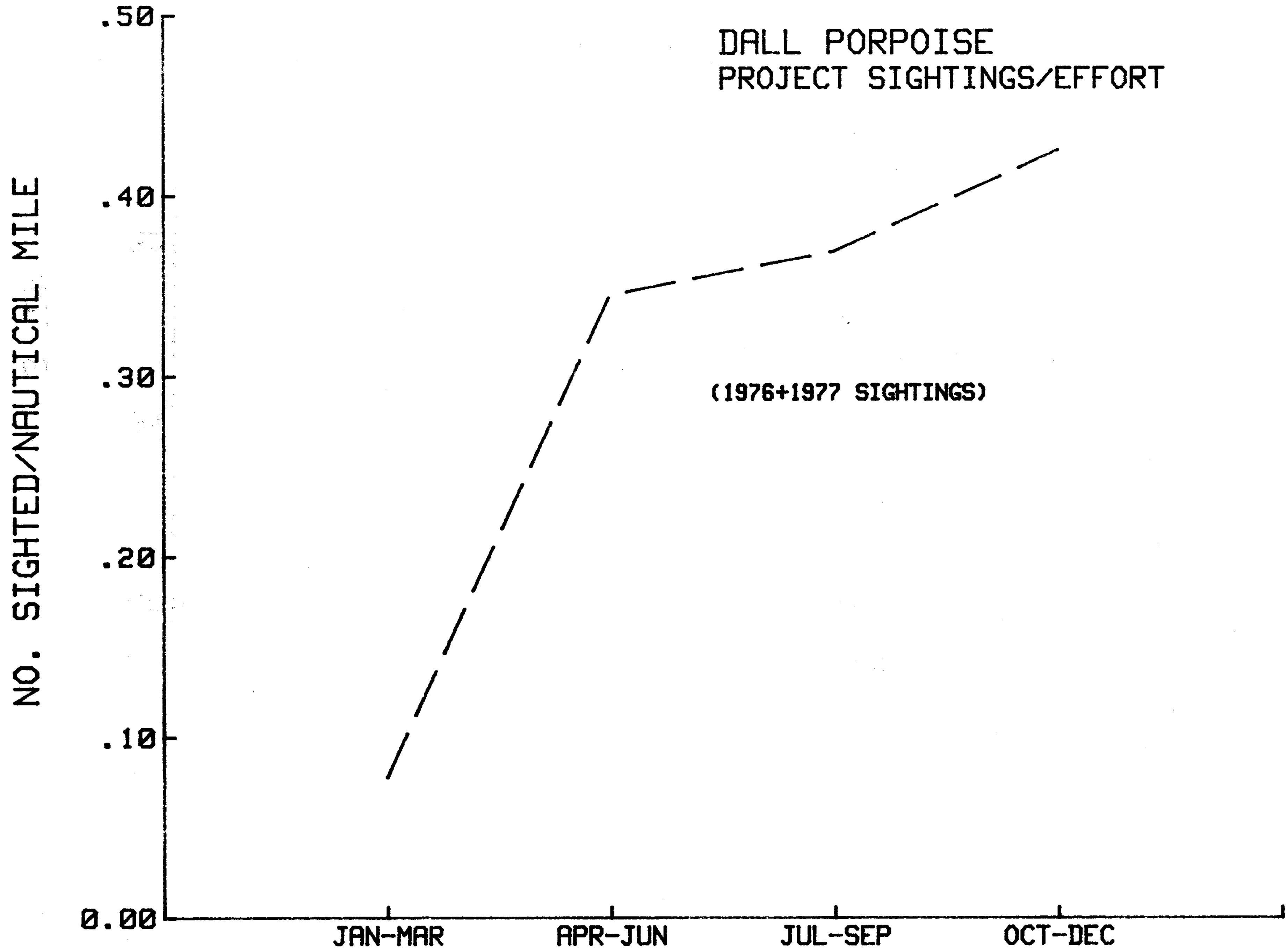
.04
.02
0.00
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC


DALL PORPOISE
PROJECT SIGHTINGS/EFFORT
(1976+1977 SIGHTINGS)
NO. SIGHTED/NAUTICAL MILE
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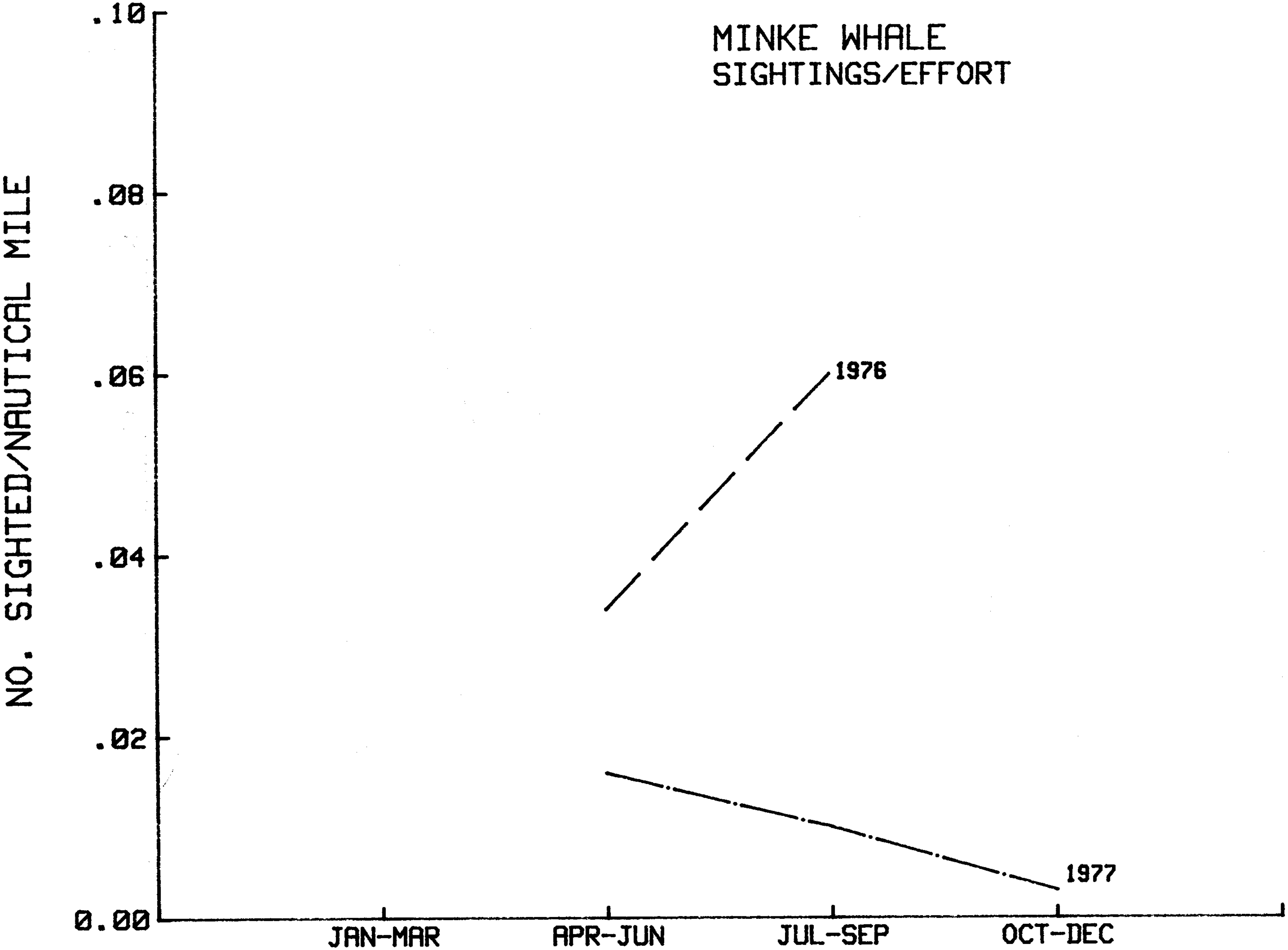
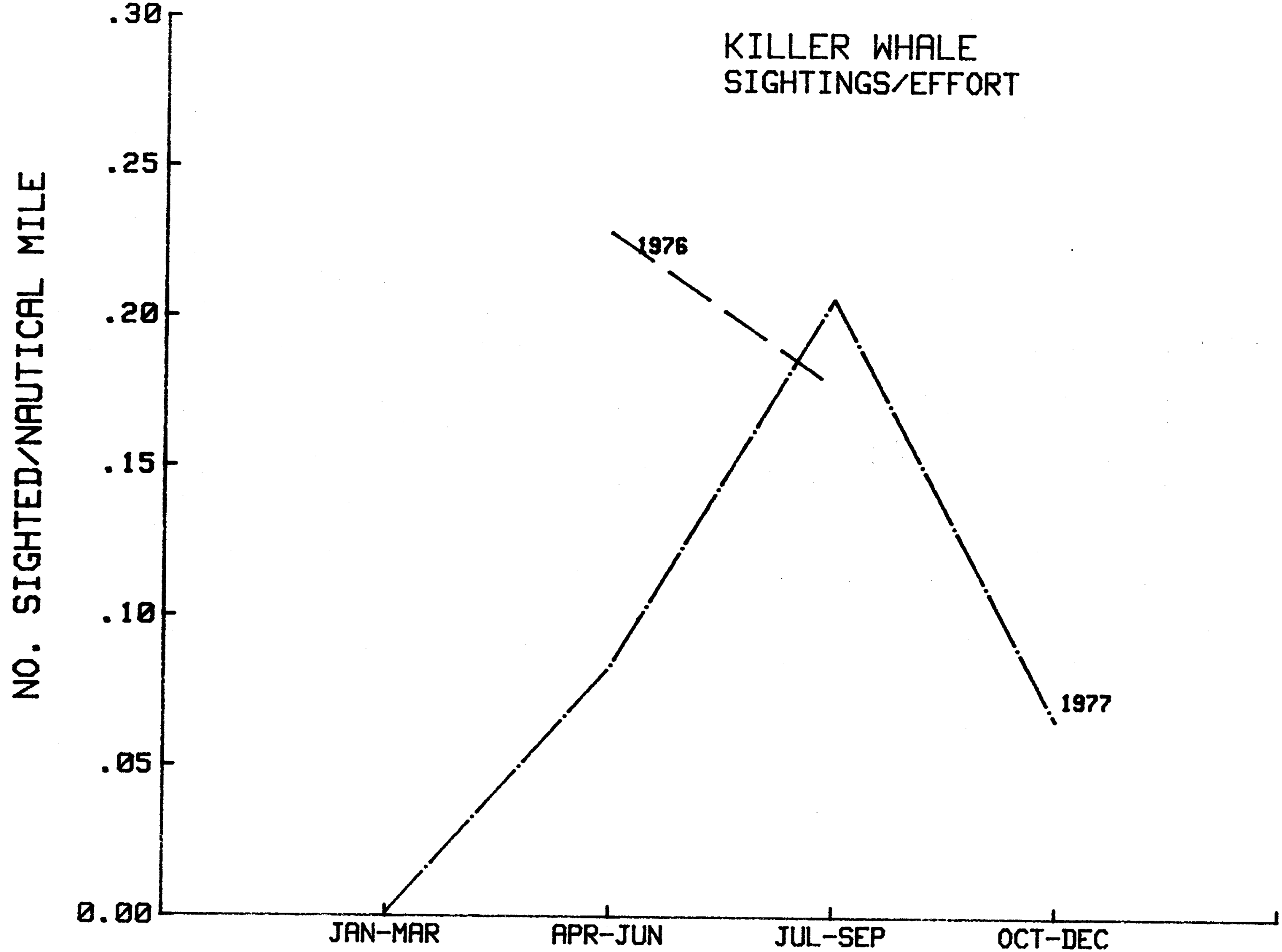
.40
.30
.20
.10
0.00
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC


MINKE WHALE
SIGHTINGS/EFFORT
NO. SIGHTED/NAUTICAL MILE
.10
.08
.06
.04
.02
0.00
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC
1976
1977


KILLER WHALE
SIGHTINGS/EFFORT
NO. SIGHTED/NAUTICAL MILE
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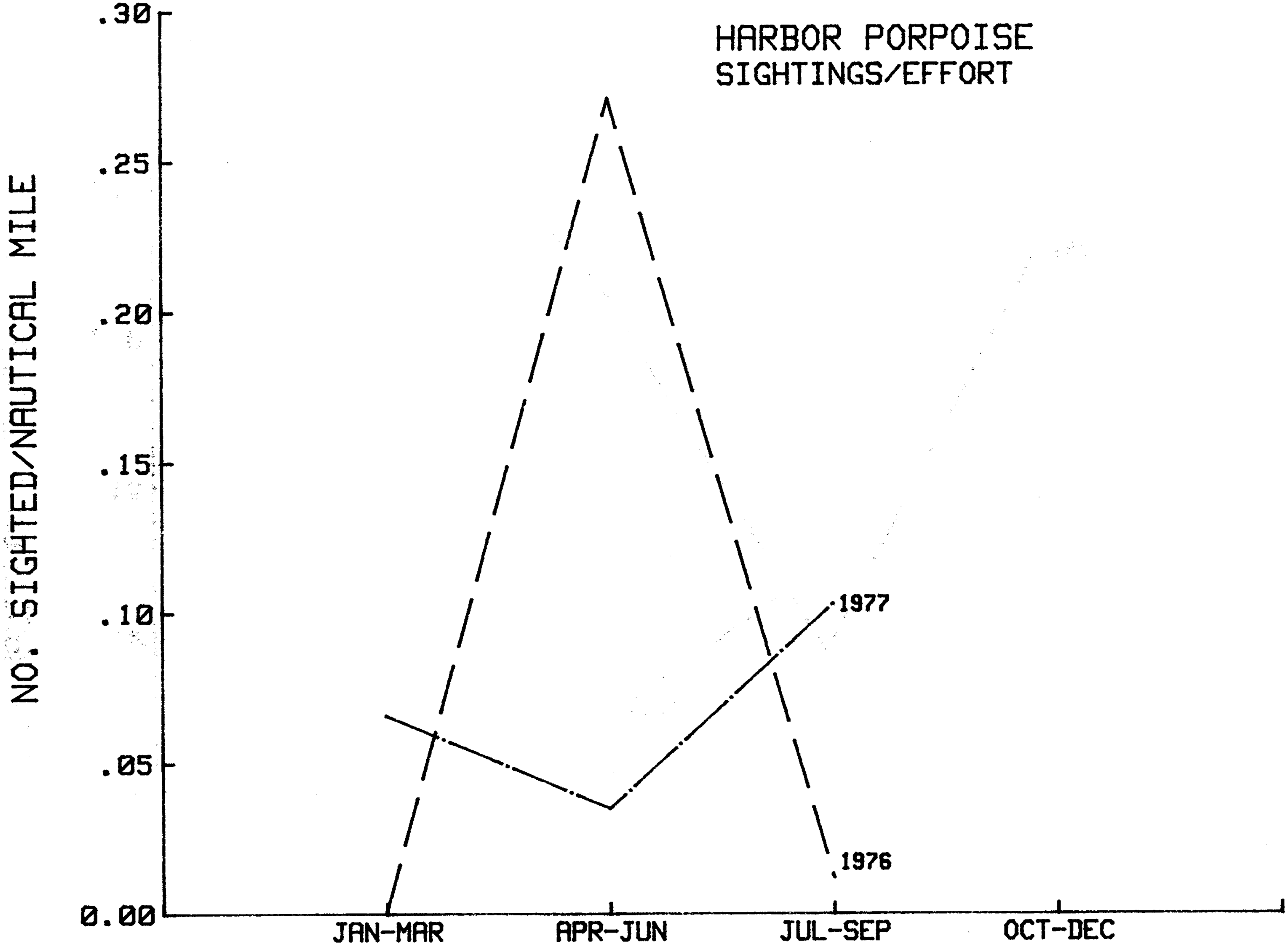
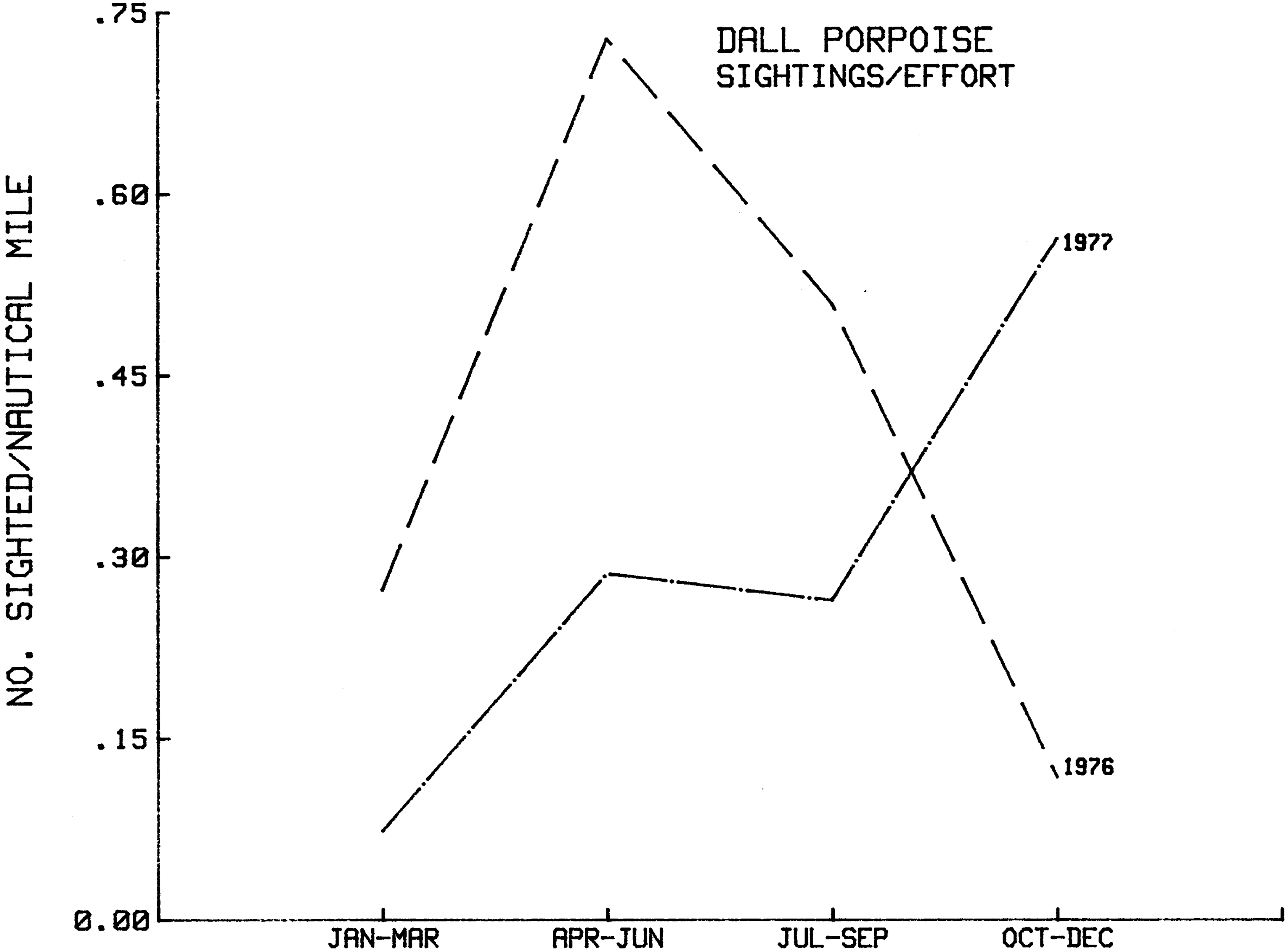
.25
.20
.15
.10
.05
0.00
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC
1976
1977


HARBOR PORPOISE
SIGHTINGS/EFFORT
NO. SIGHTED/NAUTICAL MILE
.30
.25
.20
.15
.10
.05
0.00
1977
1976
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC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SIGHTINGS/EFFORT
NO. SIGHTED/NAUTICAL MILE
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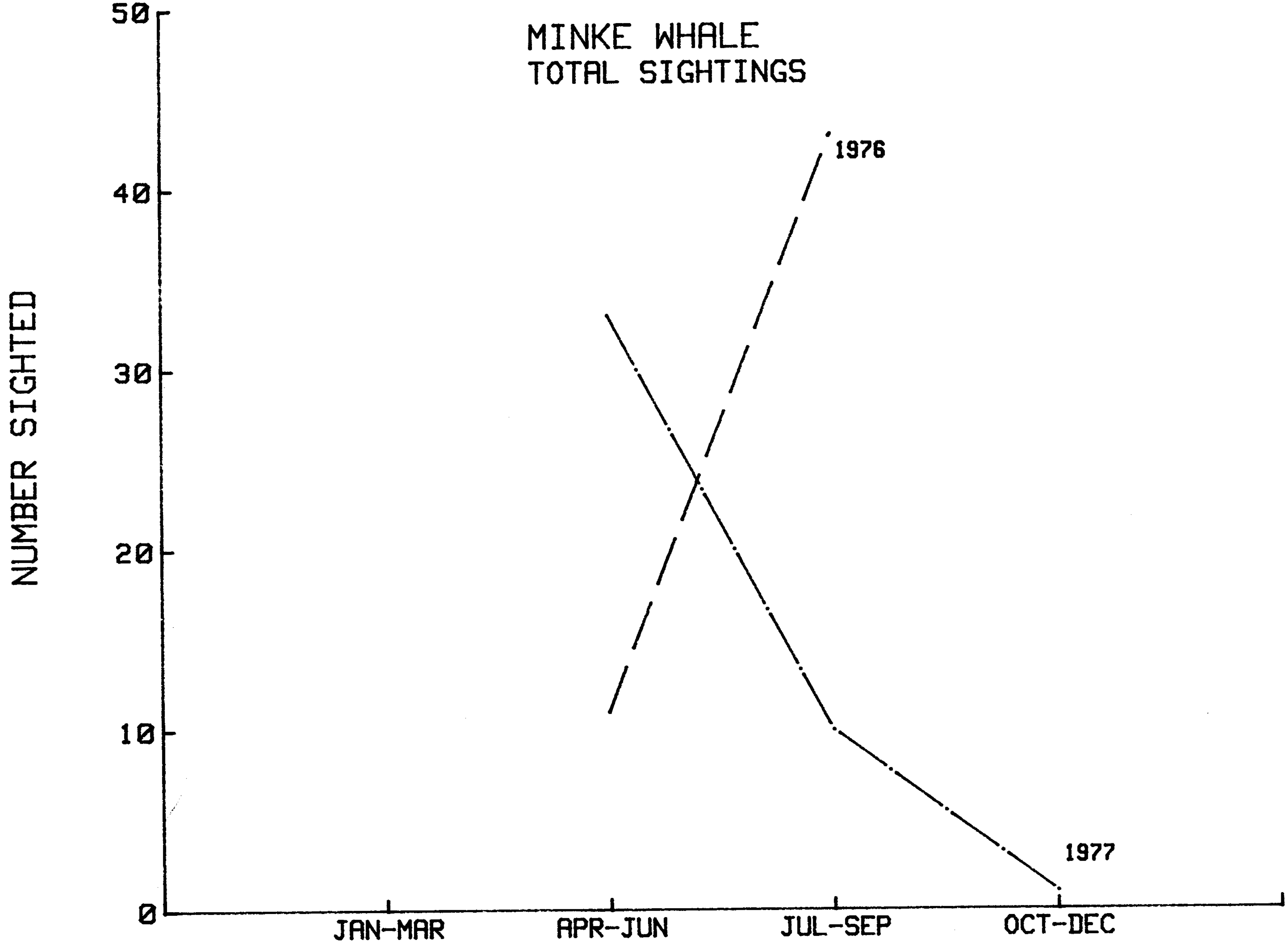
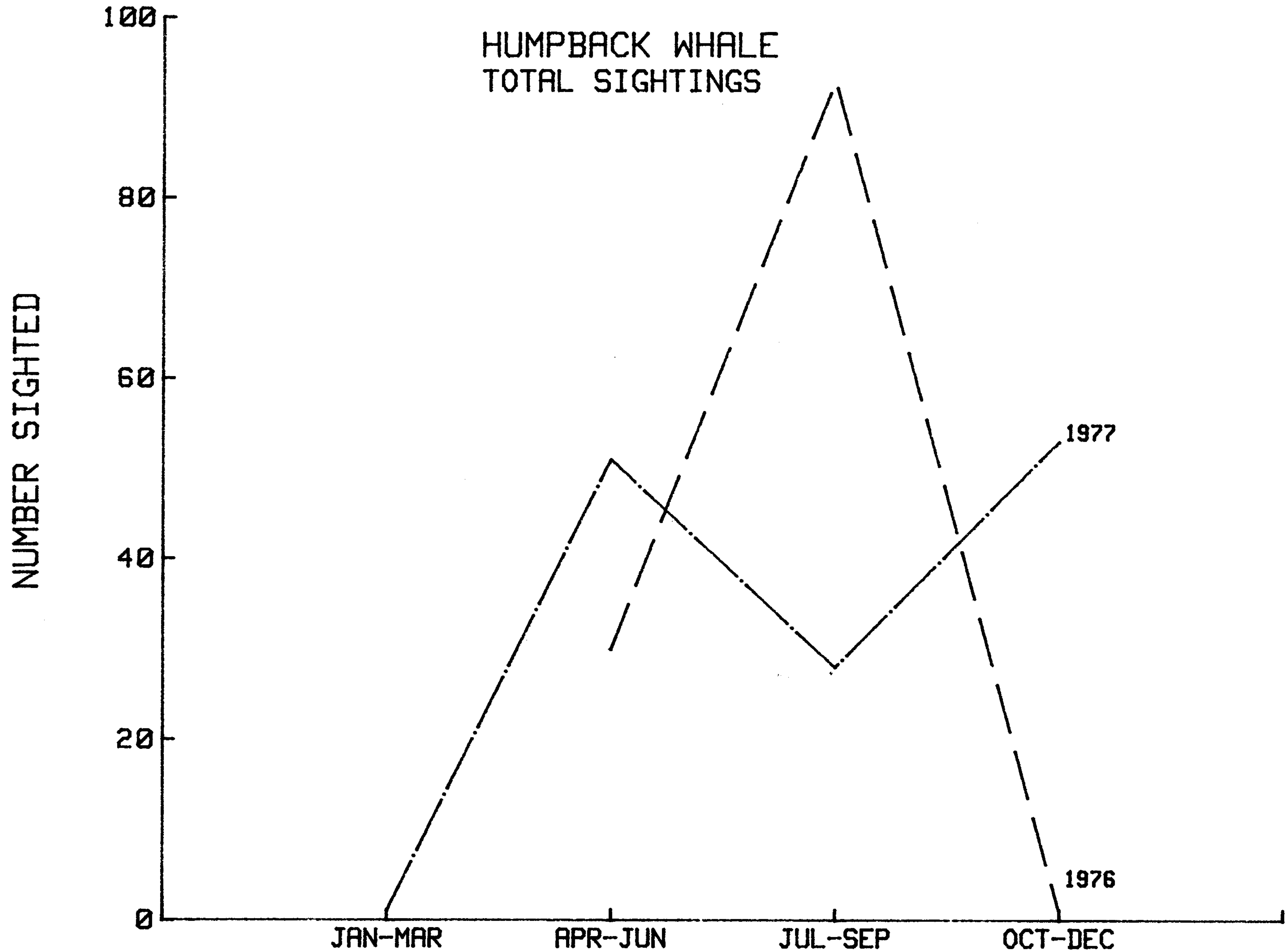
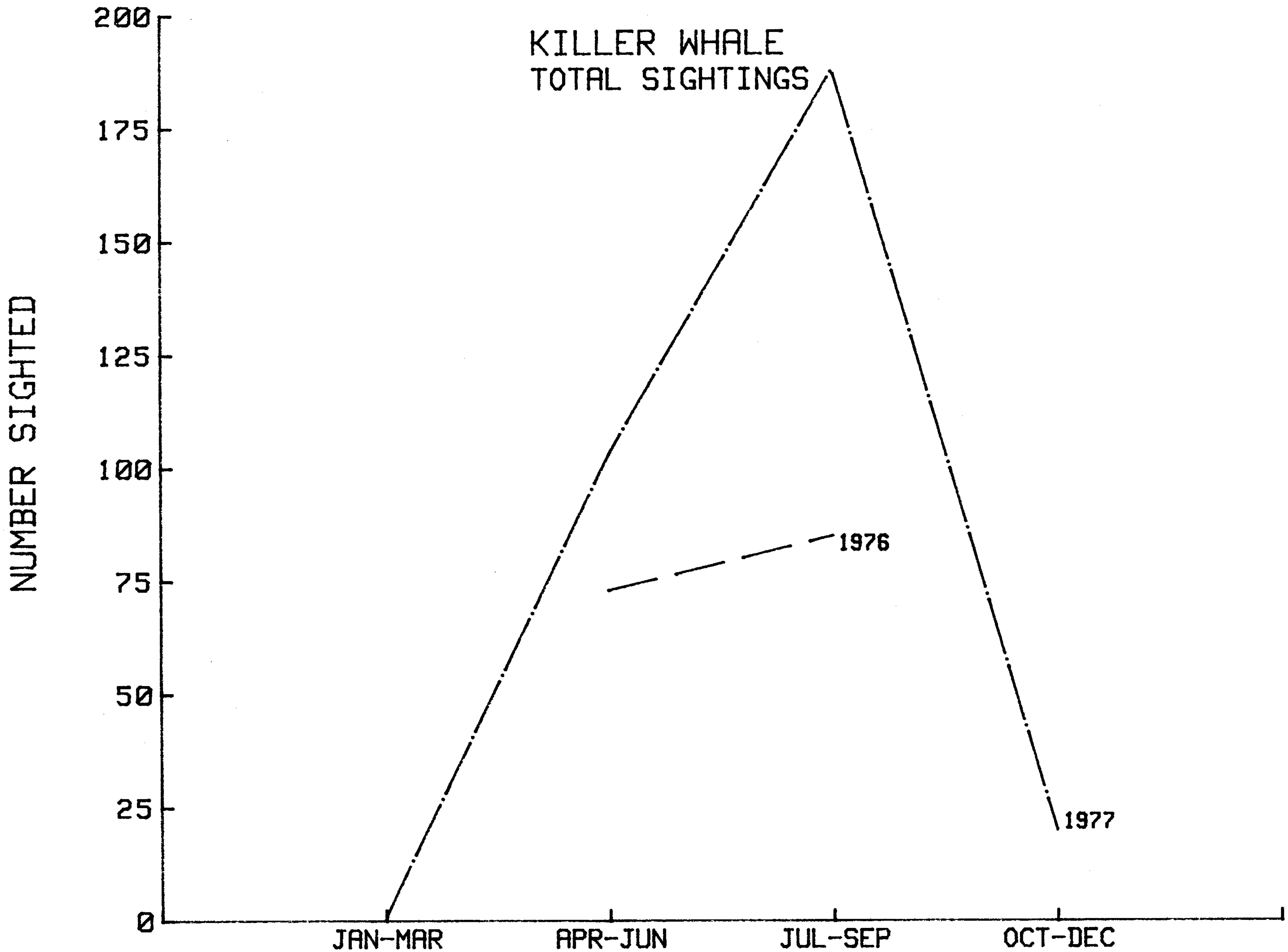
.45
.30
.15
0.00
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC
1977
1976



MINKE WHALE
TOTAL SIGHTINGS
NUMBER SIGHTED
50
40
30
20
10
0
1976
1977
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC


HUMPBACK WHALE
TOTAL SIGHTINGS
NUMBER SIGHTED
100
80
60
40
20
0
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC
1977
1976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TOTAL SIGHTINGS
NUMBER SIGHTED
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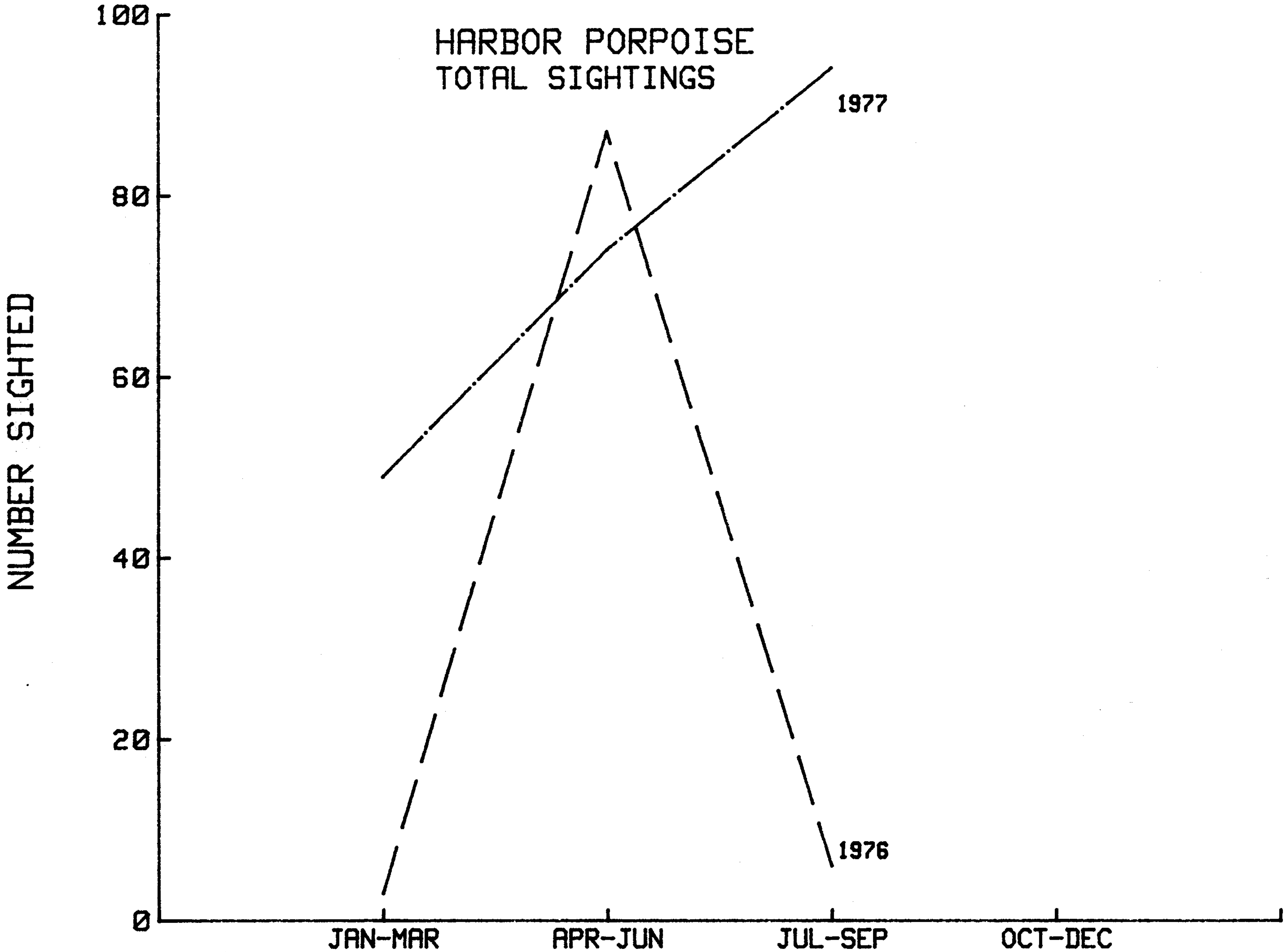
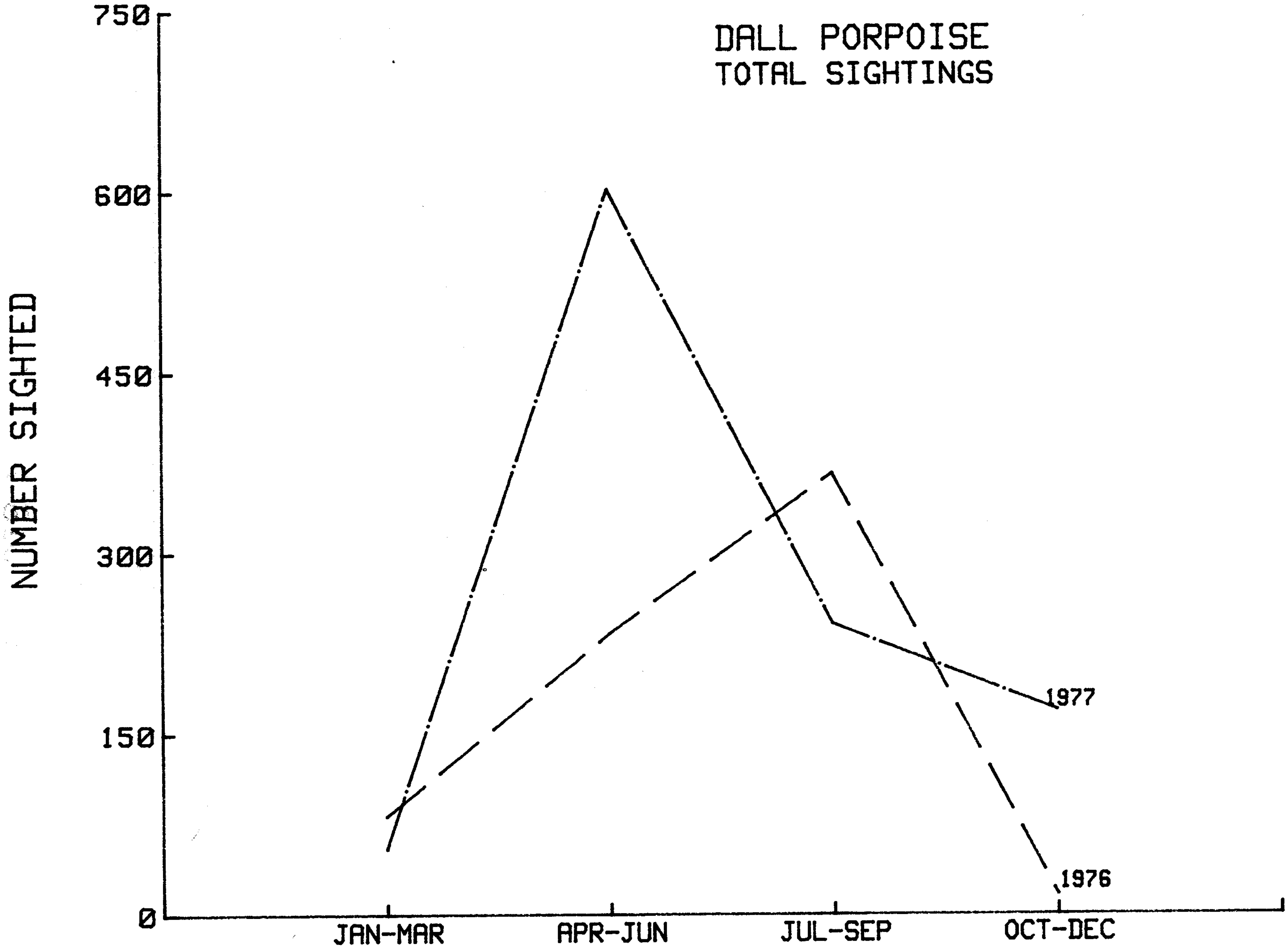
125
100
75
50
25
0
1976
1977
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC


HARBOR PORPOISE
TOTAL SIGHTINGS
NUMBER SIGHTED
100
80
60
40
20
0
1977
1976
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC


DALL PORPOISE
TOTAL SIGHTINGS
NUMBER SIGHTED
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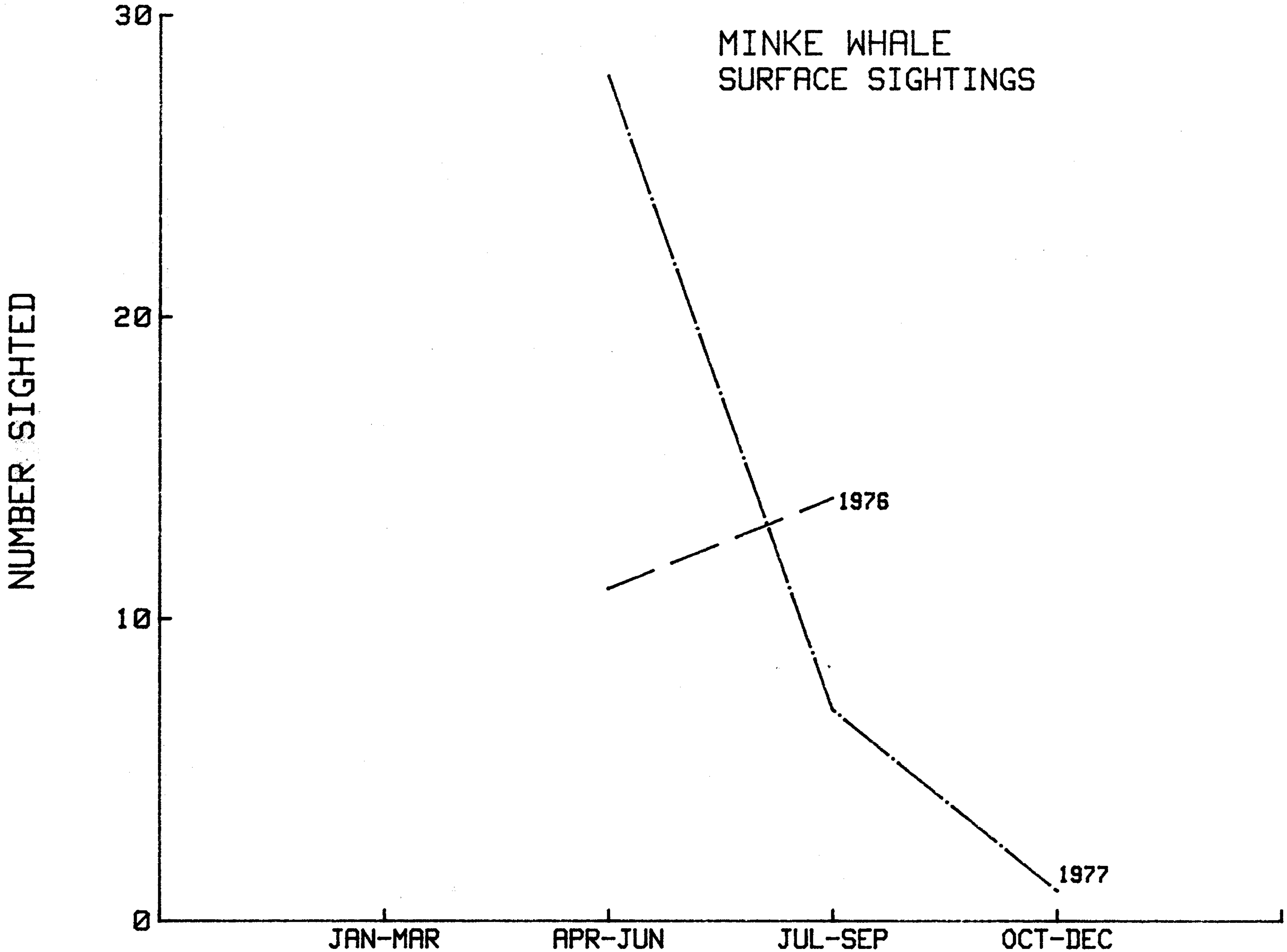
600
450
300
150
0
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC
1977
1976


MINKE WHALE
SURFACE SIGHTINGS
NUMBER SIGHTED
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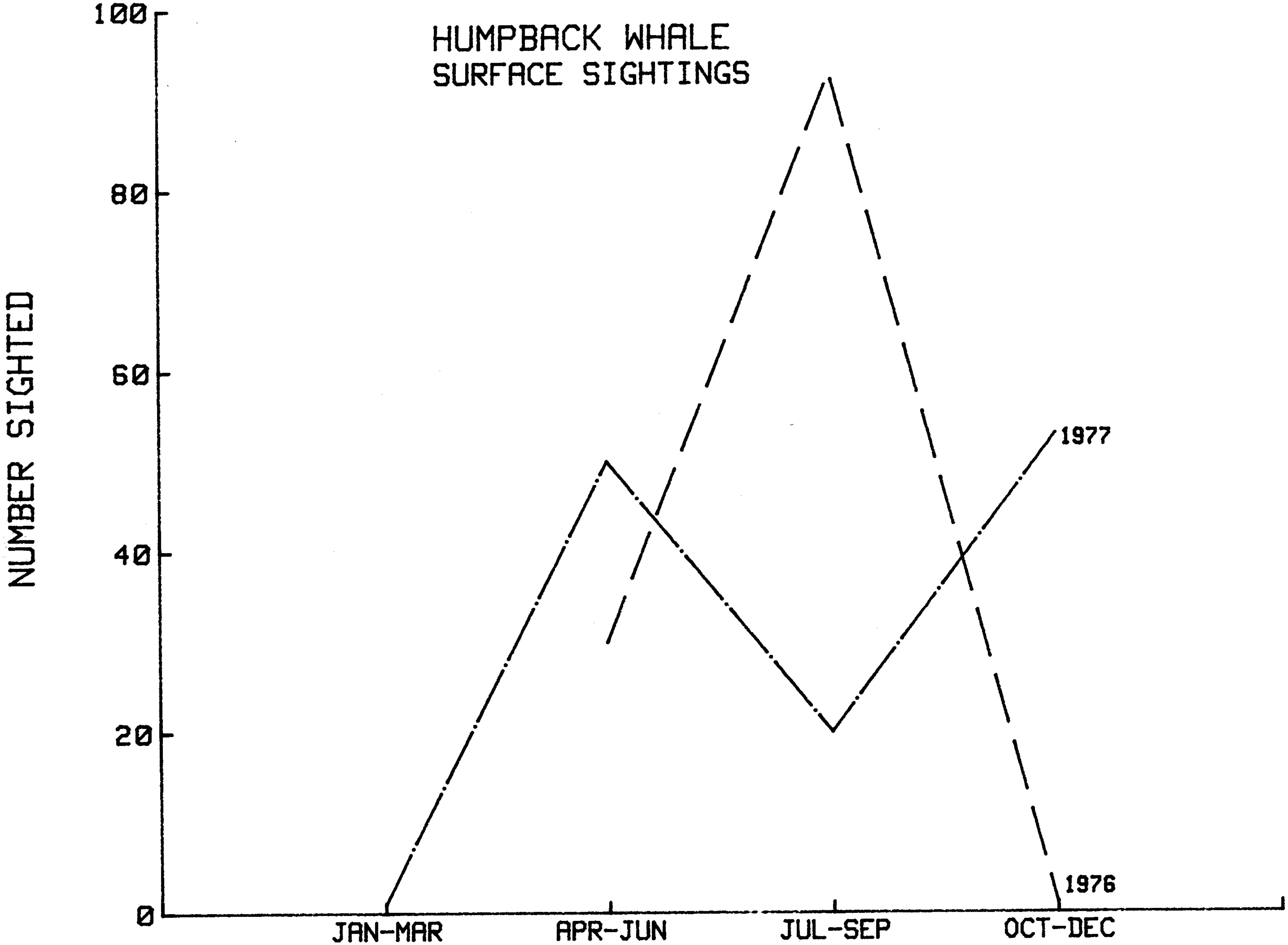
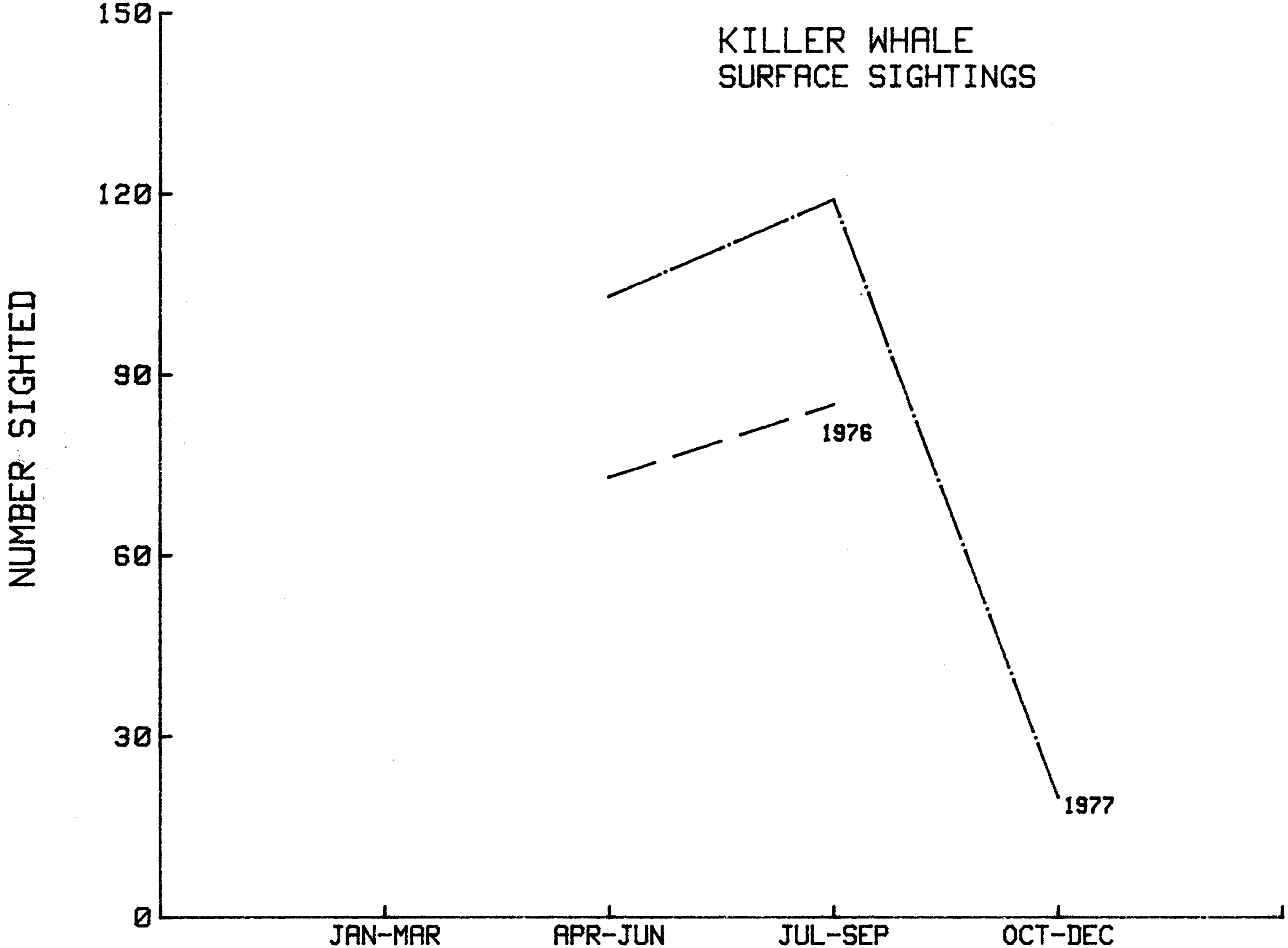
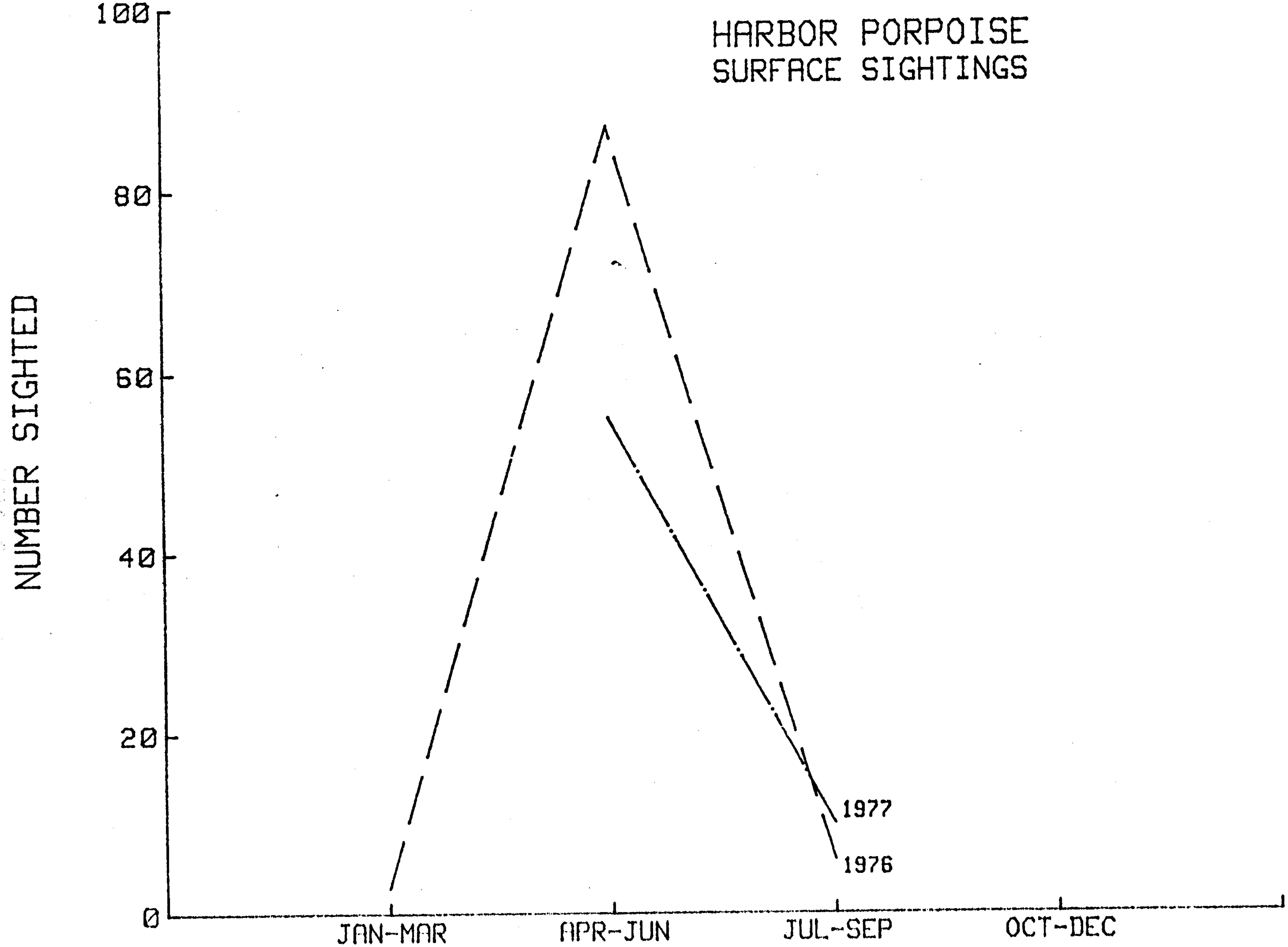
20
10
0
1976
1977
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC

706


HUMPBACK WHALE
SURFACE SIGHTINGS
NUMBER SIGHTED
100
80
60
40
20
0
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC
1977
1976



KILLER WHALE
SURFACE SIGHTINGS
NUMBER SIGHTED
150
120
90
60
30
0
1976
1977
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC


HARBOR PORPOISE
SURFACE SIGHTINGS
NUMBER SIGHTED
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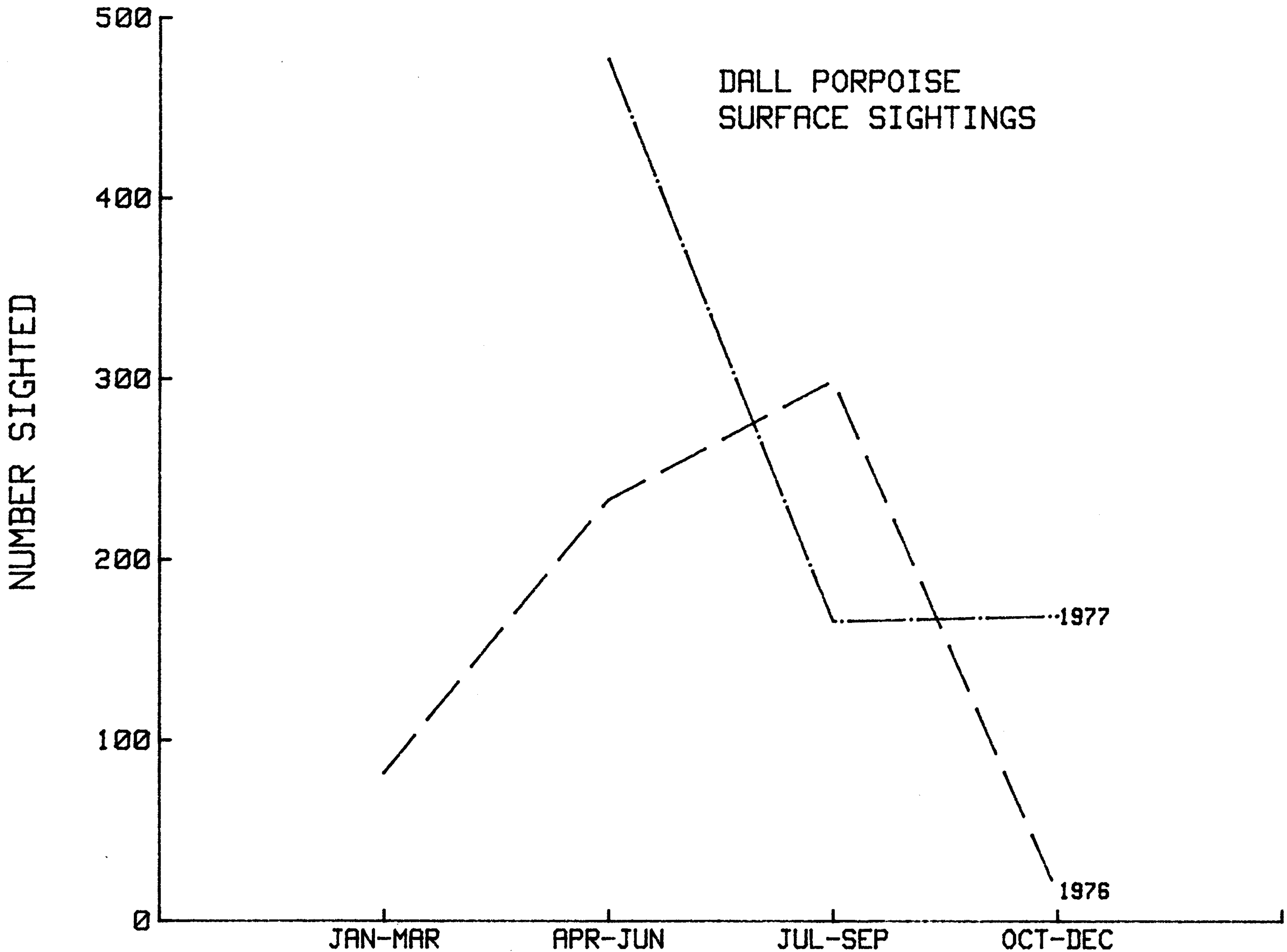
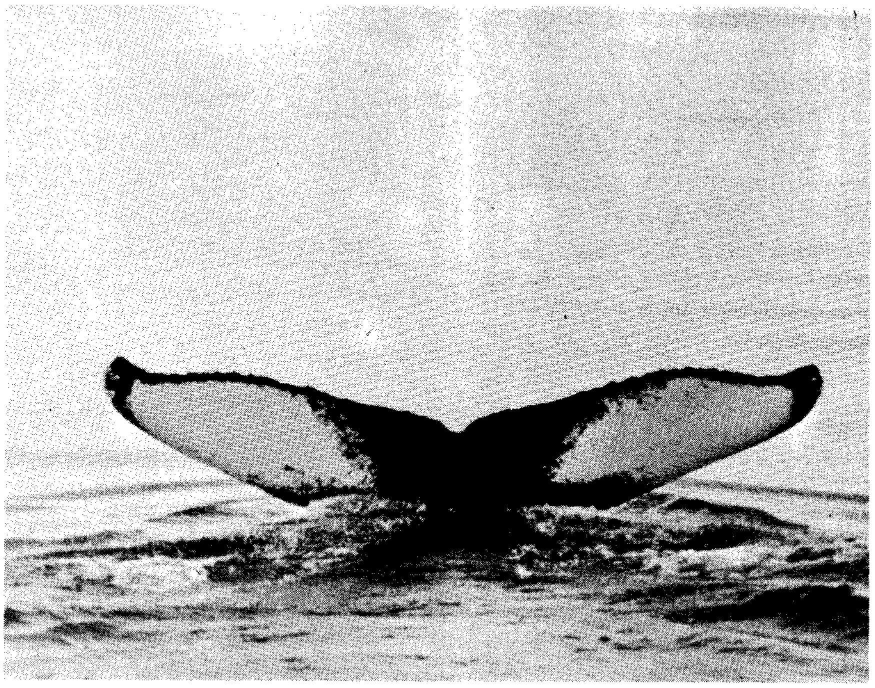
80
60
40
20
0
JAN-MAR
APR-JUN
JUL.-SEP
OCT-DEC
1977
1976

709

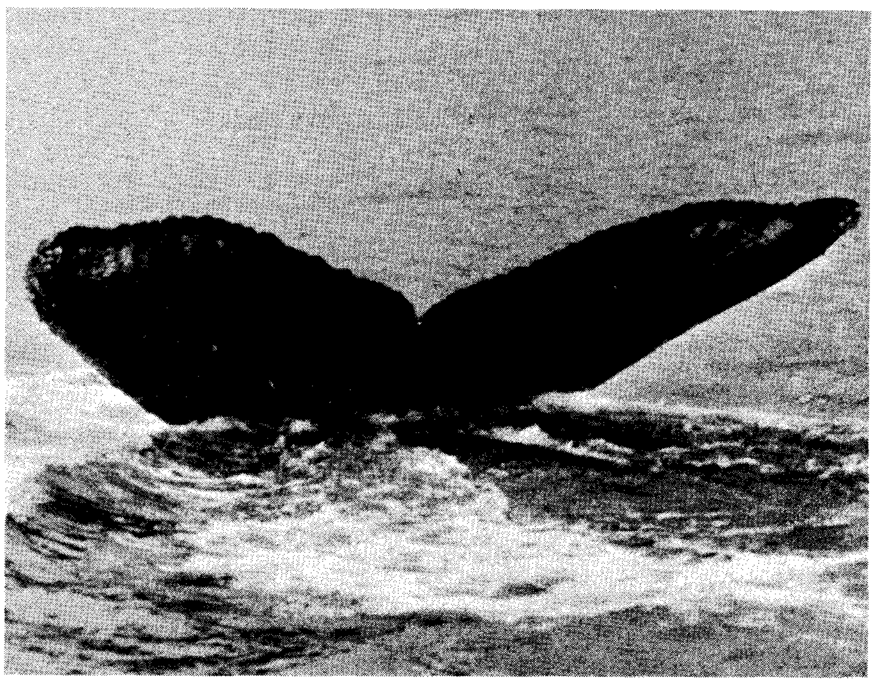


DALL PORPOISE
SURFACE SIGHTINGS
NUMBER SIGHTED
500
400
300
200
100
0
JAN-MAR
APR-JUN
JUL-SEP
OCT-DEC
1977
1976

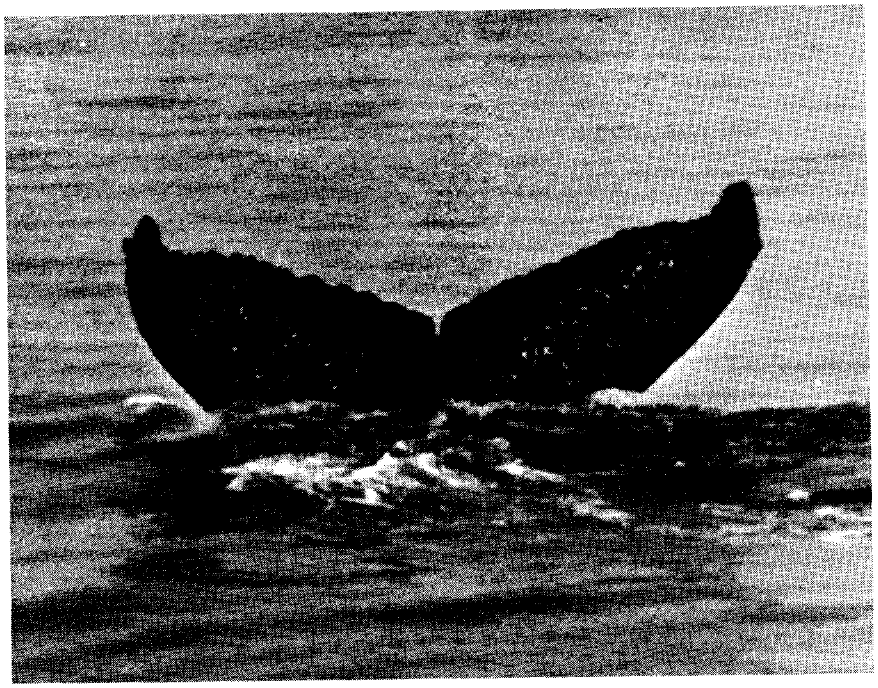
APPENDIX 3



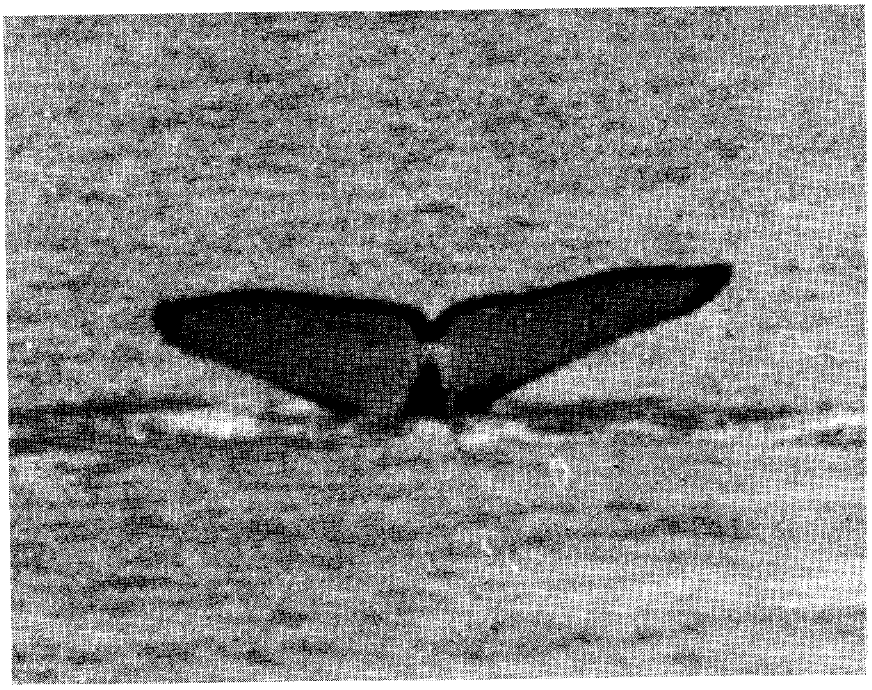
Initial Sighting- 6/77 Resight 6/78 Resight 8/78



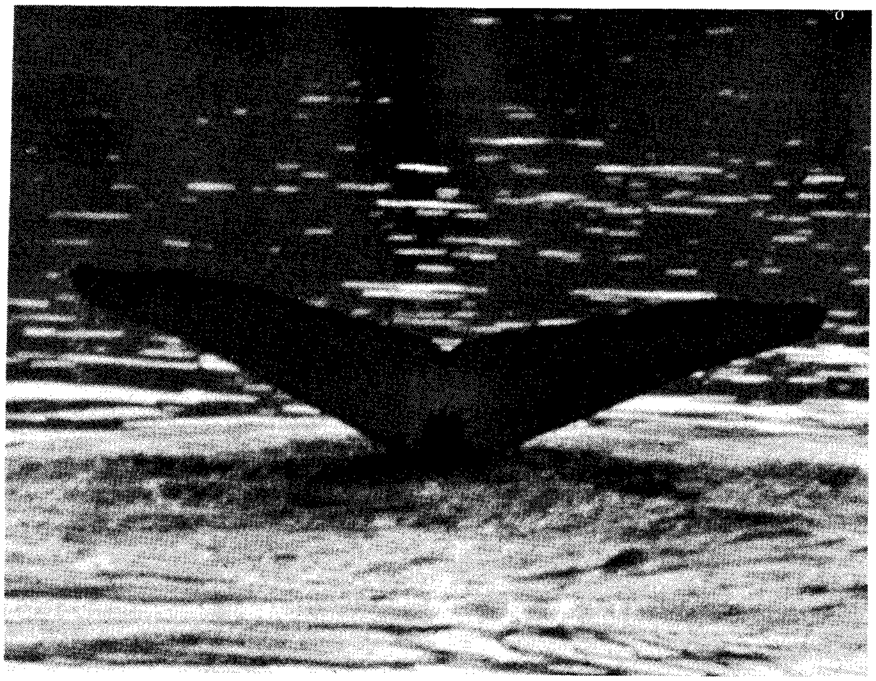
Initial sighting- 6/77 Resight 8/78



Initial Sighting- 5/77 Resight 8/77 Resight 6/78



Initial Sighting 8/76 No Resights



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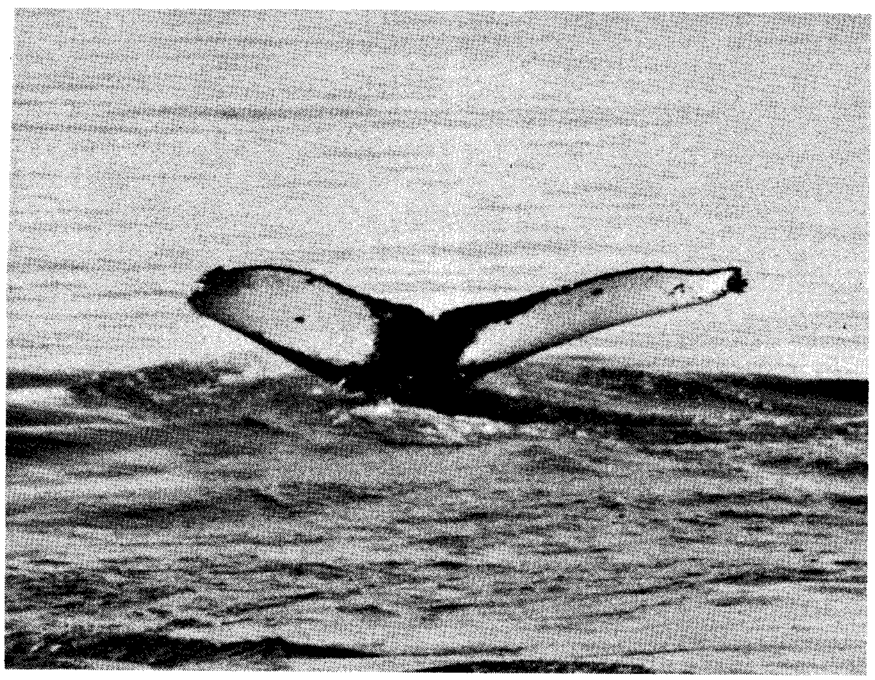

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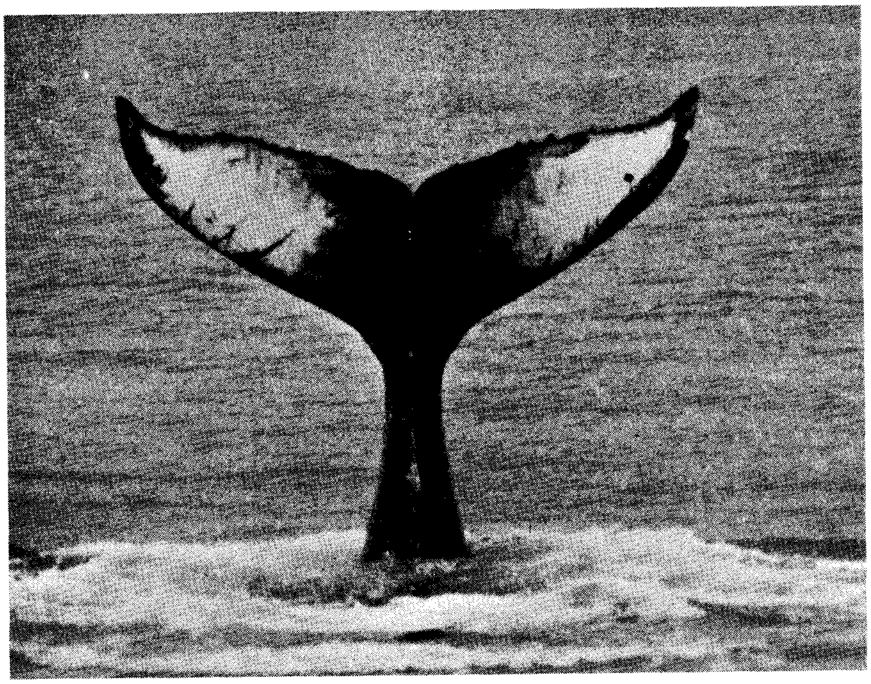

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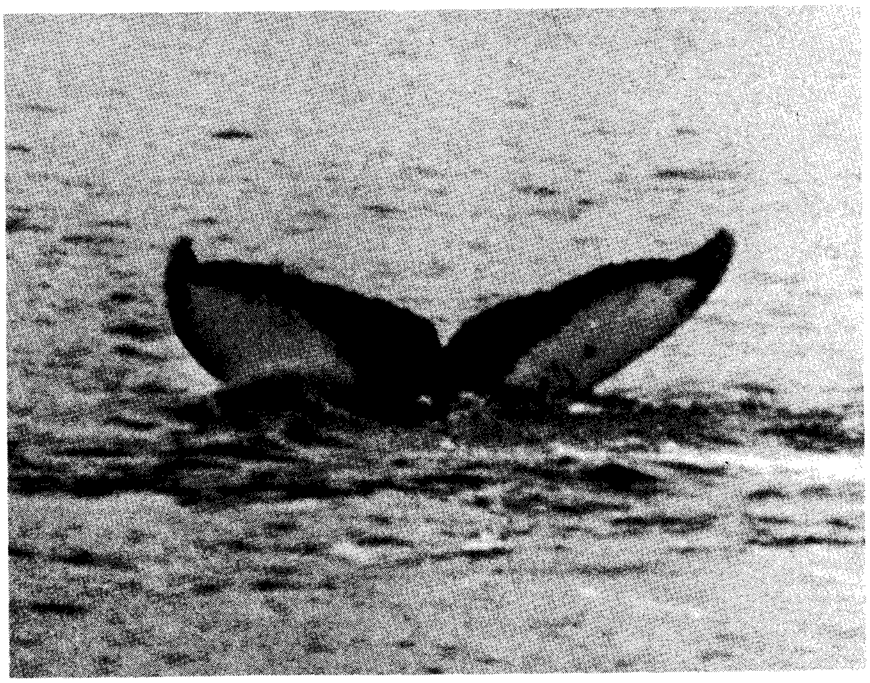

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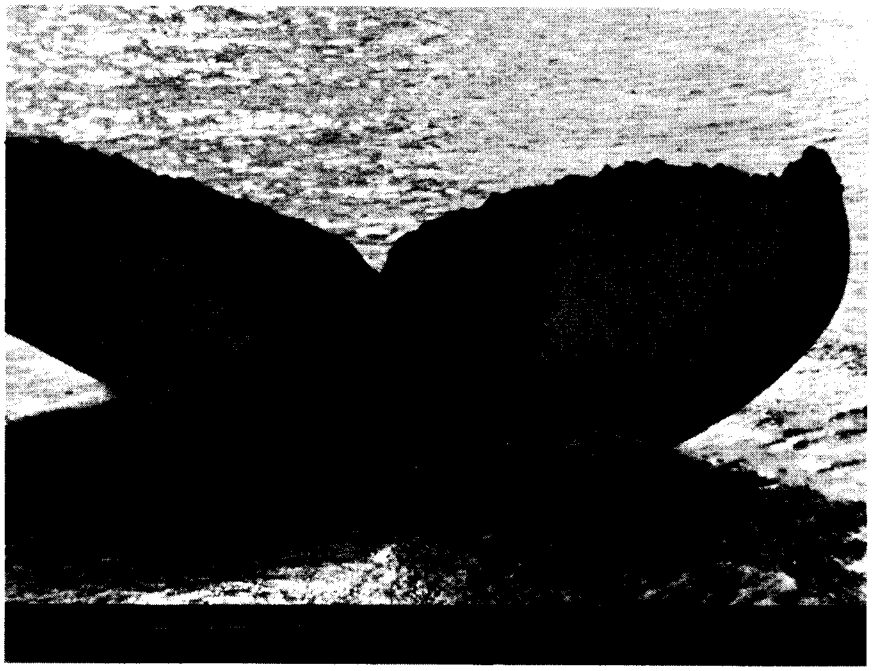

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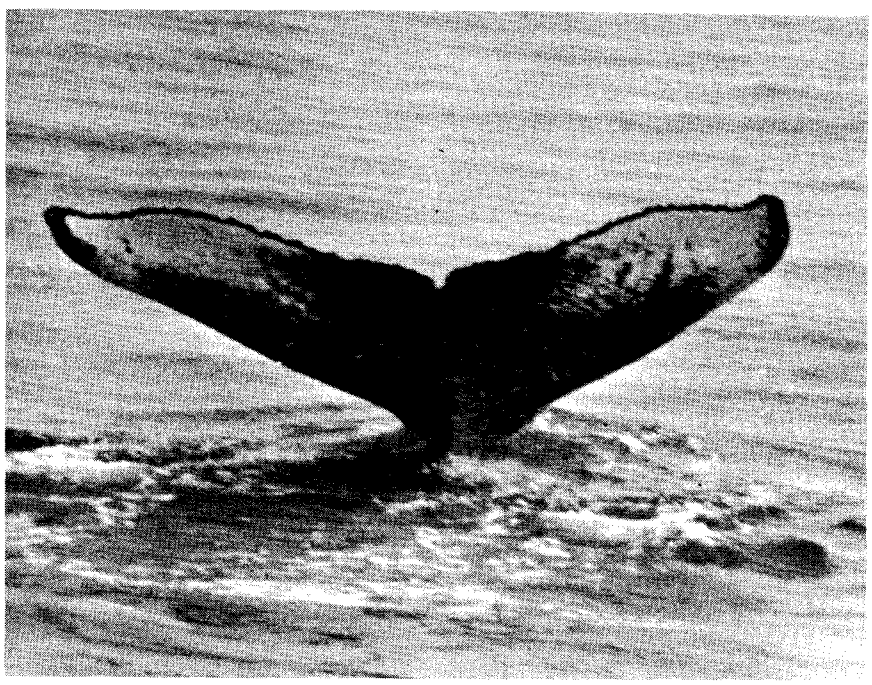

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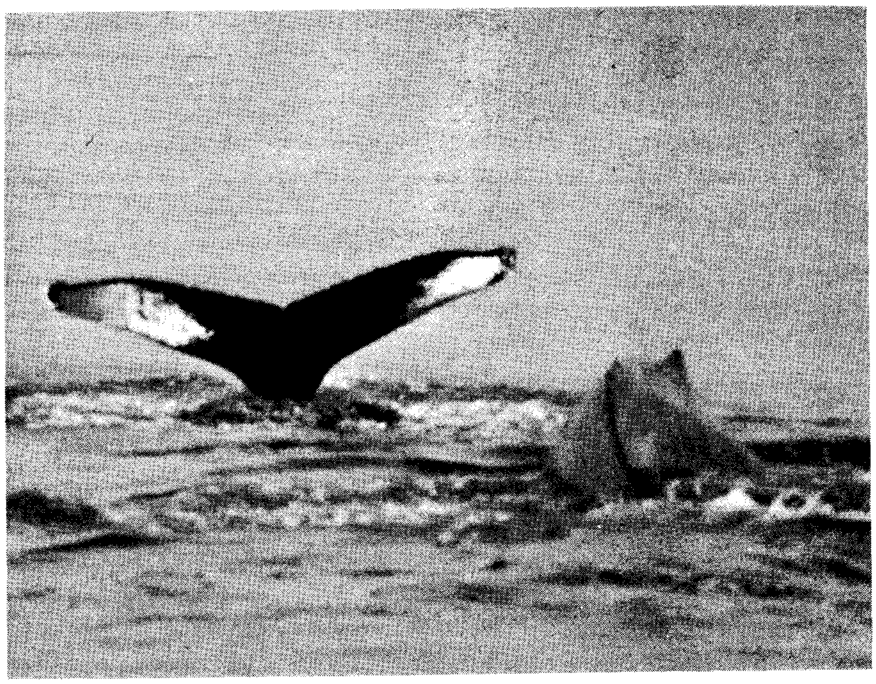

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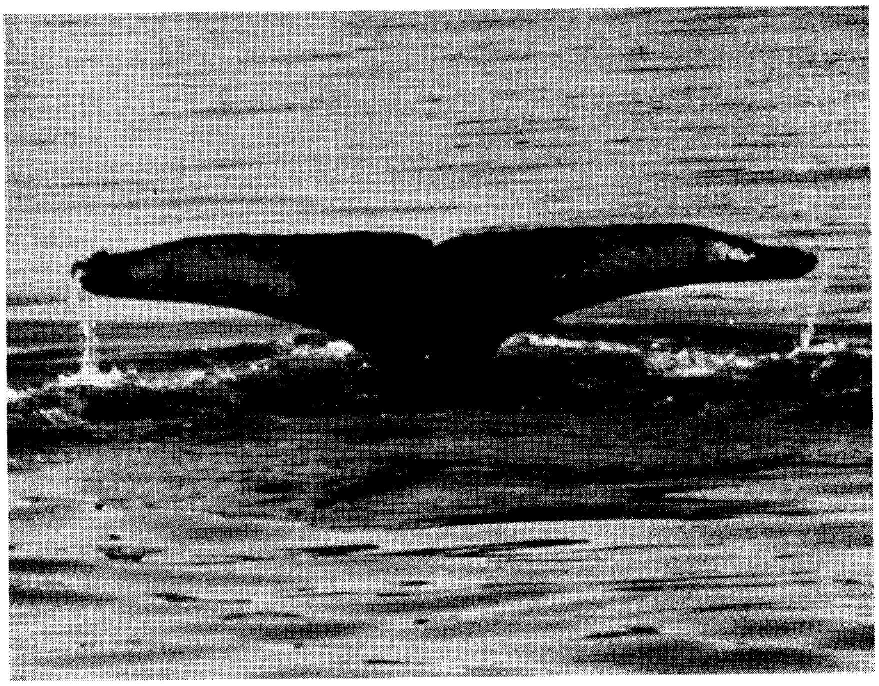

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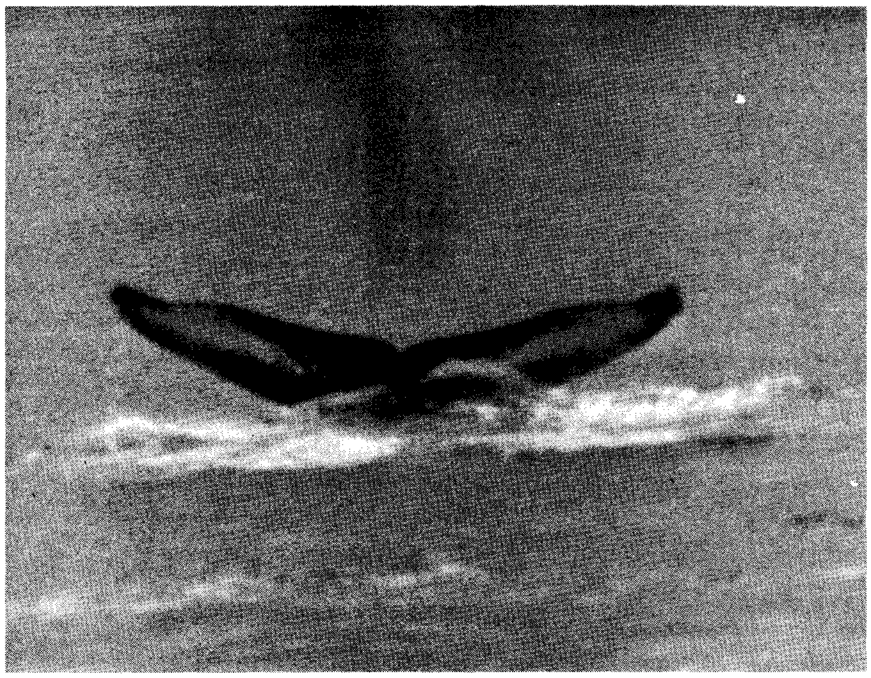

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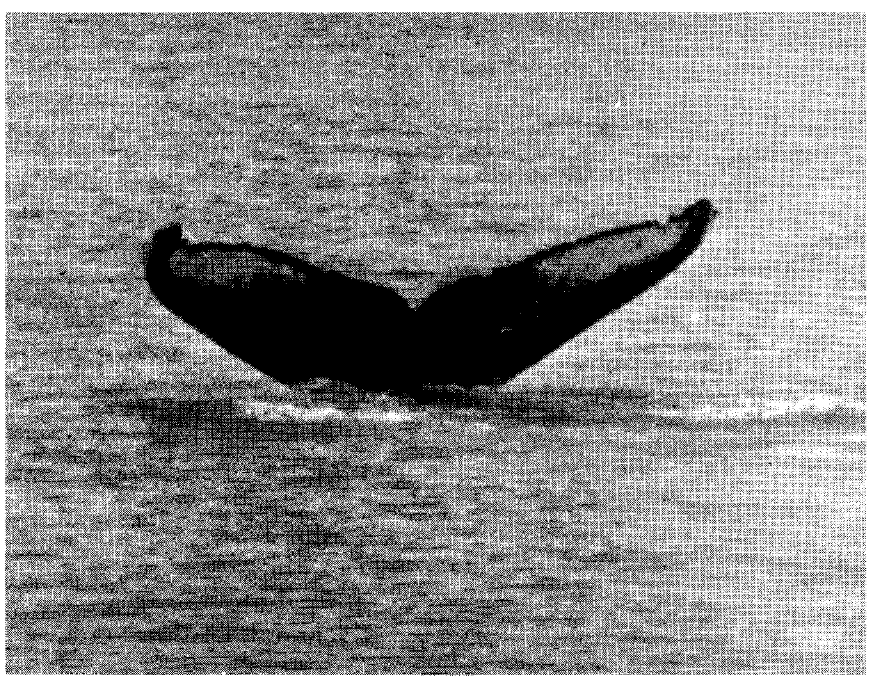

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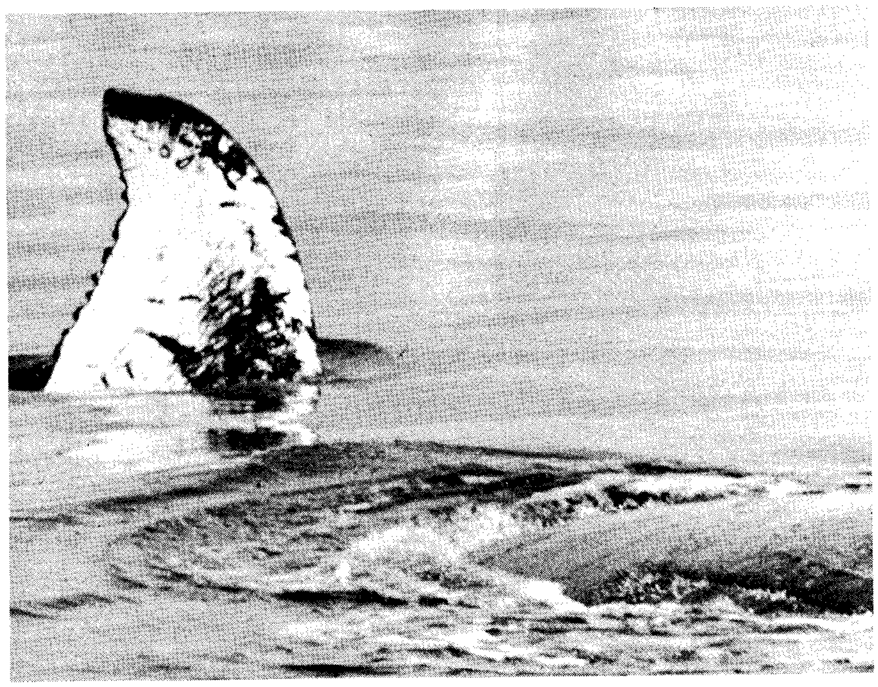

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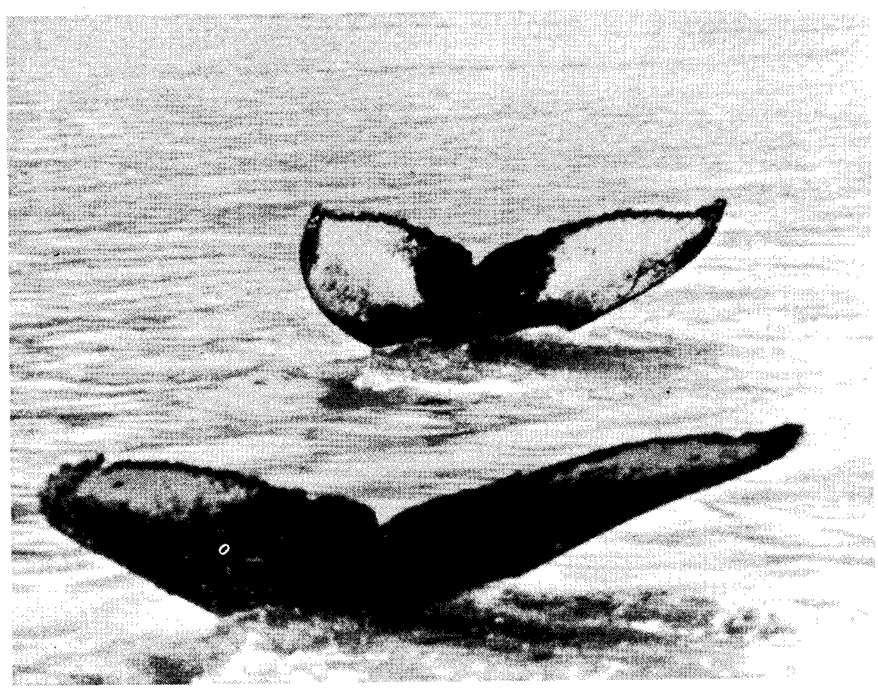

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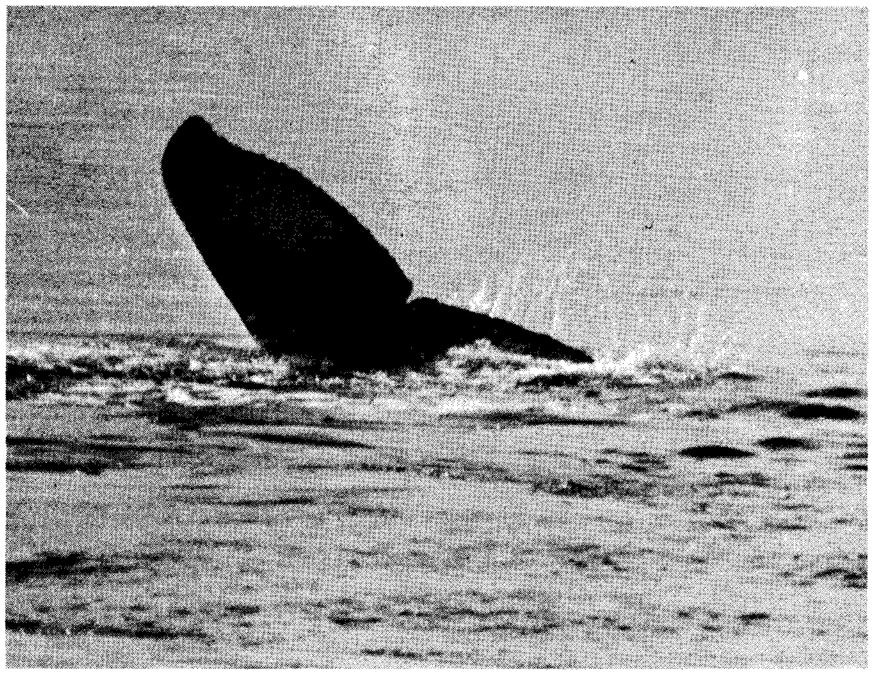

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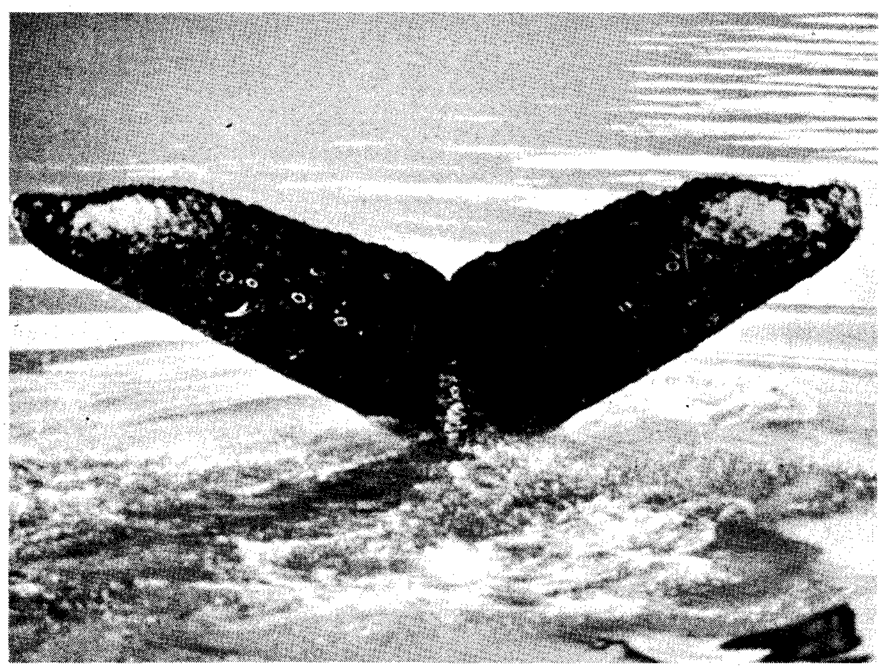

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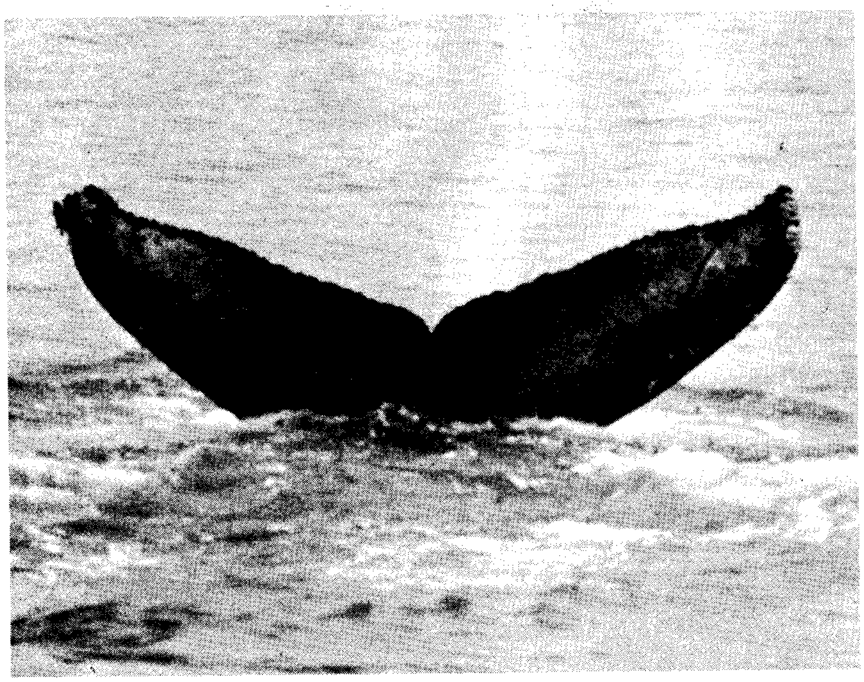

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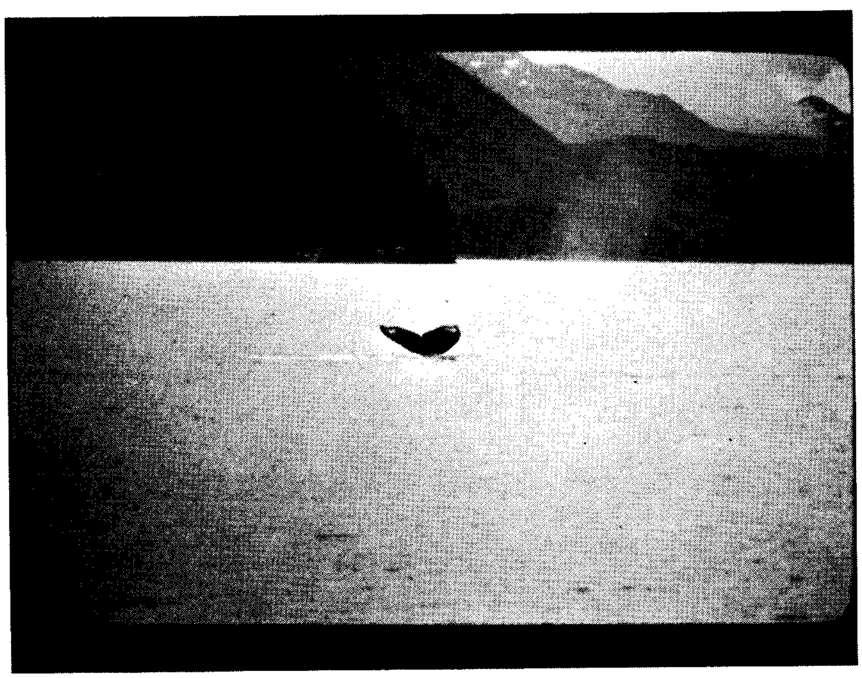

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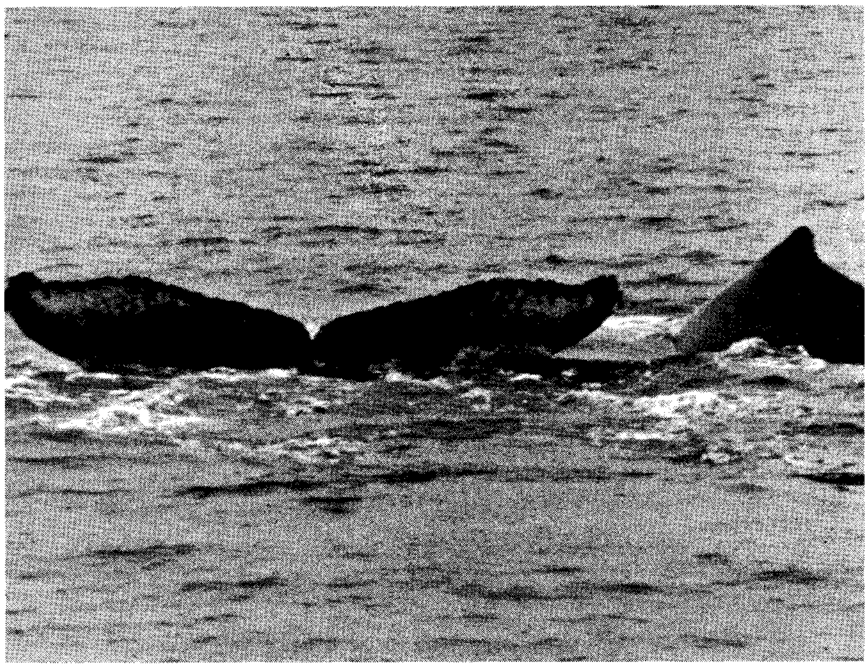

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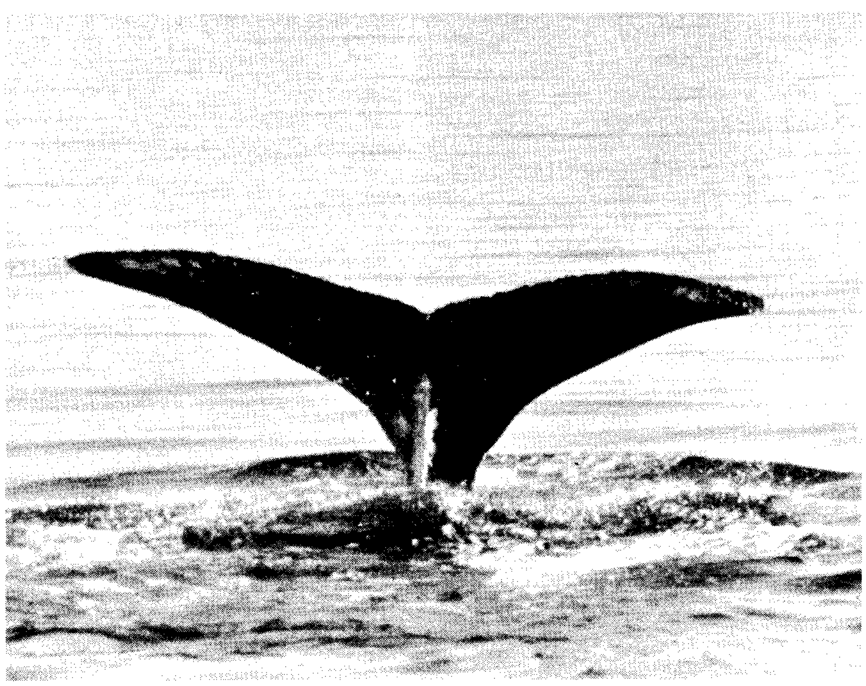

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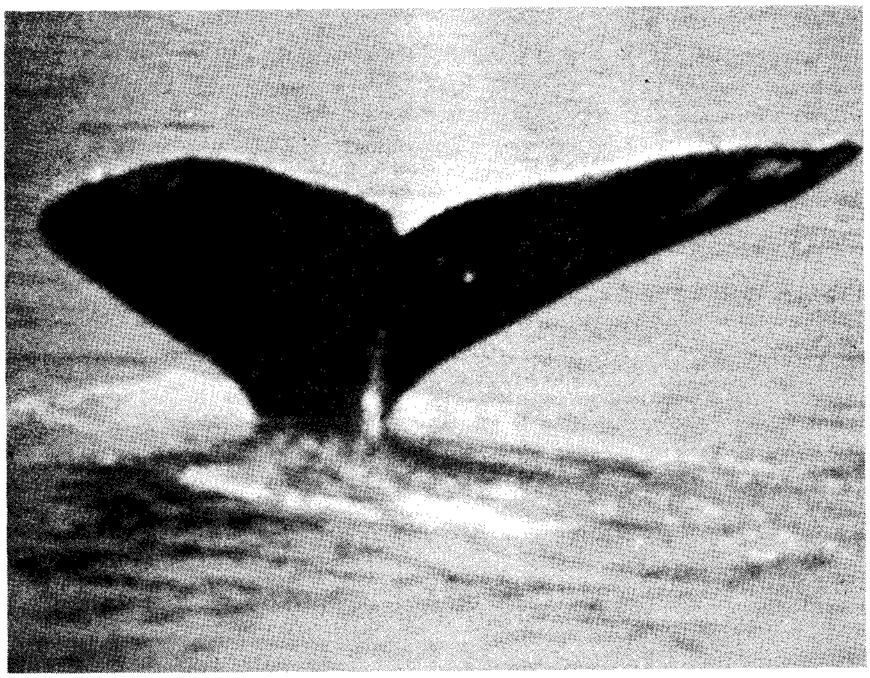

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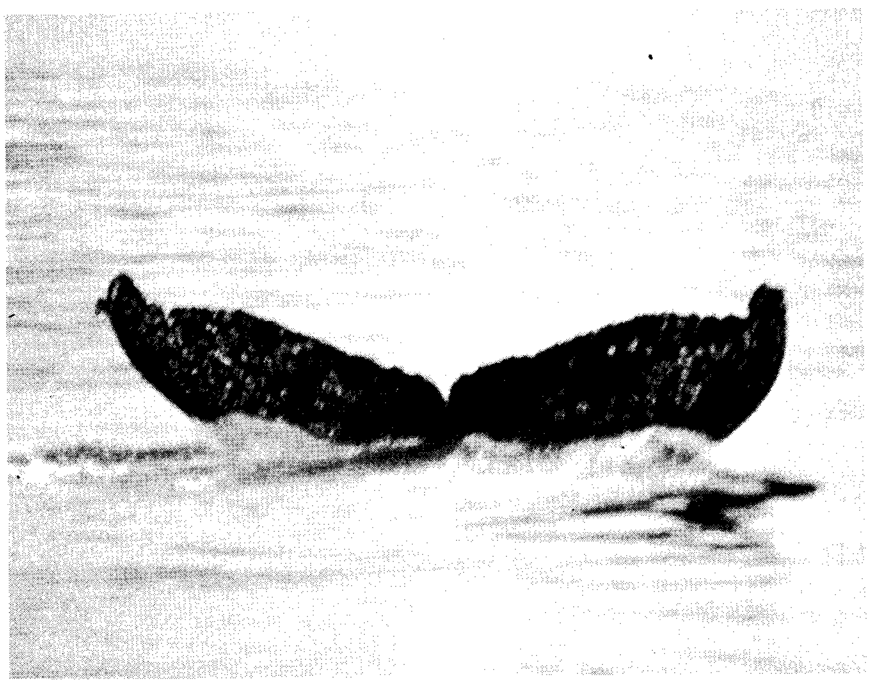

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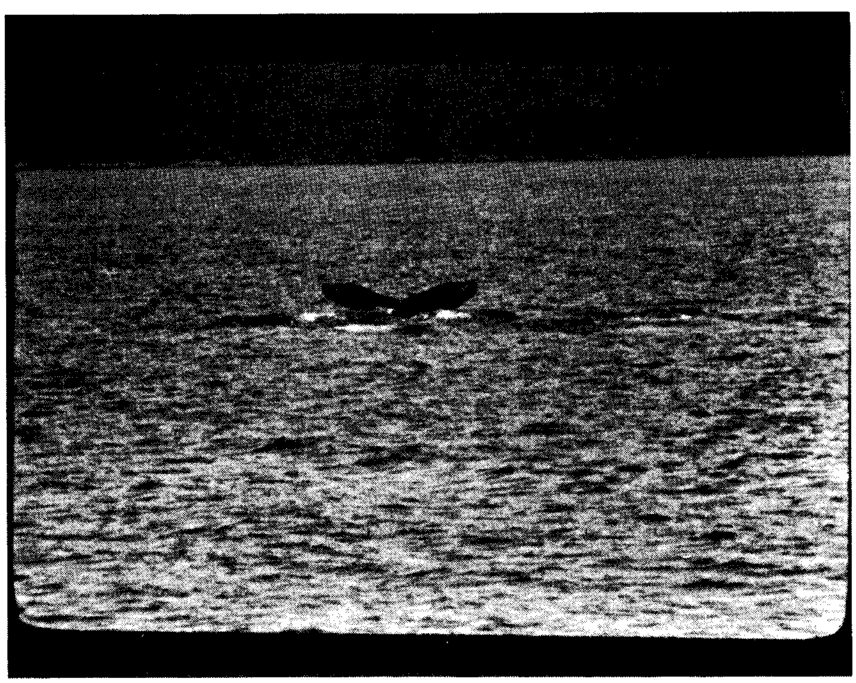
Initial Sighting- 6/77 No Resights



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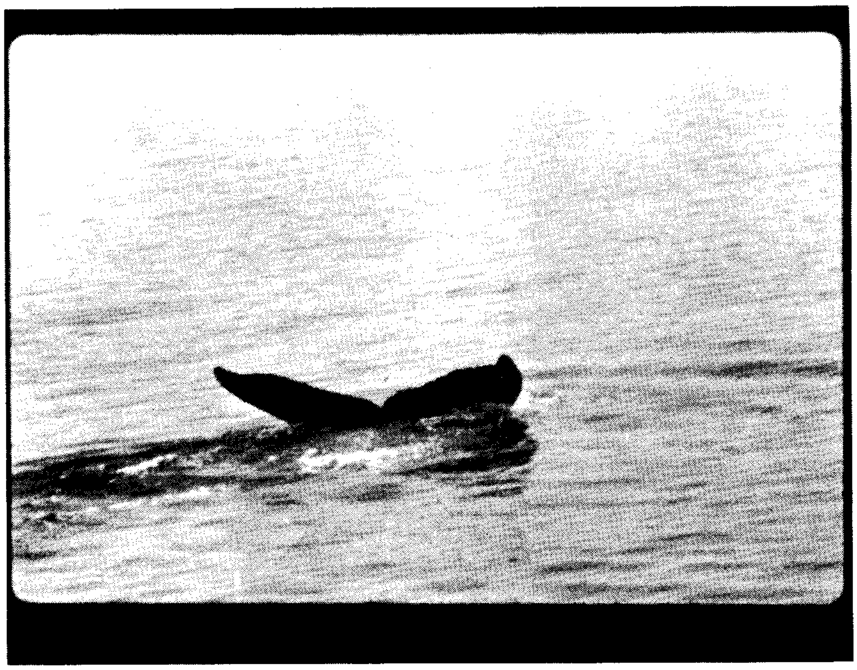

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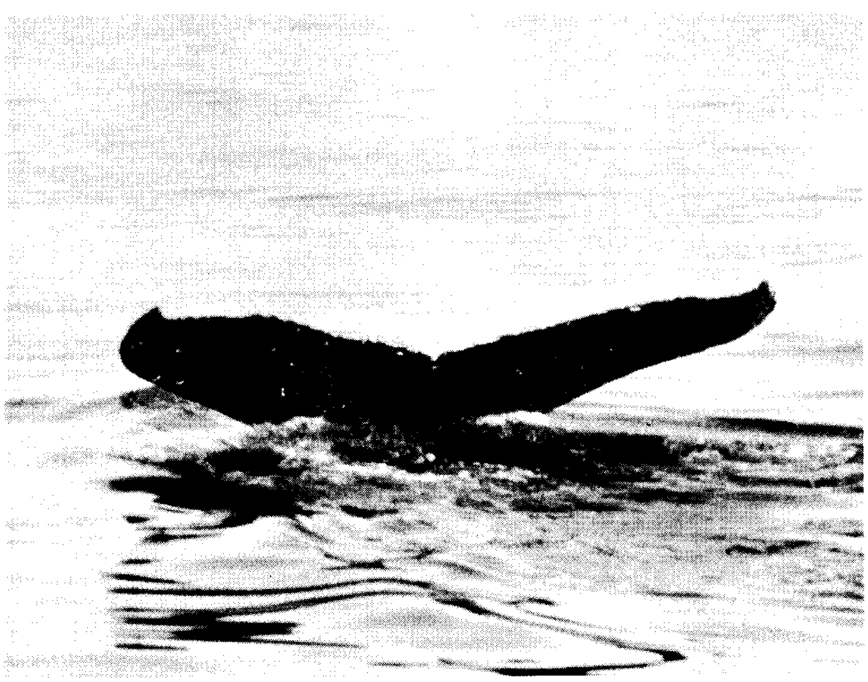

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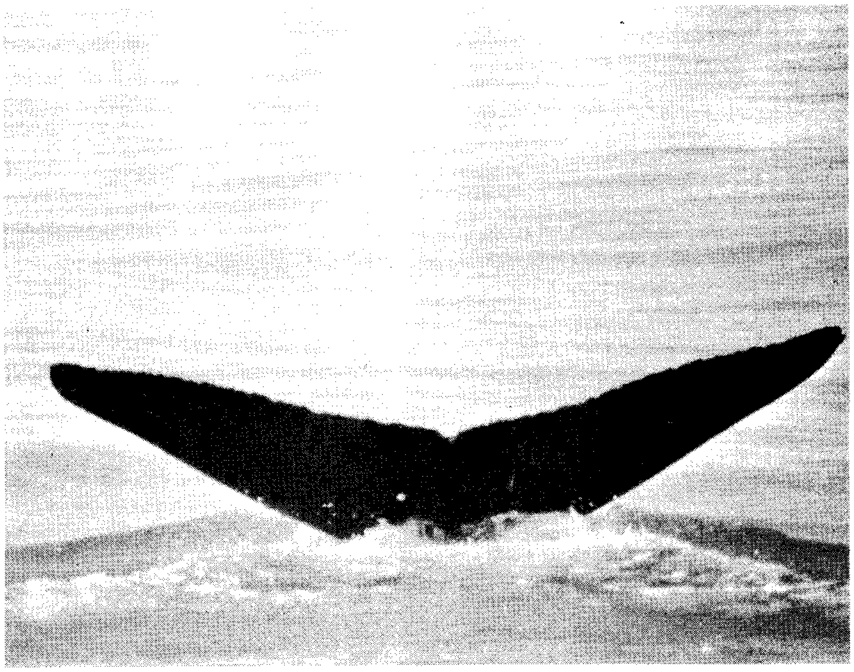
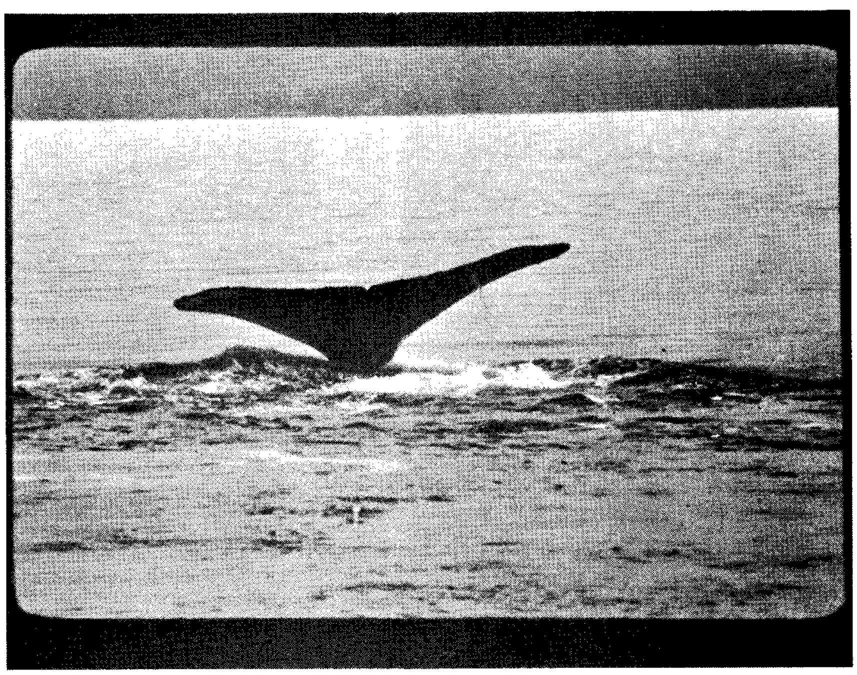


Initial Sighting- 5/77   No Resights

(This was a calf accompanied by an adult whale near Icy Bay in the Gulf of Alaska)



Initial Sighting- 6/77   No Resights

Contract #03-5-022-69
Research Unit #486
Reporting Period
April 1, 1976 -
Sept.30, 1977
Number of Pages: 284 + V

Final Report

Demersal Fish and Shellfish Assessment in Selected Estuary Systems of Kodiak Island

James E. Blackburn
Alaska Department of Fish and Game
P.O. Box 686
Kodiak, Alaska 99615

January 31, 1979

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SUMMARY

A total of 240 otter trawl hauls were successfully completed in Ugak and Alitak Bays on Kodiak Island during June, July, August and September 1976 and March 1977. The predominant taxa captured in order of importance were snow crab, king crab, yellowfin sole, shrimp, great sculpin, flathead sole, yellow Irish Lord, Pacific halibut, Pacific cod, walleye pollock, starry flounder and *Gymnocanthus*. Features of temporal and spatial distribution and limited comments on growth and food habits are presented.

The catch composition was remarkably similar throughout the study area with the exception of Deadman Bay, which had smaller catches and a somewhat unique species assemblage. The fish captured in Deadman Bay consisted of a greater abundance of eelpouts, snailfish, stout eelblenny and longsnout prickleback than occurred elsewhere, and lesser abundances of everything else except flathead sole, great sculpin and capelin.

Predominant species captured during summer in middle and outer Alitak Bay were yellowfin sole, great sculpin, juvenile walleye pollock and Pacific halibut. In March the predominant species were yellowfin sole, starry flounder, great sculpin, and juvenile walleye pollock.

The predominant taxa captured during summer in inner Ugak Bay were yellowfin sole, flathead sole, great sculpin, capelin, yellow Irish Lord, Pacific halibut and *Gymnocanthus*. During March the predominant taxa were yellowfin sole, *Gymnocanthus*, great sculpin, starry flounder, capelin, big skate, walleye pollock and rock sole.

The predominant taxa captured during summer in middle Ugak Bay were yellowfin sole, *Gymnocanthus*, yellow Irish Lord, flathead sole, great sculpin, halibut and big skate. During March they were yellowfin sole, great sculpin, *Gymnocanthus*, capelin, starry flounder, walleye pollock, yellow Irish Lord and rock sole.

The predominant taxa captured during summer in outer Ugak Bay were Pacific cod, yellowfin sole, yellow Irish Lord, great sculpin, big skate, rock sole, halibut, *Gymnocanthus*, arrowtooth flounder, butter sole, and starry flounder. In March they were yellowfin sole, great sculpin, *Gymnocanthus*, rock sole, yellow Irish Lord, halibut, walleye pollock, starry flounder, flathead sole and capelin.

There was a trend for fewer species to be captured toward the heads of the bays. The mean size of several species was related to location in Ugak Bay and to depth, with greater size at greater depth in all cases.

Most fish species moved to deeper water in winter while only a couple species displayed no seasonal movement and no fish species was found to move to shallower water in winter. Some species apparently moved into the bays during winter.

The food habits of 239 fish specimens of 14 species (2 cod, 4 sculpins, and 8 flounders) were examined to some extent from both lower Cook Inlet (Blackburn 1978) and Kodiak. On the basis of percent occurrence in the two sampling areas, the predominant prey taxon was caridean shrimp, principally the pandalid species *Pandalus borealis* and *P. goniurus* and crangonid species. Fishes were the second most important prey taxon, with capelin and stout eelblenny the commoner identifiable species.

INTRODUCTION

General Nature and Scope of Study

This study was intended to document the use of Kodiak Island estuaries by fish and shellfish. Estuaries are generally known to be important to production of fisheries resources, but the existing level of knowledge around Kodiak is extremely heterogeneous. Some commercial species have been studied extensively, yet for many species the area has been only superficially reconnoitered at best.

This study and Outer Continential Shelf Environmental Assessment Program (OCSEAP) Research Unit (R.U.) 485 (Harris and Hart 1977) are designed to sample virtually all the habitats within Ugak, Kaiugnak and Alitak bays. This study, however, is addressed to the demersal epifauna that are vulnerable to capture by otter trawl, specifically, fish and crustacean shellfish.

Specific Objectives

A. Determine the spatial and temporal (June-September, March) distribution, relative abundance and inter-relationships of the various demersal finfish and shellfish species in the study area.

B. Determine the growth rate and food habits of selected demersal fish species.

C. Conduct literature survey to obtain and summarize an ordinal level documentation of commercial catch, stock assessment data, distribution as well as species and age group composition of various shellfish species in the study area.

D. Obtain basic oceanographic and atomspheric data to determine any correlations between these factors and migrations and/or relative abundance of various demersal fish and shellfish species encountered.

Relevance to Problems of Petroleum Development

The imminent oil exploration in the Kodiak shelf lease area constitutes a potential for environmental degradation and it is a legal requirement of the leasing agency, Bureau of Land Management (BLM) to consider this potential as a part of the cost of leasing. This study was funded by BLM as a part of the program to satisfy their requirements, however, the objectives as stated in the previous section of this report, are oriented toward resource investigations. This is necessary and appropriate since many of the biological features of the lease area are poorly known, as stated in the section on Status of Knowledge, and since the various features of the community are inextricably interlinked.

The demersal community is an important segment of the marine community in the Kodiak lease area. It is highly productive, supports a number of valuable fisheries and most of the species of this community have pelagic stages in their life history which would place them in a wide variety of habitats at different times during the year. The larval and early juvenile stages of many species are found in the near surface and nearshore zones where, it would seem, oil development impact would be most severe. Targeting studies upon these probably susceptible stages to the exclusion of the other life history stages would be inappropriate. Similarly a premature decision as to which habitats (demersal or pelagic - nearshore) would be most susceptible to oil development impact would be inappropriate. The inescapable conclusion is that knowledge of the demersal community is very important to the process of locating sensitive areas and sensitive taxa.

This study broadens the base of knowledge of the demersal community in the two bays, Ugak and Alitak.

Acknowledgements

Mr. Peter Jackson must be given the credit for planning and implementing this study. The time between funding and study implementation, little more than one month, attests to the difficulties overcome. I also wish to thank him for the continuing guidance and encouragement. All of the accomplishments of this study are to the credit of Peter Jackson.

The skipper, Adolph Curry, and crew of the F/V BIG VALLEY deserve considerable credit for the successful completion of this study.

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This study was supported by the Bureau of Land Management through interagency agreement with the National Oceanic and Atmospheric Administration, under which a multi-year program responding to needs of petroleum development of the Alaskan continental shelf is managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office.

CURRENT STATE OF KNOWLEDGE

Alaska is unique in the United States in that it remains poorly reconnoitered, ichthyologically. As Wilimovsky (1958) states: "Although there have been a number of separate lists and descriptive summaries, such as Evermann and Goldsborough's 'Fishes of Alaska', none of these publications contain keys to, or sufficient descriptive data with which to identify, the fish fauna." Wilimovsky (1958) presented the first key to fishes of Alaska and has continued his study of Alaskan ichthyofauna. In 1964 he presented additional distributional information in the Inshore Fish Fauna of the Aleutian Archipelago. Other individuals have continued to add to ichthyological information; McPhail (1965) described a new ronquil from the Aleutians; Hubbard and Reeder (1965) presented New Locality Records for Alaskan Fishes; Quast (1968) published new records for 14 species; and

Peden (1970) described a new cottid (this is not a complete list). The most recent list of fishes from the United States and Canada published by the American Fisheries Society (Bailey et al.,1970) does not include a number of fishes captured in this study. The knowledge of Alaska fishes is growing and Wilimovsky's key is becoming out of data. Quast and Hall (1972) updated the distribution information with a list of Alaska fishes. However, the distribution knowledge, even now, is illogically discontinuous. For example the following entries from Quast and Hall (1972) (altered slightly for readability): *Liparis callyodon*, recorded from the Bering Sea, Aleutian Islands, Kenai Peninsula and southeastern Alaska to Washington (note: this is a common species in intertidal areas, even in Kodiak, where it has never been reported); *Occella verrucosa*, recorded from the Bering side of Alaskan Peninsula, and southeastern Alaska to California; *Gymnocanthus galeatus* (one of the species captured abundantly in this study but not reliably separated from *G. pistiliger*) recorded from the Sea of Japan to Arctic Ocean, Bering Sea, Aleutian Islands, Cook Inlet, Kodiak Island and southeast Alaska.

Intensive commercial fisheries exist in the Kodiak area for king crab, tanner crab, shrimp, Dungeness crab, Pacific halibut, Pacific herring, and salmon. Knowledge of these fisheries has been accumulating, however, of those species only halibut and herring are important in this study. Halibut have been studied extensively and they are known to collect for spawning in mid-winter; an important spawning site is offshore of the southern end of Kodiak Island. The eggs and larvae are pelagic for about 6 months then assume a benthic existence in shallow water. They grow to about 7 cm by age 1, 17 cm at age 2, and 30 cm, 40 cm, 49 cm, 57 cm, 64 cm at successive ages in the Kodiak area. Female halibut grow faster and live longer than males and most males mature by the time they are 8 years old while the average age of maturity for females is about 12 years. This information and more is contained in the numerous publications of the International Pacific Halibut Commission.

Information on herring is much more limited and generally does not apply to the east side of Kodiak Island as the bulk of the herring occur and are taken in Shelikof Strait.

A comprehensive survey of demersal fish resources in the Kodiak shelf area was conducted as part of a study by the International Pacific Halibut Commission (IPHC) during 1961-1963 (Hughes 1974). The National Marine Fisheries Service (NMFS) conducted extensive surveys around Kodiak during late spring, summer and into early fall of 1973 through 1975 (Hughes and Alton 1974; Pereyra and Ronholt 1976). The two surveys have been summarized and compared by Pereyra and Ronholt (1976). The Fisheries Research Board of Canada (FRBC) conducted otter trawl surveys of the Kodiak Shelf area with 81 samples in August and September 1963 and 15 samples in February 1965 (Westerheim 1967).

Comprehensive work on demersal fishes within the bays of Kodiak Island has not been conducted. The ADF&G has conducted research on commercial species and certain information is available, however, demersal fish distribution and abundance is not known.

Life historical information on demersal fish is generally available, however, little information specific to the Kodiak area is available.

A survey of near shore fish was conducted simultaneously with this study by Outer Continental Shelf Environmental Assessment Program (OCSEAP) R.U. 485 by the University of Washington Fisheries Research Institute (Harris and Hartt 1977).

STUDY AREA (Fig 1)

The study area for this project includes all water deeper than 10 fathoms and inside a line drawn between headlands of Ugak and Alitak bays on Kodiak Island (Figure 1).

Ugak Bay, located on the east side of Kodiak Island, is about 19 miles long and gradually narrows from about 4 miles wide at its mouth to the very narrow extreme eastern end. The shoreline is rocky and precipitous and rocky outcrops occur throughout the bay. There is no sill at the mouth of Ugak Bay to influence bottom water conditions within the bay. A trough about 53 fathoms deep extends into Ugak Bay to about Eagle Harbor where the bottom shoals sharply to about 14 fathoms. West of Saltery Cove is a basin at the head of Ugak Bay with a maximum depth of 53 fathoms from which extend two arms each with sills at their mouths of $1\frac{1}{2}$ and 9 fathoms and basins 25 fathoms deep.

Alitak Bay, located on the extreme southern end of Kodiak Island is about 27 miles long and nearly 8 miles wide at its mouth. It narrows gradually to its head in Deadman Bay. Tributary to Alitak Bay about halfway along its length are Portage Bay on the east and Olga Bay through Moser Bay on the west. Olga and Moser bays are not included within the study area. The terrain varies from rolling tundra near the mouth of the bay to rocky with precipitous shorelines, reefs and rocky outcrops within the bay. There is a sill about 25 fathoms deep across the mouth of Alitak Bay where mud and sandy shell bottom types are found. Depths increase into Portage, Sulua and Deadman bays. In Portage Bay and Sulua Bay the depths are 30 to 40 fathoms and 25 fathoms, respectively. The bottom is muddy and rocky and modestly extensive littoral zones occur. From the shoreline in Deadman Bay the bottom Descends precipitously to 60 to 98 fathom depths and has rocky ridges that necessitate trawling at one depth, generally along the axis of the bay.

SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Data Collection

A systematic sampling scheme was chosen as the appropriate method of station selection. Otter trawl stations were chosen by gridding the entire study area deeper than 10 fathoms (18m) into one-nautical-mile squares after eliminating areas know to be untrawlable. This yielded 30 blocks in Ugak Bay and 57 blocks in Alitak Bay. Based upon estimates of four days work in each bay and about eight stations per day, all areas in Ugak Bay and odd numbered areas in Alitak Bay were chosen as sampling stations. Trawl sites within these blocks were randomly chosen to be on trawlable bottom.

Sampling was conducted with a 400 mesh eastern otter trawl which had a 30m footrope, a 27m headrope and was 26m in total length with a 4m long cod end. The net was constructed with 4 inch mesh at the mouth and 3½ inch mesh in the body and cod end and had a 1¼ inch mesh cod end liner. It was equipped with 15 floats 20 cm in diamter on the headrope, and had no tickler or rollers. The bridles were 9m long and the doors were 2.1m (9 ft.) by 1.5m (7 ft.) Astoria V design. This net is considered to open 1.5m high by 12.2m wide. The net was pulled with a 3 to 1 scope for 20 minutes at 3 knots so that 1 nautical mile (1.85km) was covered and approximately 0.02261 km^2 were covered in each standard haul. When the net was brought to the surface the cod end was retrieved with a lazy line and the catch was randomly split. The fuller tub was chosen for sorting. The percent of the total catch contained in the fuller tub was visually estimated by each crew member, the estimates were averaged and this figure was used to expand the sorted catch into the estimate of total catch.

Catches were sorted by species as possible and each species was weighed, counted and directly recorded on the keypunch data form. Unidentified species were preserved for later identification.

Field work was conducted by two employees of ADF&G and one person from the University of Alaska (OCSEAP Research Unit 5). The two ADF&G crew members handled the fish catch and the University of Alaska crew member handled invertebrates. Since the stations were close together and hauls were 20 minutes, time limited the sampling to sorting, identifying, counting, weighing, and occasionally taking length frequencies and stomach samples.

Data Limitations

"The community of demersal fishes and invertebrates observed during faunal surveys and the relative importance of species or species groups within the community is largely a function of the sampling tools employed. Trawls, as most gears employed to sample the marine biota, are selective. Sizes and even species of fish captured are influenced by mesh size used, particularly that in the cod end. Even species within the size range which theoretically would be retained if engulfed in the trawl, may differ in their ability to escape through the mouth of the net. The selective features of trawls thus alter the species composition and sizes and quantities of species captured from that which occur in its path. The degree to which the "apparent" distribution and relative abundance differs from the actual is unknown. Thus it is important to note that subsequent discussions of distribution and relative abundance of demersal species and communities reflect the results obtained with the sampling gear employed." (Alverson et al. 1964, p. 44-45)

RESULTS (Tab 1,2,3)

A total of 240 otter trawl hauls were completed with satisfactory gear performance (Table 1). From the fish captured 16 families and 54 species were identified, the common and scientific names of which are presented in Table 2. The catch per unit of effort (CPUE) by taxon, month and bay is presented in Table 3 and is discussed in detail below.

Relative Abundance (Tab 4,5,6,7,8)

The predominant taxa captured in both bays in order of decreasing abundance were snow crab, king crab, yellowfin sole, shrimp, great sculpin, flathead sole, yellow Irish Lord, Pacific halibut, starry flounder, Pacific cod, and walleye pollock (Table 4). (The information on king crab and snow crab is presented for completeness and courtesy of Feder and Jewett 1977.)

The predominant families of fish captured in both bays in order of decreasing abundance were flounders, sculpins, cod, skates, smelt, eelpouts, snailfish, herring, sandfish and sea poachers (Table 5). The predominant flounders in order of decreasing abundance were yellowfin sole, flathead sole, Pacific Halibut, starry flounder, rock sole, arrowtooth flounder, and butter sole (Table 6). The predominant cods were Pacific cod and walleye pollock. (Table 7). The predominant sculpins in order of decreasing numbers captured were great sculpin, yellow Irish Lord, *Gymnocanthus*, spinyhead sculpin, staghorn sculpin, and bigmouth sculpin (Table 8).

Spatial Distribution (Tab 9,10)

The catch composition was remarkably similar throughout the study area with the exception of Deadman Bay, which had smaller catches and a somewhat unique species assemblage (Tables 9 and 10). Deadman Bay is much deeper than any other area sampled and is partially isolated from the open ocean by a 40m deep sill at the mouth of Alitak Bay.

There was a trend for fewer species to be present toward the heads of the bays. The mean number of taxa captured in each area of each bay by season was as follows:

	Inner	Middle	Outer
Ugak Summer	13.9	16.6	16.6
Ugak March	16.9	18.6	18.1
Alitak Summer	10.1	12.7	13.2
Alitak March	12.3	19.6	16.4

In Ugak Bay the catches were increasingly predominated by fewer species toward the head of the bay.

Inner Alitak (Table 9)

The catches in Deadman Bay, the inner portion of Alitak, were much smaller than elsewhere (Tables 8,9). Catches in Deadman Bay in summer were 21 kg/haul while catches were about 80 kg/haul in middle and outer Alitak and 70 to 190 kg/haul in Ugak Bay (Tables 8,9). In March, catches averaged 33 kg/haul in Deadman Bay and 115 to 140 kg/haul in all other areas (Tables 8,9).

The fish captured in Deadman Bay consisted of a greater abundance of soft eelpout shortfin eelpout, wattled eelpout, snailfish,stout eelblenny and longsnout prickleback than occurred elsewhere. Smooth lumpsucker and soft eelpout were both unique to Deadman Bay while buttersole, *Gymnocanthus*, Pacific tomcod and Pacific sandfish were frequent elsewhere and never captured in Deadman Bay. Of the common species in the study area, only flathead sole, great sculpin and capelin even approached being equally abundant in Deadman Bay and other parts of Alitak Bay; capelin being more abundant there in March than in middle and outer Alitak Bay (Table 10).

The predominant taxa captured in Deadman Bay in summer in order of decreasing abundance were great Sculpin, eelpouts, yellowfin sole, snailfish and flathead sole (Table 10). In March they were starry flounder, great sculpin, yellowfin sole, and capelin. The catches in March were less unique in Deadman Bay than during summer, due primarily to the decreased abundance of eelpouts and snailfish, the increased abundance of starry flounder and capelin and the trend for some of the species to move deeper and into Deadman Bay in winter.

The station furthest toward the head of Deadman Bay had a species assemblage that was slightly different from that of other Deadman Bay stations. There were more yellowfin sole and flathead sole, and fewer eelpouts, longsnout pricklebacks and slightly fewer snailfish. Thus, this station and to a lesser extent the station adjacent to it had species assemblages that displayed similarities to both outer Alitak and Deadman bays.

Middle and Outer Alitak Bay (Table 9)

Middle Alitak Bay (5 stations near and inside of Middle Reef) and outer Alitak Bay (16 stations outside of Middle Reef) had virtually identical species composition. The predominant species captured during summer in these 2 areas in order of decreasing abundance were, yellowfin sole, great sculpin, walleye pollock and Pacific halibut. In middle Alitak, flathead sole, big skate and eelpouts also occurred at more than 2 kg/haul while in outer Alitak starry flounder, flathead sole and rock sole were the remaining species occurring at 2 kg/haul. In March the predominant species in order of decreasing abundance were yellowfin sole, starry flounder,great sculpin and juvenile walleye pollock. In middle Alitak in March herring was the only other species occurring at more than 2 kg/haul while in outer Alitak halibut was the only additional species with more than 2 kg/haul.

The total catch in these areas in summer was about the same as in middle Ugak Bay and much less than in outer Ugak Bay. The winter catch in these areas was considerably greater than in summer and was greater than in any other area in winter. The mean number of taxa identified per haul was considerably greater in winter in these areas, increasing from 12.7 taxa in summer to 19.6 taxa in March in middle Alitak and from 13.2 to 16.4 taxa in winter in outer Alitak.

The increased abundance of yellowfin sole in March in middle and outer

Alitak accounts for a large portion of the increased catch. Starry flounder and herring also increased significantly in abundance during winter in these areas.

Pollock, herring, searcher, Alaska plaice, and starry flounder were considerably more abundant in these 2 areas than anywhere else and during winter whitespotted greenling were more abundant here than elsewhere.

Within this area there were some small differences in catch composition among the stations. The predominant species at the outermost or furthest south station were rock sole, great sculpin, Pacific cod, yellow Irish Lord, and halibut while yellowfin sole constituted less than 2% of the catch at this station (it was sampled only in June, July and August). Fish captured at this station were also strangely colored, such as halibut that were orange on the blind side.

Although the catch of king crab was addressed by RU 5 in these studies, it would be inappropriate to ignore it here, since the catches in the shallow zone at the mouth of Alitak in March were by far the largest catches made in the entire study. Several thousand pounds of king crab were captured, even in short tows. The 90 ft. sampling vessel was noticeably slowed by the accumulated catch in a 10 minute tow. Sampling was not completed in this area during March so that harm would not be brought to king crab. These crab were collected in shallow water as they do annually where egg hatch, molting and mating occur. All of these activities are especially vulnerable stages in the life history of this species.

<u>Inner Ugak Bay</u> (Table 10)

The predominant taxa captured during summer in inner Ugak Bay (8 stations) in order of decreasing abundance were yellowfin sole, flathead sole, great sculpin, capelin, yellow Irish Lord, Pacific halibut and *Gymnocanthus*. During March the predominant taxa in order of decreasing abundance were yellowfin sole, *Gymnocanthus*, great sculpin, starry flounder, capelin, big skate, walleye pollock and rock sole (Table 10).

The catches in all of Ugak bay were considerably larger in March than in summer. In every summer month the catches in Ugak Bay were smaller in the inner portion but in March they were slightly larger than in middle or outer Ugak. The large March catches were 68% yellowfin sole in inner Ugak while they were about 30% yellowfin sole in middle and outer Ugak Bay. During summer the proportion of yellowfin sole in inner Ugak Bay was not as high 57%, but was still much larger than the 32% and 16% yellowfin sole in middle and outer Ugak Bay.

Other fish that were more abundant in inner Ugak Bay in March than in summer were starry flounder, *Gymnocanthus*, big skate, walleye pollock, capelin and rock sole.

<u>Middle Ugak Bay</u> (Table 10)

The predominant taxa captured during summer in middle Ugak Bay (8 stations) in order of decreasing abundance were yellowfin sole, *Gymnocanthus*, yellow Irish Lord, flathead sole, great sculpin, halibut and big skate. During March they were yellowfin sole, great sculpin, *Gymnocanthus*, capelin, starry flounder, walleye pollock, yellow Irish Lord and rock sole.

Gymnocanthus was the only species that was more abundant in this area through out the year than it was anywhere else. Capelin were more abundant in middle Ugak Bay in March than anywhere else at any time and starry flounder abundance in Ugak Bay in March was greatest in this area. But starry flounder were considerably more abundant in Alitak in March than in Ugak Bay. Most species were more abundant in either the inner or outer area of Ugak Bay than in the middle area.

Outer Ugak Bay (Table 10)

The predominant taxa captured during summer in outer Ugak Bay (9 stations) in order of decreasing abundance were Pacific cod, yellowfin sole, yellow Irish Lord, great sculpin, big skate, rock sole, halibut, *Gymnocanthus*, arrowtooth flounder, butter sole and starry flounder. In March they were yellowfin sole, great sculpin, *Gymnocanthus*, rock sole, yellow Irish Lord, halibut,walleye pollock, starry flounder, flathead sole and capelin.

Although Pacific cod were predominant in this area they were captured in large number in relatively few hauls. Of 34 hauls made in this area in summer large adult Pacific cod catches of 50 to 580 kg occurred in only 5. Adult Pacific cod occurred in small numbers in other areas of Ugak Bay but were virtually absent from Alitak Bay (Tables 9 and 10). Adult Pacific cod were not captured in March.

Yellow Irish Lord were more abundant in this area than any other. They were about half as abundant in middle Ugak Bay and in very small numbers in Alitak Bay. They were present in greatest abundance in June, when the largest catch, 250 kg/20 minute haul, occurred. Great sculpin were also more abundant in this area than any other, although they were a significant portion of the catch in all areas. Big skate and arrowtooth flounder were more abundant in this area in the summer than in any other area. During winter smaller sized big skates were present in greatest abundance in inner Ugak Bay while arrowtooth flounders were nearly absent in the entire study area. Rock sole, halibut, and butter sole were more abundant in both summer and March in this area than in any other. Rock sole seemed to move further within the bay in winter while halibut and butter sole were less abundant in all the study area in March (Tables 9,10).

CPUE by Depth and Location (Table 11)

As has been discussed above, the abundance of fish was generally greater near the mouth of the bay than further within the bay. In order to separately examine the effects of distance into the bay and depth upon catch rate, Multiple Linear Regression was employed. However, this test requires that the independent variables (depth and distance into the bay) be minimally correlated, a condition which is satisfied only in Ugak Bay.

The CPUE of total fish and eleven taxa were regressed on depth and distance into Ugak Bay and a number of significant relationships were found. There were a greater number of significant relationships with distance into the bay, indicating the importance of location.

Fish Size by Depth and Location (Table 12)

The mean fish weight increased significantly with increased depth in Ugak Bay for yellow Irish Lord, yellowfin sole, arrowtooth flounder, Pacific halibut, *Gymnocanthus*, and starry flounder (Table 12).

The mean weight of several species was found to be related to the distance from the mouth of the bay. Some species were smaller toward the head of the bay than toward the mouth. This trend was exhibited by *Gymnocanthus*, yellowfin sole, and yellow Irish Lord. Species that exhibited the reverse trend, larger toward the head of the bay than toward the mouth, were flathead sole and Pacific cod.

A very large part of the variation in size was correlated with the combination of sample depth and distance toward the head of the bay for several species. These species, and the multiple correlation coefficients are: yellowfin sole, .93; yellow Irish Lord,.88; *Gymnocanthus*,.78; and arrowtooth flounder, .70.

Aggregation (Table 13)

The degree of aggregation varied by species and season. Pacific cod were by far the most highly aggregated species with walleye pollock, arrowtooth flounder, rock sole and starry flounder displaying considerable aggregation (coefficient of variation greater than 2.0) during some portion of the year. In contrast, yellowfin sole were distributed with unusual uniformity during the summer.

Temporal Distribution (Tab 9,10)

The total catches were larger in winter than in summer in all areas except outer Ugak Bay, the mean number of species captured per haul was larger in winter in all areas and the distribution of total catches was different in winter in Ugak Bay (Tables 9 and 10). In Ugak the total catches were smaller further within the bay during summer but in winter the total catch was fairly uniform throughout with insignificantly higher catches occurring in inner Ugak Bay (Table 9).

Most of the demersal fish migrated to deeper water during winter. This change of distribution was indicated by shifts in depth of abundance or depth of occurrence, and by shifts in size by depth zone (smaller size during winter at a given depth or within the study area).

Taxa which were smaller in winter and/or smaller in each depth zone in winter were skates, Pacific cod, Pacific tomcod, shortfin eelpout, searcher, longsnout prickleback, daubed shanny, *Gymnocanthus*, great sculpin,snailfish, arrowtooth flounder, rex sole, flathead sole, Pacific halibut, rock sole, yellowfin sole, starry flounder and Alaska plaice (in Alitak Bay only).

Taxa which were deeper in March than during summer were starry flounder, butter sole, arrowtooth flounder, Alaska plaice, whitespotted greenling, masked greenling, Pacific tomcod, staghorn sculpin, yellow Irish Lord, *Gymnocanthus* (in Alitak), daubed shanny, wattled eelpout, shortfin eelpout, searcher and snailfish. Taxa that were sufficiently abundant that changes in depth distribution by season should have been apparent but that demonstrated no change were spinyhead sculpin and bigmouth sculpin. However, spinyhead sculpin did increase in abundance at the very head of Ugak Bay and did move further into Alitak in March.

A number of taxa apparently tended to move out of the bays for winter (or they assumed a refuge), based on lower catch rates in March. These taxa were big skate , Pacific cod, arrowtooth flounder, flathead sole, butter sole, dover sole, stout eelblenny and perhaps Pacific halibut. Some taxa that left during winter were most common or unique to Deadman Bay. These taxa were longsnout prickleback, shortfin eelpout, wattled eelpout, soft eelpout and snailfish.

A number of taxa descended into the 51 to 82m depth zone of Alitak or into Deadman Bay during winter, based on higher catch rates. These taxa were Alaska plaice, butter sole, starry flounder, halibut, Pacific cod, Pacific tomcod, Pacific herring, capelin, searcher, daubed shanny, staghorn sculpin, whitespotted greenling and masked greenling.

A number of taxa apparently moved into the bays during winter (based on higher catch rates) either from shallower depths or from outside the bay. These taxa were starry flounder, yellowfin sole, capelin, herring into Alitak, sablefish juveniles, sturgeon poacher, staghorn sculpins and spinyhead sculpins (Walleye pollock also, but see below).

Known or postulated spawning assemblages account for variations in the abundance of several species. Capelin collected in the bays in winter before their spring spawning period and eulachon abundance in March and June corresponds with May to June spawning. Starry flounder and sturgeon poacher abundances in the bays in March probably were spawing aggregations.

The catch fluctuations of some species apparently were associated with distribution features of particular size classes. The black cod captured in greater abundance in March were juveniles. The large catches of sandfish in late summer were almost entirely age 0 fish that had just grown to the size they could be captured. Walleye pollock were almost exclusively juveniles and there was a switch in size classes captured that took place between August and September in Ugak Bay and between September and March in Alitak Bay.

Food Habits

The analysis of food habits of fishes in Ugak and Alitak bays was accomplished by contract to the University of Washington Fisheries Research Institute and is presented in Appendix 1. A few additional observations were made and are presented by Feder and Jewett (1977), pg. 29.

Results by Species

Yellowfin Sole (Tab 11,12,13,Fig 6, App Tab 1, App Fig 1,2,3,4)

Yellowfin sole were remarkable in their predictability more than any other feature. In Ugak Bay the summer (June through September) distribution was not random. It displayed a greater uniformity than random as indicated by the coefficient of variation, which ranged from 0.58 to 0.78 (Table 13). Throughout the study area the only region of markedly different abundance was within Deadman Bay where catches were reduced (Appendix Table 1, Appendix Figures 1,2,3,4). Outside of Deadman Bay yellowfin sole occurred in every haul but one in each of Alitak and Ugak bays. The CPUE was not related to depth or distance into Ugak Bay (Table 11 and Appendix Table 1) but fish size was strongly related to both factors, with mean fish size increasing with depth and decreasing with distance into Ugak Bay (Table 12). In Alitak Bay mean fish size also tended to decrease with depth and distance into the bay but due to the strong correlation between water depth and distance within Alitak Bay (coefficient of correlation greater than 0.9) the two factors could not be statistically tested in the same way.

Yellowfin sole were considerably smaller during March than during summer (Table 14). Size increased with depth during all months but during March the size at the greatest depth was similar to the size at the shallowest summer sampling depth. This shift is indicative of a shift to deeper waters in winter. The length frequencies collected did not provide an insignt into growth (Figure 6).

Flathead Sole (Tab 11,12,Fig 3, App Tab 2, App Fig 5,6,7,8)

The catch of flathead sole was greater in Ugak Bay than in Alitak Bay and catches were greatest near the mouth of Ugak Bay (Table 11, Appendix Figures 5,6,7,and 8). The CPUE was not significantly related to depth in August (Table 11) and appeared to bear no consistent relation to depth in either bay in any month (Appendix Table 2). The size of flathead sole did not bear any relation to depth in Ugak Bay in August (Table 12) and never showed a consistent relationship to depth in Ugak Bay. However, in Alitak, size of fish increased with each increasing depth interval in every month but August. The size of flathead sole increased significantly with increasing distance into Ugak Bay in August (Table 12), however, the raw data is much less convincing than the calculated statistical significance. In most months the catches with the largest mean sizes occurred near the mouth of the bay, thus, size of flathead sole appears to be inconsistently and weakly related to distance into the bay.

The CPUE of flathead sole was considerably less in March than during summer, with September catches in Ugak Bay also considerably lower than earlier. The mean size of flathead sole was also considerably lower in March in both bays than during summer.

The August length frequency in 5 mm intervals for flathead sole in Ugak Bay displays a mode at 150 mm, which could be one to five years of age when compared with the growth data presented by Pereyra et al. (1976) from the Bering Sea (Figure 3).

Starry Flounder (Tab 3,11,12 App Tab 3, App Fig 9,10,11,12)

The predominant feature of starry flounder catches was the cyclical abundance with greatest catches in winter and least in mid-summer (Table 3). The March CPUE's were 10 to 20 times those in July and the frequency of occurrence was 27% during summer and 93% in March. There was a tendency in Ugak Bay ($p < .05$) for starry flounder size to average larger at greater depth (Table 12) and size was smaller in March in each depth interval, indicative of a bathymetric shift to greater depths in winter.

Starry flounder were infrequent in Ugak Bay during June through August with no apparent concentration. In September a concentration occurred at the mouth of the bay and in March the greatest concentration was within the bay (Appendix Figures 9,10,11,12 and Table 11). This could be construed as influx to the bay from the continental shelf. During summer the CPUE of starry flounder tended to be greater shallower with the consequent greatest densities in the 29 to 50 m zone at the mouth of Alitak Bay (Appendix Figures 11,12 and Appendix Table 3). During March the greatest densities were at intermediate depths, the 51 to 82 m zone of Alitak Bay and the 51 to 72 m zone of Ugak Bay (Appendix Table 2).

Pacific Halibut (Tab 11,12,14,Fig 5, App Tab 4, App Fig 13,14,15,16)

The catches of halibut displayed relatively weak trends. Catches did not vary systematically by depth (Table 11 and Appendix Table 4), however, they were more abundant near the mouths of the bays and virtually absent from Deadman Bay (Table 11, and Appendix Figures 13,14,15,16).

Most halibut captured were small, less than 60 cm (Figure 5) and monthly mean weights ranged from 0.5 to 1.8 kg per fish (Table 14). There was no relation between fish size and distance into Ugak Bay (Table 12), however, the few halibut captured in Deadman Bay averaged smaller than those captured in the shallower outer Alitak Bay. Average size was significantly greater deeper in Ugak Bay (Table 12) and, after unusually large fish are removed from the data, size displayed a seasonal maximum in summer and minimum in March. The CPUE displayed a very weak seasonality with greater catches in summer and smaller catches in March.

Rock Sole (Tab 3,11,14, Fig 7, App Tab 5, App Fig 17, 18, 19,20)

The CPUE of rock sole was greatest near the mouths of both bays in summer and in March (Appendix Figures 17,18,19,20 and Table 11) and definitely decreased with increasing depth, and consequently distance into Alitak Bay, but only very weakly decreased with increasing depth in Ugak Bay (Table 11 and Appendix Table 5).

The seasonal features of rock sole distribution were very different in Alitak and Ugak bays. In Alitak Bay the CPUE displayed a cyclic seasonal sequence with greatest catches in June and July and minimum catches in March (Table 3). Frequency of occurrence also was cyclic with lowest frequency in June and greatest in August. In Ugak Bay the CPUE did not display a clear cyclic pattern (Table 3), however, the frequency of occurrence was clearly minimal in August.

The mean size of rock sole was least in March and highest in summer although in the individual months it was highly variable, with large catches of unusually large or small fish strongly affecting mean size (Table 14).

Length frequencies did not provide an insight into growth (Figure 7).

Arrowtooth Flounder (Tab 3,11,14 Fig 2, App Tab 6,App Fig 21,22,23,24)

Arrowtooth flounder CPUE was greater near the mouths of the bays (Table 11, Appendix Figures 21,22,23,24) and unrelated to depth (Table 9 and Appendix Table 6). The CPUE was seasonally cyclic with a peak in summer and a minimum in March (Table 3). Size was cyclic with largest fish in summer and smallest in March and size increased simply with depth. The size range captured was generally quite small (Figure 2). Monthly mean weights in the two bays ranged from 15 to 29 gms in winter and 38 to 136 gms in summer (Table 14).

The August length frequency in 5 mm intervals for arrowtooth flounder displays moded at 170 mm, 250 mm, 300 mm and 340 mm (Figure 2). These sizes are strongly suggestive of successive age classes, ages 1 through 4, but this conclusion could not be reached without more complete data.

Butter Sole (Tab 14, Fig 7, App Tab 7, App Fig 25,26,27,28)

Butter sole CPUE was greater near the mouths of the bays (Appendix Figures 25,26,27,28) and tended to decrease with depth during summer (Appendix Table 7). Butter sole obviously migrated to deeper waters in winter and shallower inshore waters in summer as shown by the depth distribution (Appendix Table 7) and the areal distribution (Appendix Figures 25,26,27,28). The CPUE in Ugak Bay displayed a bimodality with greatest values in June and August-September and lowest in July and March as though the majority of butter sole had migrated through the Ugak Bay sampling depths and spent the summer shallower, or in another area.

Mean fish size during summer had a tendency to be greatest at intermediate depths in Ugak Bay (0.31 to 0.38 kg) and it displayed a distinct seasonal cycle with maximum size in March (670 gms) and minimum size in August(205 gm; Table 14). The monthly size in Alitak Bay did not show a simple trend, but it was based on relatively small catches.

Length frequencies did not provide an insight into growth (Figure 7).

Other Flounders (Fig 7)

Other flounders captured were sand sole, Alaska plaice, rex sole and Dover sole. Sand sole occurred in one haul in Alitak Bay and in nine hauls in Ugak Bay, eight of which were at three stations closest to Pasagshak Point. Length frequencies of sand sole did not provide growth information (Figure 7).

Alaska plaice occurred in eight hauls in Ugak Bay and in 15 hauls in Alitak Bay, was most frequent at the mouth of each bay and occurred in decidedly greater abundance at the shallowest stations. The greatest abundance was

4.8 kg per haul in the 29 to 50 m depth interval in Alitak Bay in July. In winter they were distinctly deeper in Alitak Bay.

Rex sole occurred in 12 hauls, primarily in Ugak Bay and Dover sole occurred in three hauls, all in Ugak Bay.

Great Sculpin (Tab 3,11,12,14,App Tab 11, App Fig 41,42,43,44)

Great sculpin occurred in similar abundances in both Ugak and Alitak bays (Table 3) and without consistent depth stratification in Ugak Bay (Table 11) but with a tendency to be more abundant in the 51 to 82 m depth interval in Alitak Bay (Appendix Table 11). There was a significant decrease in CPUE further into Ugak Bay (Table 11 and Appendix Figures 41 and 42) and a trend for a decrease within Alitak, inseparable from the weak depth stratification mentioned above (Appendix Figures 43 and 44).

Size of great sculpin very weakly tended to increase with depth but was unrelated to distance into Ugak Bay (Table 12). Mean size was smaller in March than during summer, indicative of a winter migration to deeper water (Table 14).

Yellow Irish Lord (Tab 3,11,12,14 App Tab 12,App Fig 45,46,47,48)

Yellow Irish Lord were considerably more abundant in Ugak Bay than in Alitak (Table 3). The CPUE increased with depth (significantly during August and September) and decreased with distance into Ugak Bay (significantly during June, July and March; Table 11 and Appendix Figures 45 and 46), trends which would have opposed one another in Alitak Bay, contributing to a relatively even distribution there (Appendix Figures 47 and 48). The size of fish increased significantly with depth and decreased significantly with distance into Ugak Bay during August (Table 12).

The seasonal distribution by depth zone (Appendix Table 12) shows that the shallowest depth zones had minimum abundance in March, indicative of migration to deeper water for winter. The size by month in Alitak supported this migration pattern, with largest average weight in June and July and smallest in March, but the size by month in Ugak was confusing; it was cyclic with greatest value in June and smallest value in August (Tables 3 and 14).

Gymnocanthus (Tab 11,12,14 App Tab 13,App Fig 49,50,51,52)

The CPUE of *Gymnocanthus* was not consistently related to depth in Ugak Bay but was related to distance into the bay (Table 11 and Appendix Table 13) with greatest catches occurring in mid-bay (Appendix Figures 49 and 50) and near the mouth of Alitak Bay (Appendix Figures 51 and 52). Size of *Gymnocanthus* during August increased with depth and decreased with distance into Ugak Bay (Table 13). Size was greatest during mid-summer and least in March, indicative of winter migration to deeper waters (Table 14). No indication of seasonal migration is present in the CPUE by depth by month (Appendix Table 13), which indicated that this species probably was fairly common at depths both deeper and shallower than those sampled in this study.

Interestingly, the spatial distribution of *Gymnocanthus* was very similar to that of capelin, one of its important food sources.

Other Sculpins (Tab 3)

The primary feature of spinyhead sculpin distribution was a pronounced depth stratification. The CPUE and frequency of occurrence by depth interval in Ugak Bay for all cruises was:51-72m, 0.06kg, 37%; 73-81 m, 0.20 kg, 72%; 82-91 m, 0.50 kg, 91%; 92-99 m, 0.75 kg, 95%; and 100-104 m, .39 kg, 89%. The CPUE and frequency of occurrence by depth interval in Alitak Bay for all cruises was: 29-50 m, 0(absent); 51-82 m, 0.09 kg, 60%; and 106-174 m (Deadman Bay), 0.01 kg, 29%. There was no evidence of seasonal migration and size was unrelated to depth.

The primary feature of bigmouth sculpin distribution also was a pronounced depth stratification. The CPUE in kg and numbers and the frequency of occurrence by depth interval in Ugak Bay for all cruises was: 51-72 m, 0 (absent); 73-81 m, 0.08 kg, 0.3 fish, 11%; 82-91 m, 0.08 kg, 0.4 fish, 26%; 92-99 m, 0.2 kg, 1.0 fish, 38%; and 100-104 m, 0.17 kg, 1.2 fish and 59%. Only incidental catches were made in Alitak Bay. There was no indication of seasonal migration and size was unrelated to depth.

The primary feature of staghorn sculpin distribution was a summer shift to waters shallower than were sampled in this study (since it is a summer resident in the intertidal) and a winter shift to deeper water, entering the samples in September and to a greater extent in March (Table 3). There was no consistent depth stratification in size or abundance, but during September and March they were less frequent and abundant in about the inner third of Ugak Bay and progressively more abundant toward the mouth. Only incidental catches of staghorn sculpin occurred in Alitak Bay.

All other sculpins were too infrequent to yield reliable distribution patterns.

Walleye Pollock (Tab 3,11,12,14 App Tab 8, App Fig 29,30,31,32)

Walleye pollock were more abundant in Alitak Bay than Ugak Bay during summer and slightly more abundant in Ugak Bay in March (Table 3). In Alitak Bay the CPUE was greatest in the 51-82 m depth interval in all months (Appendix Table 8, Appendix Figures 31 and 32). In Ugak Bay there was no apparent depth stratification (Table 11 and Appendix Table 8), no relation between CPUE and distance into the bay or between fish size and depth or distance into the bay (Table 12, Appendix Figures 29 and 30).

Virtually all walleye pollock captured were age 0 or 1 in both bays. During March they average 13-14 gms in both bays (Table 14), approximately the size of age 1 pollock (based on projections at the extreme end of length-weight and age-length figures presented by Pereyra, et al. (1976), and later confirmed by length-weight data on pollock from Kodiak). In Alitak Bay the size increased each month from 19 gms in June to 62 gms in September, approximately the size of age 1 pollock. However, in the Deadman Bay area of Alitak a few larger pollock occurred, up to 1.4 kg in mean size in summer and 50 gms in March. In Ugak Bay the smaller total catch and occasional occurrence of large pollock resulted in a greater average weight (84 gms in June decreasing to 39 gms in August and 7 gms in September), but in only 2 of 35 catches during June through August was the average weight greater than would be expected of age 1 pollock, and in these it was much greater. In September the pollock in Ugak Bay were all under about 10 gms and catches were small enough that large individuals would have affected the weight. Apparently the pollock captured in September in Ugak Bay were all age 0.

Growth of walleye pollock is indicated by the average weight information (Table 14). Pollock were approximately 7 gms in Ugak Bay in September, (age 0), 13 to 14 gms in both bays in March, and in Alitak Bay pollock were 19 gms in June, 37 gms in July, 53 gms in August and 62 gms in September (age 1). These sizes approximately correspond to the indicated ages of pollock from the Bering Sea (Pereyra et al. 1976). In the absence of length frequency information the above growth rate appears accurate and has since been independently confirmed with individual weights of age 1 pollock in January.

Pacific Cod (Tab 3,12,13,14,App Tab 9, App Fig 33,34,35,36)

The CPUE in kg was much greater in Ugak Bay than in Alitak (Table 3), however, the CPUE in number of fish was greater in Alitak Bay. All Pacific cod captured in Alitak were small 0.12 kg vs 2.17 kg in Ugak Bay and small Pacific cod did not occur in Ugak Bay until September (Table 14). In March Pacific cod averaged 0.045 kg in both bays, which is approximately the size of age 1 Pacific cod at this time of year, based on Pereyra et al. (1976).

The CPUE was greater in the mouths of the bays than within them (Appendix Figures 33,34,35,36) and in Ugak Bay it was greatest in the 92 to 99 m depth interval during June and July (Appendix Table 9). In Alitak Bay the CPUE was greatest in the 29 to 50 m depth interval during summer. Pacific cod was captured in Deadman Bay (which constituted the 106 to 174 m depth interval) only in March.

Size showed a weak tendency to increase with depth (Table 12) and did significantly increase with increased distance into Ugak Bay (Table 12).

The coefficient of variation of Pacific cod catches was generally higher than for any other fish (Table 13), indicating that catch rates of this species were subject to the greatest variability of any fish.

Pacific Tomcod (Tab 3,App Tab 10,App Fig 37,38,39 40)

Small catches of Pacific tomcod occurred in both bays throughout the year (Table 3, Appendix Figures 37,38,39,40). Catches were greatest in the shallowest depth intervals during July through September and at intermediate depths in June and March (Appendix Table 10), constituting strong evidence of migration to shallower waters in mid-summer and deeper waters in winter.

Skates (Tab 4,5,14)

Two species of skates were captured, big skate and longnose skate. Only three longnose skate were captured, all in Ugak Bay in September. A total of 44 big skates were captured, 37 of which were in Ugak Bay. The average size of this species was so great (Table 14) that although it was vastly outnumbered by the majority of other taxa, it ranked tenth in abundance and fourth among the families in weight (Tables 4 and 5).

Due to the infrequent occurrence (13% of the hauls in Ugak and 3% of the hauls in Alitak), the distributional features are not clear, however, during summer they were more frequent and abundant nearer the mouth of the bay (none were captured at any of the 12 innermost stations) and during March they were more frequent and abundant toward the head of the bay(4 of 5 occurrences and 8 of 9 fish occurred at the 12 innermost stations).

The average size was seasonally cyclic with largest fish captured in midsummer and the smallest captured in March and June (Table 14). A movement of large skates to inshore waters during summer was indicated by the cycle of average weights.

Capelin (Tab 3,14,Fig 4,App Tab 14, App Fig 53,54,55,56)

The predominant feature of capelin distribution observed in this study was a cyclic seasonal abundance with greatest catches within both bays in March and least catches in July (Table 3, Appendix Figures 53,54,55,56). A cycle of average sizes also occurred in Ugak Bay with mean weights of 15 gms in June, 13 gms in July, 11 gms in August, 7 to 9 gms (except for two very large catches of 13 gm capelin)in September, and 10 gms in March (Table 14). In March the average size was smallest (6-9 gms) in the head of the bay, greatest at the mouth of the bay (11-17 gms) and intermediate (9 to 10 gms) in mid-bay were the greatest catches of capelin occurred.

In Alitak Bay the same seasonality of catches occurred but concentrations were never as great as in Ugak Bay and capelin were much smaller, with average sizes generally 5 to 8 gms, and the largest average weight in a single haul was 11 gms.

The catch of capelin by depth (Appendix Table 14) indicates a strong depth stratification, with greatest catches deeper, especially during March.

The August length frequency in 5 mm intervals for capelin displays modes at 97 mm and 112 mm (Figure 4). Comparison with length frequency data from Cook Inlet (Blackburn 1978) and Kodiak (Harris and Hartt 1977) suggests that the 97 mm mode is age 2 capelin since ages 0 and 1 are about 20 to 35 mm and 60 to 80 mm, respectively. The 112 mm mode, however, reflected in the catches reported here and those of Harris (1977), does not seem to be large enough to be age 3. More intensive study, together with age determinations are necessary to corroborate this hypothetical growth rate.

Eulachon (Tab 3, App Fig 57,58,59,60)

Eulachon were captured only in trace amounts in Alitak Bay but in Ugak Bay they displayed a cyclic seasonal abundance with greatest catch and frequency of occurrence in June and least in August and September. Catches in March were significantly greater than in September but less than in June (Table 3). There were no areas of concentration identified (Appendix Figures 57,58,59, 60).

Eelpouts (App Tab 16)

Three species of eelpouts were captured, soft eelpout, shortfin eelpout and wattled eelpout. The soft eelpout occurred only in Deadman Bay and both the shortfin and wattled eelpouts were more abundant in Deadman Bay than anywhere else (Appendix Table 16).

The shortfin eelpout was more frequent and abundant at greater depths in both bays. In Ugak Bay shortfin eelpouts clearly displayed an inshore movement in summer and an offshore movement in winter. In March they were virtually absent from Ugak Bay; in June they occurred in small numbers, strongly increasing in CPUE and frequency of occurrence by depth, in July and August the CPUE was greatest in the 82 to 91 m and 92 to 99m depth zones, respectively, and in September they were almost exclusively below 82 m. In Alitak Bay, shortfin eelpouts were present in every haul in Deadman Bay (except during June when eelpouts were not identified to species in this area) but abundance was greatest in summer. In the 51 to 82 m depth interval of Alitak both abundance and frequency of occurrence were greatest in summer, but above 50 m they were never frequent or abundant. Apparently shortfin eelpouts migrated out of Alitak Bay in winter, since winter catches, even at the deep stations, were reduced.

Wattled eelpouts were much smaller and the catches were infrequent in Ugak Bay. Distribution trends are not clear, but wattled eelpouts were present at all but the deepest depth interval in June, were in the shallower depths in July, at generally deeper depths in August and they were absent in September and March. In Alitak Bay, wattled eelpouts were generally more abundant and frequent deeper but the abundance and frequency of occurrence below 50 m decreased from a high in June to a low in March. Apparently wattled eelpouts also migrated out of Alitak Bay in winter.

Snailfish (App Fig 65,66,67,68)

Snailfish were generally not identified to species, except for the smooth lumpsucker, four of which were captured in Deadman Bay. In Alitak Bay during summer, snailfish abundance increased with depth and distance into the bay(two inseparable factors) and snailfish were consistently present in both the 51-82 m and 106-174 m (Deadman Bay) depth zones (Appendix Figures 67 and 68). In Deadman Bay during summer they occurred in 100% of the hauls. During winter in Alitak Bay only five snailfish were captured, a considerably lower catch rate than summer.

In Ugak Bay in summer snailfish occurred more frequently at the head of the bay, at the eight innermost stations, and in March the few occurrences were in the middle to outer bay(Appendix Figures 65 and 66). In no area was the frequency of occurrence of abundance comparable to that in Deadman Bay and there was no depth stratification apparent.

Pacific Herring (Tab 3)

Pacific herring displayed a cyclic abundance in Alitak Bay with a catch minimum in July and maximum in March (Table 3). They were most abundant in the shallow area between the mouth of Alitak Bay and Deadman Bay, with only two occurrences in Deadman Bay. They were never abundant (the largest catch was 19 kg, 300 fish, in March) and location of larger catches was not consistent between cruises. In Ugak Bay herring occurred only 11 times, 8 of which were clustered in mid-bay in August.

Pacific Sandfish (Tab 3,14,App Tab 15, App Fig 61,62,63,64)

The only prominent feature in the sandfish catches was the influx of age 0 fish in the August catches (Tables 3 and 14, Appendix Table 15, Appendix Figures 61,62,63,64). These fish were considerably smaller than the mesh of the net and must have been retained by the catch already within the net, which is an indication that this species was extremely abundant.

Sea Poachers

The sturgeon poacher was commonly captured, especially in Ugak Bay where it occurred in 54% of the hauls and averaged five fish per haul. The CPUE increased with depth in Ugak Bay and decreased with depth in Alitak Bay. It was markedly more abundant in March at all depths in both bays. The winter increase in abundance was greatest in the shallowest depth zone of Alitak Bay (at the mouth of the bay), where it increased 36 fold and was greatest in the deepest depth zone of Ugak Bay, where it increased 10 fold. Sturgeon poachers were more frequent and abundant toward the mouth of Ugak Bay in the summer, but in March the greatest abundance was in the middle portion of Ugak Bay. This species obviously moved out of the sampling area in summer , but whether it moved shallower or offshore is not clear. In lower Cook Inlet this species was also much more abundant in winter, but appeared to move shallower in Summer (Blackburn 1978).

The tubenose poacher and alligator fish were occasionally captured. Both were more frequent in March and since the tubenose poacher is known to be present in the littoral zone in summer, indications were that it wintered deeper.

Pricklebacks (Tab 14)

The stout eelblenny was quite small (Table 14) but occurred in 50% of the hauls and averaged 3.4 fish per haul throughout the study. In Alitak Bay they tended to be larger, more frequent, and more abundant at greater depths but no similar trends were apparent in Ugak Bay. They were less frequent and abundant in March in both bays.

The daubed shanny, also quite small (Table 14), occurred in 30% of the hauls, averaged 2.4 fish per haul and was distinctly more abundant in Ugak Bay. During summer the CPUE and frequency of occurrence decreased with depth while mean size increased with depth. During March, daubed shannys were obviously deeper than in summer since both CPUE and frequency of occurrence was greater at all depths with a tendency to be greatest at intermediate depths (51-82 m in Alitak and 82-91 m in Ugak Bay). Apparently the daubed shanny primarily occupies depths less than 50 m during summer since summer catches decreased with depth and catches were considerably greater in winter.

The longsnout prickleback occurred in 70% of the hauls in Deadman Bay and averaged 4.4 fish per haul year round, with slightly greater abundance in summer. Only incidental numbers were captured elsewhere.

Only incidental numbers of snake prickleback were captured.

Searcher

The searcher displayed a distinct seasonal migration to shallower water in summer and deep water in winter in both Ugak and Alitak bays. In Alitak they were most abundant and most frequently present above 50 m in summer and absent in this zone in winter, while below 106 m (in Deadman Bay) they occurred only during June and March. Similarly in Ugak Bay in summer searchers were most frequent and abundant in the shallowest depth zone and both abundance and frequency of occurrence steadily decreased with greater depth. During March in Ugak Bay searchers were present in all depth zones, but were most frequent and abundant at 92 to 99 m.

Other taxa

A number of other species were captured in incidental numbers, including three commercially exploited species. Sablefish occurred in 5% of the summer hauls in Ugak Bay and 33% of the hauls in March. Rock fish occurred in 7% of the hauls throughout the study and Atka mackerel occurred in less than 1% of the hauls.

DISCUSSION

Comparison of the results of this study with surveys conducted on the continental shelf and slope in 1961 and 1973-75, which are presented by Pereyra and Ronholt (1976) provides some perspective into the uniqueness of the bays. On the shelf the catches primarily consisted of flounders, cod and sculpins, as in the bays,but rockfishes were more prominent on the shelf. Rockfish comprised 13% of the fish catch on the shelf in 1961 and 2% in 1973-75. The decrease is due to the foreign fishery for Pacific Ocean perch but even at 2%, rockfish are much more important than in the bays. The catch rates of rockfish reported in 1973-75 by Pereyra and Ronholt at less than 100 m in the Kodiak area are similar to those obtained in this study, thus, the rockfish catch in the bays is comparable to catches at similar depths outside them (the shelf surveys covered at least 3.1 times as much area in a standard haul as was covered in the present study so the CPUE figures presented here from Pereyra and Ronholt will all be divided by 3.1 for comparison).

The relative abundances of flounders captured were conspicuously different between the bays and the shelf area. Yellowfin sole, which constituted 58% of the flounders and was the predominant fish in the bays, was only incidentally captured on the shelf, with the largest CPUE in any area-depth interval being about 1 kg (converted as noted above). Arrowtooth flounder ranked 6th in abundance among flatfish in the bays but was the predominant flatfish on the shelf. Rock sole ranked 5th in abundance among flatfish in the bays but, in the Kodiak area at less than 100 m was far more abundant than any other flounder. Starry flounder, which ranked 4th in the bays was only in incidental numbers on the shelf but its high rank in the bays is based upon the high winter catches experienced. The shelf studies were not conducted in winter, only in summer, so the results would be difficult to compare for this species.

The following species had a greater CPUE in the 0-100 m depth zone in the Kodiak area than in the bays: arrowtooth flounder, rock sole, halibut, rex sole, walleye pollock, Pacific cod and marginally so cottids. While yellowfin sole and, in June, July and August in Ugak Bay, flathead sole had greater CPUE's in the bays than on the shelf at 1 to 100 m. Figures are not available to compare abundances of other species.

Most of the species are more abundant on the shelf than in the bays and this is a continuation of the trend for abundance to decrease toward the head of the bays. In general, there is very little difference between the composition of the catches in the bays and catches at similar depths outside of them (except as already noted). There are local abundances in certain areas which affect the catch composition somewhat, but these features exist within the bays as well as elsewhere.

The seasonal movement to deeper water in winter as presented here has been generalized. The timing does not appear to be synchronous for all species but a finer time distinction has not been possible. The combination of seasonal depth migration and size stratification by depth resulted in changes in size observed in the study throughout the year. For some species it is felt that the mean size is a sensitive indicator of seasonal migrations, larger size indicating shallower residence.

A winter movement into the bays by some species, starry flounder, sturgeon poacher and perhaps yellowfin sole, has been interpreted from the data, based upon much larger winter catches and maximum densities in the middle or inner portion of Ugak Bay. The same features characterized Alitak which with a very different depth regime, strongly supports the hypothesis that several species moved into the bays in winter. Movement to deeper water implies, generally, a movement out of the bays, which many of the species did.

The movement into the bays seems likely to be associated with spawning for starry flounder and perhaps sturgeon poacher. Starry flounder spawn in spring and typically concentrate near rivers or in estuaries and their young move into freshwater, even during their first year (based on personal experience). Yellowfin sole, though they were in the bays in greater abuncance in winter probably were not there for spawning. They spawn later, during summer in the Bering Sea (Pereyra et al 1976).

The most unique area in this study was Deadman Bay, which yielded much lower catches and a somewhat unique species assemblage. These catches are associated with a much greater depth, and a sill at the mouth of Alitak which would restrict deep water exchange between this bay and the ocean.

The trend for fish size to increase with increasing depth is of some consequence. This trend seems to be quite universal and implies that the shallow zones are important nursery areas for all species; juveniles of some species residing shallower and/or in different locations than other species, however. The shallow zone is the most likely zone to be impacted by oil development and juvenile fish in this zone could be affected.

NEEDS FOR FURTHER STUDY

To more fully understand the demersal fish community in the Kodiak area so that possible environmental costs of oil exploration may be more fully delimited, several areas of research seem most efficacious. The limits of areal and seasonal coverage should be expanded in several ways. The inshore surveys should be tied into the existing offshore survey information and the areal gap between them filled. This would allow a more thorough integration of knowledge of the entire shelf area. The shallow limit of demersal sampling should be extended upward and the areal coverage of nearshore work should be expanded to include other bays so that unique features of different areas may be identified. The extent of seasonal coverage should be expanded to more fully document migrations and seasonal distribution changes.

More seasonal work would also facilitate life historical study. Ichthyoplankton studies would be very helpful since they integrate the reproduction of the entire community providing information on time and location of reproduction and important life historical information. More extensive study of food habits would offer several benefits. The most obvious contribution of food habits work is the functioning of the ecosystem, the description of the prey spectra, and perhaps a delimitation of important species of stages. Food habits work will also provide a look at the marine communities through the mouths of predators, which involves a very different set of selectivities than does an otter trawl pulled across the bottom.

At the time of this writing, these research needs are about to be fulfilled in the coming year's work, along with a greater emphasis on the nearshore fishes.

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Table 1. Number of otter trawl hauls completed with satisfactory gear performance by bay and month.

	Ugak Bay	Alitak Bay
June	25	28
July	23	27
August	25	22
September	22	25
March	24	19
Total	119	121
Grand Total	240	

Table 2. List of species captured in Ugak and Alitak bays on Kodiak Island by otter trawl during June, July, August and September 1976 and March 1977.

Rajidae	
Big skate	*Raja binoculata*
Longnose skate	*Raja rhina*
Clupeidae	
Pacific herring	*Clupea harengus pallasi*
Osmeridae	
Capelin	*Mallotus villosus*
Eulachon	*Thaleichthys pacificus*
Gadidae	
Pacific cod	*Gadus macrocephalus*
Pacific tomcod	*Microgadus proximus*
Walleye pollock	*Theragra chalcogramma*
Zoarcidae	
Soft eelpout	*Bothrocara molle* [1]
Shortfin eelpout	*Lycodes brevipes*
Wattled eelpout	*Lycodes palearis*
Trichodontidae	
Pacific sandfish	*Trichodon trichodon*
Bathymasteridae	
Searcher	*Bathymaster signatus*
Stichaeidae	
Longsnout prickleback	*Lumpenella longirostris*
Daubed shanny	*Lumpenus maculatus*
Stout eelblenny	*Lumpenus medius*
Snake prickleback	*Lumpenus sagitta*
Zaproridae	
Prowfish	*Zaprora silenus*
Scorpaenidae	
Pacific ocean perch	*Sebastes alutus*
Dusky rockfish	*Sebastes ciliatus*
Anoplopomatidae	
Sablefish	*Anoplopoma fimbria*

[1] May be *B. pusillum*

Hexagrammidae	
Masked greenling	*Hexagrammos octogrammus*
Whitespot greenling	*Hexagrammos stelleri*
Atka mackerel	*Pleurogrammus monopterygius*
Cottidae	
Crested sculpin	*Blepsias bilobus*
Silver spotted sculpin	*Blepsias cirrhosus*
Spinyhead sculpin	*Dasycottus settiger*
Antlered sculpin	*Enophrys diceraus*
	Gymnocanthus spp.
Red Irish Lord	*Hemilepidotus hemilepidotus*
Yellow Irish Lord	*Hemilepidotus jordani*
Bigmouth sculpin	*Hemitripterus bolini*
Thorny sculpin	*Icelus spiniger*
Staghorn sculpin	*Leptocottus armatus*
Great sculpin	*Myoxocephalus spp.*
Tadpole sculpin	*Psychrolutes paradoxus*
Ribbed sculpin	*Triglops pingeli*
Agonidae	
Sturgeon poacher	*Agonus acipenserinus*
Smooth alligatorfish	*Anoplagonus inermis*
Tubesnout poacher	*Pallasina barbata*
Cyclopteridae	
Smooth lumpsucker	*Aptocyclus ventricosus*
Marbled snailfish	*Liparis dennyi*
Slipskin snailfish	*Liparis fucensis*
Slimy snailfish	*Liparis mucosus*
Pleuronectidae	
Arrowtooth flounder	*Atheresthes stomias*
Rex sole	*Glyptocephalus zachirus*
Flathead sole	*Hippoglossoides elassodon*
Pacific halibut	*Hippoglossus stenolepis*
Butter sole	*Isopsetta isolepis*
Rock sole	*Lepidopsetta bilineata*
Yellowfin sole	*Limanda aspera*
Dover sole	*Microstomus pacificus*
Starry flounder	*Platichthys stellatus*
Alaska plaice	*Pleuronectes quadrituberculatus*
Sand sole	*Psettichthys melanostictus*

Table 3 . Otter trawl catch in kilograms per 20 minute haul in Ugak and Alitak Bays on Kodiak Island by month, June through September 1976 and March 1977, and by taxon.

	UGAK BAY					ALITAK BAY				
Taxa	June	July	Aug.	Sept.	Mar.	June	July	Aug.	Sept.	Mar.
Big skate	.5	1.9	10.8	7.9	2.1				6.7	
Longnose skate				.2						
Pacific herring	T		.6	T	T	.3	T	.4	.7	1.6
Capelin	1.4	T	2.0	3.9	6.8	.4	T	.2	.5	.9
Eulachon	.8	T	T	T	.1	T	T	T	T	.1
Pacific cod	16.8	30.5	.3	.7	T	T	1.8	.4	.1	.2
Pacific tomcod	.1	.3	.2	T	.1	T	T	.3	T	.3
Walleye pollock	.2	.6	.1	.1	4.6	3.9	14.6	4.0	8.4	3.0
Soft eelpout							T	T	T	T
Shortfin eelpout	T	.8	.4	.3	T	.3	1.9	.5	1.1	T
Wattled eelpout	.1	T	T			.4	.4	.2	.3	.1
Pacific sandfish	T	.1	.6	.4	T	T	.2	.2	.5	T
Searcher	T	T	T	T	T	T	T	T	.1	T
Longsnout prickleback	T		T	T	T		.1	T	T	T
Daubed shanny	T	T	T	T	T		T	T	T	T
Stout eelblenny	T	T	T	T	T	T	T	T	T	T
Snake prickleback		T	T	T			T	T		
Prowfish									T	
Sebastes spp		.2	T	T	T	T	T	T	T	
Sablefish	T	T	.1	T	.3					T
Masked greenling				T	T					.2
Whitespot greenling					T	T	.1	T	T	.8
Atka mackerel		T			T			T		
Crested sculpin					T	T			T	
Silverspotted sculpin									T	
Spinyhead sculpin	.1	.6	.3	.5	.4	T	T	T	T	.1
Antlered sculpin		T								
Gymnocanthus spp	6.6	8.3	6.8	3.4	12.1	.3	.9	.1	T	.2
Red Irish Lord		T								
Yellow Irish Lord	33.0	11.0	2.4	2.5	4.3	.4	1.7	.5	.6	.3
Bigmouth sculpin	T	.2	.1	T	.1		T	T	T	
Thorny sculpin		T								T
Staghorn sculpin	T	T		.5	1.5				T	T

Table 3. (cont.)

Taxa	UGAK BAY June	July	Aug.	Sept.	Mar.	ALITAK BAY June	July	Aug.	Sept.	Mar.
Great sculpin	11.2	14.8	8.6	11.9	18.1	12.2	16.8	9.2	13.3	15.1
Tadpole sculpin									T	
Ribbed sculpin			T	T	T		T	T		T
Sculpin spp		T				.3				
Sturgeon poacher	T	T	.1	.2	1.1	T	T	T	T	T
Tubenose poacher			T		T		T		T	T
Smooth & Aleutian Alligatorfish			T		T		T			T
Smooth lumpsucker								T	T	T
Snailfish spp	T	T	.1	T	.3	0.3	1.0	1.3	1.3	T
Arrowtooth flounder	1.1	2.8	5.6	1.7	T	T	.1	.1	.2	T
Rex sole	T	T	T		T		T		T	
Flathead sole	22.5	17.7	12.9	3.1	1.9	2.3	4.3	2.9	3.4	.9
Pacific halibut	7.3	3.5	5.0	7.8	2.8	7.5	9.3	3.9	3.9	1.5
Butter sole	2.4	.5	1.7	1.8	.3	.1	.2	T	T	T
Rock sole	2.6	7.5	2.7	4.7	4.7	1.6	2.8	.7	.5	.2
Yellowfin sole	26.7	42.7	37.9	22.2	53.2	18.4	25.7	19.9	21.7	52.6
Dover sole		T	T	T						
Starry flounder	.4	.3	.7	4.5	5.6	2.9	1.2	1.9	5.0	21.9
Alaska plaice	.3	.5	T		T	.4	1.6	.3	T	.2
Sand sole		1.0	1.4	.5	.7				T	
Flounder spp	.2					1.1				

T= Trace, < 0.1 Kg

Table 4. Relative abundance and rank of major component taxa from otter trawl catches in Ugak and Alitak bays on Kodiak Island during June, July, August and September 1976 and March 1977. The weight percent of total and rank are based upon the total kg captured in standardized hauls in all months. The data on king crab and snow crab is presented courtesy of Feder and Jewett (1977).

Taxon	Ugak Bay		Alitak Bay[a]		Overall	
	Rank	wt% of total	Rank	wt% of total	Rank	wt% of total
Snow crab	3	15.8	1	25.7	1	20.7
King crab	2	16.5	2	21.9	2	19.2
Yellowfin sole	1	18.8	4	14.3	3	16.6
Shrimp	4	7.5	3	14.6	4	11.0
Great sculpin	5	6.6	5	7.1	5	6.9
Flathead sole	6	6.1	9	1.3	6	3.8
Yellow Irish Lord	7	5.6	14	0.4	7	3.0
Pacific halibut	10	2.7	8	3.0	8	2.8
Pacific cod	8	4.9	17	0.3	9	2.6
Walleye pollock	17	0.6	6	3.8	10	2.2
Starry flounder	15	1.2	7	3.1	11	2.1
Gymnocanthus	9	3.8	20	0.2	12	2.0
Big skate	11	2.4	10	0.7	13	1.6
Rock sole	12	2.3	11	0.7	14	1.5
Capelin	13	1.4	18	0.2	15	0.8
Arrowtooth flounder	14	1.2	24	<0.1	16	0.6

[a] Several taxa were more abundant in one bay than some of those in this table. In Ugak Bay buttersole ranked 16th and constituted 0.7% of the catch. In Alitiak Bay these taxa, their rank and percent of total catch were: shortfin eelpout, 12, 0.5%; snailfish spp., 13, 0.4%; Alaska plaice, 15, 0.3%; Pacific herring, 16, 0.3%; wattled eelpout, 19, 0.2%; Pacific sandfish, 21, 0.1%; whitespotted greenling, 22, <0.1%; and Pacific tomcod, 23, <0.1%.

TABLE 5. Relative abundance and rank of fish by family captured in otter trawl hauls in Ugak and Alitak bays on Kodiak Island during June, July, August and September 1976 and March 1977. The weight percent of total fish catch and rank are based upon the total kg catpured in standardized hauls in all months.

	Ugak Bay		Alitak Bay		Overall	
Family	Rank	wt% of fish	Rank	wt% of fish	Rank	wt% of fish
Flounders	1	55.4	1	61.0	1	57.5
Sculpins	2	27.5	2	20.7	2	24.9
Cod	3	9.3	3	11.0	3	9.9
Skates	4	4.0	5	2.0	4	3.2
Smelt	5	2.6	8	0.6	5	1.8
Eelpouts	6	0.3	4	2.0	6	0.9
Snailfish[a]	10	0.1	6	1.2	7	0.5
Herring	9	0.1	7	0.8	8	0.4
Sandfish	8	0.2	10	0.3	9	0.2
Sea Poachers	7	0.3	15	<0.1	10	0.2
Greenling	15	<0.1	9	0.3	11	0.1
Sablefish	11	0.1	14	<0.1	12	<0.1
Pricklebacks	12	<0.1	12	<0.1	13	<0.1
Ronquils	13	<0.1	11	0.1	14	<0.1
Rockfish	14	<0.1	13	<0.1	15	<0.1
Prowfish			16	<0.1	16	<0.1

[a]Family Cyclopteridae

TABLE 6. Relative abundance and rank of flounders from otter trawl catches in Ugak and Alitak bays on Kodiak Island during June, July, August and September 1976 and March 1977. The figures are based upon the total kg captured in standardized hauls in all months. Flounder spp accounted for 0.3% of the catch.

	Ugak Bay		Alitak Bay		Overall	
Species	Rank	wt% of family	Rank	wt% of family	Rank	wt% of family
Yellowfin sole	1	56.4	1	61.7	1	58.8
Flathead sole	2	18.2	4	6.6	2	13.6
Pacific halibut	3	8.1	3	12.9	3	10.0
Starry flounder	6	3.5	2	13.4	4	7.5
Rock sole	4	6.7	5	3.0	5	5.2
Arrowtooth flounder	5	3.5	7	0.2	6	2.2
Butter sole	7	2.1	8	0.2	7	1.3
Alaska plaice	9	0.3	6	1.3	8	0.7
Sand sole	8	1.1	9	<0.1	9	0.7
Rex sole	11	<0.1	10	<0.1	10	<0.1
Dover sole	10	<0.1			11	<0.1

Table 7. Relative abundance and rank of cod from otter trawl catches in Ugak and Alitak bays on Kodiak Island during June, July, August and September 1976 and March 1977. The figures are based upon the total kg captured in standardized hauls in all months.

Species	Ugak Bay Rank	Ugak Bay wt% of family	Alitak Bay Rank	Alitak Bay wt% of family	Overall Rank	Overall wt% of family
Pacific cod	1	88.2	2	6.9	1	54.1
Walleye pollock	2	10.3	1	91.5	2	44.4
Pacific tomcod	3	1.5	3	1.6	3	1.5

TABLE 8. Relative abundance and rank of sculpins from otter trawl catches in Ugak and Alitak bays on Kodiak Island during June, July, August and September 1976 and March 1977. The figures are based upon the total kg captured in standardized hauls in all months. Unidentified sculpins consisted of 0.2% of the catch.

Species	Ugak Bay Rank	Ugak Bay wt% of family	Alitak Bay Rank	Alitak Bay wt% of family	Overall Rank	Overall wt% of family
Great sculpin	1	39.9	1	91.8	1	56.3
Yellow Irish Lord	2	33.9	2	5.0	2	24.8
Gymnocanthus	3	23.2	3	2.2	3	16.6
Spinyhead sculpin	5	1.2	4	0.3	4	0.9
Staghorn sculpin	4	1.3	5	0.1	5	0.9
Bigmouth sculpin	6	0.3	6	<0.1	6	0.3
Ribbed sculpin	8	<0.1	7	<0.1	7	<0.1
Red Irish Lord	7	<0.1			8	<0.1
Crested sculpin	11	<0.1	8	<0.1	9	<0.1
Antlered sculpin	9	<0.1			10	<0.1
Thorny sculpin	10	<0.1	9	<0.1	11	<0.1
Silverspotted sculpin			10	<0.1	12	<0.1
Tadpole sculpin			11	<0.1	13	<0.1

Table 9. Catch per 20 minute otter trawl haul and standard error by subarea of Alitak Bay and by season for the predominant taxa. Taxa are listed in order of abundance in the total catches from the entire study.

	Summer			March		
Taxon	Inner	Middle	Outer	Inner	Middle	Outer[1]
Yellowfin sole	3.01±0.86	22.99± 4.04	30.38±2.91	4.95±1.69	94.88±12.20	69.98±20.92
Great sculpin	8.68±2.48	17.62± 2.69	13.93±1.83	11.57±6.62	15.49± 4.89	18.35± 7.07
Flathead sole	1.38±0.22	4.22± 0.66	3.81±0.40	0.64±0.15	1.77± 0.56	0.46± 0.12
Yellow Irish Lord	0.07±0.04	0.37± 0.12	1.24±0.64	0	0.45± 0.11	0.39± 0.16
Pacific halibut	0.04±0.03	9.00± 2.58	8.45±1.45	0.54±0.21	1.38± 1.11	2.44± 2.10
Pacific cod	0	0.01± 0.01	1.00±0.72	0.19±0.17	0.09± 0.05	0.28± 0.18
Walleye pollock	0.33±0.15	12.92± 7.06	10.01±4.48	0.67±0.32	4.98± 1.06	3.82± 1.36
Starry flounder	0.48±0.28	1.00± 0.47	4.14±1.07	11.84±3.68	13.00± 5.14	38.38±14.15
Gymnocanthus	0	0	0.59±0.31	0	0.29± 0.17	0.21± 0.16
Big skate	0	4.28± 2.91	1.75±1.27	0	0	0
Rock sole	0.01±0.01	0.60± 0.41	2.30±1.17	0	0.05± 0.05	0.69± 0.44
Capelin	0.64±0.31	0.79± 0.66	0.03±0.01	2.33±0.74	0.08± 0.04	0.05± 0.03
Arrowtooth flounder	0	0.03± 0.02	0.18±0.04	T ± T	0.05± 0.03	0.01± 0.01
Eelpout spp.	3.88±0.70	2.28± 0.63	0.43±0.09	0.25±0.08	0.10± 0.07	0.28± 0.20
Butter sole	0	0	0.18±0.07	0	0.06± 0.05	0.08± 0.04
Snail fish	2.77±0.54	0.81± 0.48	0.19±0.09	0.02±0.02	0.01± 0.01	0
Alaska plaice	0	0	1.05±0.49	0	0.66± 0.55	0.06± 0.06
Sand sole	0	0	0.02±0.02	0	0	0
Pacific herring	0.01±0.01	0.74± 0.47	0.42±0.13	0.03±0.03	4.60± 3.64	1.03± 0.39
Spinyhead sculpin	0.01± T	0.07± 0.04	0.02±0.01	0.01±0.01	0.32± 0.12	0.07± 0.04
Pacific sandfish	0	0.39± 0.26	0.26±0.06	0	0.04± 0.02	0.02± 0.02
Staghorn sculpin	0	0	0.01±0.01	0	0.05± 0.05	0.03± 0.03
Sturgeon poacher	T ± T	0	T ± T	0	0.09± 0.06	0.15± 0.09
Pacific tomcod	0	0	0.15±0.10	0	0.33± 0.32	0.52± 0.32
Eulachon	0.01±0.01	0.03± 0.01	0.02±0.01	0	0.21± 0.11	0.13± 0.08
Total Fish	21.56±3.39	78.37±13.98	81.41±7.18	33.69±6.76	140.94±16.14	139.29±40.74
Number of Hauls	27	14	61	7	5	7

T = < 0.01 kg per haul
[1]Sampling of outer Alitak was considerably abbreviated in March due to unusually high densities of breeding King crab.

Table 10. Catch per 20 minute otter trawl haul and standard error by subarea of Ugak Bay and by season for the predominant taxa. Taxa are listed in order of abundance in the total catches from the entire study.

	Summer			March		
Taxon	Inner	Middle	Outer	Inner	Middle	Outer
Yellowfin sole	40.21± 6.16	27.63±2.95	30.53± 3.72	89.01±41.38	38.10±3.24	32.38±4.31
Great sculpin	6.57± 1.62	5.30±0.82	21.70± 2.92	6.63± 2.63	21.63±4.06	26.08±5.77
Flathead sole	7.73± 1.35	8.79±1.28	25.20± 4.73	0.86± 0.31	1.61±0.49	3.44±0.88
Yellow Irish Lord	2.61± 0.60	10.34±2.14	23.22± 7.70	0.14± 0.07	4.38±1.02	8.53±2.79
Pacific halibut	2.26± 0.70	4.75±0.85	10.09± 1.96	1.47± 0.76	1.43±0.74	5.58±2.63
Pacific cod	0.81± 0.48	1.94±0.75	31.03±17.97	0.01± 0.01	0.03±0.03	0.04±0.03
Walleye pollock	0.09± 0.03	0.08±0.02	0.54± 0.25	3.90± 0.84	4.55±2.03	5.26±2.38
Starry flounder	0.79± 0.35	0.31±0.16	2.98± 1.38	6.32± 1.95	7.07±2.06	3.49±1.24
Gymnocanthus	2.06± 0.48	10.50±1.44	6.04± 1.42	8.36± 1.97	17.86±3.71	9.94±2.61
Big skate	0	2.86±2.20	12.04± 5.16	5.20± 2.60	0.53±0.53	0.68±0.68
Rock sole	0.79± 0.24	1.27±0.23	10.17± 2.20	2.16± 0.96	3.16±1.00	8.75±2.25
Capelin	3.77± 2.00	1.94±0.85	0.12± 0.05	5.55± 1.98	12.13±1.90	2.62±1.56
Arrowtooth flounder	1.45± 0.50	1.92±0.53	4.88± 0.98	T ± T	0.02±0.01	0.01±0.01
Eelpout spp.	0.54± 0.18	0.22±0.04	0.52± 0.14	T ± T	T ± T	0
Butter sole	0.20± 0.07	1.26±0.97	3.13± 1.14	0	0.34±0.34	0.50±0.30
Snailfish	0.14± 0.06	T ± T	0.06± 0.04	0	T ± T	0.96±0.65
Alaska plaice	0	0.01±0.01	0.55± 0.34	0	0	0.20±0.15
Sand sole	0	0.70±0.61	1.38± 0.65	0	0.28±0.28	1.87±1.26
Pacific herring	0	0.23±0.15	0.22± 0.20	T ± T	0	0
Spinyhead sculpin	0.08± 0.03	0.26±0.05	0.79± 0.22	0.33± 0.03	0.26±0.08	0.69±0.21
Pacific sandfish	0.26± 0.09	0.28±0.10	0.33± 0.10	0.02± 0.01	0.18±0.05	0.01±0.01
Staghorn sculpin	0.03± 0.03	0.15±0.06	0.24± 0.11	0.08± 0.06	1.13±0.40	3.38±0.60
Sturgeon poacher	0.02± T	0.08±0.03	0.23± 0.08	0.39± 0.19	2.10±0.60	0.92±0.37
Pacific tomcod	0.03± 0.02	0.09±0.03	0.36± 0.17	0.01± 0.01	0.11±0.04	0.34±0.14
Eulachon	0.19± 0.07	0.37±0.14	0.16± 0.05	0.04± 0.02	0.11±0.03	0.17±0.06
Total Fish	71.02±10.16	81.46±8.17	187.56±25.67	130.72±43.49	117.59±7.48	116.76±11.30
Number of Hauls	29	32	34	8	8	8

T = < 0.01 kg per haul

Table 11. Correlation coefficients between CPUE of fish, sample depth and distance into Ugak Bay[1].

TAXON	DEPTH					DISTANCE INTO UGAK BAY				
	June	July	Aug	Sept	Mar	June	July	Aug	Sept	Mar
Total fish	+.19	+.13	-.22*	-.06	-.44*	-.67***	-.45*	-.51***	-.37	+.17
Yellowfin sole	-.23	+.01	-.19	+.09	-.56*	-.30	+.24	-.02	+.39	+.41
Flathead sole	+.25	+.02	-.10	+.03	-.14*	-.57**	-.35	-.62***	-.28	-.52***
Starry flounder				-.48*	-.26				-.31	+.38
Pacific halibut	+.01	-.26	-.17	-.08	-.04	-.58***	-.15	-.38*	-.47*	-.27
Rock sole	-.01	-.20	-.32*	-.06	-.17*	-.55***	-.54***	-.30*	-.46*	-.49***
Arrowtooth flounder	-.39**	+.15	-.08	+.25	+.30	-.35**	-.49*	-.51**	-.24	-.13
Walleye pollock	+.14	-.39**	+.07	+.09	+.17	-.26	-.38**	+.04	+.68***	-.05
Pacific cod	+.32	+.19				-.38	-.28			
Yellow Irish Lord	+.25	+.26	+.74***	+.51*	+.32	-.51*	-.63***	-.27	-.05	-.56*
Great sculpin	-.05	-.16	-.32**	+.16	+.36	-.53**	-.45*	-.51***	-.45*	-.52*
Gymnocanthus	-.23	+.29	-.04	+.40	-.09	-.36*	-.34	-.51**	+.25	-.17

* significant relationship, p<.05
** significant relationship, p<.01
*** significant relationship, p<.005

[1] Distance measured from a line across the mouth of the bay to the center of each station.

Table 12. Correlation coefficients between mean fish size (kg/fish), sample depth and distance into Ugak Bay[1] during summer[2] as determined by multiple linear regression.

TAXON	CORRELATION COEFFICIENTS		
	SINGLE FACTOR		
	Depth	Distance into Bay	Multiple Correlation
Yellowfin sole	.770***	-.679***	.927***
Flathead sole	-.174	.586***	.587**
Starry flounder	.427*	-.072	.430
Pacific halibut	.497*	.073	.521
Rock sole	.197	-.406	.454
Arrowtooth flounder	.691***	.149	.702***
Butter sole	.029	.007	.039
Walleye pollock	.143	.233	.270
Pacific cod	.182	.558***	.561***
Great sculpin	.287	-.042	.288
Yellow Irish Lord	.837***	-.456*	.878***
Gymnocanthus	.432*	-.723***	.784***

* significant relationship, $p<.05$
** significant relationship, $p<.01$
*** significant relationship, $p<.005$

[1] Distance measured from a line across the mouth of the bay to the center of each station.
[2] Regressions were computed on data from all summer months for starry flounder, butter sole and Pacific cod; on data from July and August for walleye pollock and on data from August for all other taxa.

Table 13. Coefficient of variation[1] of CPUE of several predominant taxa, by month from Ugak Bay.

Taxon	June	July	Aug	Sept	March
Total fish	.96	1.02	.67	.81	.59
Yellowfin sole	.72	.77	.58	.78	1.32
Flathead sole	1.25	1.48	.76	.91	1.01
Starry flounder	2.54	2.93	2.74	2.14	.90
Pacific Halibut	1.24	1.46	1.06	1.52	1.72
Rocksole	1.39	1.89	2.34	1.64	1.08
Arrowtooth flounder	2.75	1.51	1.05	.86	2.05
Walleye pollock	3.04	2.83	1.59	1.26	1.11
Pacific cod	2.51	3.90	5.00[2]	2.35	2.46
Yellow Irish Lord	1.51	.99	.96	.79	1.34
Great Sculpin	1.10	1.12	1.28	1.26	.80
Gymnocanthus spp.	1.35	1.15	.98	1.18	.73

[1] Coefficient of variation = standard deviation ÷ mean.
[2] Only one catch.

Table 14. Mean size of fish in grams (or kg when decimal is present, i.e. skates) from otter trawl catches in Ugak and Alitak Bays on Kodiak Island by month, June through September 1976 and March 1977, and by taxon.

Taxa	UGAK BAY June	July	Aug.	Sept.	Mar.	ALITAK BAY June	July	Aug.	Sept.	Mar.
Big skate	6.66	14.82	20.72	19.30	5.13	-	-	-	23.79	-
Longnose skate	-	-	-	1.83	-	-	-	-	-	-
Pacific herring	35	-	77	90	10	54	48	84	88	63
Capelin	15	13	11	13	10	6	8	9	9	7
Eulachon	65	56	40	69	48	63	28	45	40	87
Pacific cod	2252	2348	6580	1023	47	192	131	137	143	44
Pacific tomcod	98	52	130	97	25	69	58	121	63	16
Walleye pollock	84	46	40	7	13	19	37	53	62	14
Soft eelpout	-	-	-	-	-	-	8	10	9	12
Shortfin eelpout	38	36	33	28	17	35	46	29	25	15
Wattled eelpout	47	38	145	-	-	277	237	335	272	317
Pacific sandfish	77	132	10	10	26	56	67	39	31	51
Searcher	30	34	103	51	11	27	56	70	69	24
Longsnout prickleback	20	-	20	15	5	-	34	30	24	14
Daubed shanny	4	5	6	9	4	-	8	8	9	8
Stout eelblenny	6	5	6	7	4	10	5	6	7	7
Snake prickleback	-	35	44	31	-	-	27	50	-	-
Prowfish	-	-	-	-	-	-	-	-	180	-
Sebastes spp	-	468	30	17	10	272	99	45	47	-
Sablefish	160	180	482	90	154	-	-	-	-	130
Masked greenling	-	-	-	10	60	-	-	-	-	77
Whitespot greenling	-	-	-	-	23	20	328	10	34	120
Atka macherel	-	170	-	-	213	-	-	400	-	-
Crested sculpin	-	-	-	-	65	60	-	-	60	-
Silverspotted sculpin	-	-	-	-	-	-	-	-	10	-
Spinyhead sculpin	42	57	48	74	61	40	31	62	30	62
Antlered sculpin	-	8	-	-	-	-	-	-	-	-
Gymnocanthus spp	183	236	246	234	151	156	173	141	20	63
Red Irish Lord	-	680	-	-	-	-	-	-	-	-
Yellow Irish Lord	225	211	149	179	191	110	150	86	60	29

Table 14. (cont.)

Taxa	UGAK BAY June	July	Aug.	Sept.	Mar.	ALITAK BAY June	July	Aug.	Sept.	Mar.
Bigmouth sculpin	153	352	128	30	175	-	160	190	570	-
Thorny sculpin	-	25	-	-	-	-	-	-	-	15
Staghorn sculpin	475	40	-	449	278	-	-	-	292	112
Great sculpin	742	798	760	789	621	691	926	885	852	525
Tadpole sculpin	-	-	-	-	-	-	-	-	3	-
Ribbed sculpin	-	-	30	10	23	-	21	18	-	26
Sculpin spp	-	42	-	-	-	153	-	-	-	-
Sturgeon poacher	67	60	49	113	61	43	10	32	27	34
Tubenose poacher	-	-	10	-	7	-	10	-	10	8
Smooth & Aleutian Alligatorfish	-	-	5	-	5	-	10	-	-	10
Smooth lumpsucker	-	-	-	-	-	-	-	1330	680	880
Snailfish spp	177	131	241	130	1938	137	289	251	367	50
Arrowtooth flounder	38	136	76	98	14	39	45	57	61	29
Rex sole	65	120	33	-	5	-	35	-	30	-
Flathead sole	49	82	43	48	23	64	62	82	58	43
Pacific halibut	1030	1092	1085	1055	1077	1513	1758	1427	1029	506
Butter sole	312	291	205	218	670	142	115	83	160	82
Rock sole	226	315	276	455	209	116	92	126	166	50
Yellowfin sole	283	294	249	241	111	193	240	232	214	182
Dover sole	-	310	10	40	-	-	-	-	-	-
Starry flounder	1218	1515	1325	1263	985	1452	1581	1585	1606	1302
Alaska plaice	1115	1346	360	-	877	834	2043	828	880	622
Sand sole	-	525	683	584	718	-	-	-	325	-
Flounder spp	624	-	-	-	-	43	-	-	-	-

T = Trace ≤0.1 kg

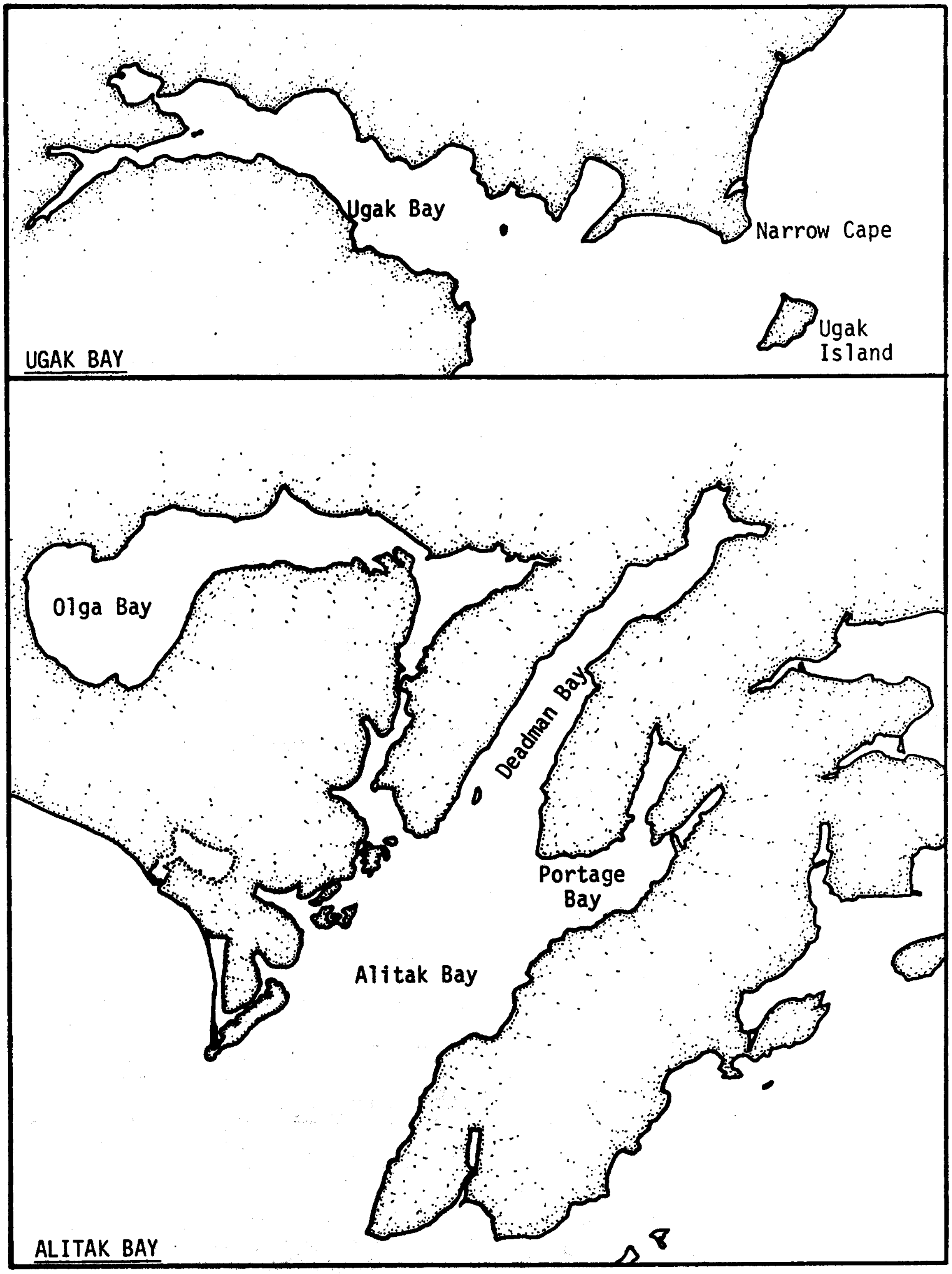


Figure 1. Diagram of the study areas, Ugak and Alitak bays on Kodiak Island.

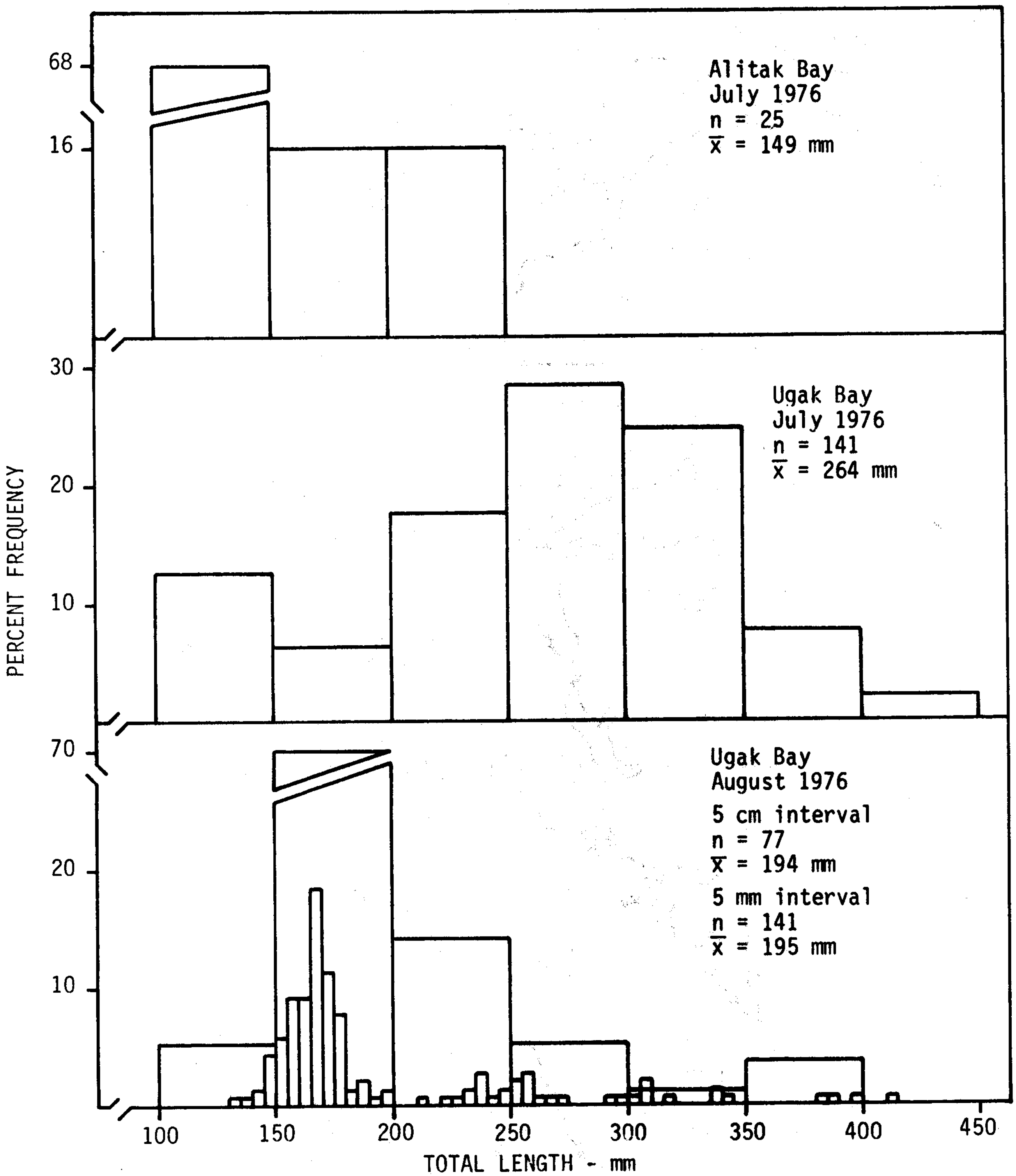


Figure 2. Length frequency distributions of arrowtooth flounder from samples of otter trawl catches in Ugak and Alitak bays during July and August, 1976.

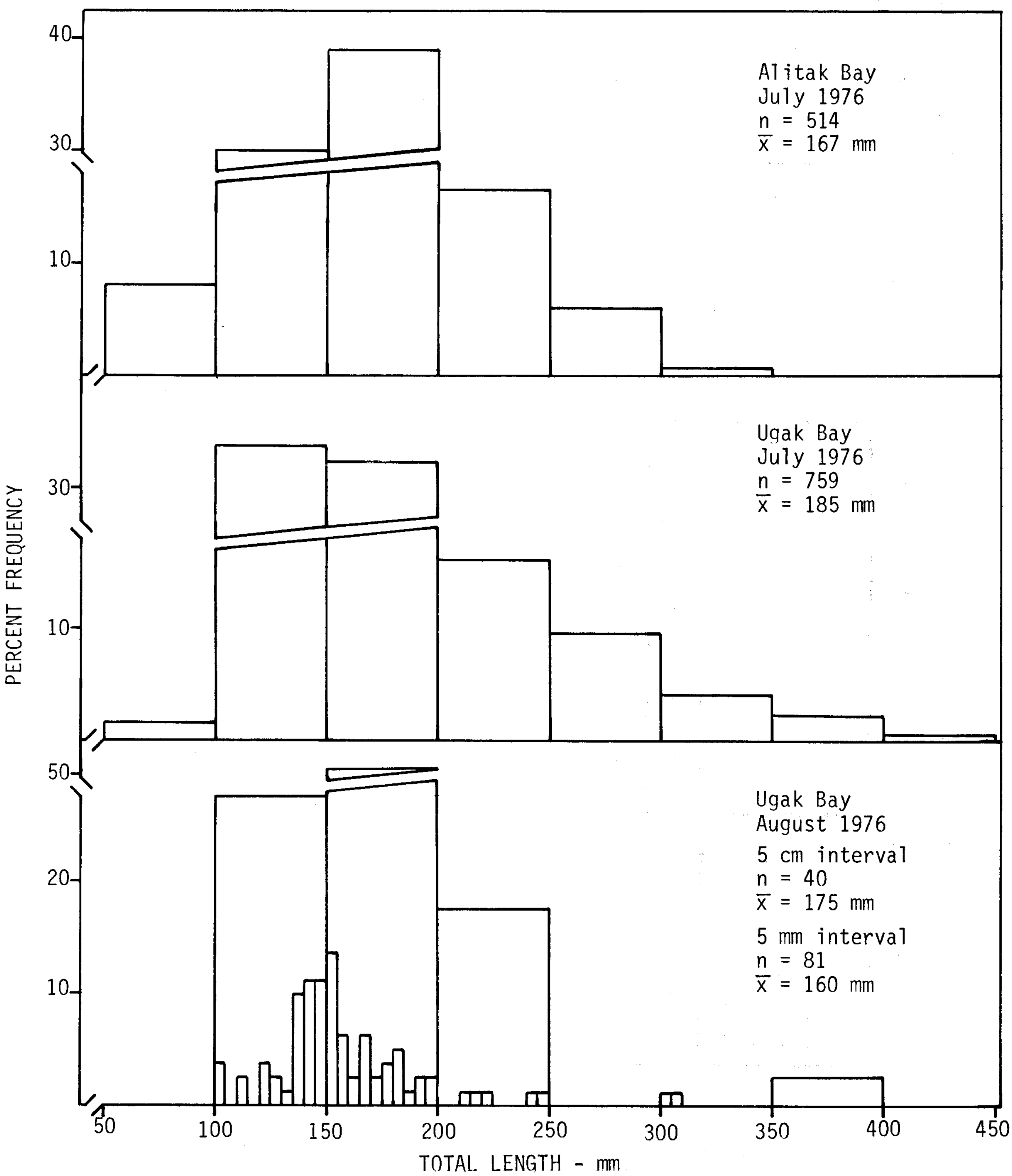


Figure 3. Length frequency distributions of flathead sole from samples of otter trawl catches in Ugak and Alitak bays during July and August, 1976. Data presented in 5 cm and/or 5 mm intervals as indicated.

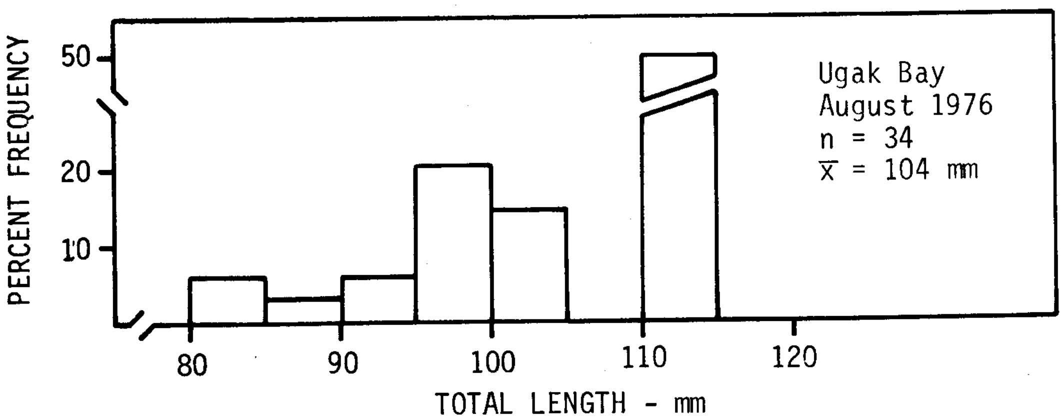


Figure 4. Length frequency distribution of capelin from samples of otter trawl catches in Ugak Bay in August 1976.

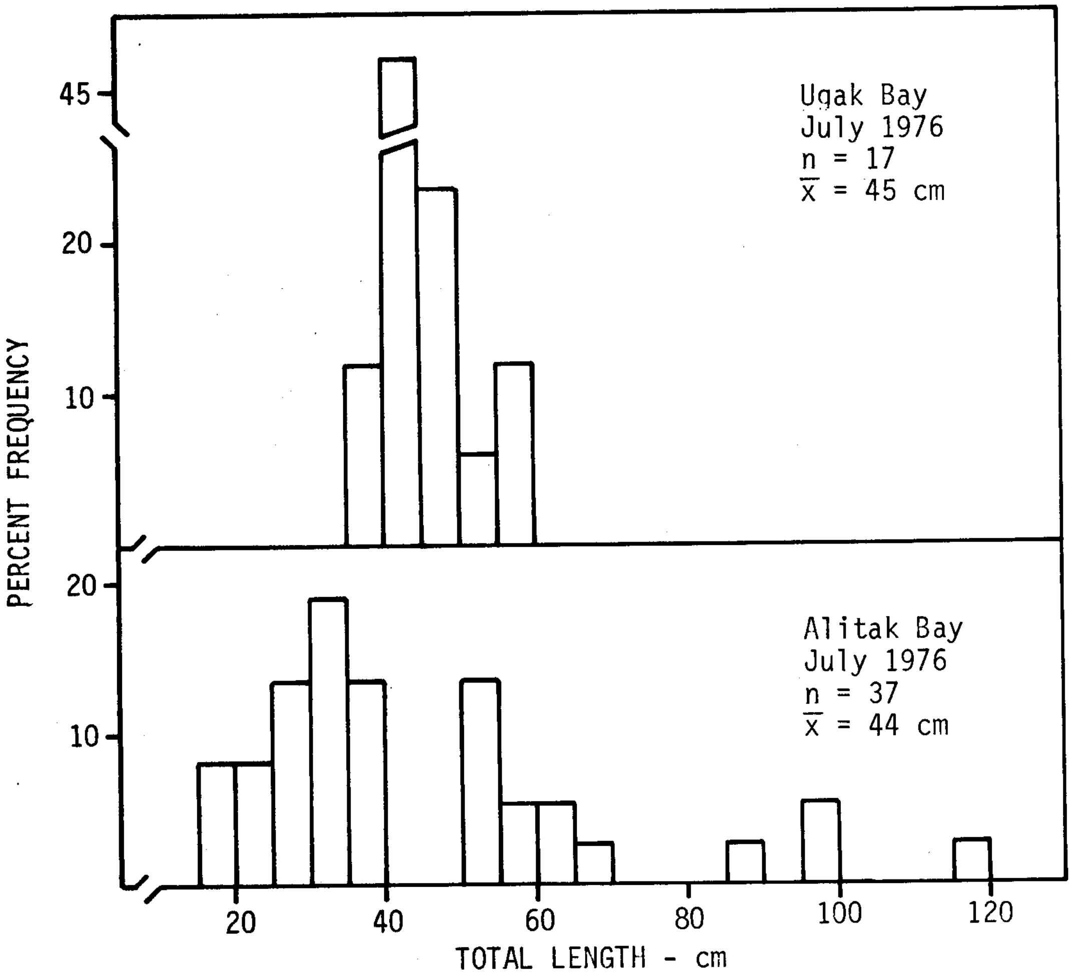


Figure 5. Length frequency distributions of Pacific halibut from samples of otter trawl catches in Ugak and Alitak bays during July 1976.

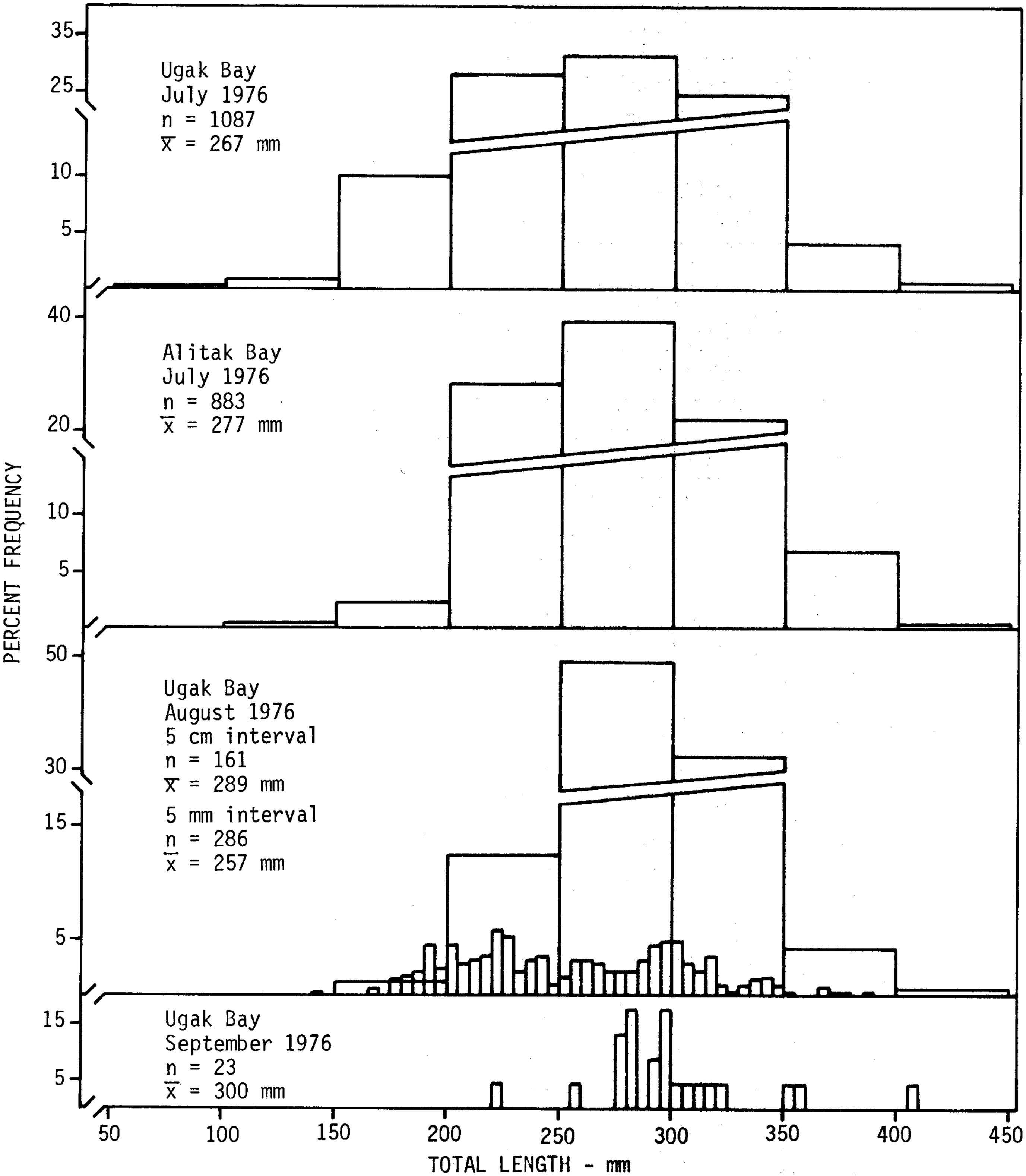


Figure 6. Length frequency distributions of yellowfin sole from samples of otter trawl catches in Ugak and Alitak bays during July, August and September, 1976. Data presented in 5 cm and/or 5 mm intervals as indicated.

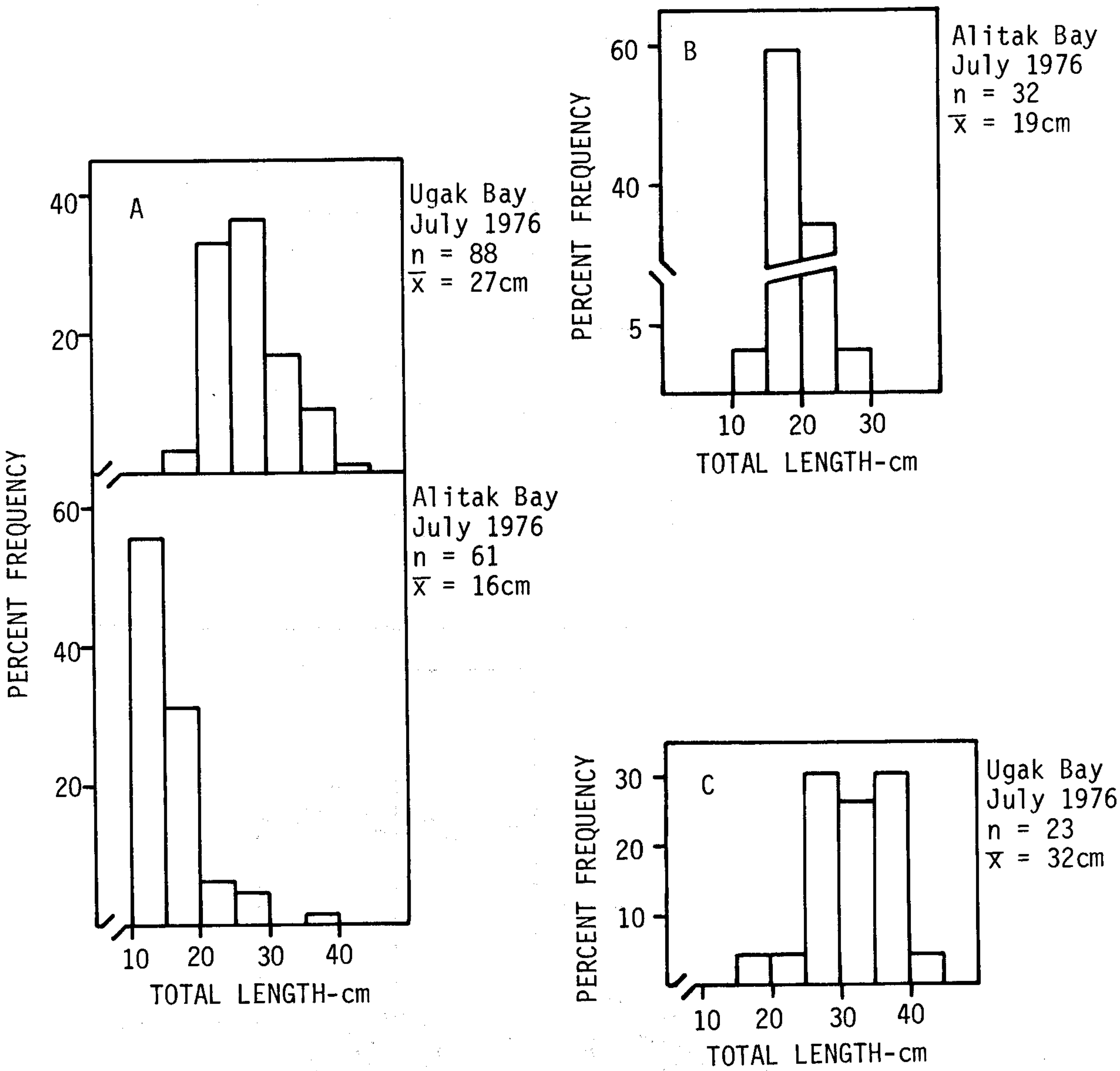


Figure 7. Length frequency distributions of rocksole (A), butter sole (B) and sandsole (C) from samples of otter trawl catches in Ugak and Alitak bays during July, 1976.

Appendix Table 1. Otter trawl catch per unit effort and standard error of yellowfin sole by depth interval and month in Ugak and Alitak bays on Kodiak Island, June through September, 1976 and March, 1977.

Depth, m	June	July	August	September	March
Ugak Bay					
51 - 72	25.0 ± 7.0	41.7 ± 10.0	46.7 ± 11.6	21.9 ± 6.5	196.6 ± 165.3
73 - 81	44.5 ± 16.5	34.7 ± 9.8	26.5 ± 9.6	14.6 ± 0.7	68.0 ± 18.7
82 - 91	21.4 ± 3.8	76.4 ± 21.6	47.4 ± 9.6	26.5 ± 10.2	30.0 ± 4.0
92 - 99	24.9 ± 4.8	9.6 ± 1.6	30.1 ± 7.3	23.3 ± 10.0	28.0 ± 4.3
100 - 104	13.6 ± 1.3	48.2 ± 3.5	27.3 ± 3.2	19.5 ± 4.1	34.9 ± 4.0
Alitak Bay					
29 - 50	35.4 ± 7.6	41.5 ± 7.5	32.2 ± 7.6	28.9 ± 9.0	24.5 ± 15.0
51 - 82	13.2 ± 4.4	24.6 ± 3.8	23.8 ± 12.2	33.8 ± 5.9	91.5 ± 13.0
106 - 174	2.3 ± 0.9	4.2 ± 3.1	0.9 ± 0.7	4.9 ± 1.5	4.9 ± 1.7

Appendix Table 2. Otter trawl catch per unit effort and standard error of flathead sole by depth interval and month in Ugak and Alitak bays on Kodiak Island, June through September, 1976 and March, 1977.

Depth, m	June	July	August	September	March
Ugak Bay					
51 - 72	6.4± 3.3	13.2± 3.7	15.1±5.0	1.8±0.4	1.9±1.0
73 - 81	19.4± 8.1	11.1± 3.0	11.0±3.9	0.9±0.4	1.9±0.9
82 - 91	24.3±11.5	40.1±14.5	14.6±4.2	5.4±1.1	3.1±1.5
92 - 99	42.2±14.9	7.8± 3.3	9.5±3.7	3.4±2.1	2.3±0.7
100 - 104	5.1± 0.3	13.6± 1.2	11.9±4.9	1.8±0.7	1.0±0.2
Alitak Bay					
29 - 50	2.5± 0.7	6.3± 1.1	4.1±1.2	3.1±1.1	0.2±0.2
51 - 82	2.3± 0.4	3.7± 0.4	3.5±1.6	5.2±1.1	1.1±0.3
106 - 174	1.7± 0.5	2.2± 0.6	0.7±0.2	0.9±0.2	0.6±0.1

Appendix Table 3. Otter trawl catch per unit effort and standard error of starry flounder by depth interval and month in Ugak and Alitak bays on Kodiak Island, June through September, 1976 and March, 1977.

Depth, m	June	July	August	September	March
Ugak Bay					
51 - 72	0.0	0.9±0.6	0.9±0.9	16.0±14.3	12.7± 5.0
73 - 81	1.3±0.7	0.0	0.0	7.2± 5.0	5.2± 2.1
82 - 91	0.4±0.3	0.0	1.4±1.1	3.4± 1.8	2.9± 1.0
92 - 99	0.0	0.3±0.3	0.0	1.3± 0.8	3.7± 1.0
100 - 104	0.0	0.0	0.5±0.5	1.3± 0.9	6.8± 2.1
Alitak Bay					
29 - 50	6.4±4.5	2.3±1.0	3.5±2.7	8.9± 3.1	1.4± 0.6
51 - 82	1.0±0.4	0.9±0.5	1.0±1.0	5.5± 2.9	33.0±10.1
106 - 174	1.0±1.0	0.0	0.6±0.6	0.4± 0.2	11.8± 3.7

Appendix Table 4. Otter trawl catch per unit effort and standard error of Pacific halibut by depth interval and month in Ugak and Alitak bays on Kodiak Island, June through September, 1976 and March, 1977.

Depth, m	June	July	August	September	March
Ugak Bay					
51 - 72	6.0±3.6	7.5±3.2	8.2±3.8	6.2± 3.1	1.1±1.1
73 - 81	9.6±5.2	1.0±1.0	3.3±3.3	7.2± 2.9	2.8±2.1
82 - 91	6.2±2.6	4.3±3.2	4.3±1.2	10.2± 6.8	5.9±3.9
92 - 99	9.2±6.0	0.8±0.7	6.1±3.5	12.1±10.4	2.6±2.1
100 - 104	3.9±0.9	3.0±0.9	3.2±1.0	4.4± 1.6	1.5±0.7
Alitak Bay					
29 - 50	13.2±4.3	15.3±5.6	4.1±1.6	2.7± 1.2	0.2±0.1
51 - 82	7.0±2.7	9.3±3.2	8.2±4.8	7.0± 2.8	2.3±1.5
106 - 174	0.1±0.1	0.0	0.0	0.1± 0.1	0.5±0.2

Appendix Table 5. Otter trawl catch per unit effort and standard error of rocksole by depth interval and month in Ugak and Alitak bays on Kodiak Island, June through September, 1976 and March, 1977.

Depth, m	June	July	August	September	March
Ugak Bay					
51 - 72	3.7±3.4	13.5± 6.7	4.0± 1.0	2.4±1.3	3.9±3.9
73 - 81	1.7±0.9	0.6± 0.2	10.5±10.5	3.1±1.1	7.4±3.2
82 - 91	2.0±0.5	12.4±10.7	0.6± 0.1	8.2±4.0	4.5±2.3
92 - 99	4.6±2.3	7.0± 5.5	0.6± 0.5	8.4±7.3	5.4±3.0
100 - 104	0.3±0.2	1.2± 0.3	1.8± 1.2	1.0±0.5	2.7±1.0
Alitak Bay					
29 - 50	4.6±4.5	7.9± 6.1	1.4± 0.8	0.6±0.3	1.8±1.4
51 - 82	T	0.3± 0.1	0.6± 0.3	0.8±0.5	0.1±0.1
106 - 174	0.0	0.0	T	0.0	0.0

T = <0.05

Appendix Table 6. Otter trawl catch per unit effort and standard error of arrowtooth flounder by depth interval and month in Ugak and Alitak bays on Kodiak Island, June through September, 1976 and March, 1977.

Depth, m	June	July	August	September	March
Ugak Bay					
51 - 72	4.3±3.6	2.5±1.0	8.1±4.7	0.9±0.6	T
73 - 81	1.1±1.0	0.1±0.1	2.7±2.6	1.5±1.0	0.0
82 - 91	0.2±0.1	3.2±0.8	5.2±1.4	1.6±0.6	0.0
92 - 99	0.4±0.1	5.6±3.6	4.9±1.9	2.1±0.6	T
100 - 104	0.1±0.1	1.4±0.9	6.0±2.7	1.8±0.7	T
Alitak Bay					
29 - 50	0.1±0.1	0.3±0.1	0.3±0.1	0.4±0.2	0.0
51 - 82	0.0	T	0.1±0.1	0.2±0.1	T
106 - 174	0.0	0.0	0.0	0.0	T

T = <0.05

Appendix Table 7. Otter trawl catch per unit effort and standard error of buttersole by depth interval and month in Ugak and Alitak bays on Kodiak Island, June through September, 1976 and March, 1977.

Depth, m	June	July	August	September	March
Ugak Bay					
51 - 72	3.5±3.5	1.8±1.4	7.5±6.0	10.2±9.8	0.0
73 - 81	4.3±4.0	0.0	0.6±0.6	2.6±2.6	1.0±0.6
82 - 91	2.0±1.4	0.3±0.2	0.2±0.1	0.3±0.2	0.1±0.1
92 - 99	1.1±0.5	0.0	0.2±0.2	0.0	0.0
100 - 104	0.6±0.4	0.1±0.1	0.0	0.2±0.1	0.2±0.2
Alitak Bay					
29 - 50	0.4±0.3	0.6±0.3	0.1±0.1	0.1±0.1	0.0
51 - 82	0.0	0.0	0.0	0.0	0.1±T
106 - 174	0.0	0.0	0.0	0.0	0.0

T = <0.1

Appendix Table 8. Otter trawl catch per unit effort and standard error of walleye pollock by depth interval and month in Ugak and Alitak bays on Kodiak Island, June through September, 1976 and March, 1977.

Depth, m	June	July	August	September	March
Ugak Bay					
51 - 72	0.1±0.1	2.5± 1.4	0.1±0.1	0.2±0.1	2.6±2.0
73 - 81	0.2± T	T	0.0	0.0	3.1±1.2
82 - 91	T	0.4± 0.4	0.2±0.1	0.1± T	5.5±3.9
92 - 99	0.7±0.6	0.0	0.1±0.1	0.1±0.1	3.4±1.3
100 - 104	0.0	T	T	0.1± T	5.8±1.8
Alitak Bay					
29 - 50	4.9±2.8	2.6± 1.6	1.1±0.6	1.0±0.5	0.3±0.3
51 - 82	5.3±2.7	30.7±22.0	12.6±3.6	18.1±8.7	5.0±0.8
106 - 174	0.1± T	0.5± 0.4	0.4±0.3	0.4±0.3	0.6±0.3

T = <0.05

Appendix Table 9. Otter trawl catch per unit effort and standard error of Pacific cod by depth interval and month in Ugak and Alitak bays on Kodiak Island, June through September, 1976 and March, 1977.

Depth, m	June	July	August	September	March
Ugak Bay					
51 - 72	T	0.3± 0.3	0.0	0.2±0.2	0.0
73 - 81	0.3± 0.3	0.0	0.0	0.0	0.1± T
82 - 91	6.8± 3.5	3.4± 2.4	0.8±0.8	1.4±0.9	0.0
92 - 99	70.7±34.1	132.8±113.5	0.0	1.0±1.0	T
100 - 104	1.2± 1.2	3.6± 1.3	0.0	0.1±0.1	T
Alitak Bay					
29 - 50	T	4.9± 4.8	0.9±0.9	0.1±0.1	0.1±0.1
51 - 82	0.1± 0.1	0.3± 0.2	0.2±0.2	0.1±0.1	0.2±0.1
106 - 174	0.0	0.0	0.0	0.0	0.2±0.2

T = <0.05

Appendix Table 10. Otter trawl catch per unit effort and standard error of Pacific tomcod by depth interval and month in Ugak and Alitak bays on Kodiak Island, June through September, 1976 and March, 1977.

Depth, m	June	July	August	September	March
Ugak Bay					
51 - 72	0.1±0.1	1.4±1.1	0.4±0.2	0.1±0.1	0.0
73 - 81	0.0	0.0	0.2±0.2	0.0	T
82 - 91	0.2±0.1	0.1±0.1	0.1± T	0.0	0.1± T
92 - 99	0.3±0.1	0.0	0.1±0.1	0.0	0.6±0.2
100 - 104	0.1±0.1	0.0	0.0	0.0	0.1± T
Alitak Bay					
29 - 50	0.1± T	T	0.8±0.7	0.1±0.1	0.0
51 - 82	0.0	0.0	0.0	T	0.5±0.3
106 - 174	0.0	0.0	0.0	0.0	0.0

T = <0.05

Appendix Table 11. Otter trawl catch per unit effort and standard error of great sculpin by depth interval and month in Ugak and Alitak bays on Kodiak Island, June through September, 1976 and March, 1977.

Depth, m	June	July	August	September	March
Ugak Bay					
51 - 72	8.7±6.4	22.03±9.24	15.9±7.8	6.0± 4.1	10.6±10.5
73 - 81	11.6±6.0	3.32±1.2	13.1±9.4	9.6± 6.2	10.5± 3.6
82 - 91	11.8±1.9	25.1 ±6.1	4.3±2.1	11.8± 4.8	17.1± 7.4
92 - 99	14.4±9.9	14.3 ±9.6	4.0±2.4	25.2±16.3	17.7±10.0
100 - 104	3.8±2.7	4.7 ±1.4	9.4±3.8	10.6± 6.5	25.5± 4.7
Alitak Bay					
29 - 50	12.7±3.3	20.4 ±6.2	10.6±6.6	3.9± 0.9	11.7± 4.6
51 - 82	16.3±4.1	18.8 ±3.9	13.4±5.5	16.3± 2.4	18.3± 5.3
106 - 174	5.2±1.2	7.6 ±2.4	3.7±0.6	18.0± 8.7	11.6± 6.6

Appendix Table 12. Otter trawl catch per unit effort and standard error of yellow Irish Lord by depth interval and month in Ugak and Alitak bays on Kodiak Island, June through September, 1976 and March, 1977.

Depth, m	June	July	August	September	March
Ugak Bay					
51 - 72	17.6±14.8	5.3± 3.4	0.2±0.1	0.9±0.4	T
73 - 81	20.1± 8.7	11.9±11.6	0.7±0.3	0.3±0.2	1.8±0.8
82 - 91	25.0± 5.9	14.0± 5.0	2.3±0.6	2.8±0.4	4.7±2.2
92 - 99	80.1±44.3	12.3± 6.2	3.6±1.0	3.5±1.2	5.9±3.9
100 - 104	14.2± 4.5	12.0± 1.7	4.9±0.9	3.0±1.0	6.0±2.6
Alitak Bay					
29 - 50	0.6± 0.4	4.6± 4.3	0.4±0.2	0.2±0.1	0.0
51 - 82	0.4± 0.1	0.4± 0.2	1.0±0.4	1.1±0.3	0.4±0.1
106 - 174	0.1± 0.1	0.0	T	0.1±0.1	0.0

T - <0.05

Appendix Table 13. Otter trawl catch per unit effort and standard error of *Gymnocanthus* by depth interval and month in Ugak and Alitak bays on Kodiak Island, June, through September, 1976 and March, 1977.

Depth, m	June	July	August	September	March
Ugak Bay					
51 - 72	13.5±10.4	5.4±2.5	7.4±2.7	0.5±0.1	11.6±6.8
73 - 81	5.0± 2.4	9.7±8.1	7.3±5.7	1.0±0.1	15.4±4.7
82 - 91	6.5± 1.6	4.4±2.7	4.8±1.7	3.7±1.0	11.9±3.8
92 - 99	3.4± 1.4	2.4±0.8	6.1±3.1	4.0±3.8	9.2±3.9
100 - 104	5.2± 1.8	20.4±3.9	9.4±4.3	4.8±2.0	11.5±3.5
Alitak Bay					
29 - 50	0.8± 0.2	2.6±2.0	0.3±0.1	T	0.6±0.6
51 - 82	0.0	0.2±0.1	0.0	0.0	0.2±0.1
106 - 174	0.0	0.0	0.0	0.0	0.0

T = <0.05

Appendix Table 14. Otter trawl catch per unit effort and standard error of capelin by depth interval and month in Ugak and Alitak bays on Kodiak Island, June through September, 1976 and March, 1977.

Depth, m	June	July	August	September	March
Ugak Bay					
51 - 72	0.1± T	T	0.1±0.1	0.2± 0.2	0.6±0.4
73 - 81	0.2±0.1	T	0.2±0.2	0.0	2.0±0.7
82 - 91	0.9±0.3	0.1± T	0.5±0.3	5.2± 4.6	5.1±2.7
92 - 99	4.6±3.5	T	4.7±3.1	16.3±16.3	5.8±2.8
100 - 104	1.2±0.6	1.2±0.1	5.0±3.7	0.1± T	12.7±1.8
Alitak Bay					
29 - 50	0.1± T	T	T	T	T
51 - 82	1.0±0.8	0.1± T	T	T	0.1± T
106 - 174	T	T	0.5±0.2	1.9± 1.1	2.3±0.7

T = <0.05

Appendix Table 15. Otter trawl catch per unit effort and standard error of Pacific sandfish by depth interval and month in Ugak and Alitak bays on Kodiak Island, June through September, 1976 and March, 1977.

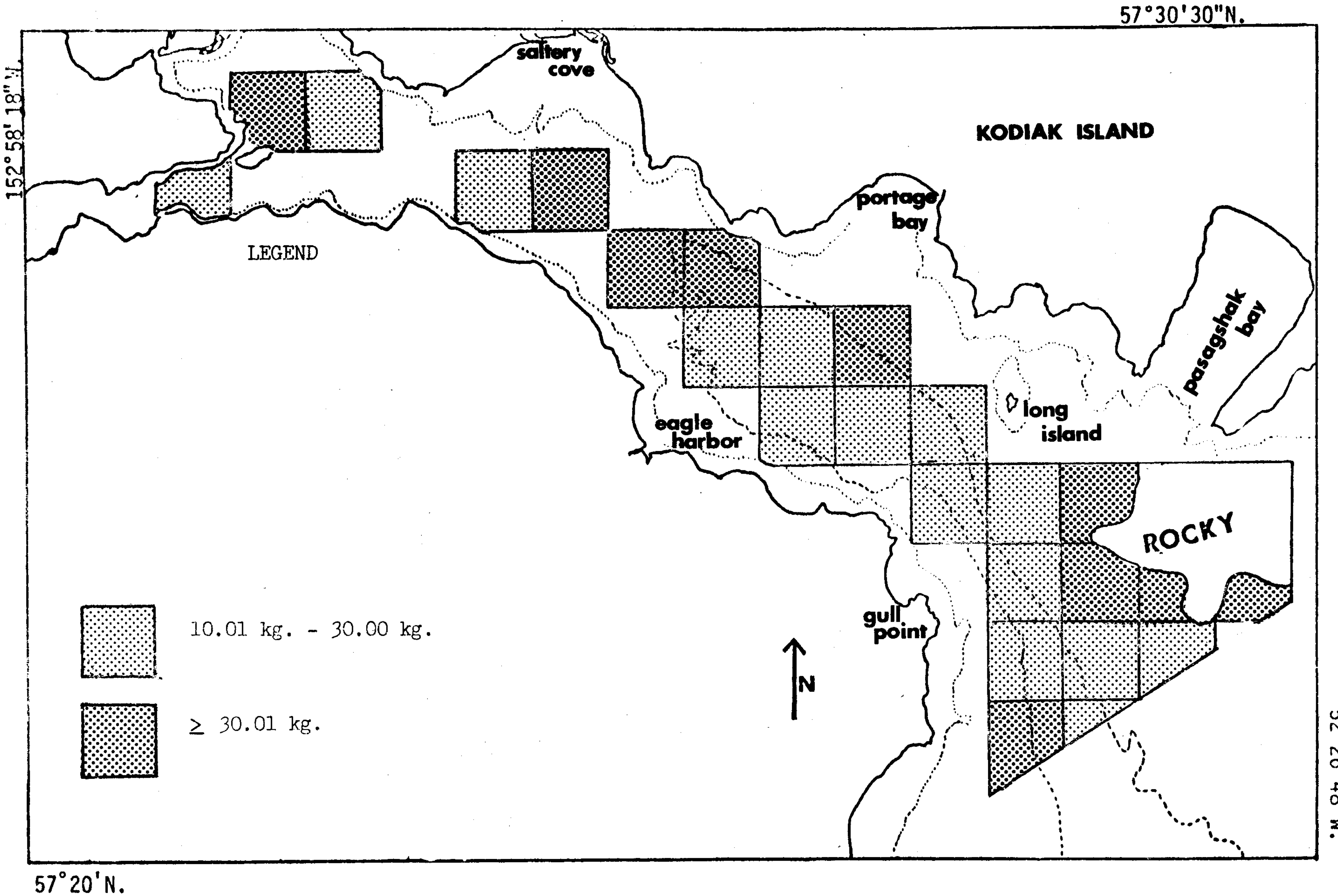
Depth, m	June	July	August	September	March
Ugak Bay					
51 - 72	0.0	0.0	0.8±0.3	0.3±0.1	0.0
73 - 81	T	0.0	0.4±0.3	0.1±0.1	0.1±0.1
82 - 91	0.1±T	0.4±0.3	0.5±0.1	1.0±0.3	T
92 - 99	0.1±T	0.1±0.1	1.0±0.3	0.1±0.1	T
100 - 104	0.0	T	0.7±0.4	T	0.1±T
Alitak Bay					
29 - 50	T	0.1±T	0.1±T	0.3±0.2	0.0
51 - 82	T	0.3±0.2	0.6±0.4	0.9±0.3	T
106 - 174	0.0	0.0	0.0	0.0	0.0

T = <0.05

Appendix Table 16. Otter trawl catch per unit effort and standard error of eelpouts by depth interval and month in Ugak and Alitak bays on Kodiak Island, June through September, 1976 and March, 1977.

Depth, m	June	July	August	September	March
Ugak Bay					
51 - 72	0.1±0.1	T	0.2±0.1	T	0.0
73 - 81	T	0.1± T	0.4±0.2	0.0	0.0
82 - 91	0.1±0.1	2.0±0.8	0.5±0.2	0.3±0.1	T
92 - 99	0.5±0.2	1.2±0.8	0.6±0.3	0.4±0.3	0.0
100 - 104	0.3±0.3	0.4±0.2	0.6±0.3	0.2±0.2	0.0
Alitak Bay					
29 - 50	0.4±0.2	0.1±0.1	0.1±0.1	T	T
51 - 82	1.8±0.5	1.1±0.3	0.8±0.3	1.4±0.7	0.2±0.1
106 - 174	3.3±0.9	8.4±1.8	1.7±0.3	2.8±0.9	0.3±0.1

T = <0.05



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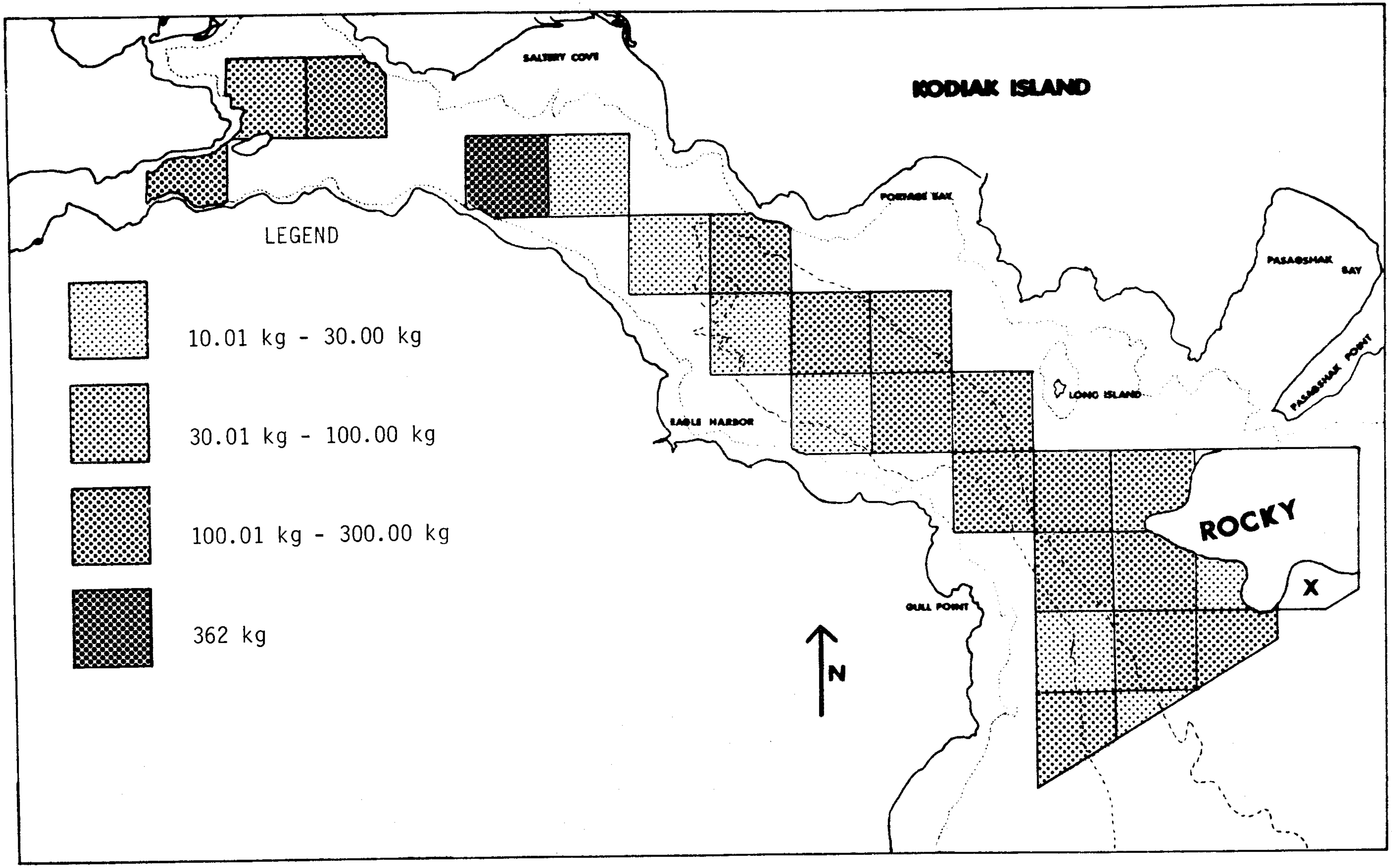
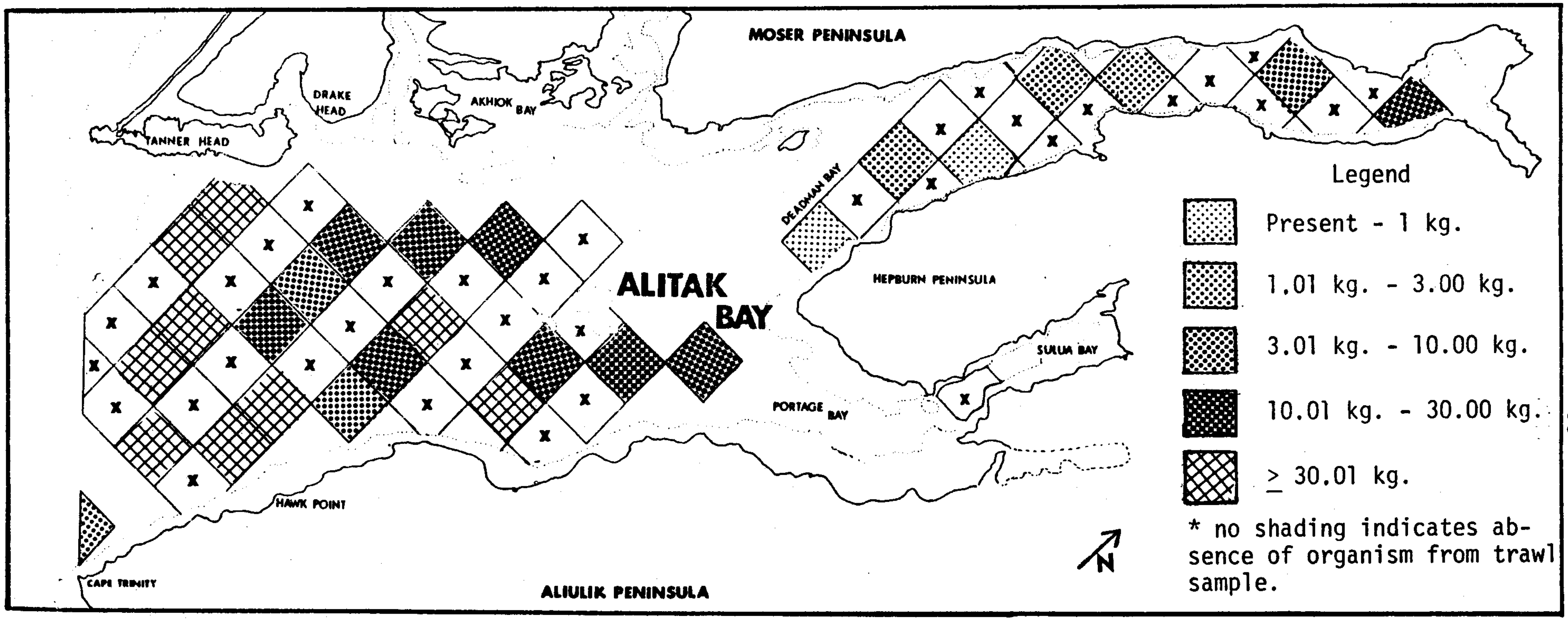
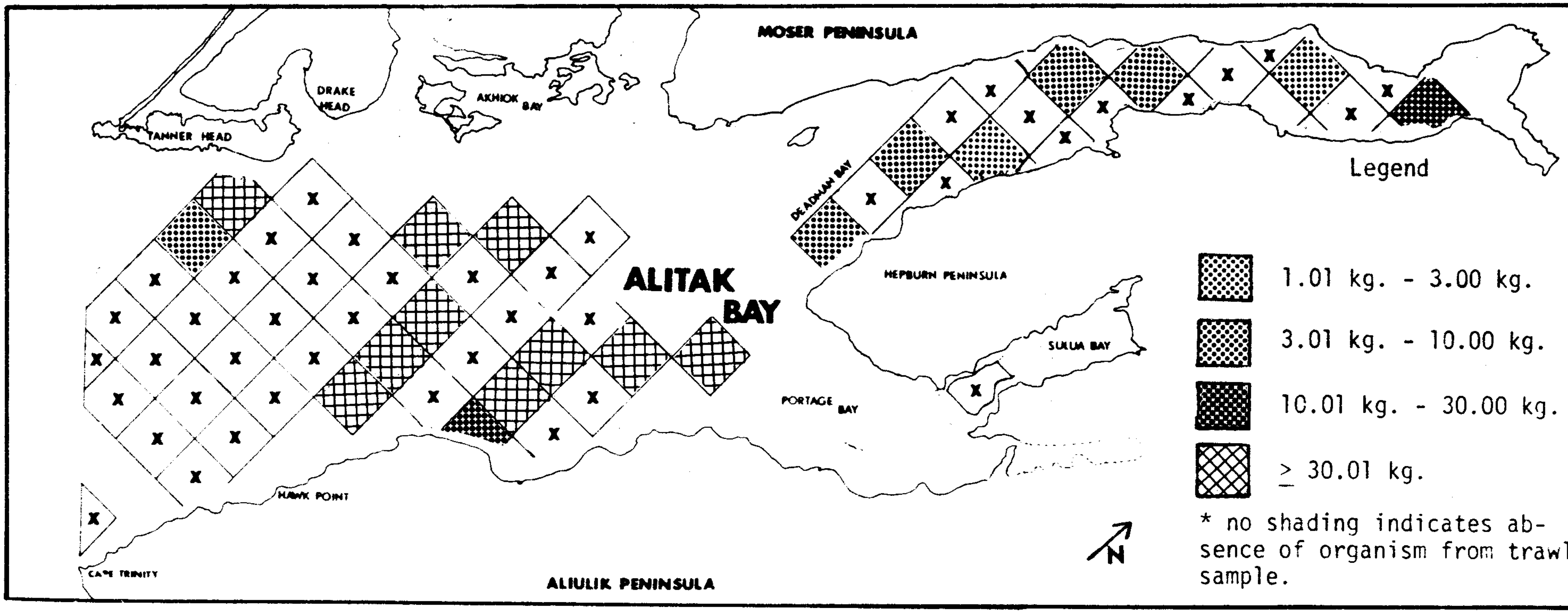
App. Fig. 1. Distribution and mean catch in kg per 20 minute tow of yellowfin sole in Ugak Bay during June, July, August and September, 1976.



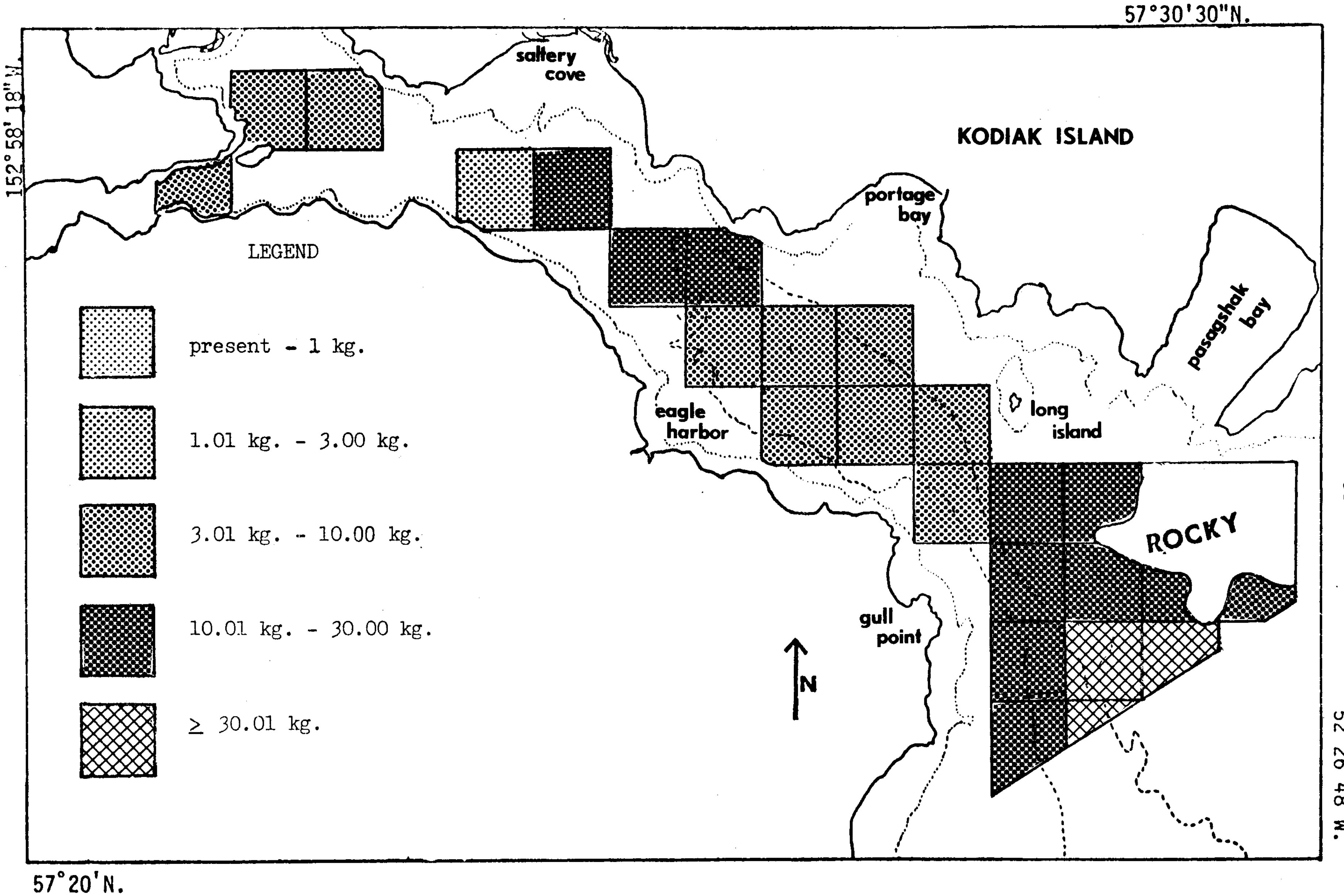
App. Fig. 2. Distribution and mean catch in kg per 20 minute tow of yellowfin sole in Ugak Bay during March, 1977. Note the greater value of the shading in this figure than in others. X indicates station not sampled.



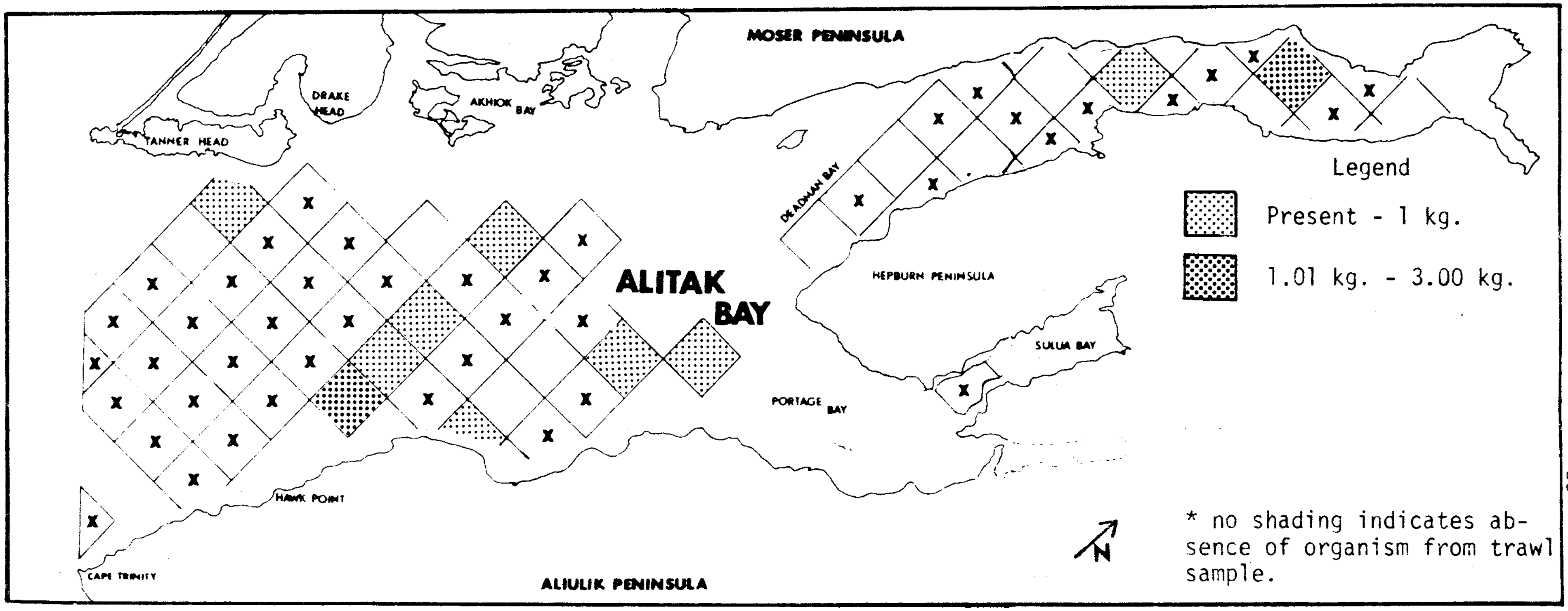
App. Fig. 3. Distribution and mean catch in kg per 20 minute tow of yellowfin sole in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



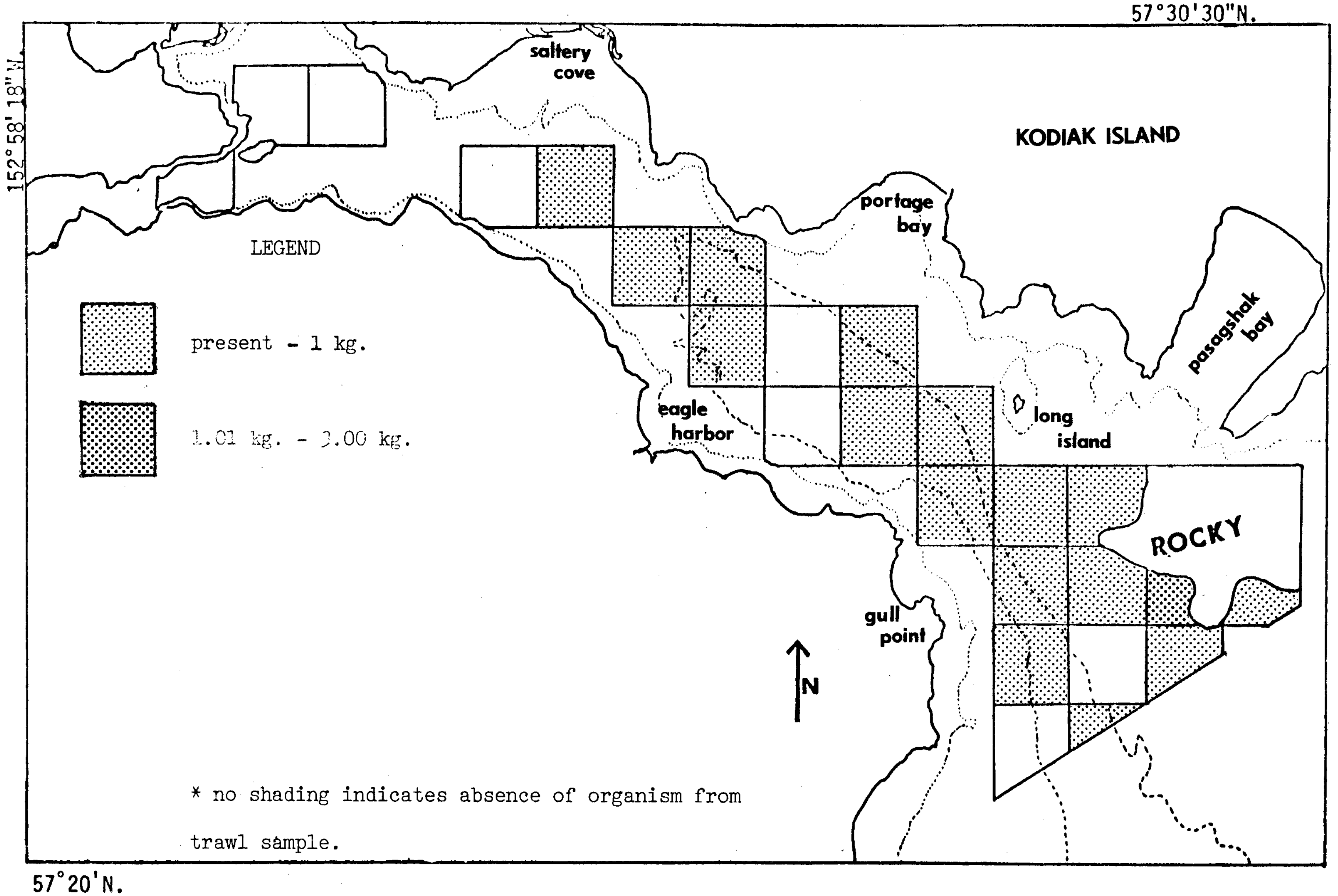
App. Fig. 4. Distribution and mean catch in kg per 20 minute tow of yellowfin sole in Alitak Bay during March, 1977. X indicates station not sampled.



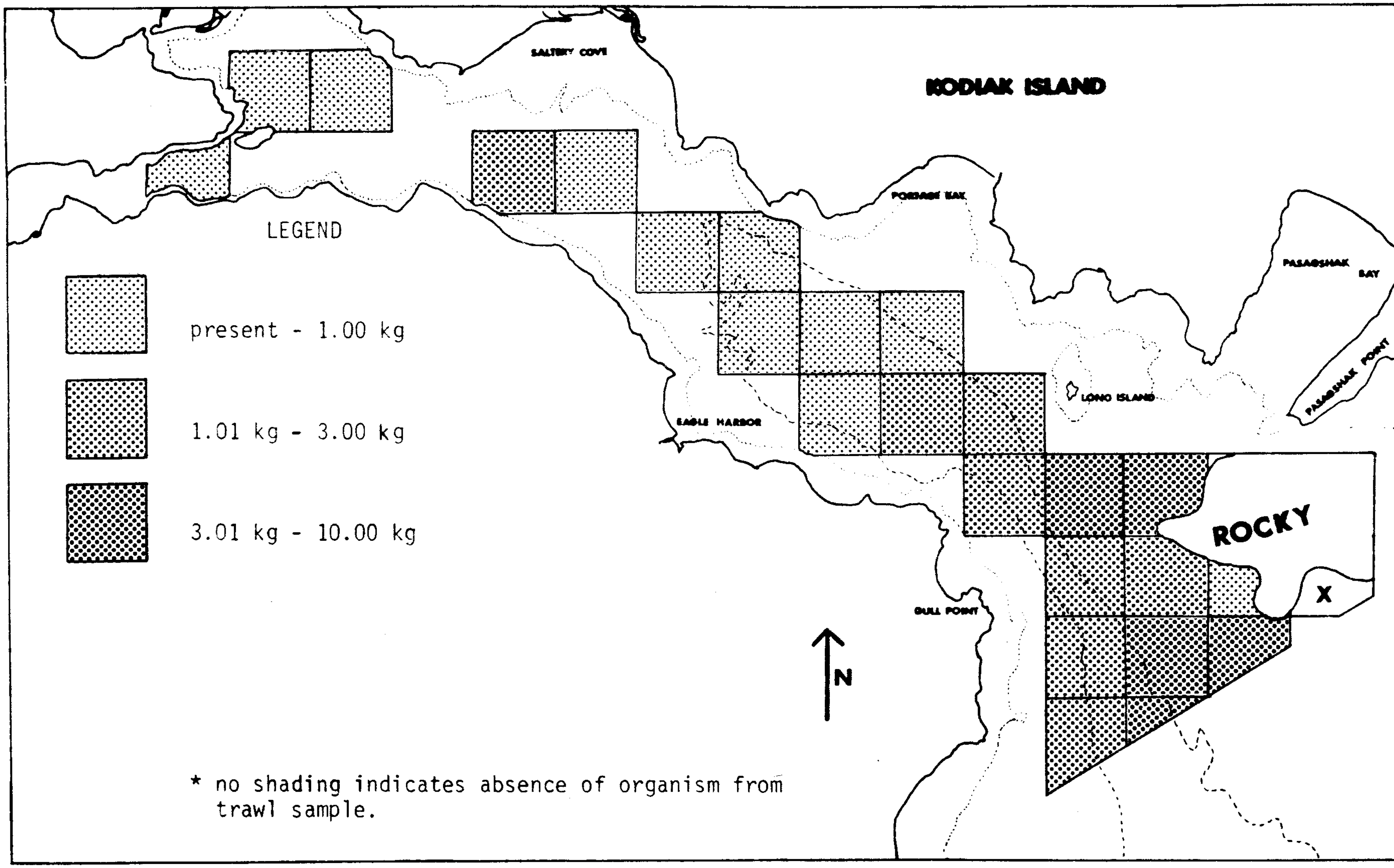
App. Fig. 5. Distribution and mean catch in kg per 20 minute tow of flathead sole in Ugak Bay during June, July, August and September, 1976.



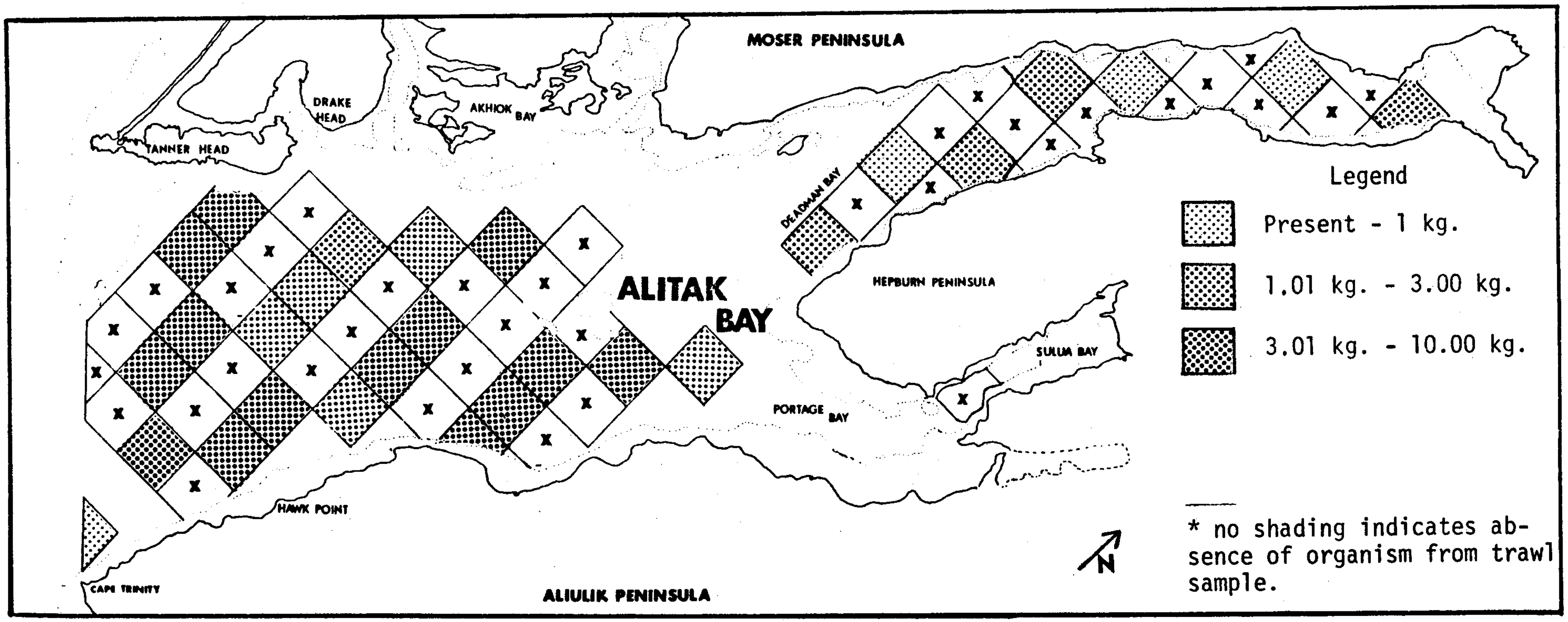
App. Fig. 36. Distribution and mean catch in kg per 20 minute tow of Pacific cod in Alitak Bay during March, 1977. X indicates station not sampled.



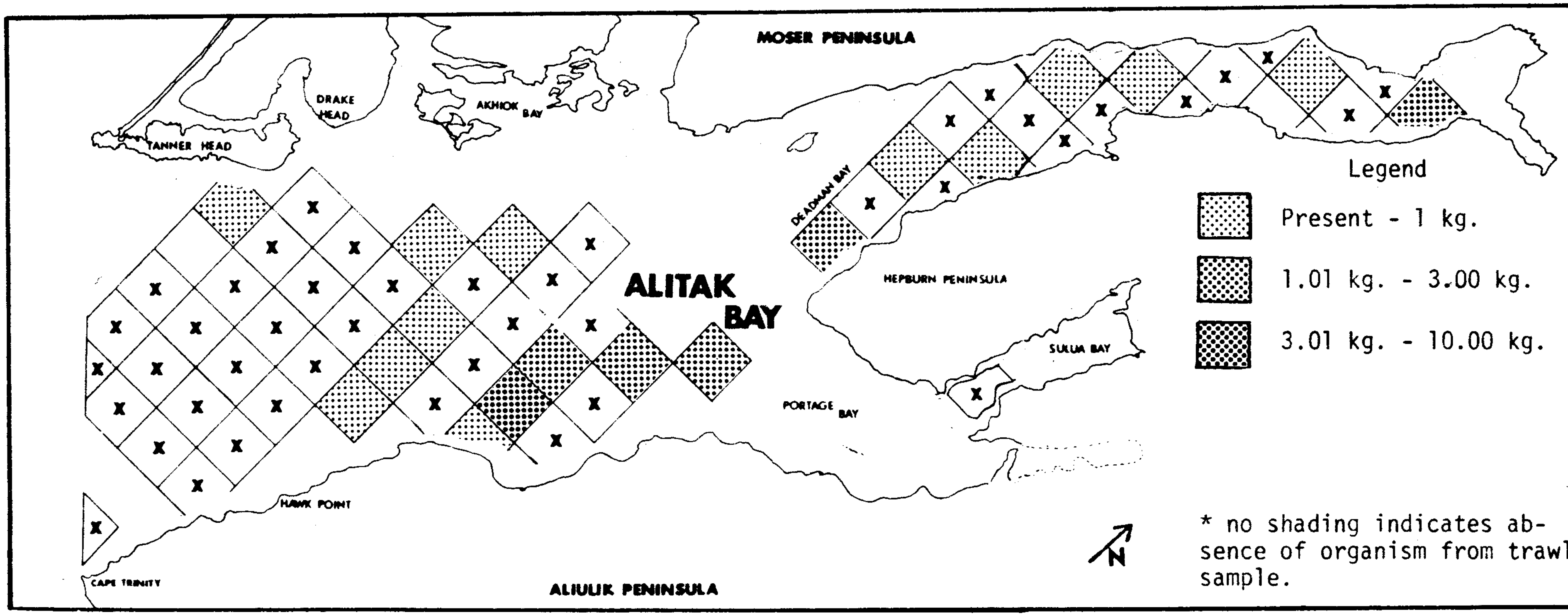
App. Fig. 37. Distribution and mean catch in kg per 20 minute tow of Pacific tomcod in Ugak Bay during June, July, August and September, 1976.



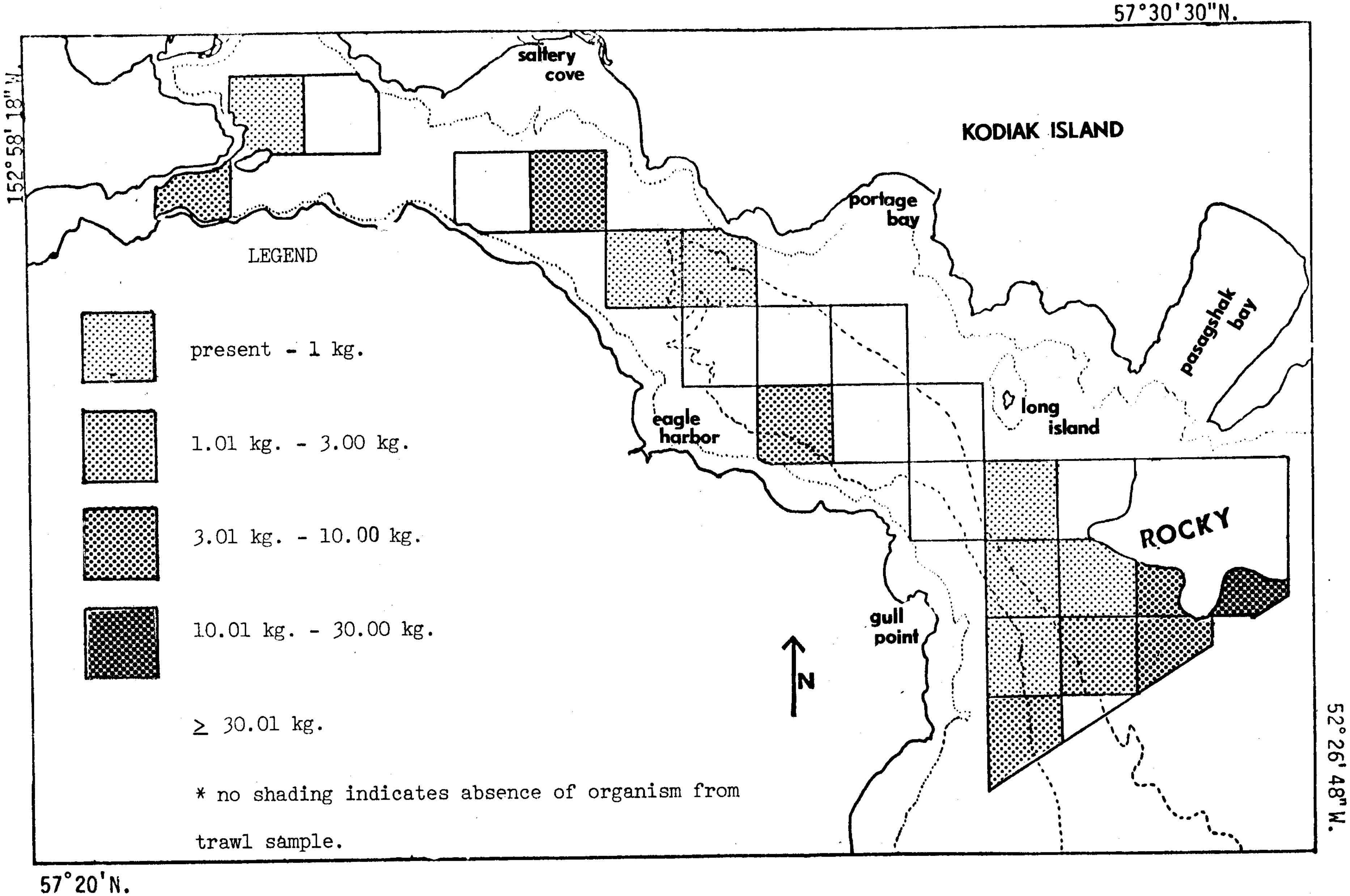
App. Fig. 6. Distribution and mean catch in kg per 20 minute tow of flathead sole in Ugak Bay during March, 1977. X indicates station not sampled.



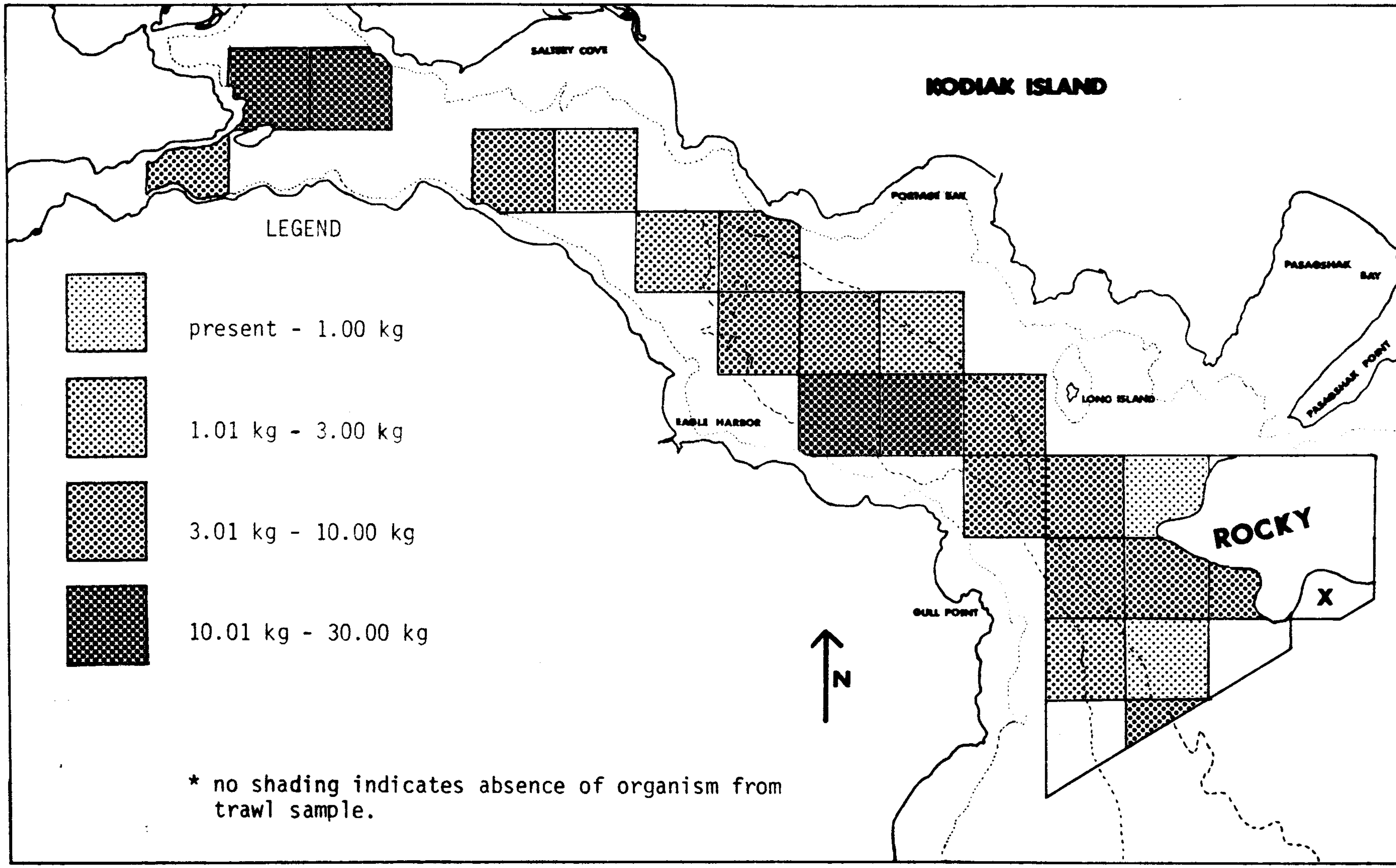
App. Fig. 7. Distribution and mean catch in kg per 20 minute tow of flathead sole in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



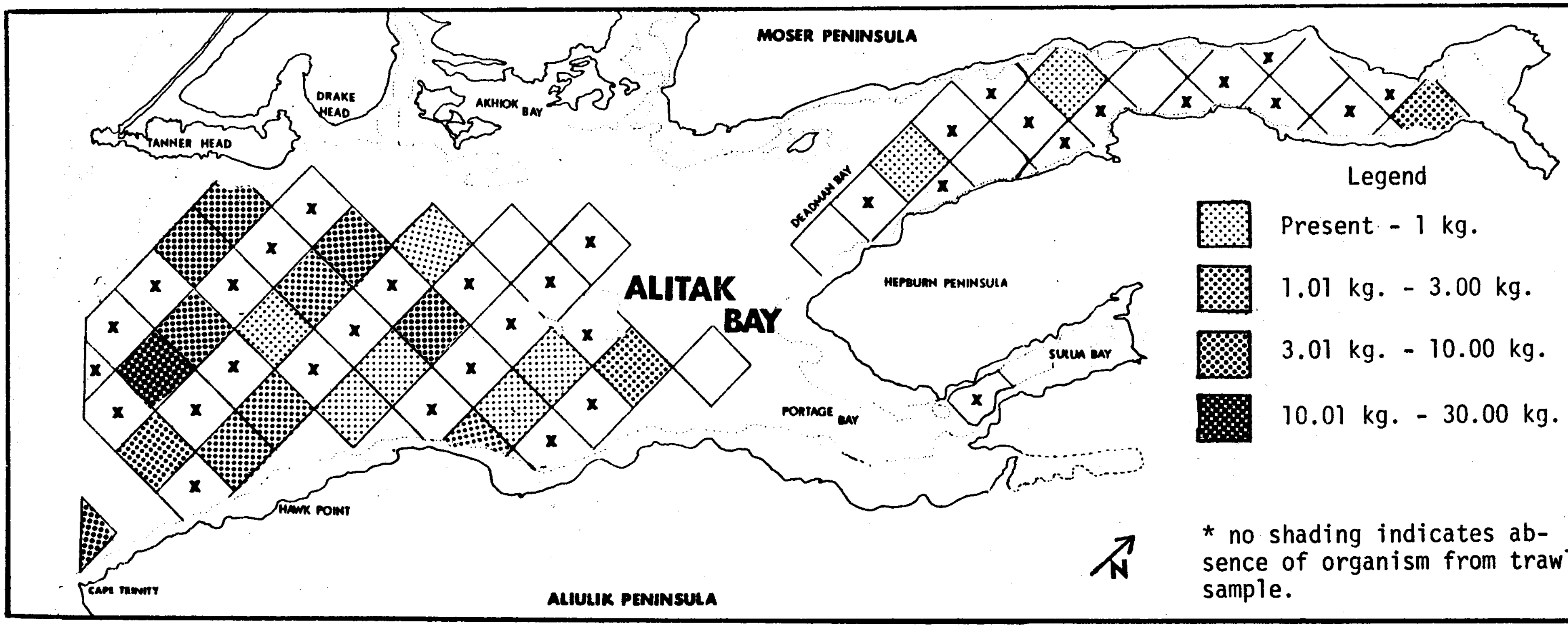
App. Fig. 8. Distribution and mean catch in kg per 20 minute tow of flathead sole in Alitak Bay during March, 1977. X indicates station not sampled.



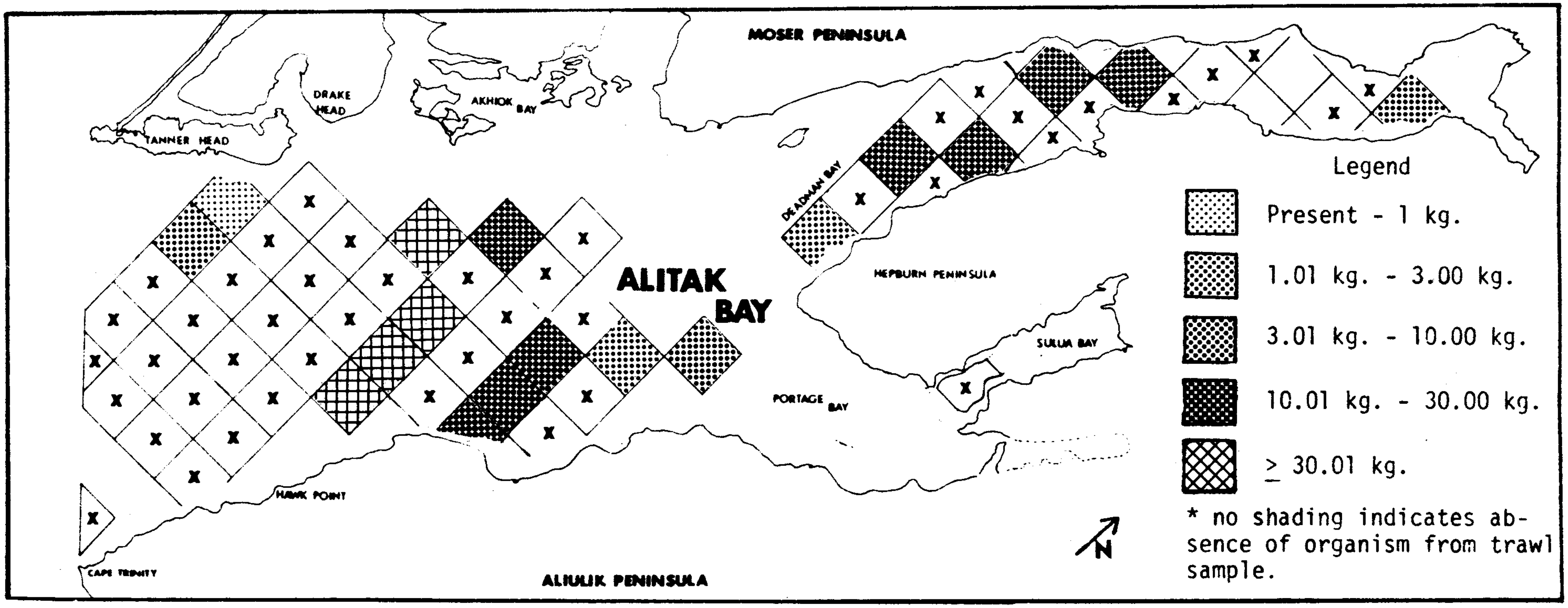
App. Fig. 9. Distribution and mean catch in kg per 20 minute tow of starry flounder in Ugak Bay during June, July, August and September, 1976.



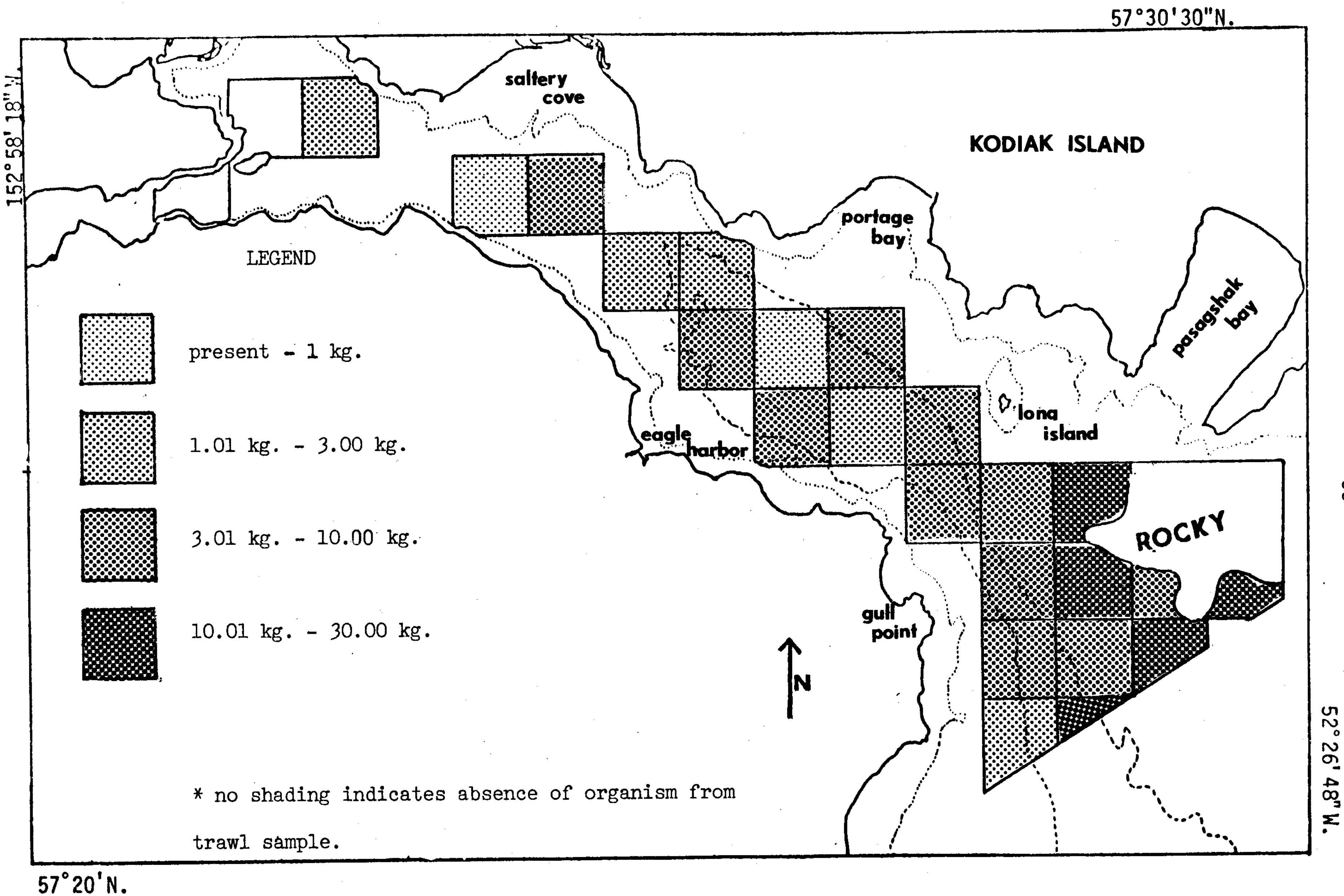
App. Fig. 10. Distribution and mean catch in kg per 20 minute tow of starry flounder in Ugak Bay during March, 1977. X indicates station not sampled.



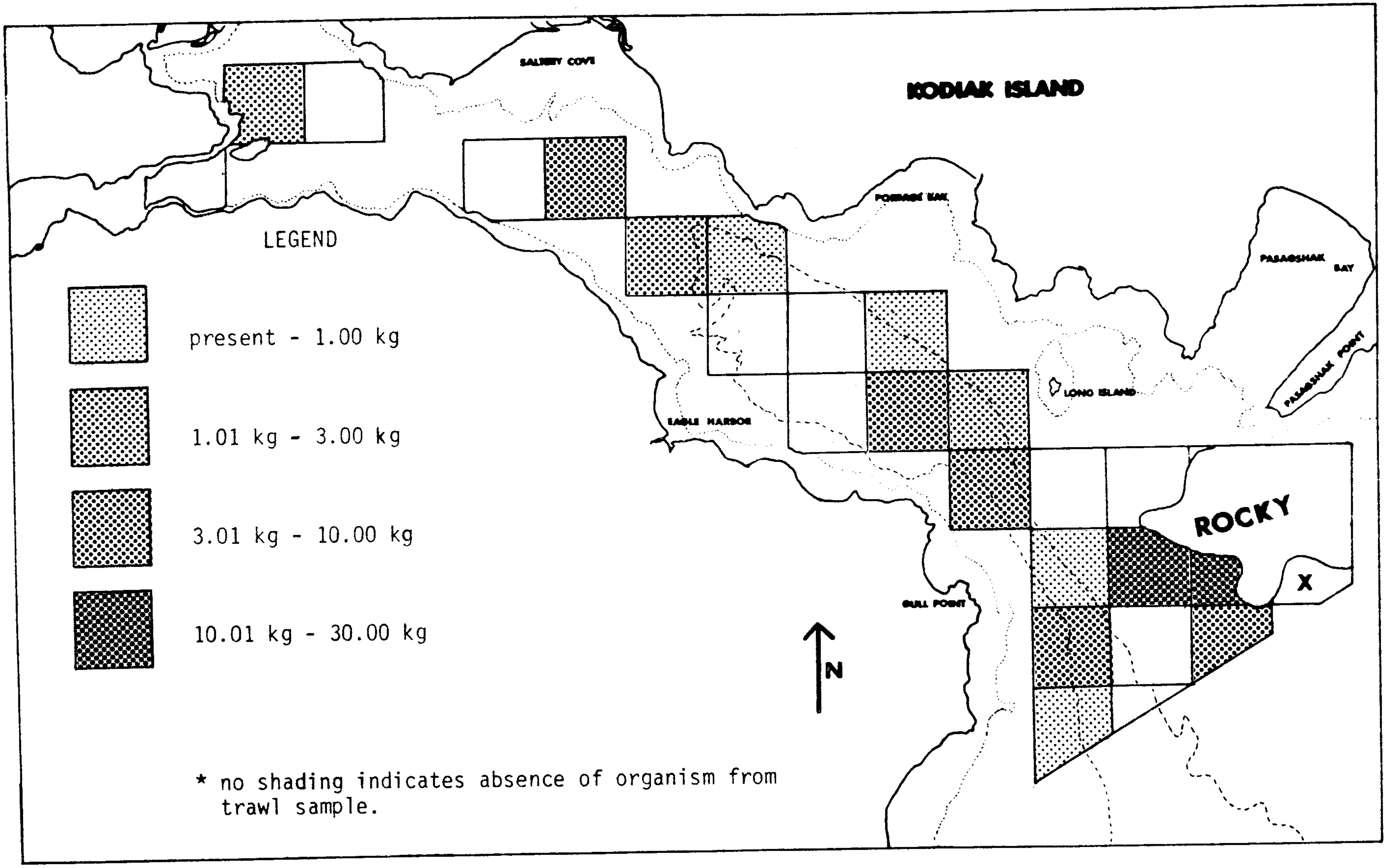
App. Fig. 11. Distribution and mean catch in kg per 20 minute tow of starry flounder in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



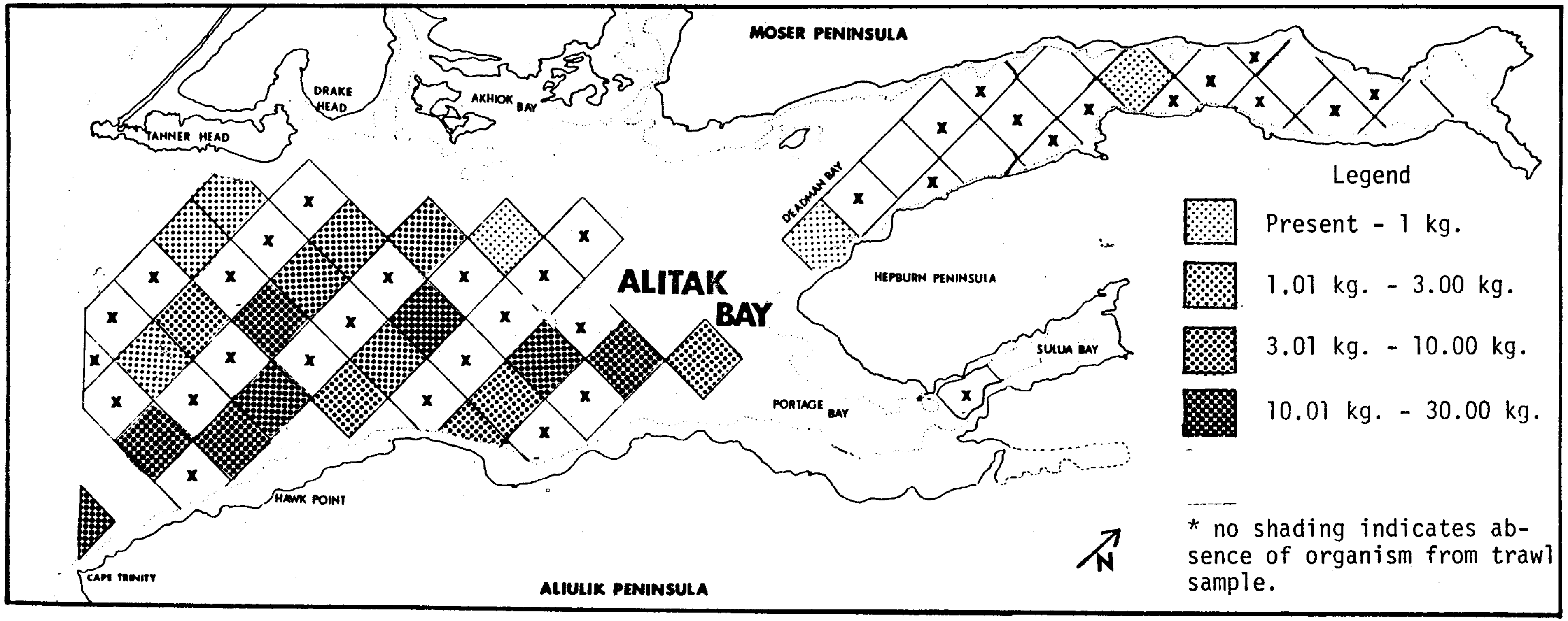
App. Fig. 12. Distribution and mean catch in kg per 20 minute tow of starry flounder in Alitak Bay during March, 1977. X indicates station not sampled.



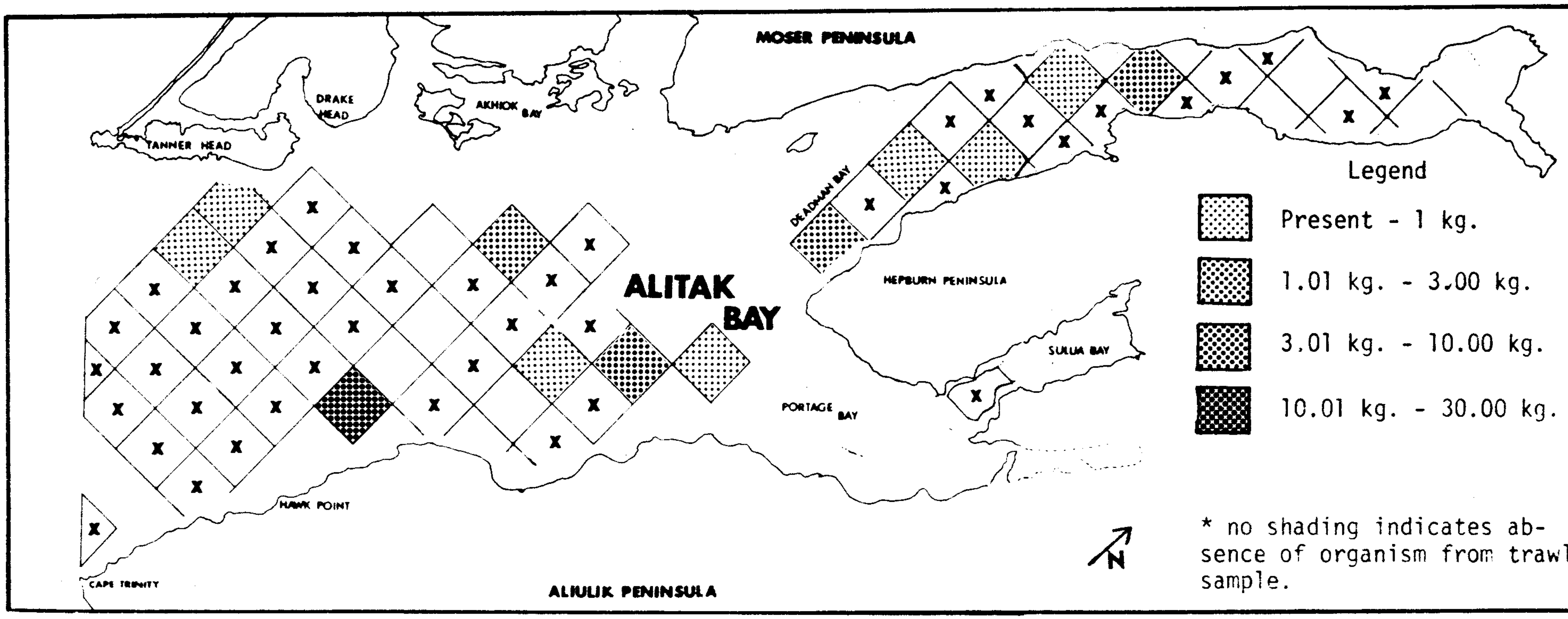
App. Fig. 13. Distribution and mean catch in kg per 20 minute tow of Pacific halibut in Ugak Bay during June, July, August and September, 1976.



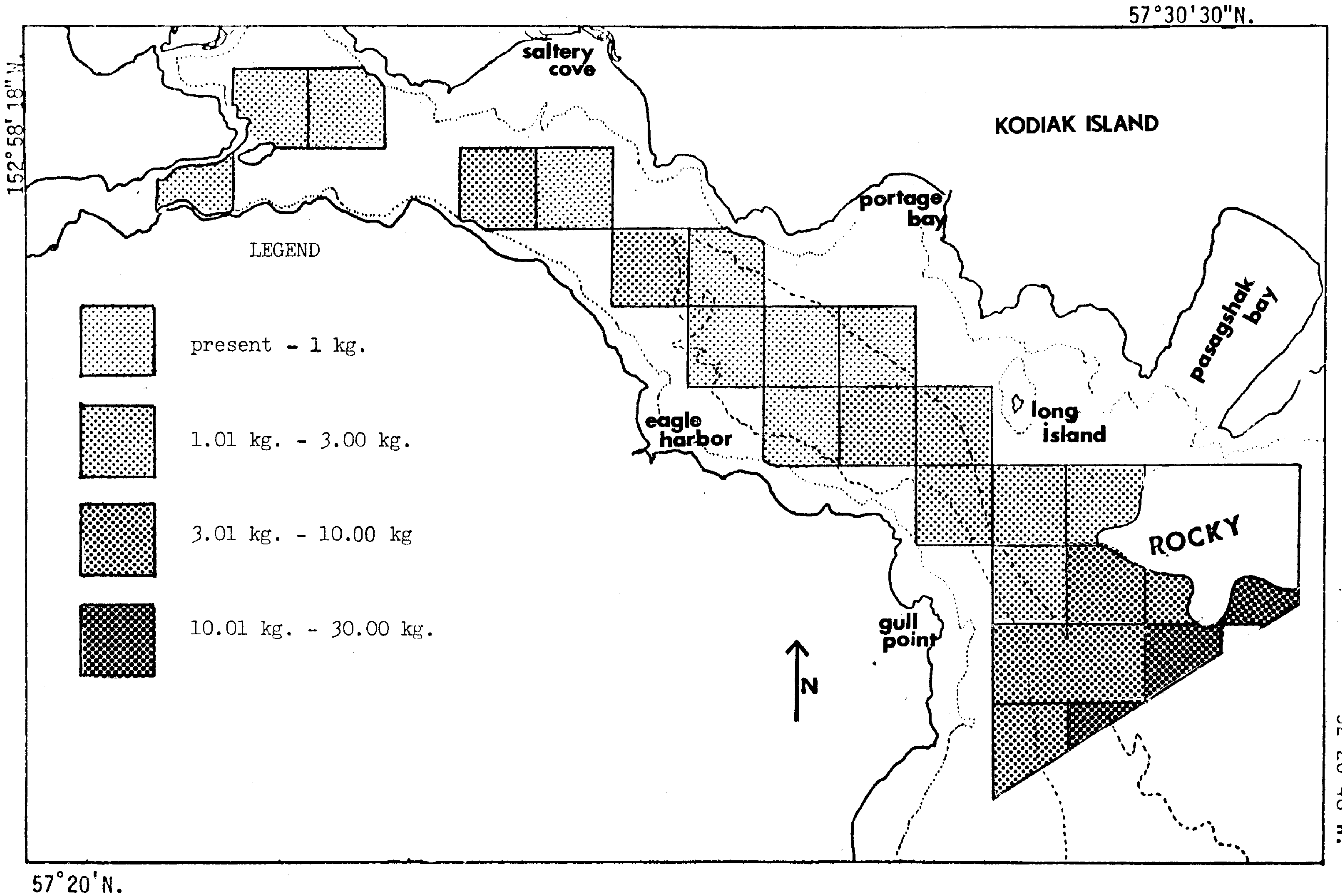
App. Fig. 14. Distribution and mean catch in kg per 20 minute tow of Pacific halibut in Ugak Bay during March, 1977. X indicates station not sampled.



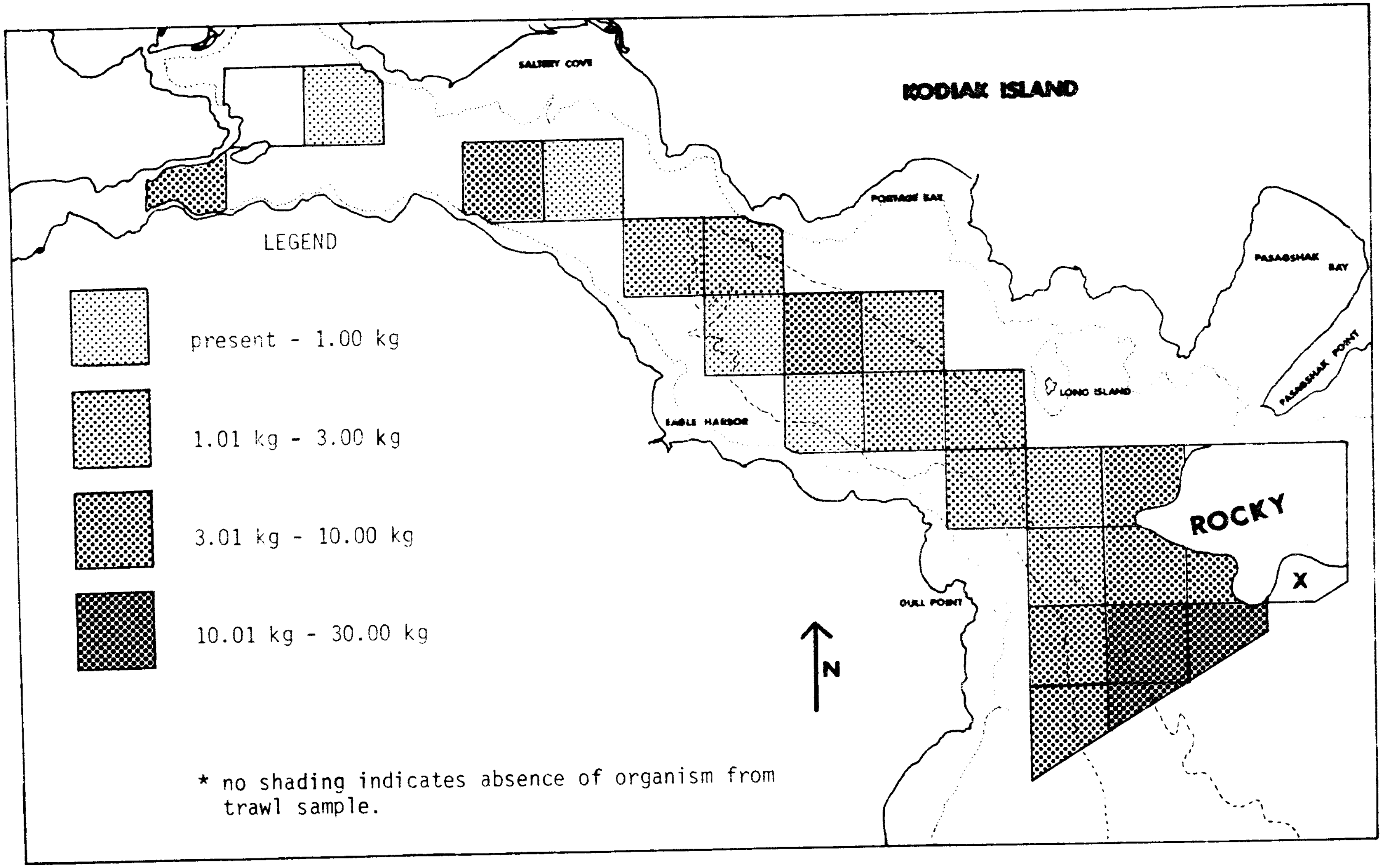
App. Fig. 15. Distribution and mean catch in kg per 20 minute tow of Pacific halibut in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



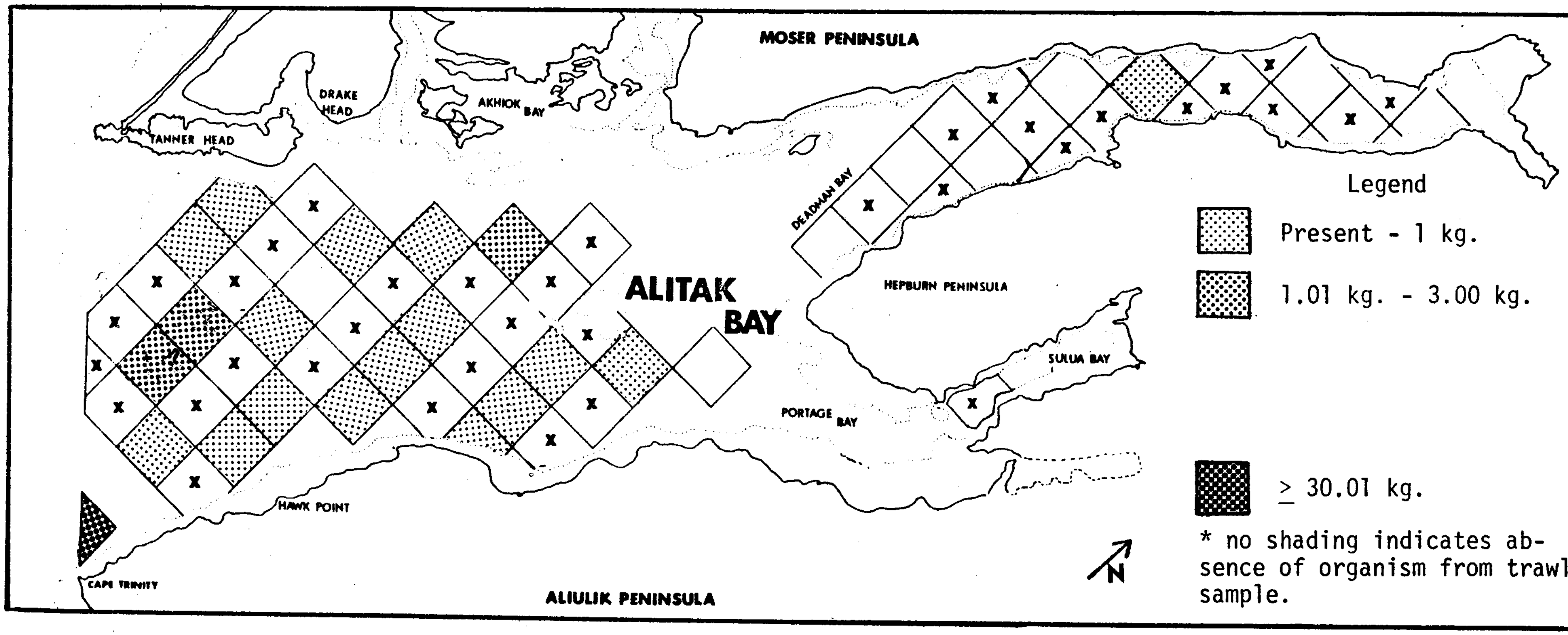
App. Fig. 16. Distribution and mean catch in kg per 20 minute tow of Pacific halibut in Alitak Bay during March, 1977. X indicates station not sampled.



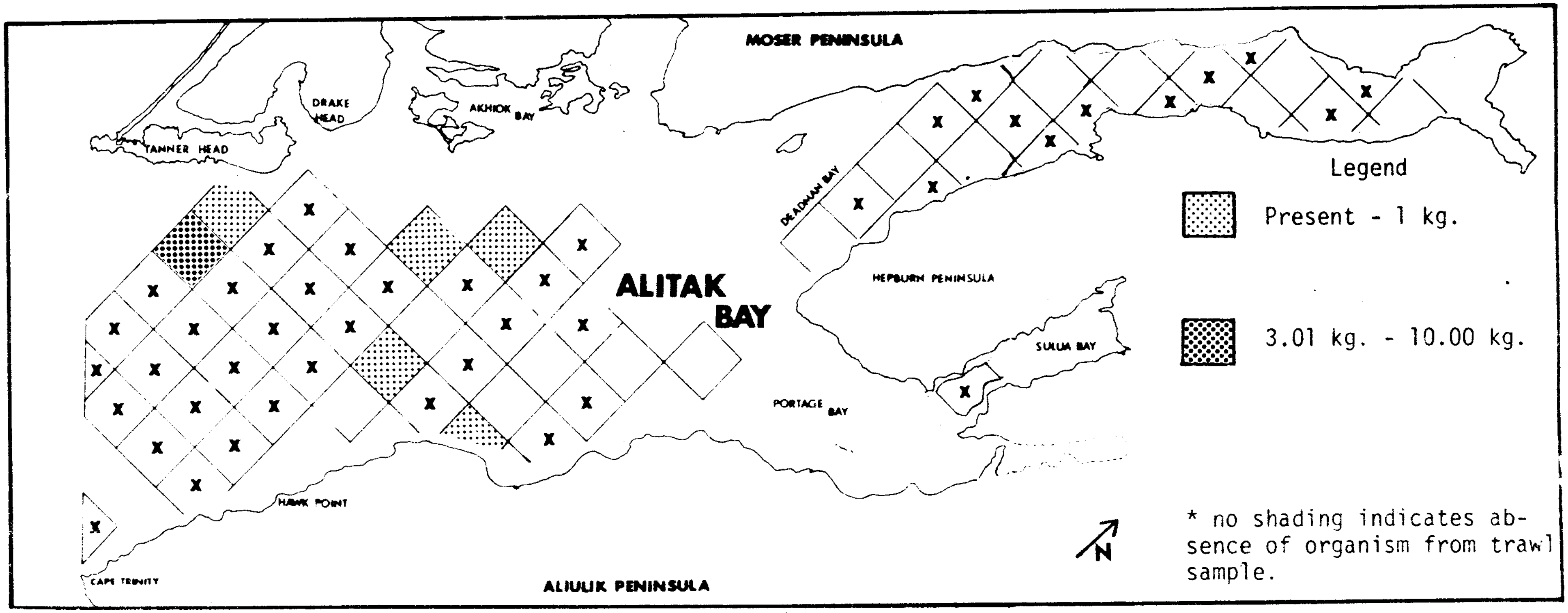
App. Fig. 17. Distribution and mean catch in kg per 20 minute tow of rock sole in Ugak Bay during June, July, August and September, 1976.



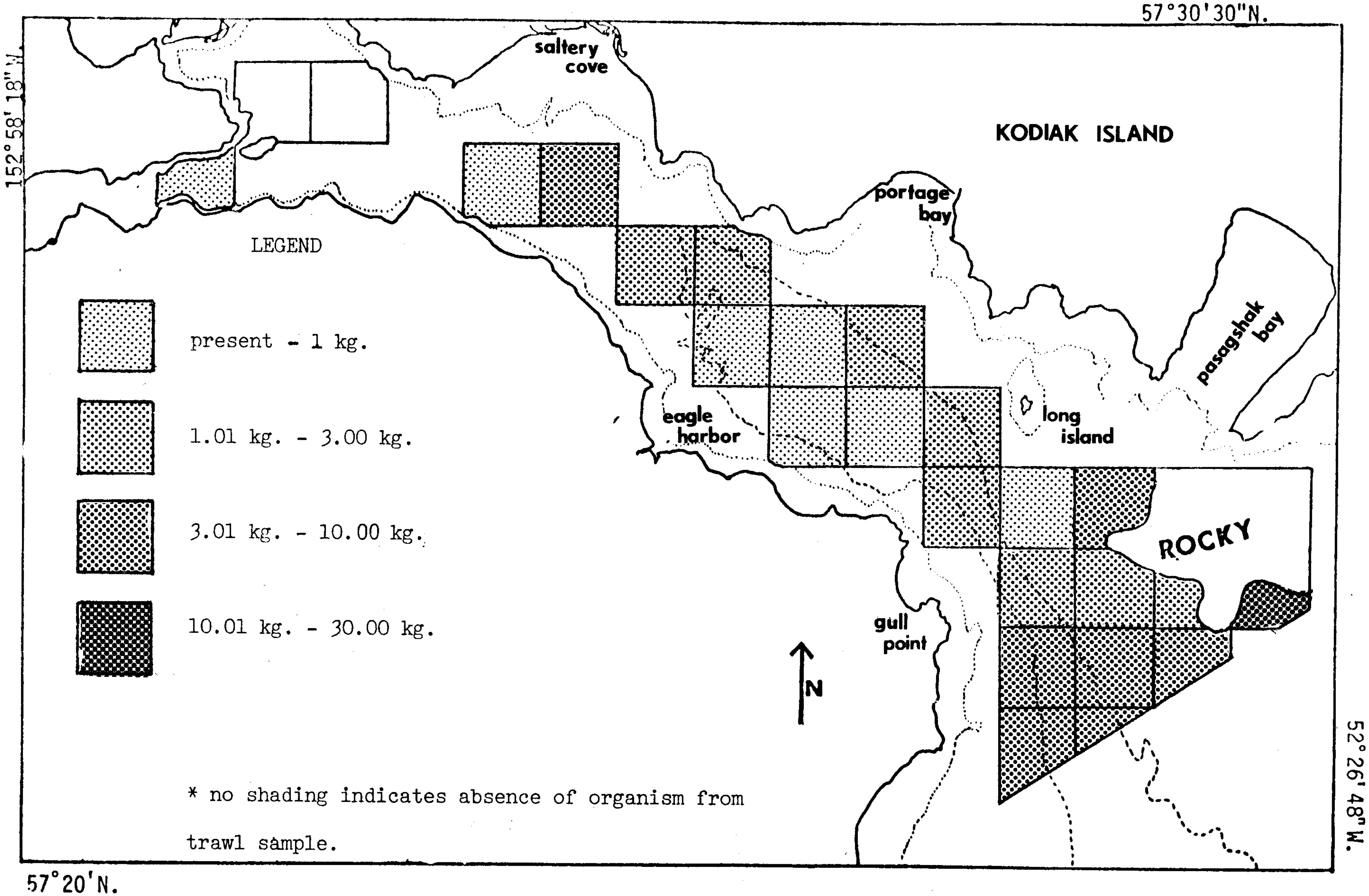
App. Fig. 18. Distribution and mean catch in kg per 20 minute tow of rock sole in Ugak Bay during March, 1977. X indicates station not sampled.



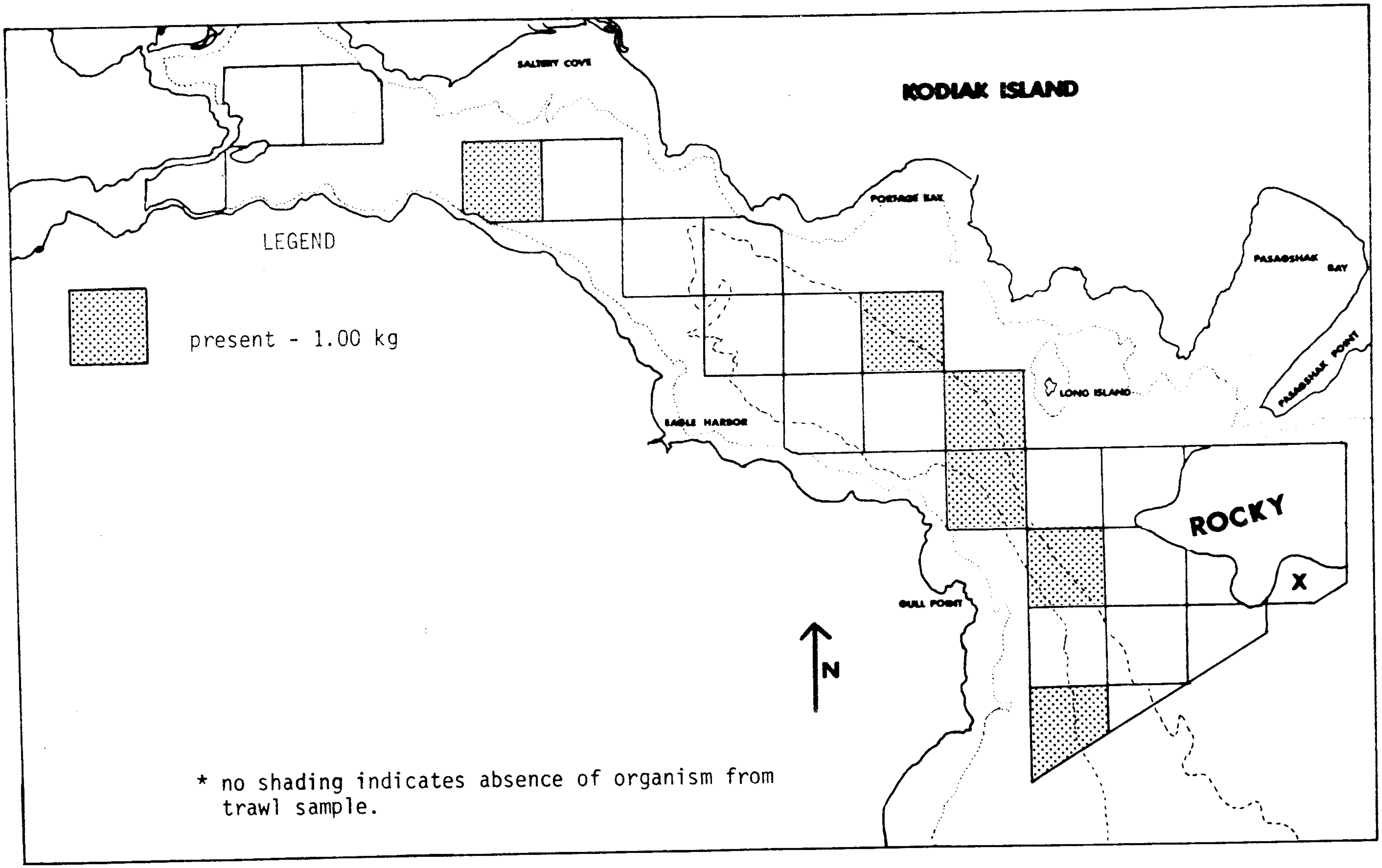
App. Fig. 19. Distribution and mean catch in kg per 20 minute tow of rock sole in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



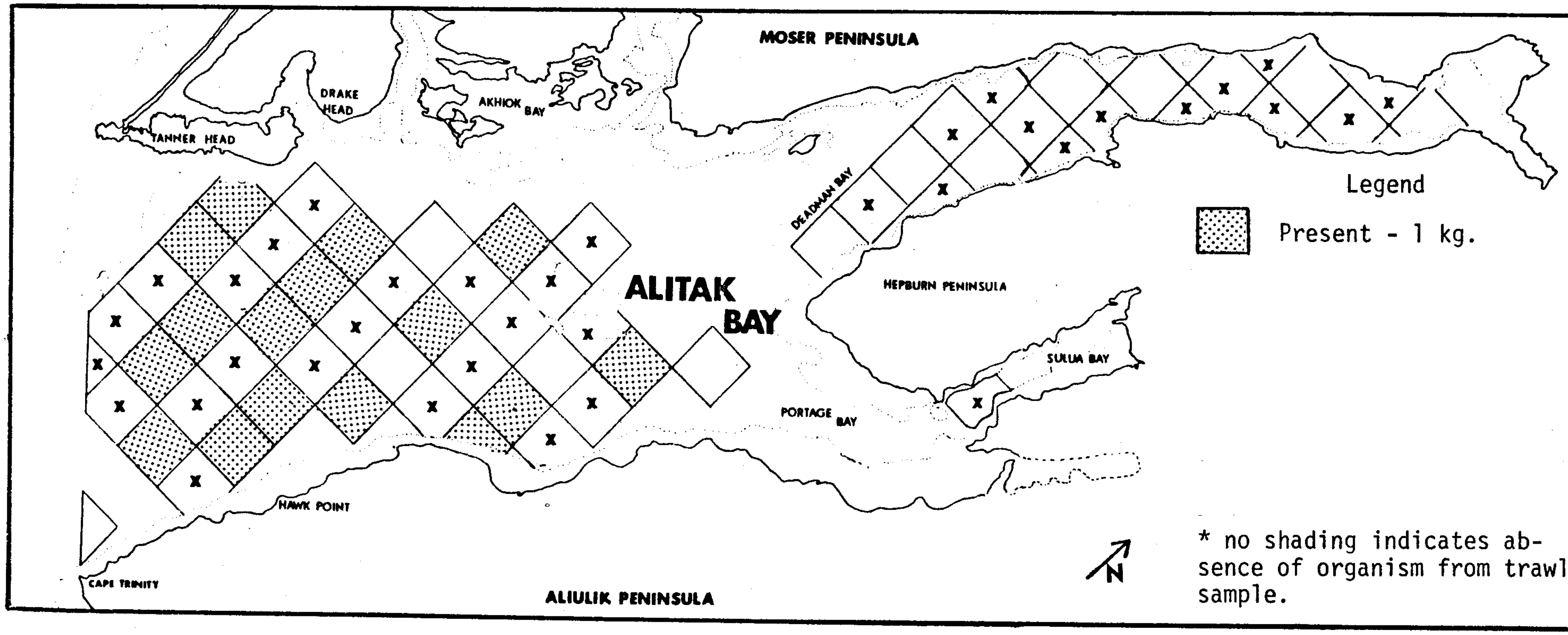
App. Fig. 20. Distribution and mean catch in kg per 20 minute tow of rock sole in Alitak Bay during March, 1977, X indicates station not sampled.



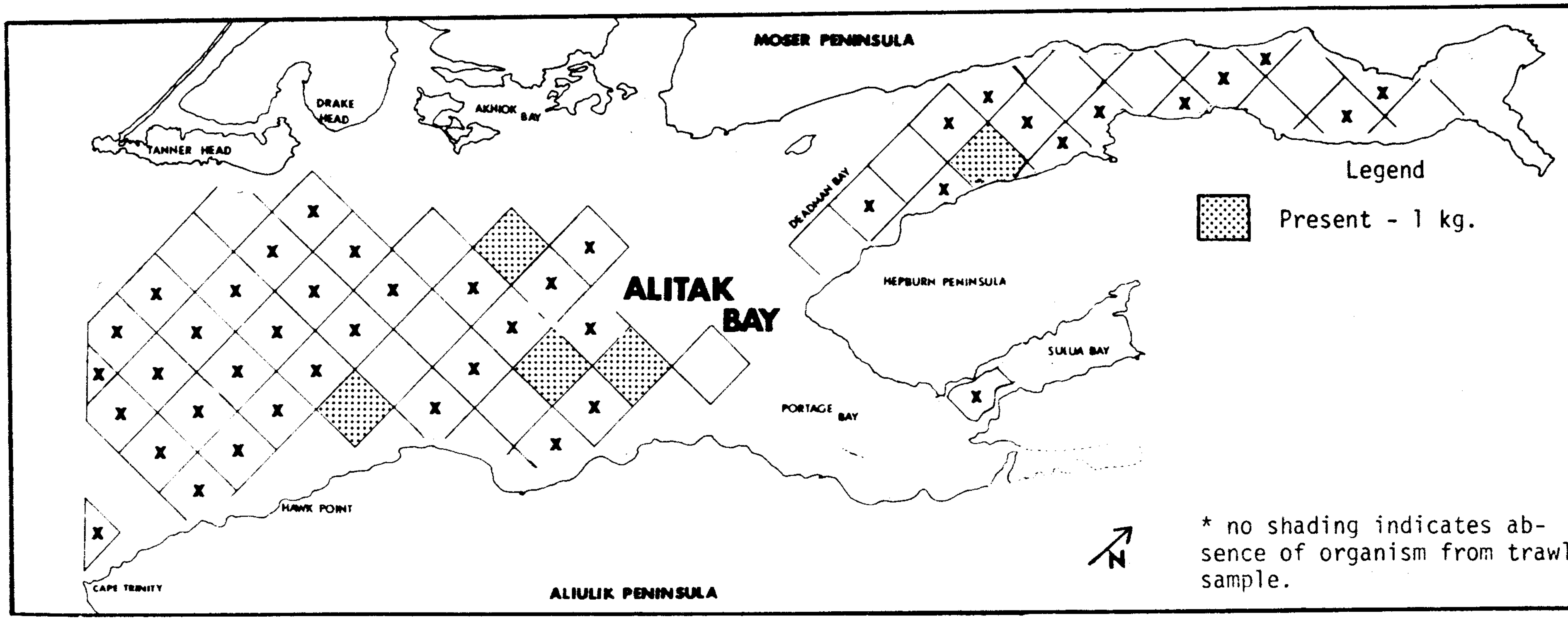
App. Fig. 21. Distribution and mean catch in kg per 20 minute tow of arrowtooth flounder in Ugak Bay during June, July, August and September, 1976.



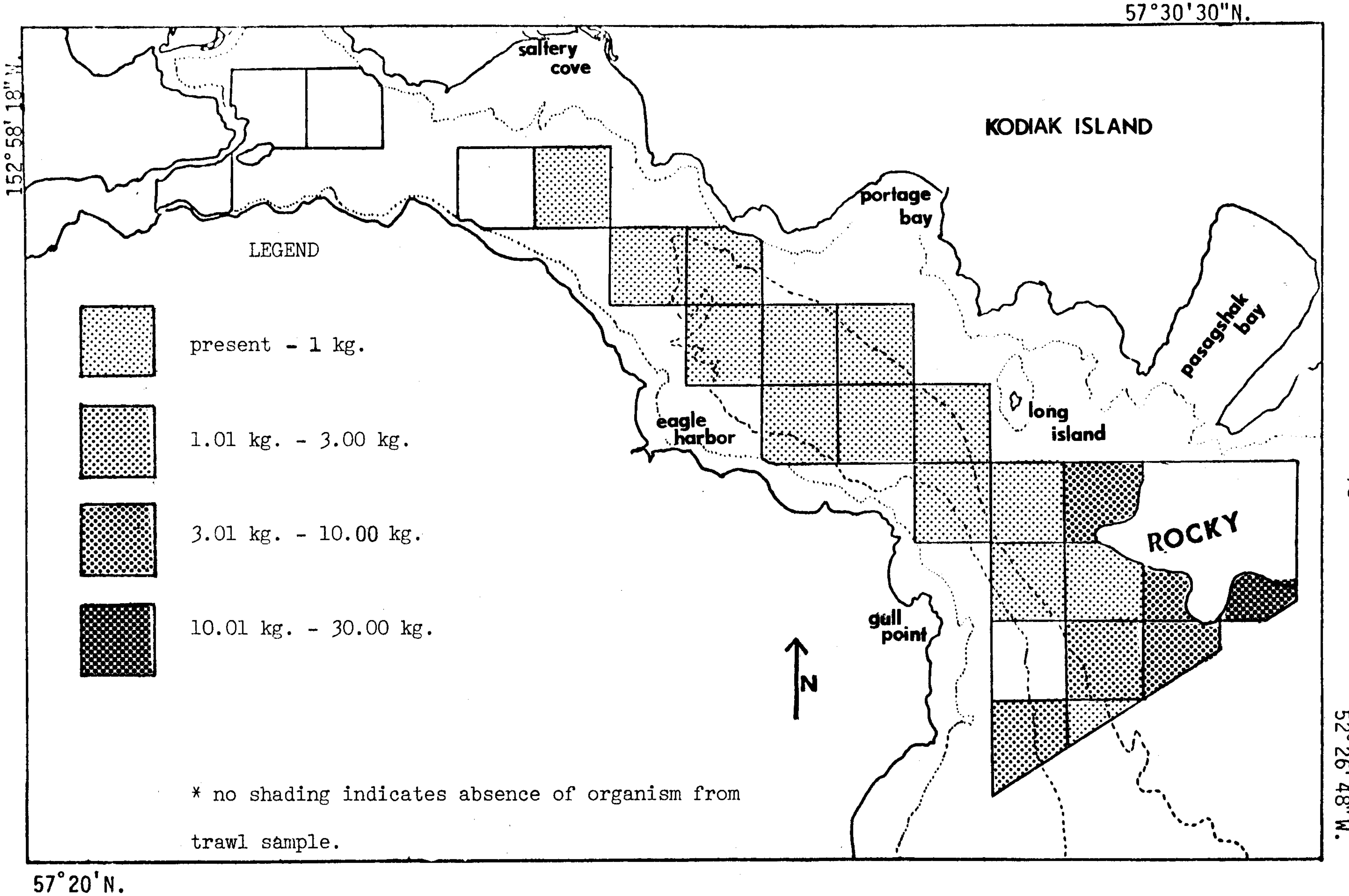
App. Fig. 22. Distribution and mean catch in kg per 20 minute tow of arrowtooth flounder in Ugak Bay during March, 1977. X indicates station not sampled.



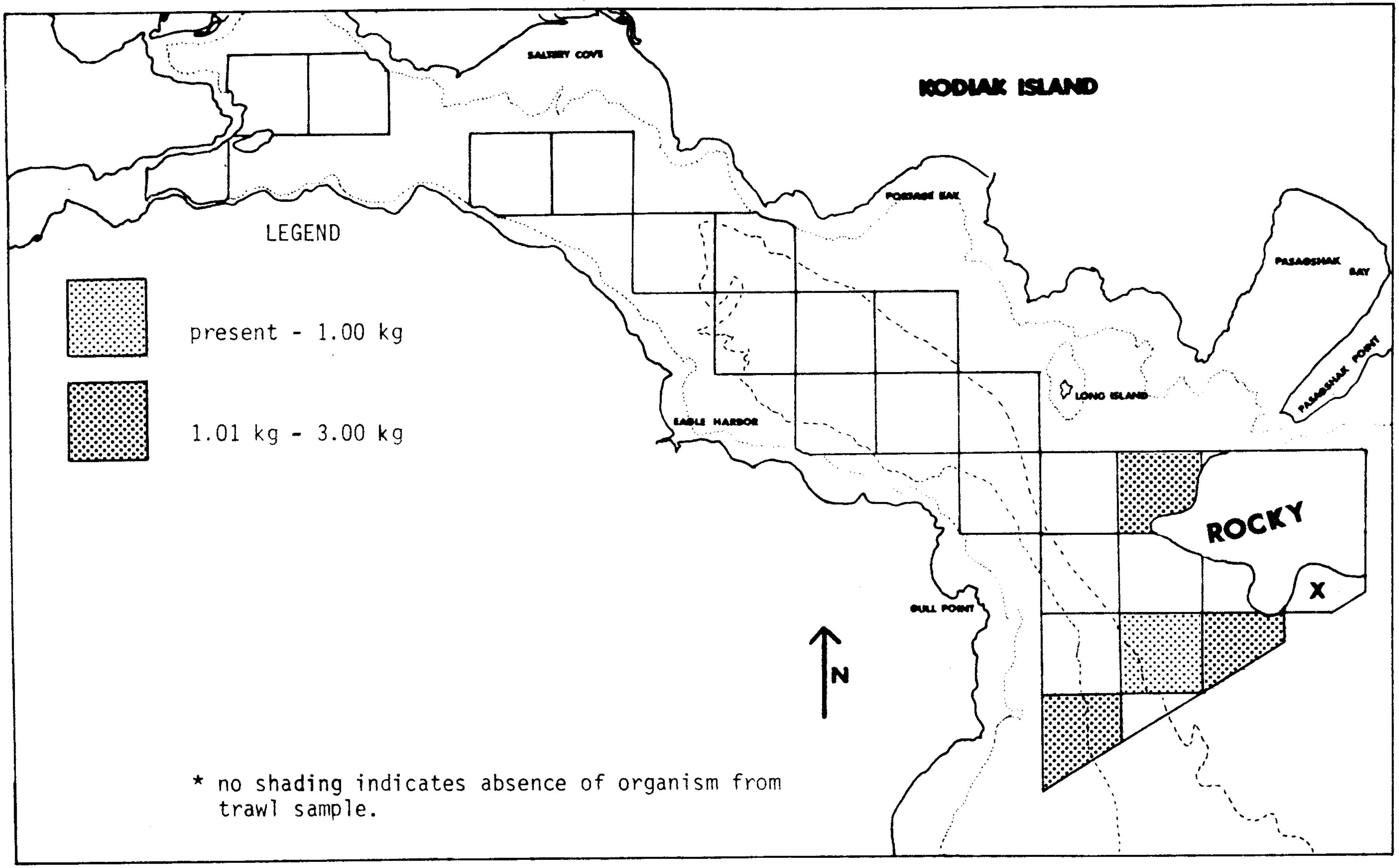
App. Fig. 23. Distribution and mean catch in kg per 20 minute tow of arrowtooth flounder in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



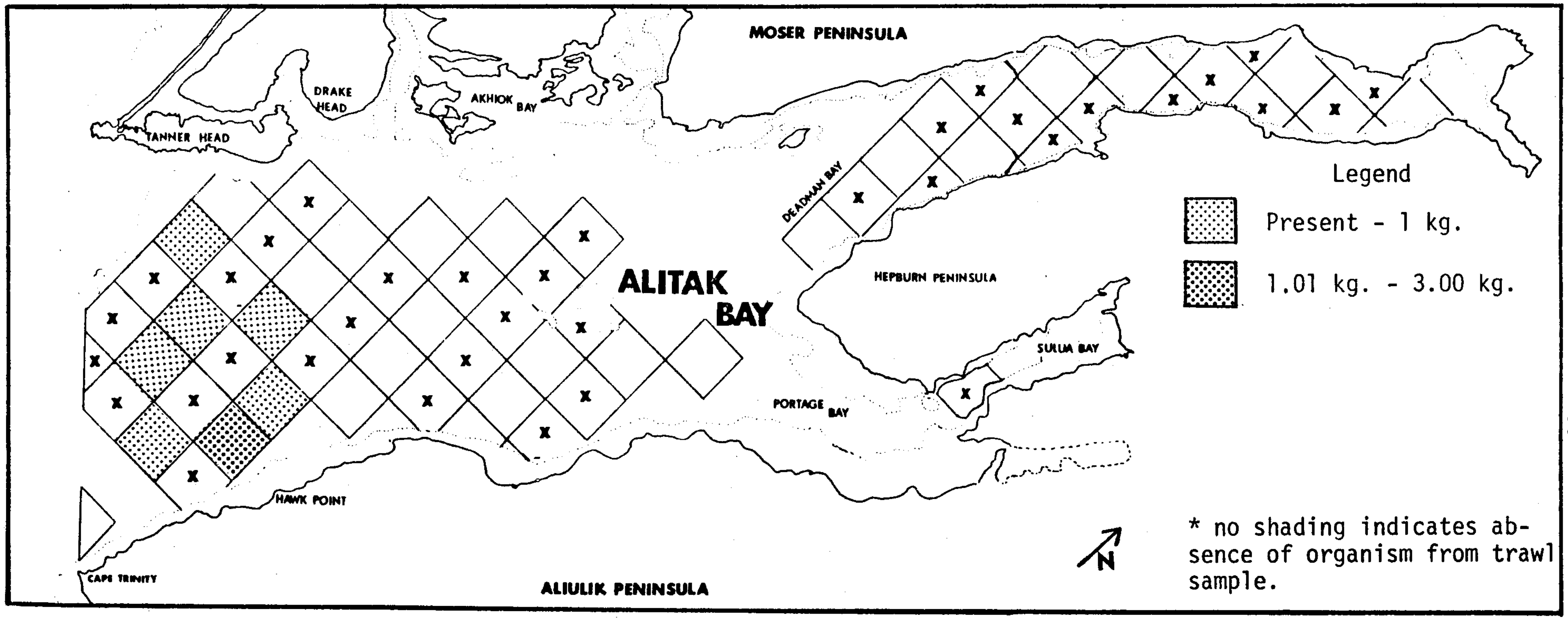
App. Fig. 24. Distribution and mean catch in kg per 20 minute tow of arrowtooth flounder in Alitak Bay during March, 1977. X indicates station not sampled.



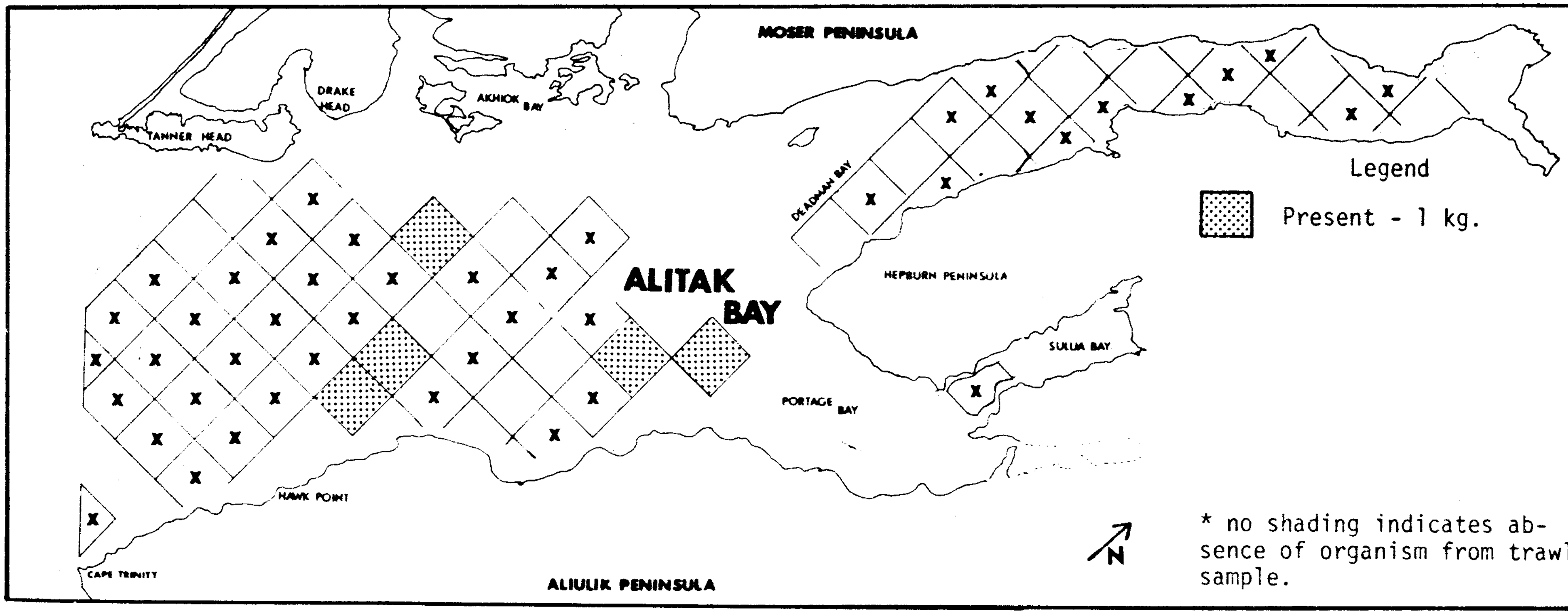
App. Fig. 25. Distribution and mean catch in kg per 20 minute tow of butter sole in Ugak Bay during June, July, August and September, 1976.



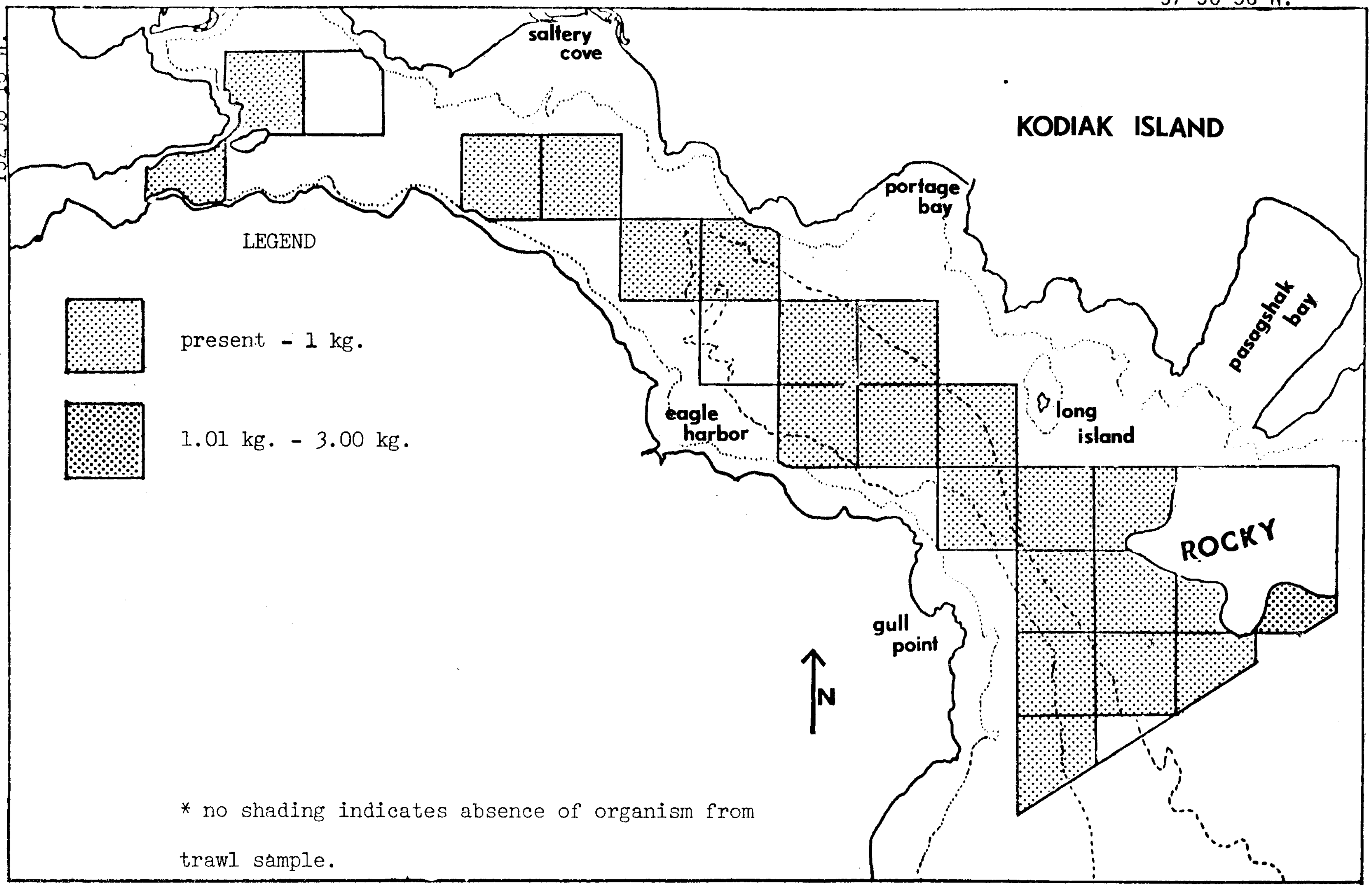
App. Fig. 26. Distribution and mean catch in kg per 20 minute tow of butter sole in Ugak Bay during March, 1977. X indicates station not sampled.



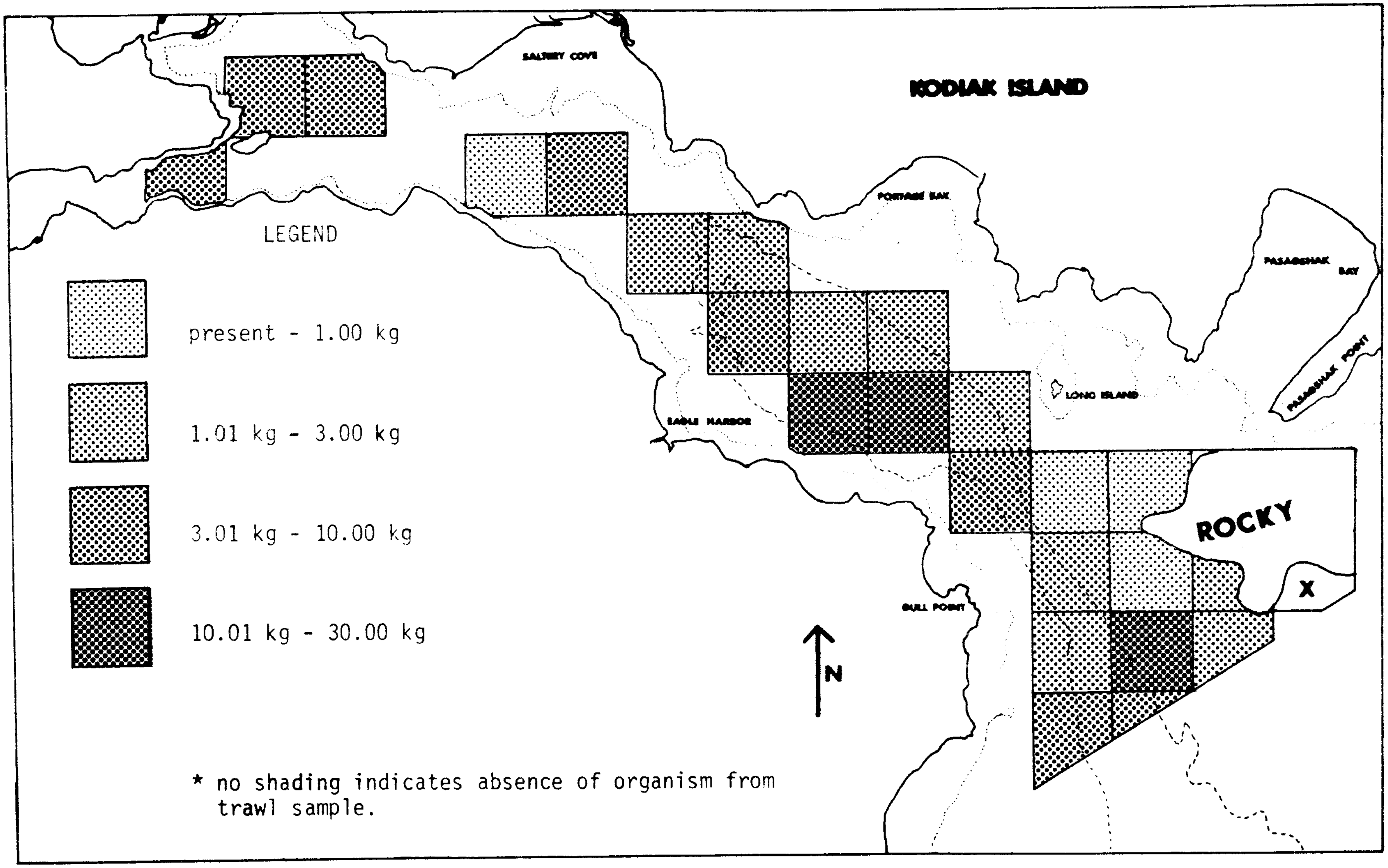
App. Fig. 27. Distribution and mean catch in kg per 20 minute tow of butter sole in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



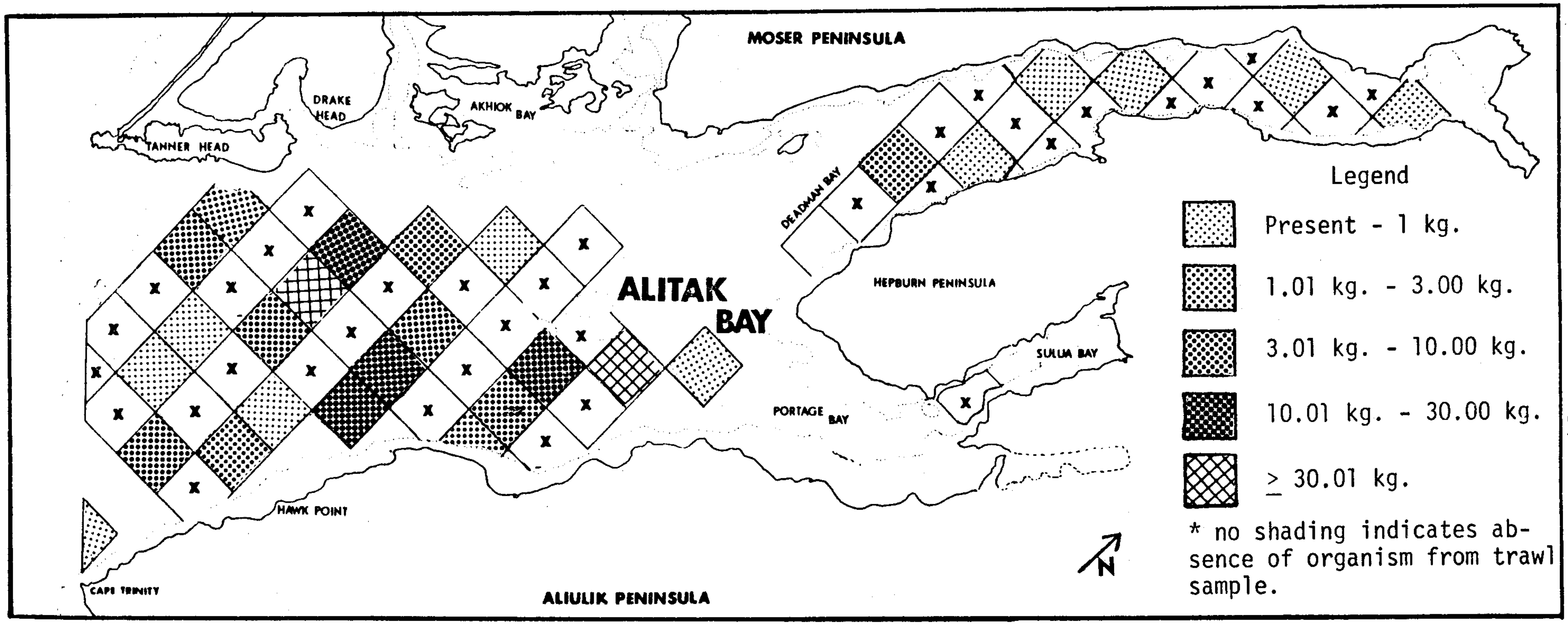
App. Fig. 28. Distribution and mean catch in kg per 20 minute tow of butter sole in Alitak Bay during March, 1977. X indicates station not sampled.



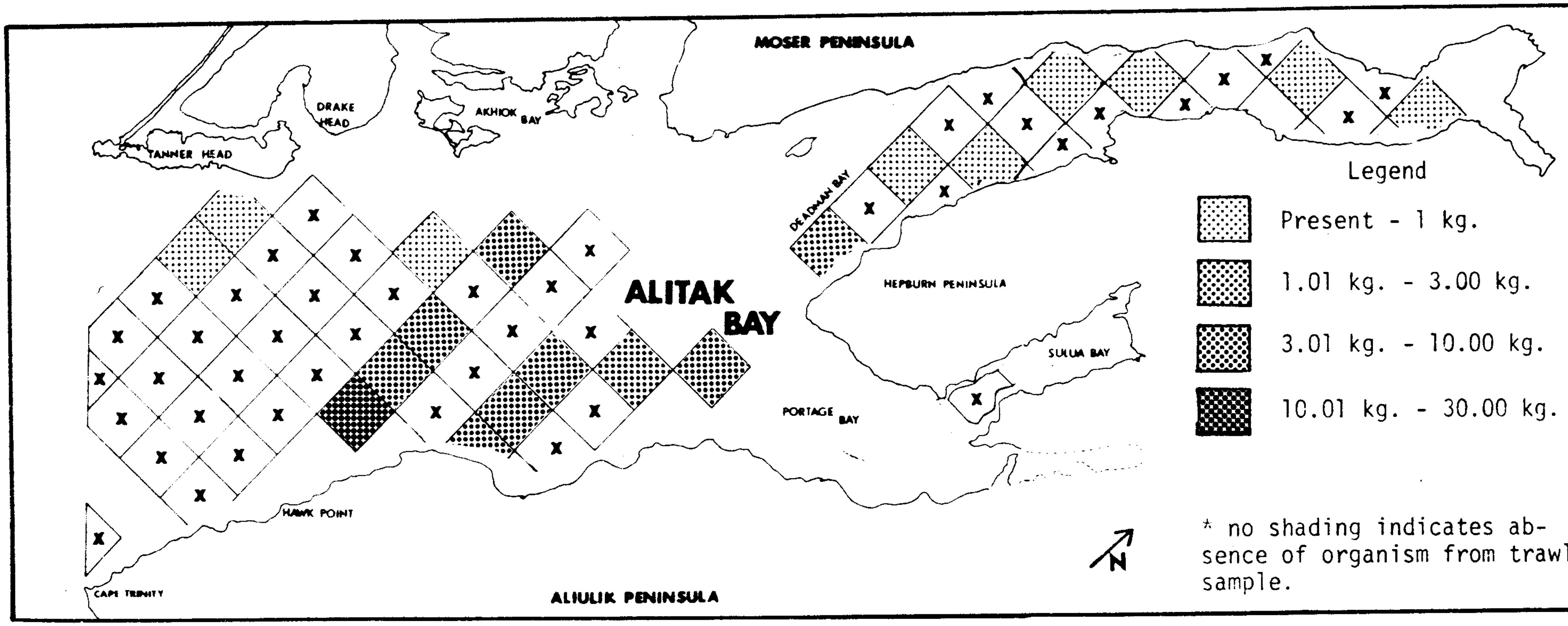
App. Fig. 29. Distribution and mean catch in kg per 20 minute tow of walleye pollock in Ugak Bay for June, July, August and September, 1976.



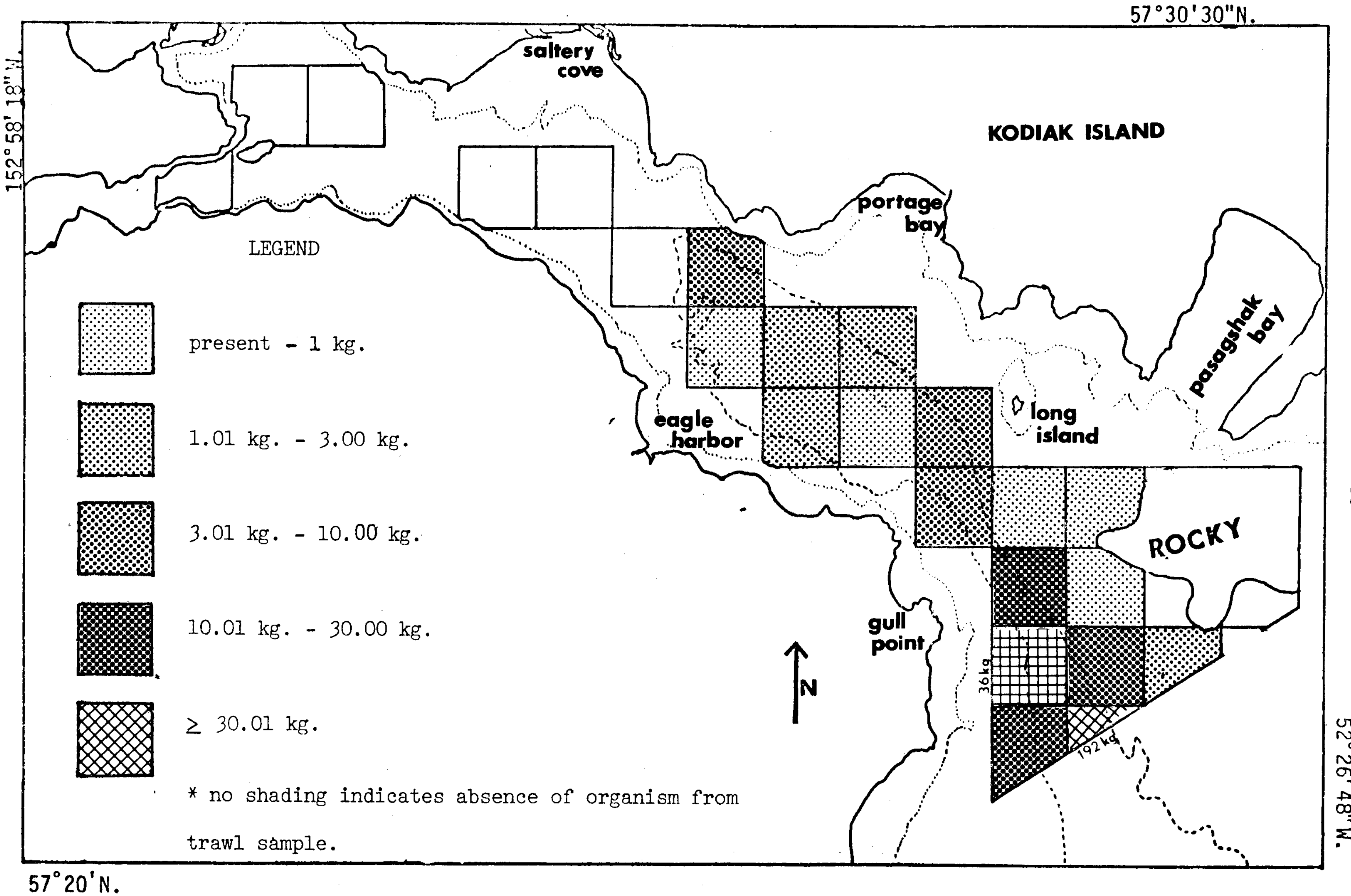
App. Fig. 30. Distribution and mean catch in kg per 20 minute tow of walleye pollock in Ugak Bay during March, 1977. X indicates station not sampled.



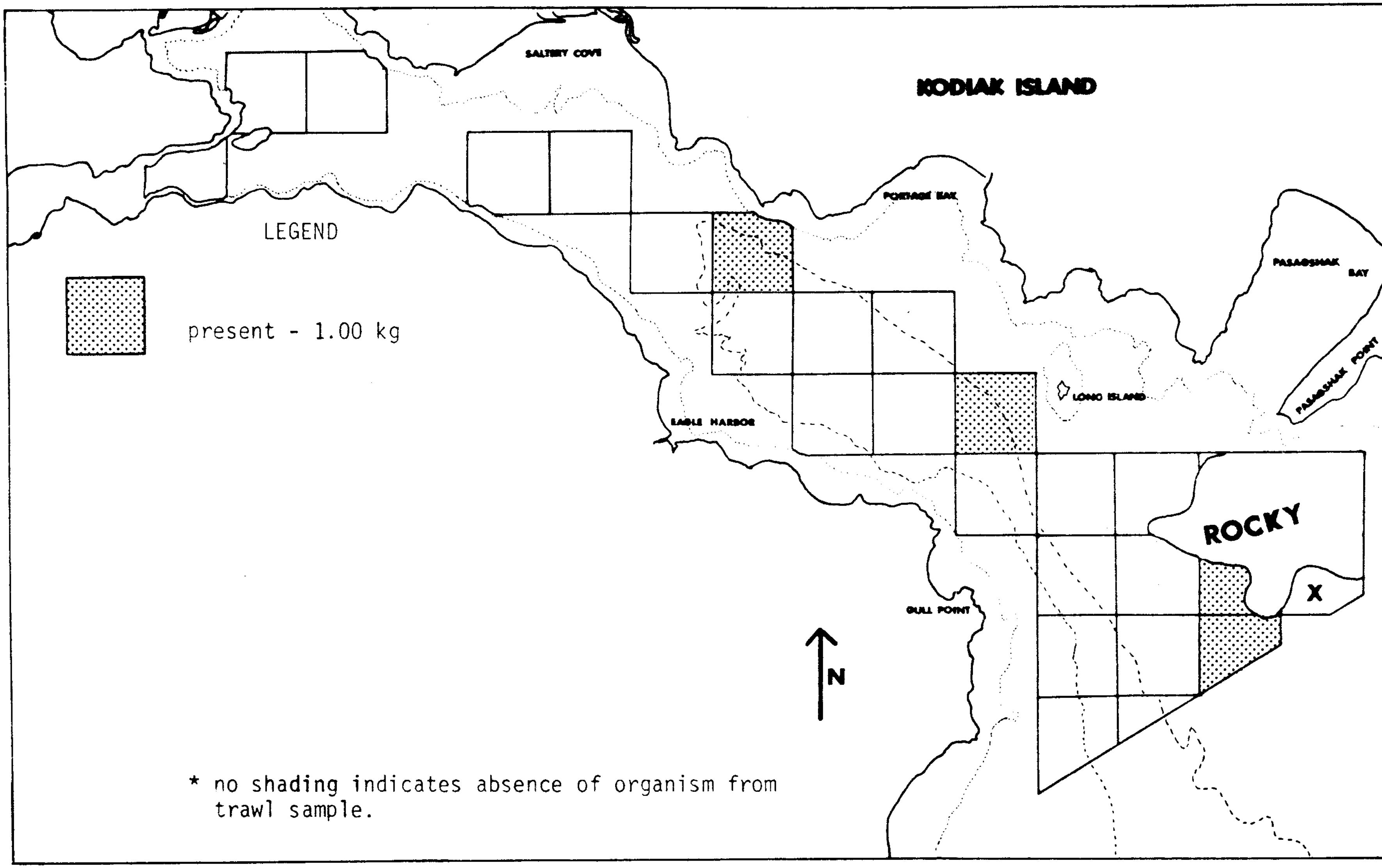
App. Fig. 31. Distribution and mean catch in kg per 20 minute tow of walleye pollock in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



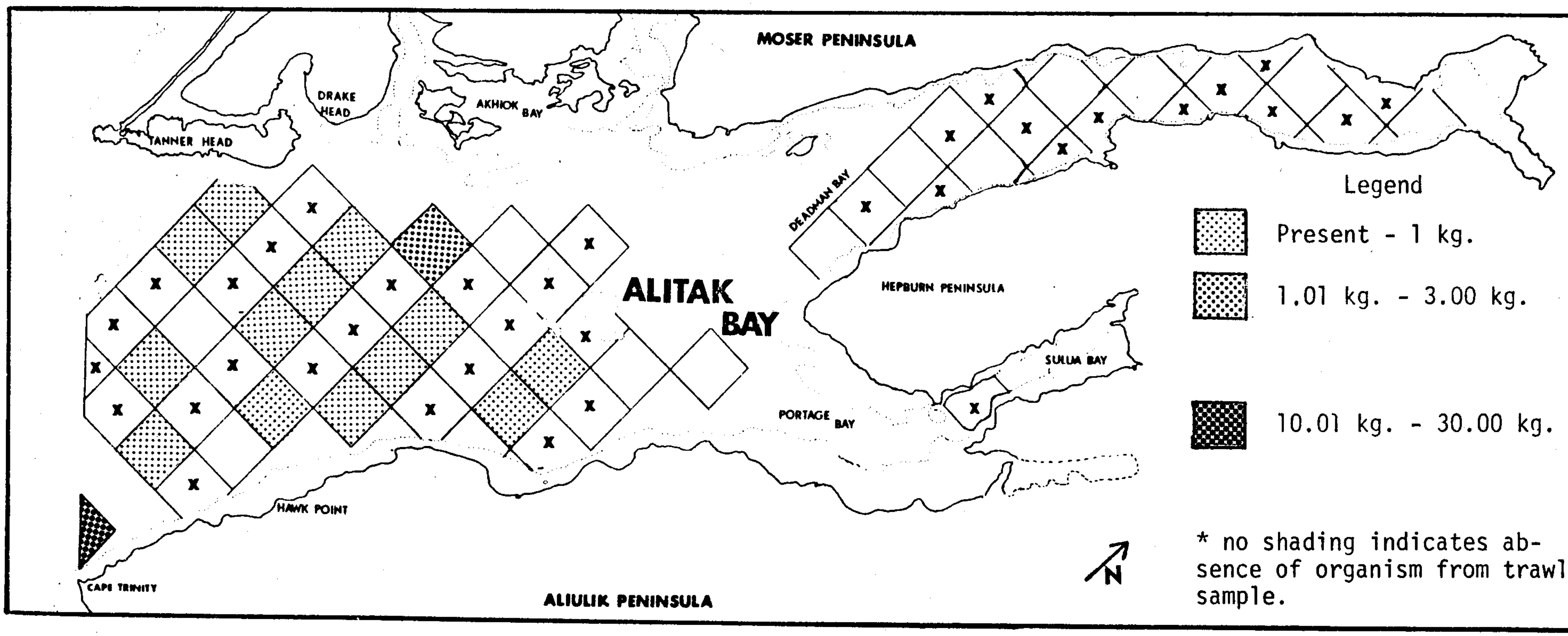
App. Fig. 32. Distribution and mean catch in kg per 20 minute tow of walleye pollock in Alitak Bay during March, 1977. X indicates station not sampled.



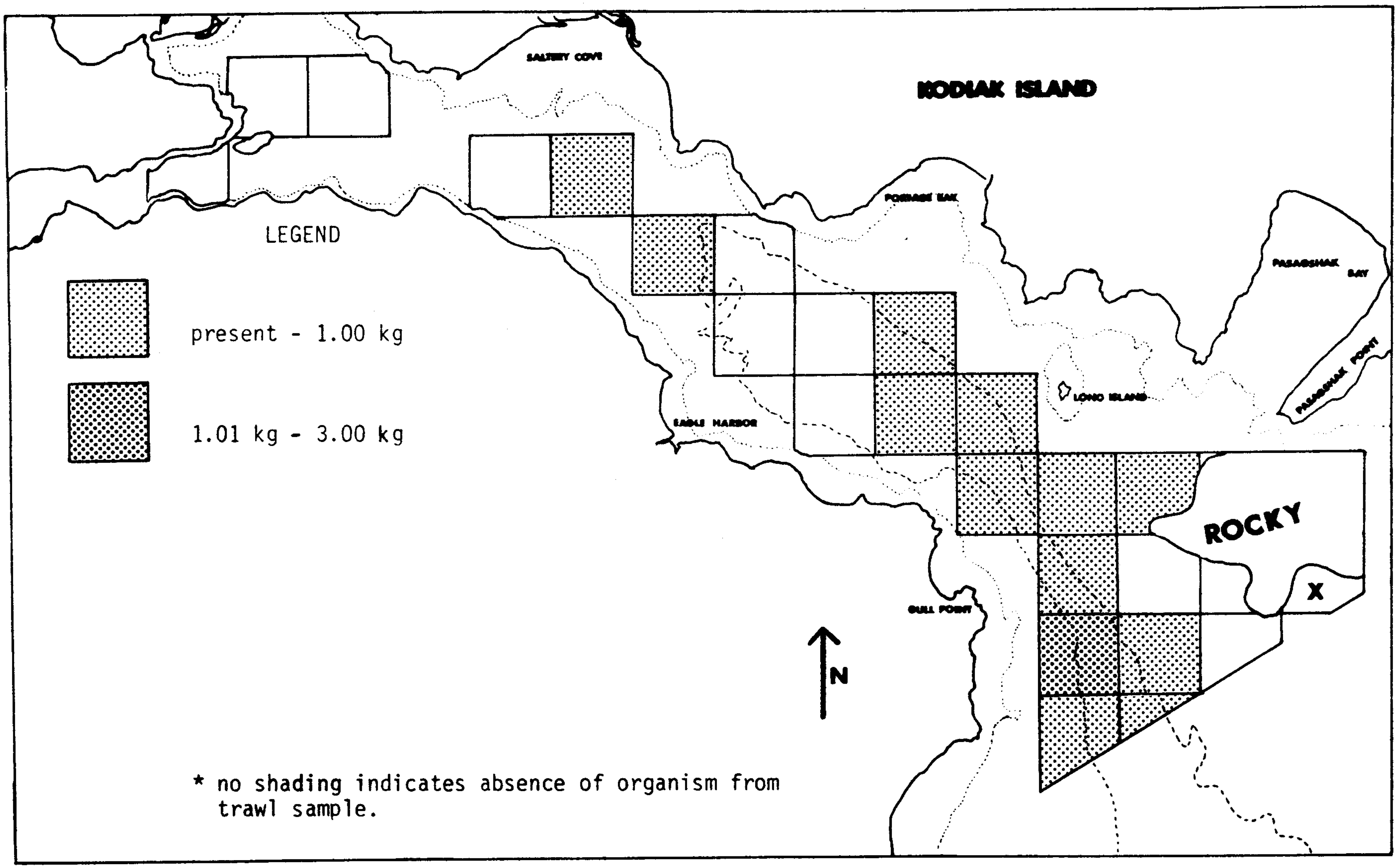
App. Fig. 33. Distribution and mean catch in kg per 20 minute tow of Pacific cod in Ugak Bay during June, July, August and September, 1976.



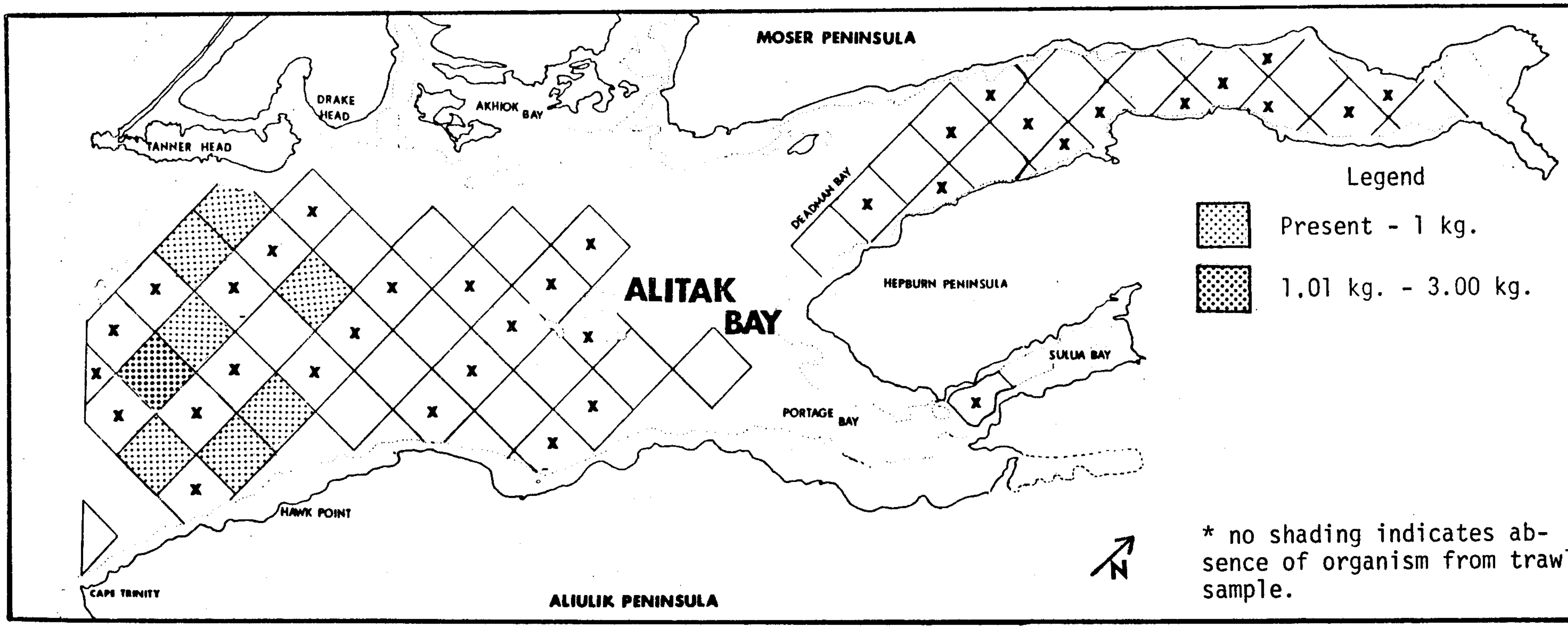
App. Fig. 34. Distribution and mean catch in kg per 20 minute tow of Pacific cod in Ugak Bay for March, 1977. X indicates station not sampled.



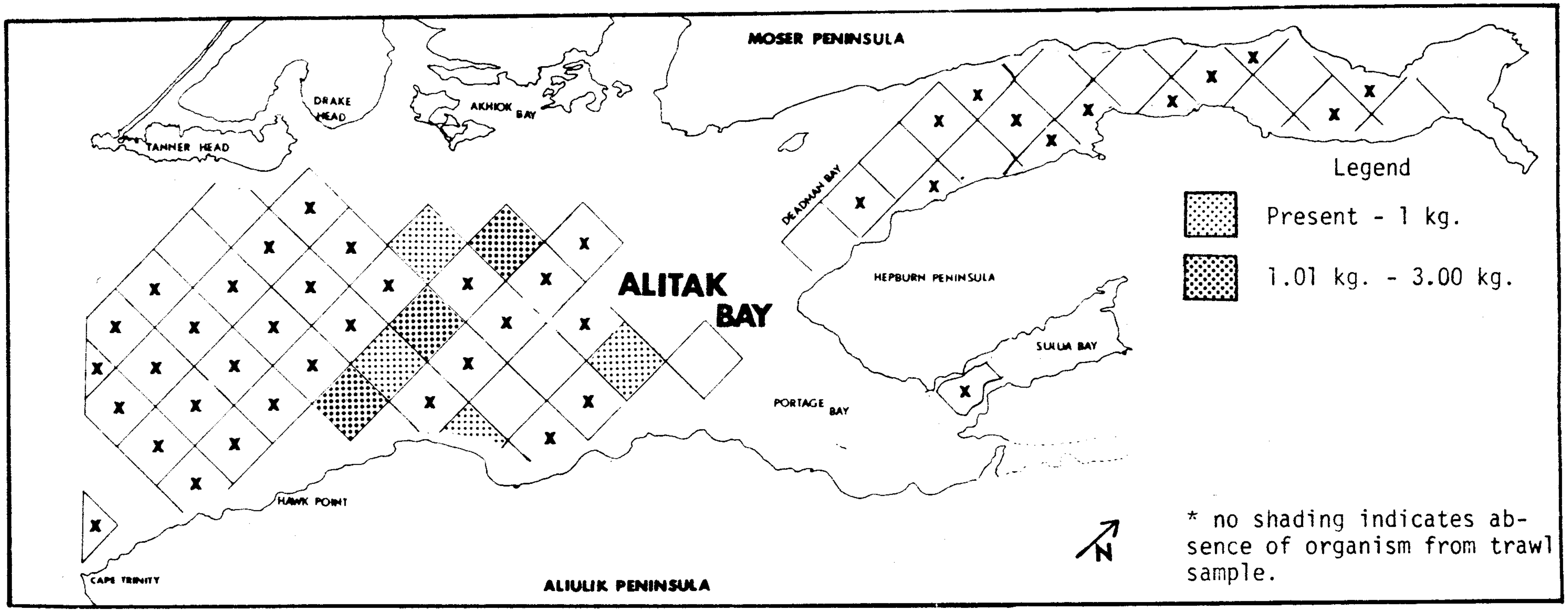
App. Fig. 35. Distribution and mean catch in kg per 20 minute tow of Pacific cod in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



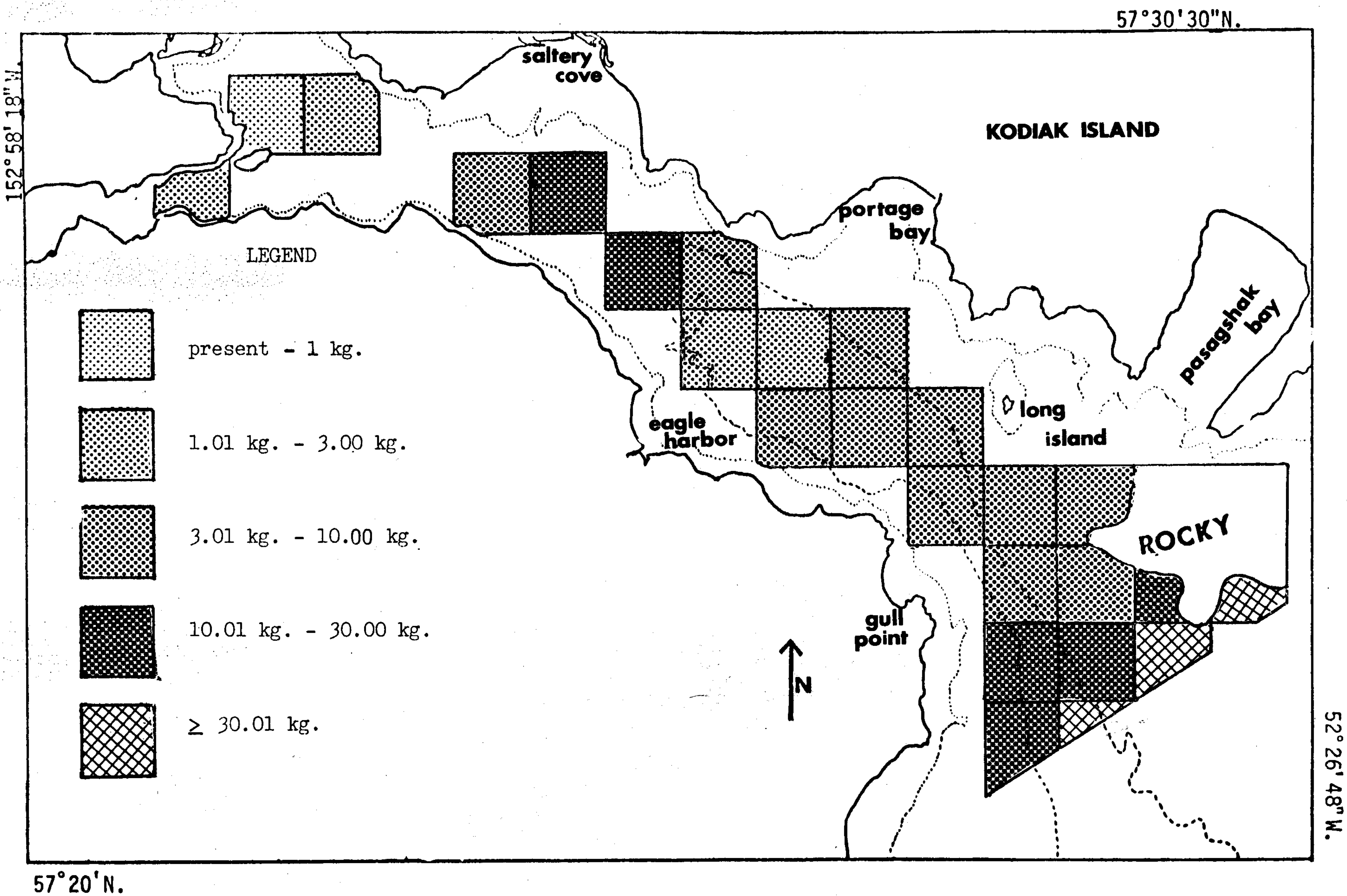
App. Fig. 38. Distribution and mean catch in kg per 20 minute tow of Pacific tomcod in Ugak Bay during March, 1977. X indicates station not sampled.



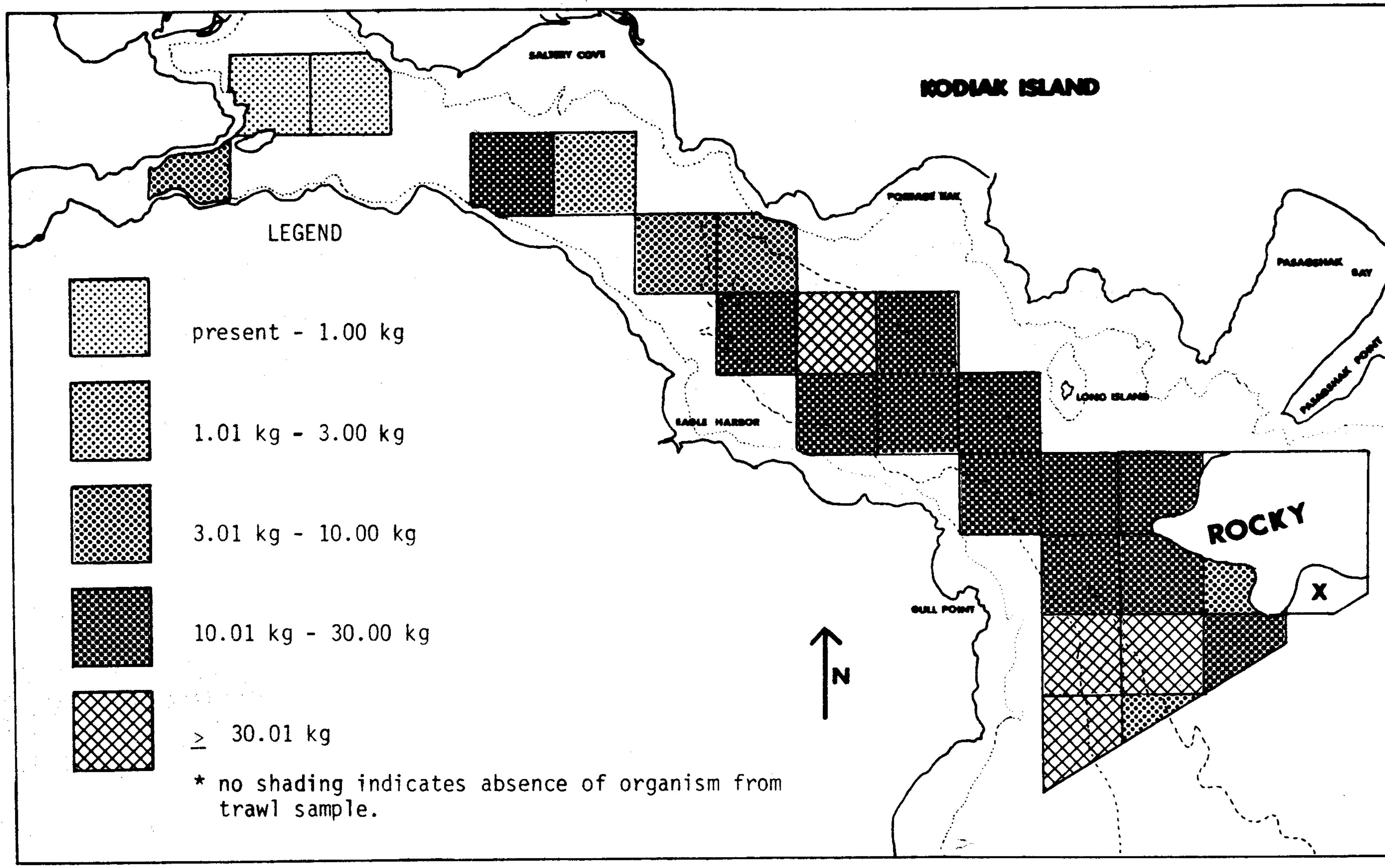
App. Fig. 39. Distribution and mean catch in kg per 20 minute tow of Pacific tomcod in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



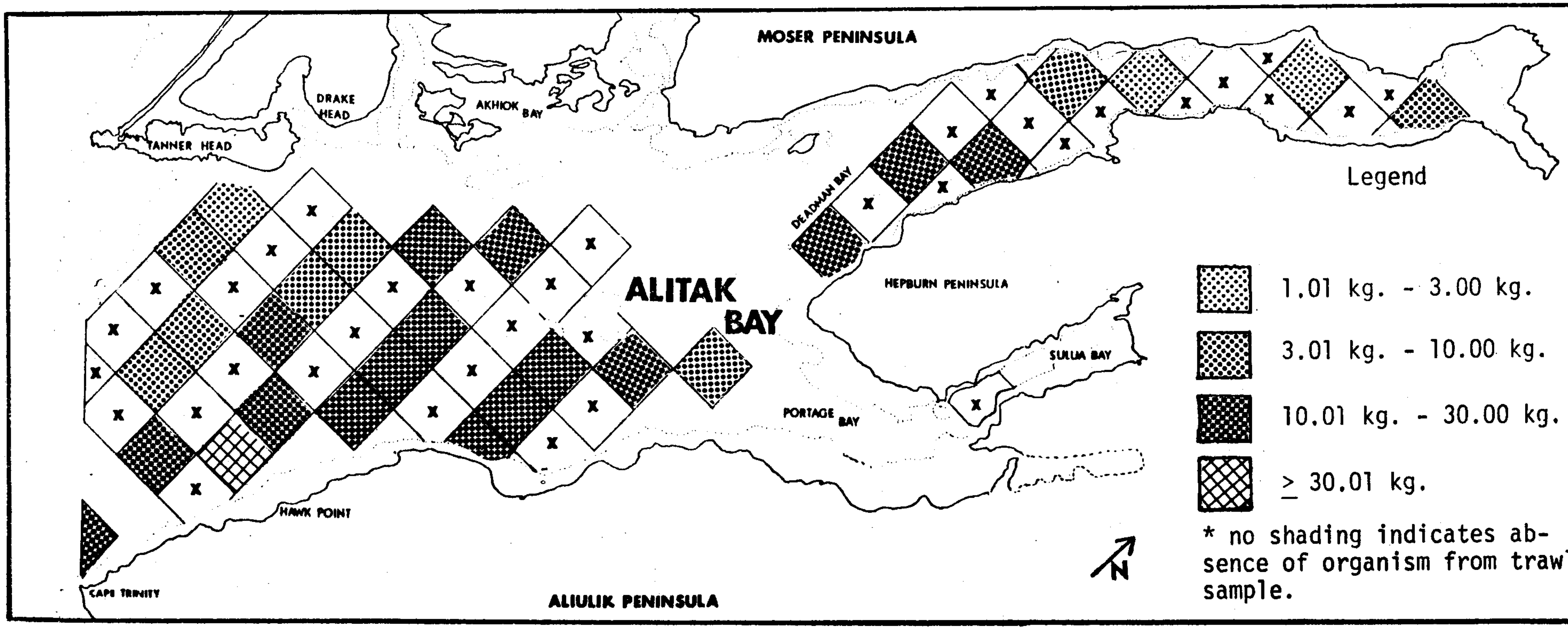
App. Fig. 40. Distribution and mean catch in kg per 20 minute tow of Pacific tomcod in Alitak Bay during March, 1977. X indicates station not sampled.



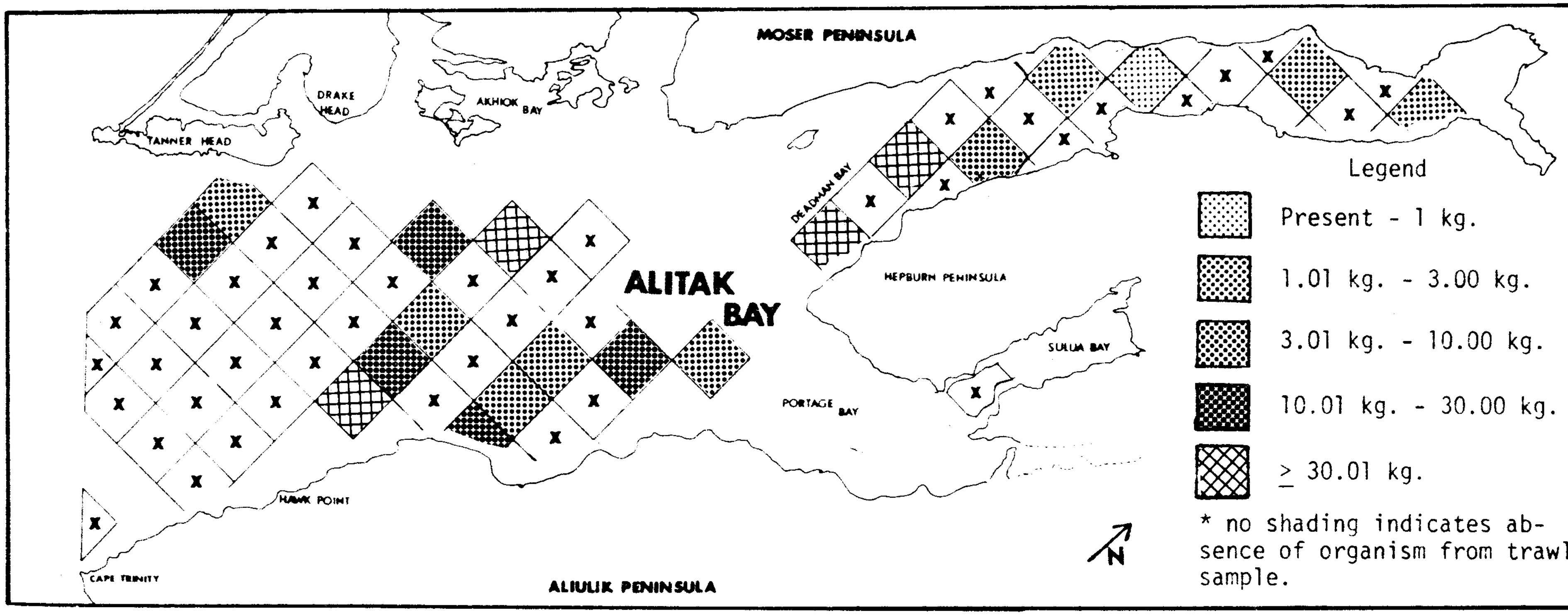
App. Fig. 41. Distribution and mean catch in kg per 20 minute tow of great sculpin in Ugak Bay during June, July, August and September, 1976.



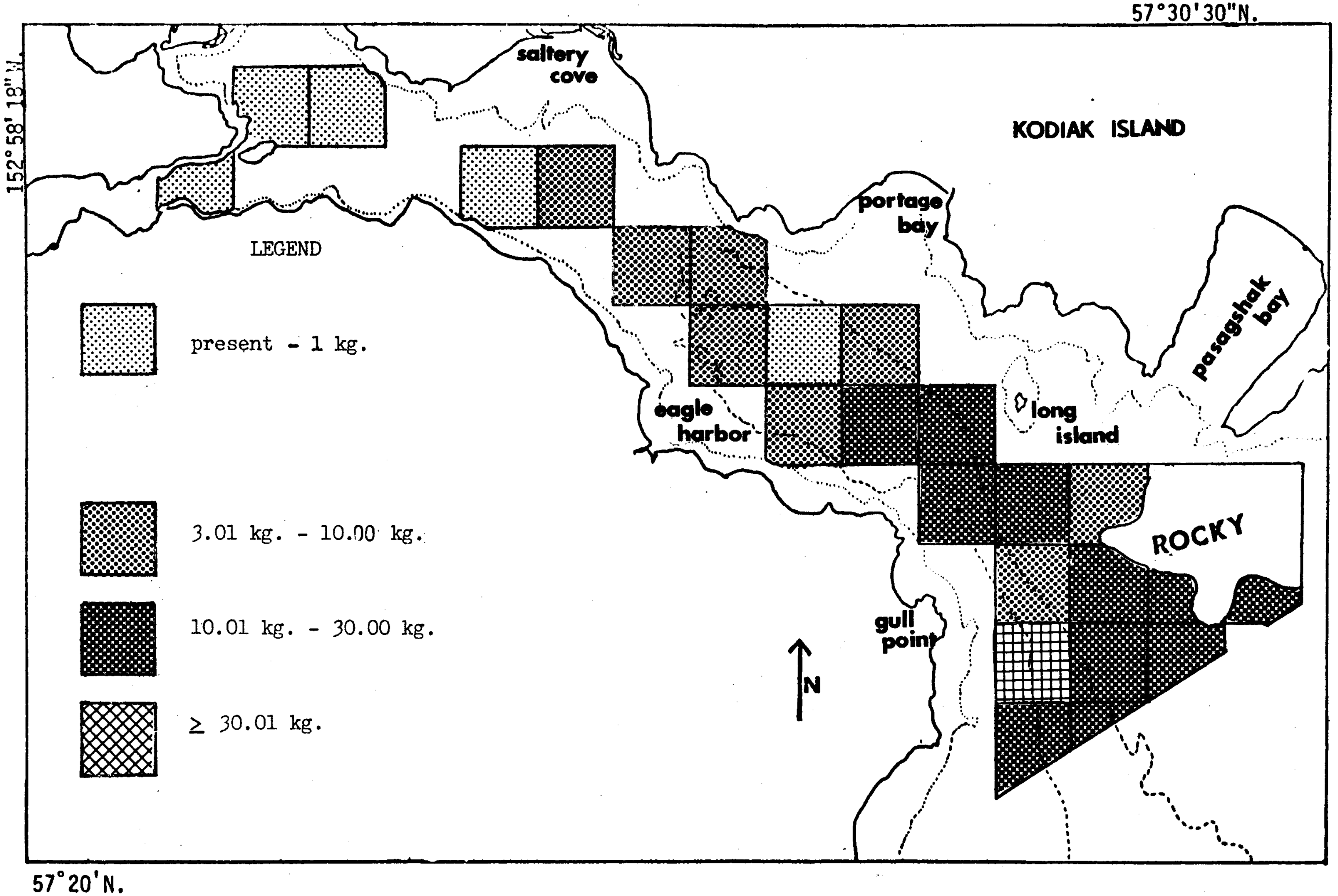
App. Fig. 42. Distribution and mean catch in kg per 20 minute tow of great sculpin in Ugak Bay during March, 1977. X indicates station not sampled.



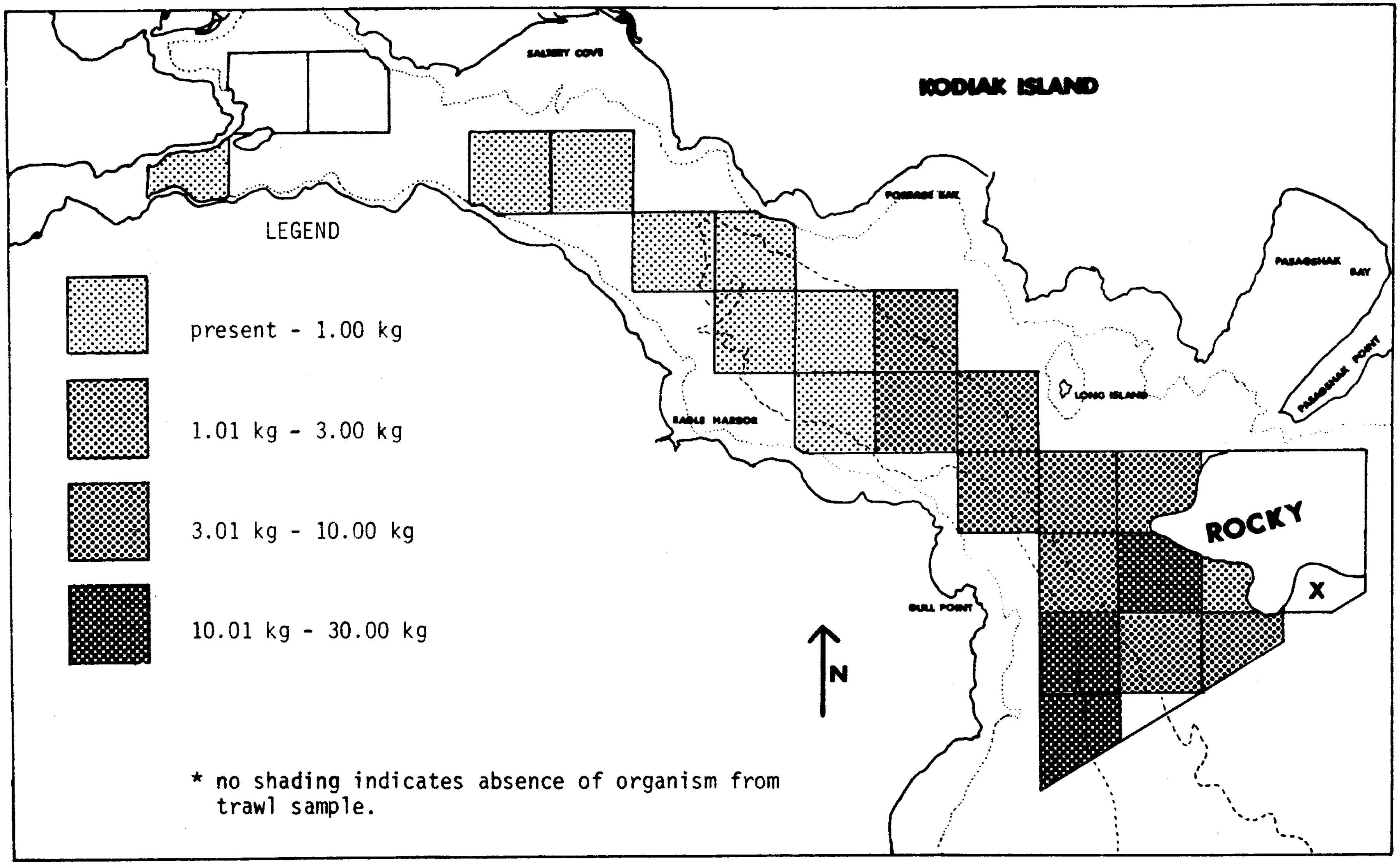
App. Fig. 43. Distribution and mean catch in kg per 20 minute tow of great sculpin in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



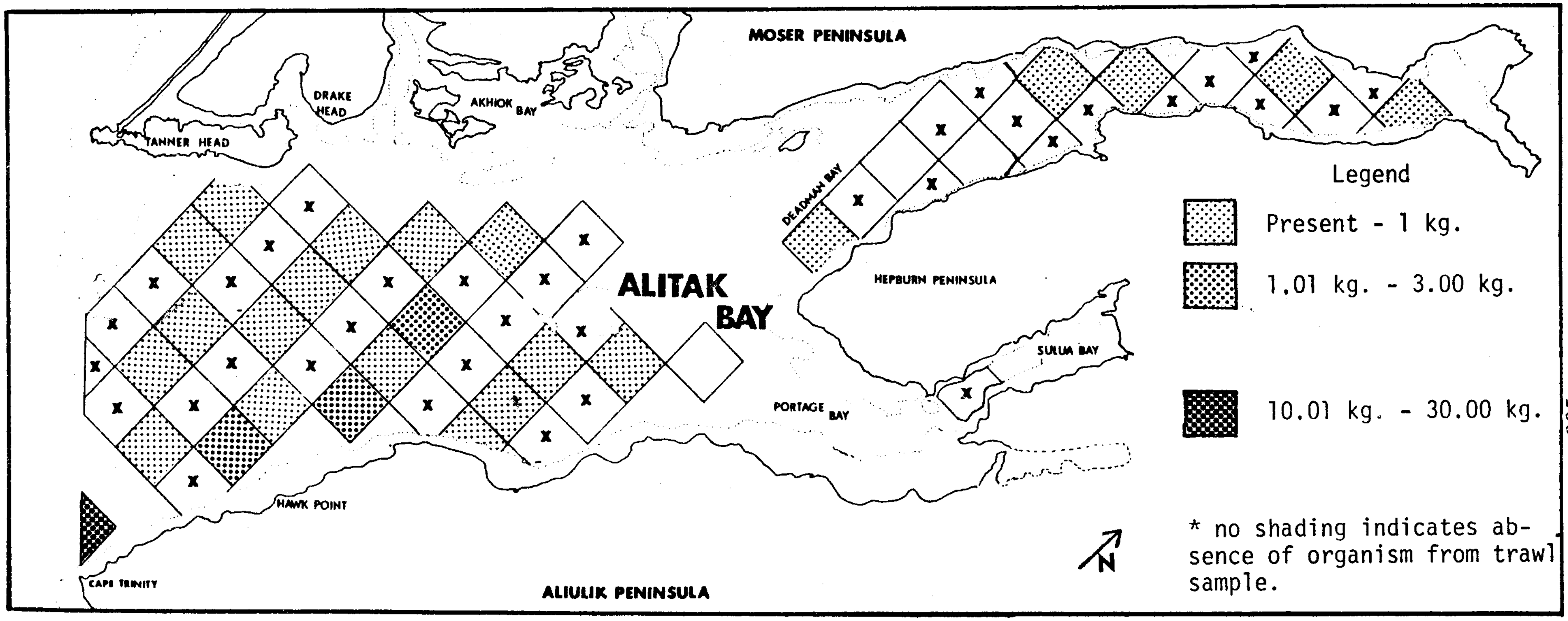
App. Fig. 44. Distribution and mean catch in kg per 20 minute tow of great sculpin in Alitak Bay during March, 1977. X indicates station not sampled.



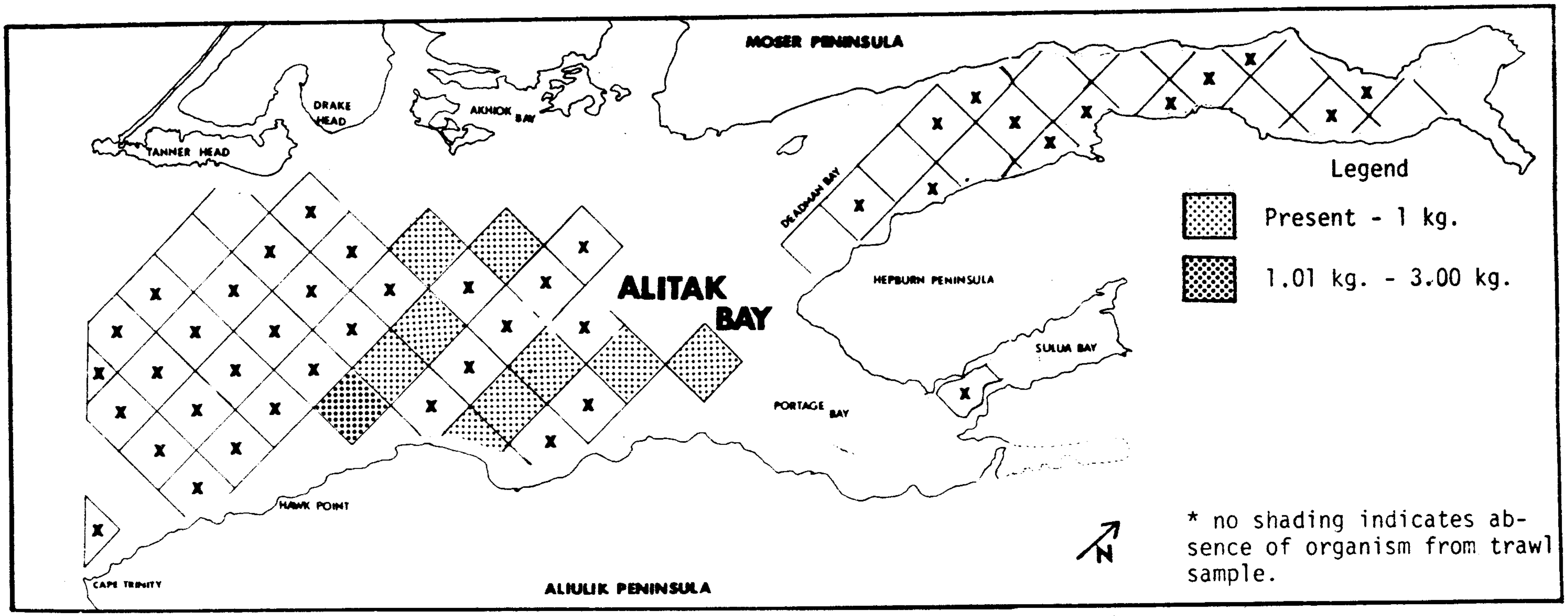
App. Fig. 45. Distribution and mean catch in kg per 20 minute tow of yellow Irish Lord in Ugak Bay during June, July, August and September, 1976.



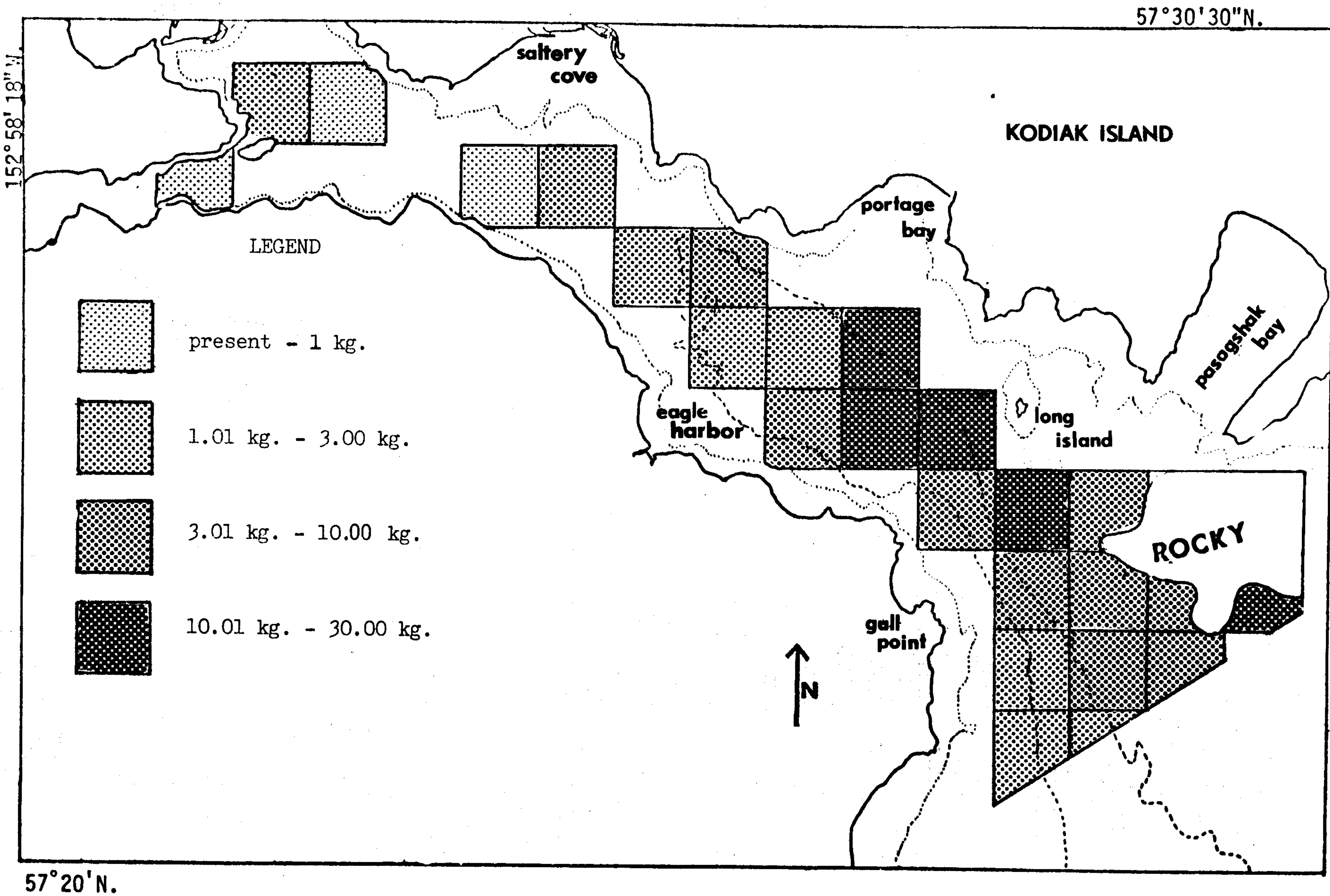
App. Fig. 46. Distribution and mean catch in kg per 20 minute tow of yellow Irish Lord in Ugak Bay during March, 1977. X indicates station not sampled.



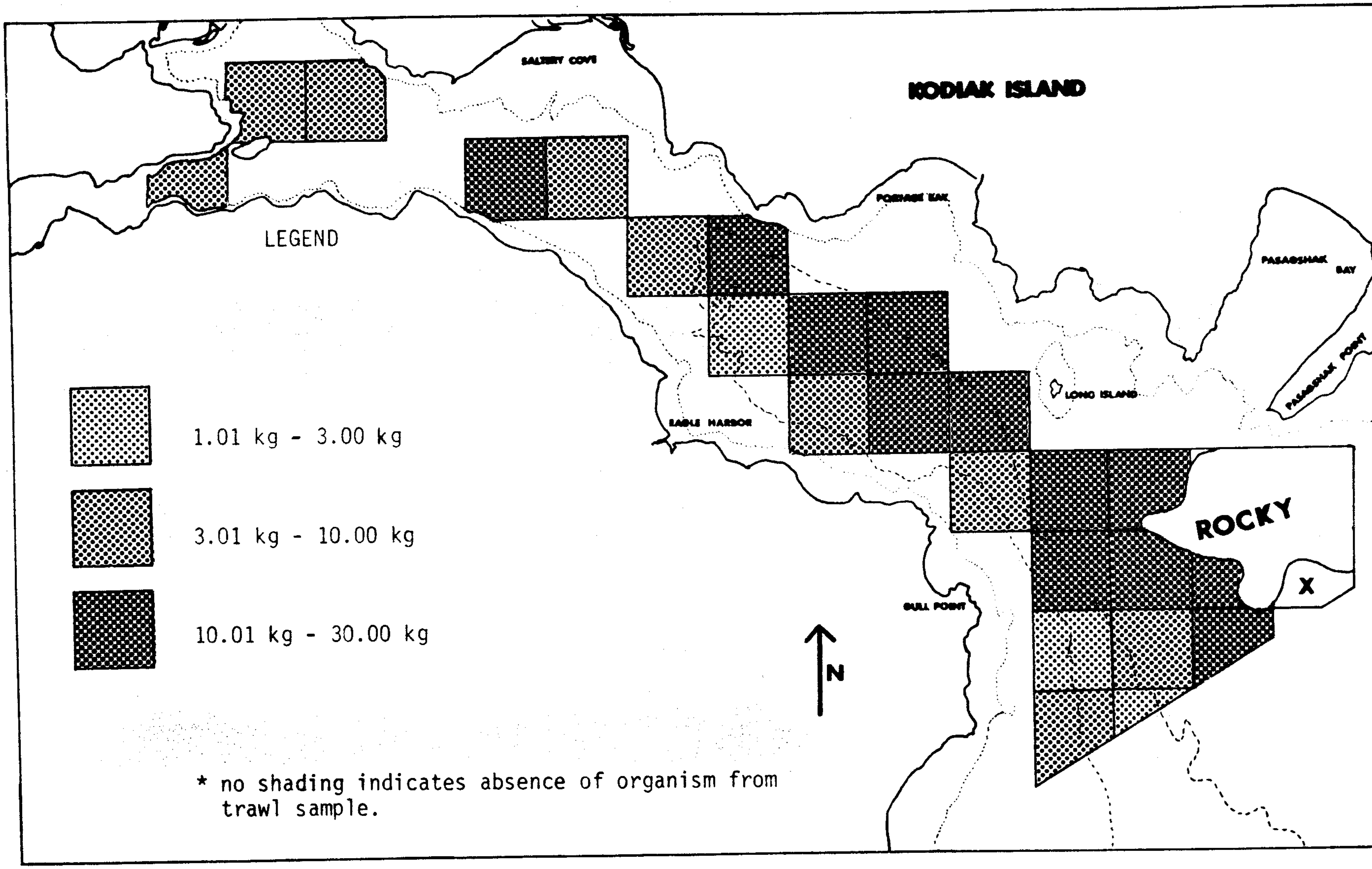
App. Fig. 47. Distribution and mean catch in kg per 20 minute tow of yellow Irish Lord in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



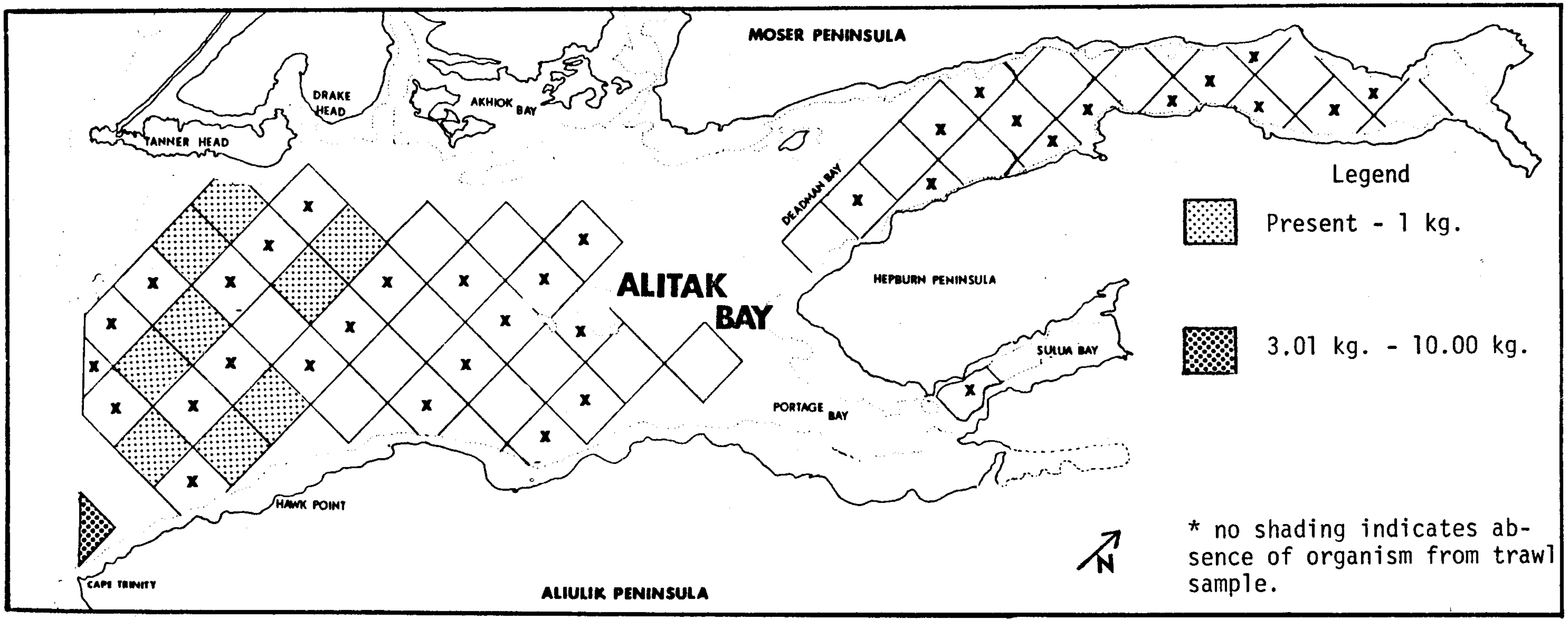
App. Fig. 48. Distribution and mean catch in kg per 20 minute tow of yellow Irish Lord in Alitak Bay during March, 1977. X indicates station not sampled.



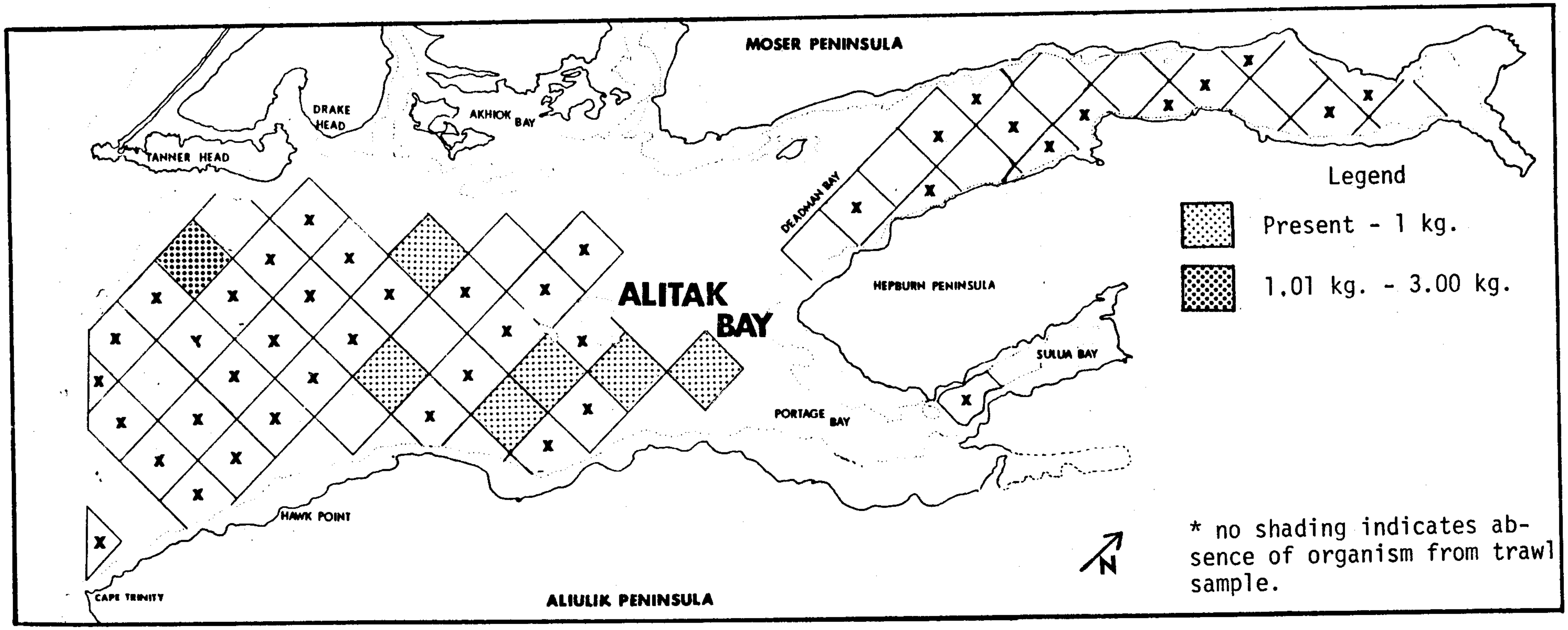
App. Fig. 49. Distribution and mean catch in kg per 20 minute tow of *Gymnocanthus* in Ugak Bay during June, July, August and September, 1976.



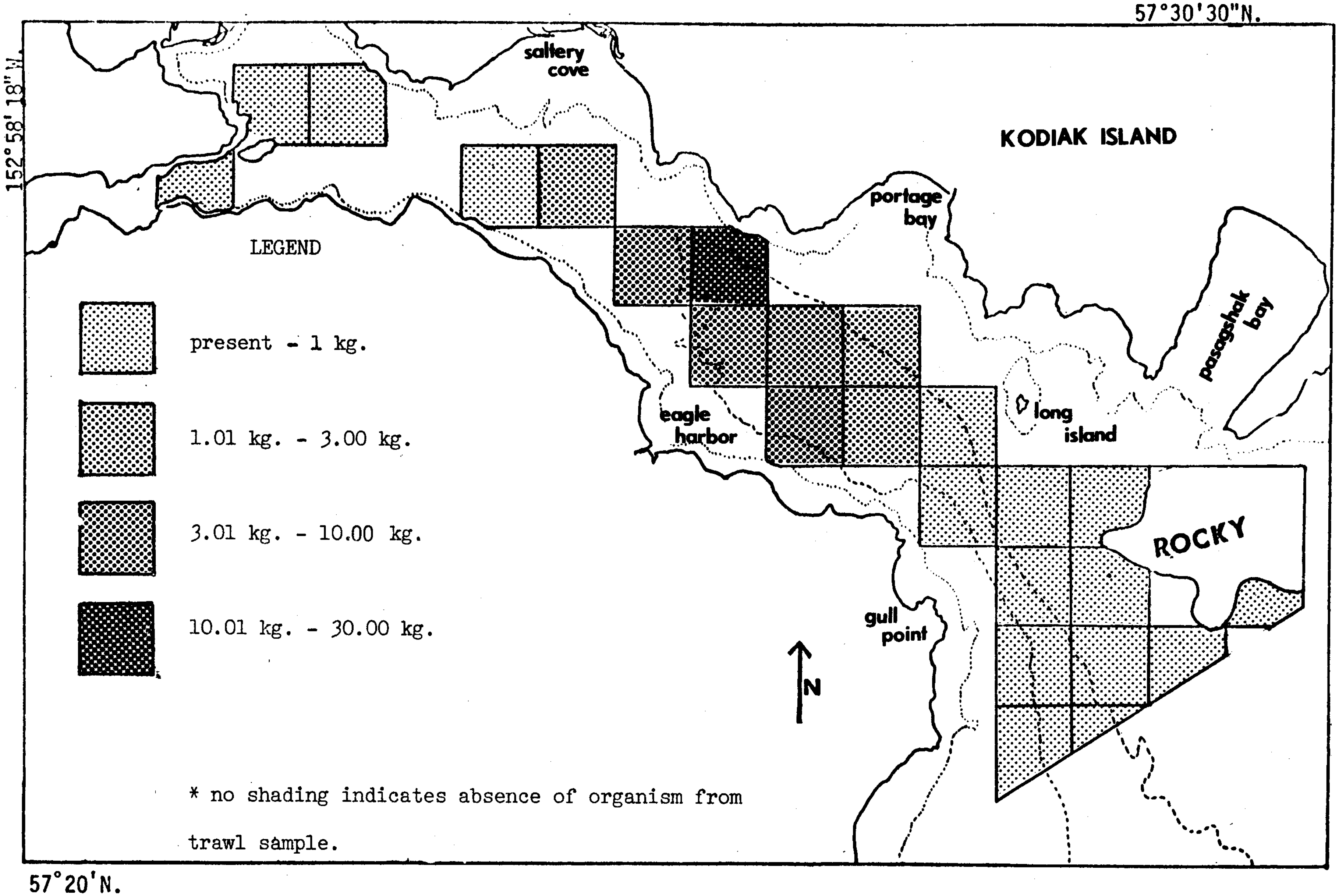
App. Fig. 50. Distribution and mean catch in kg per 20 minute tow of *Gymnocanthus* in Ugak Bay during March, 1977. X indicates station not sampled.



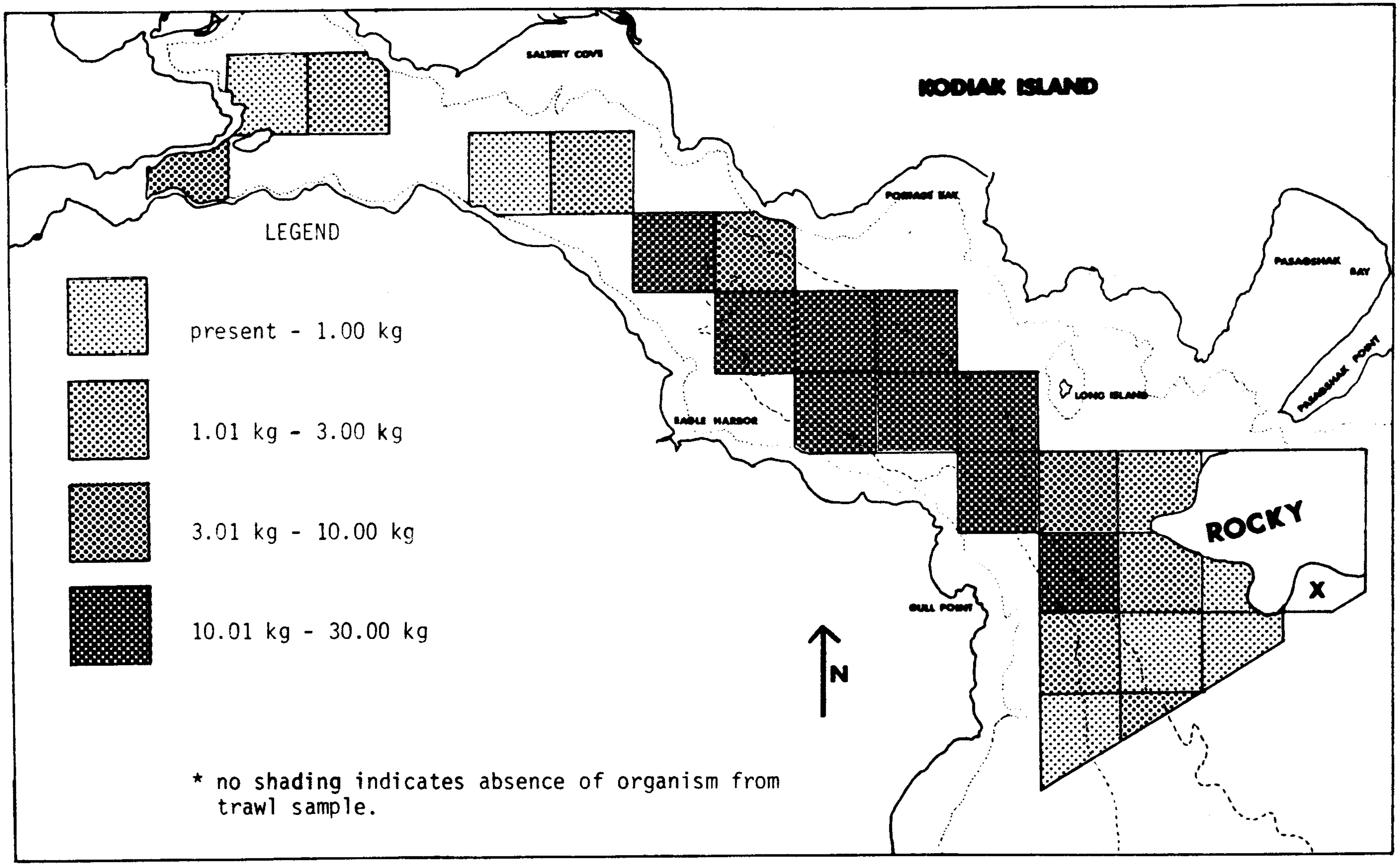
App. Fig. 51. Distribution and mean catch in kg per 20 minute tow of *Gymnocanthus* in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



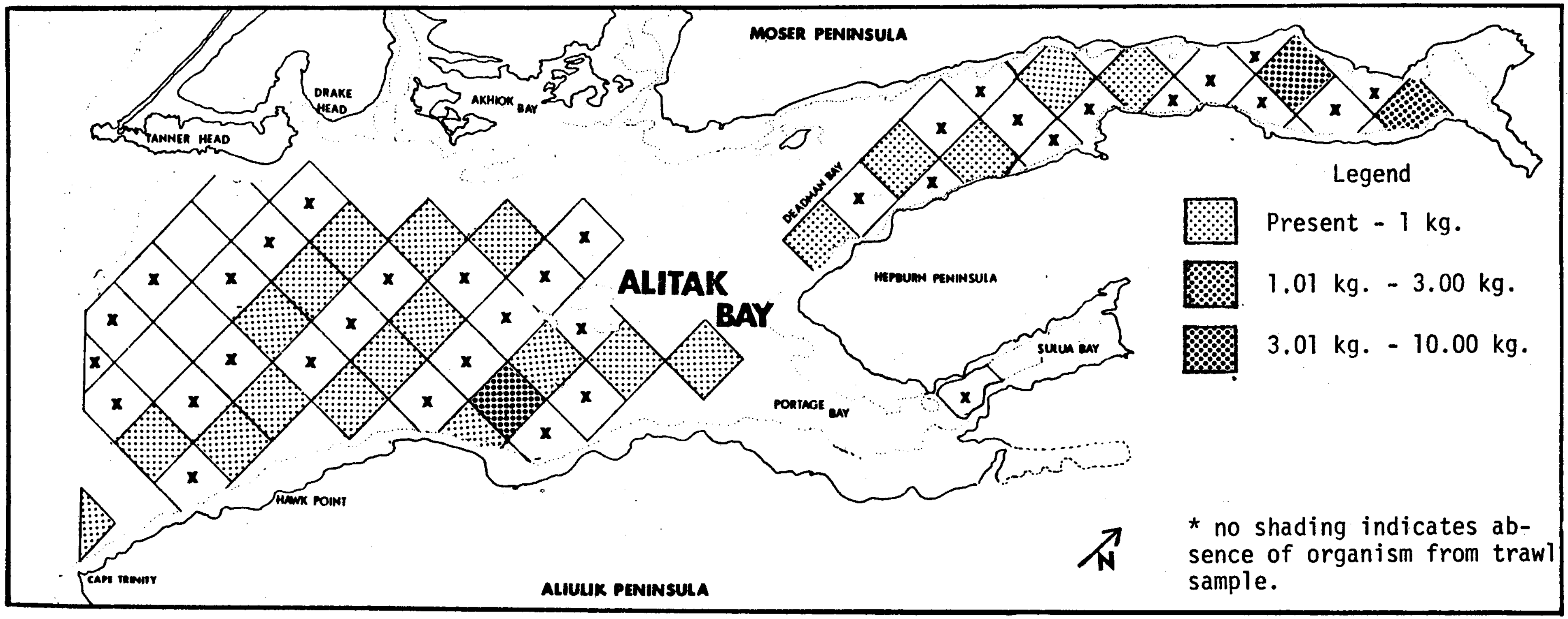
App. Fig. 52. Distribution and mean catch in kg per 20 minute tow of *Gymnocanthus* in Alitak Bay during March, 1977. X indicates station not sampled.



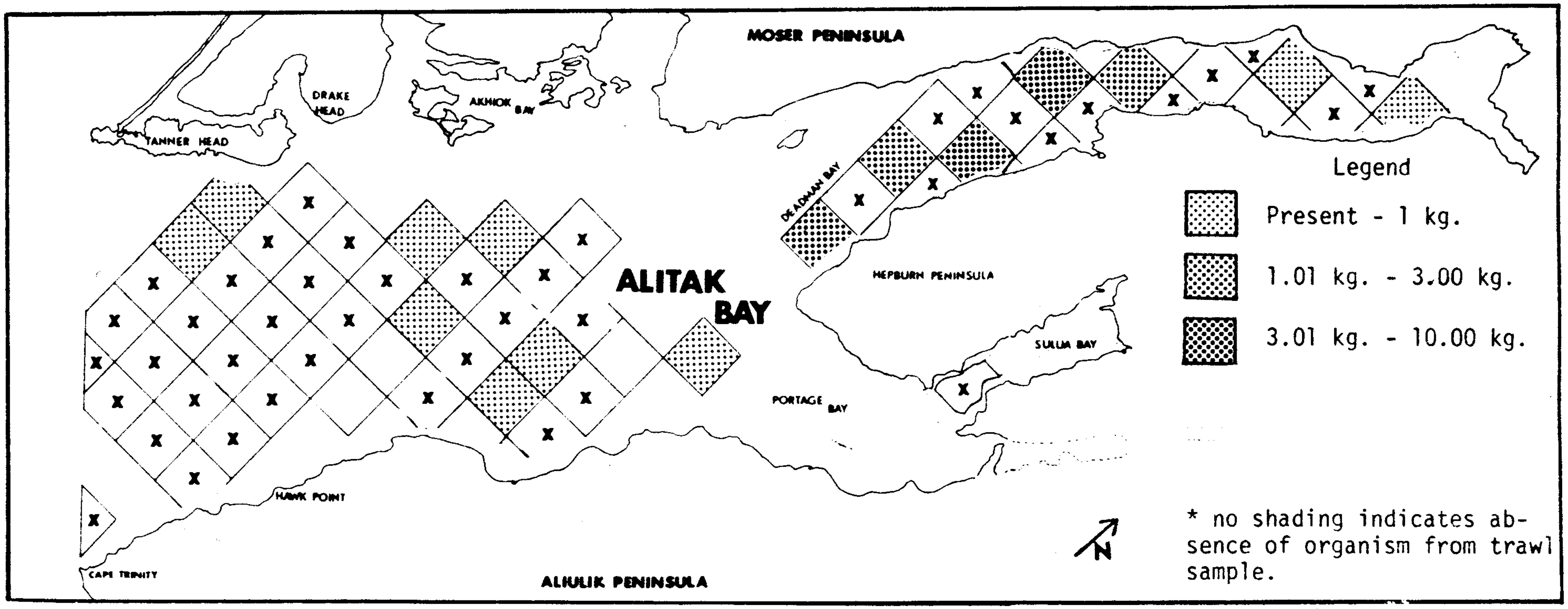
App. Fig. 53. Distribution and mean catch in kg per 20 minute tow of capelin in Ugak Bay during June, July, August and September, 1976.



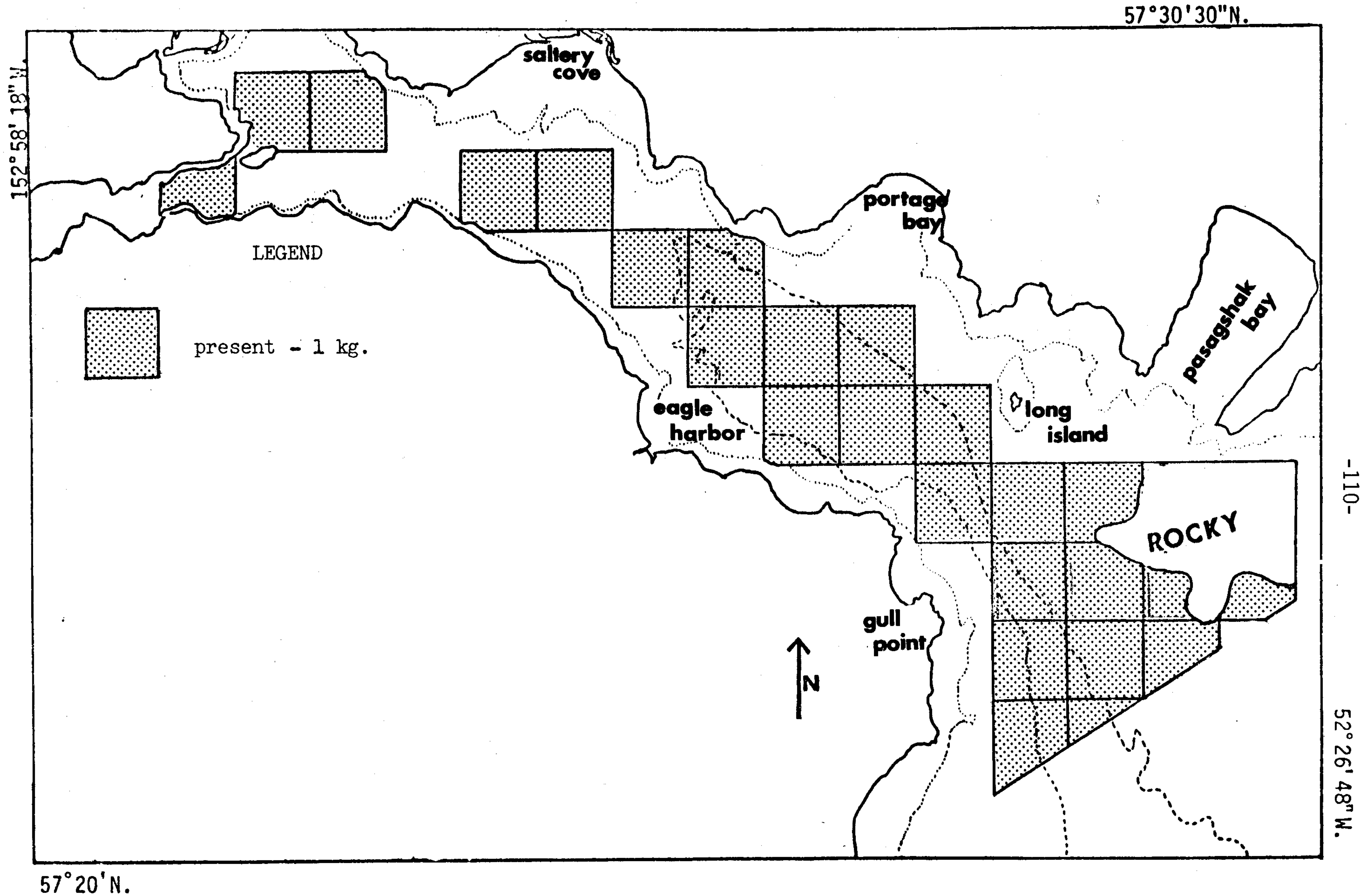
App. Fig. 54. Distribution and mean catch in kg per 20 minute tow of capelin in Ugak Bay during March, 1977. X indicates station not sampled.



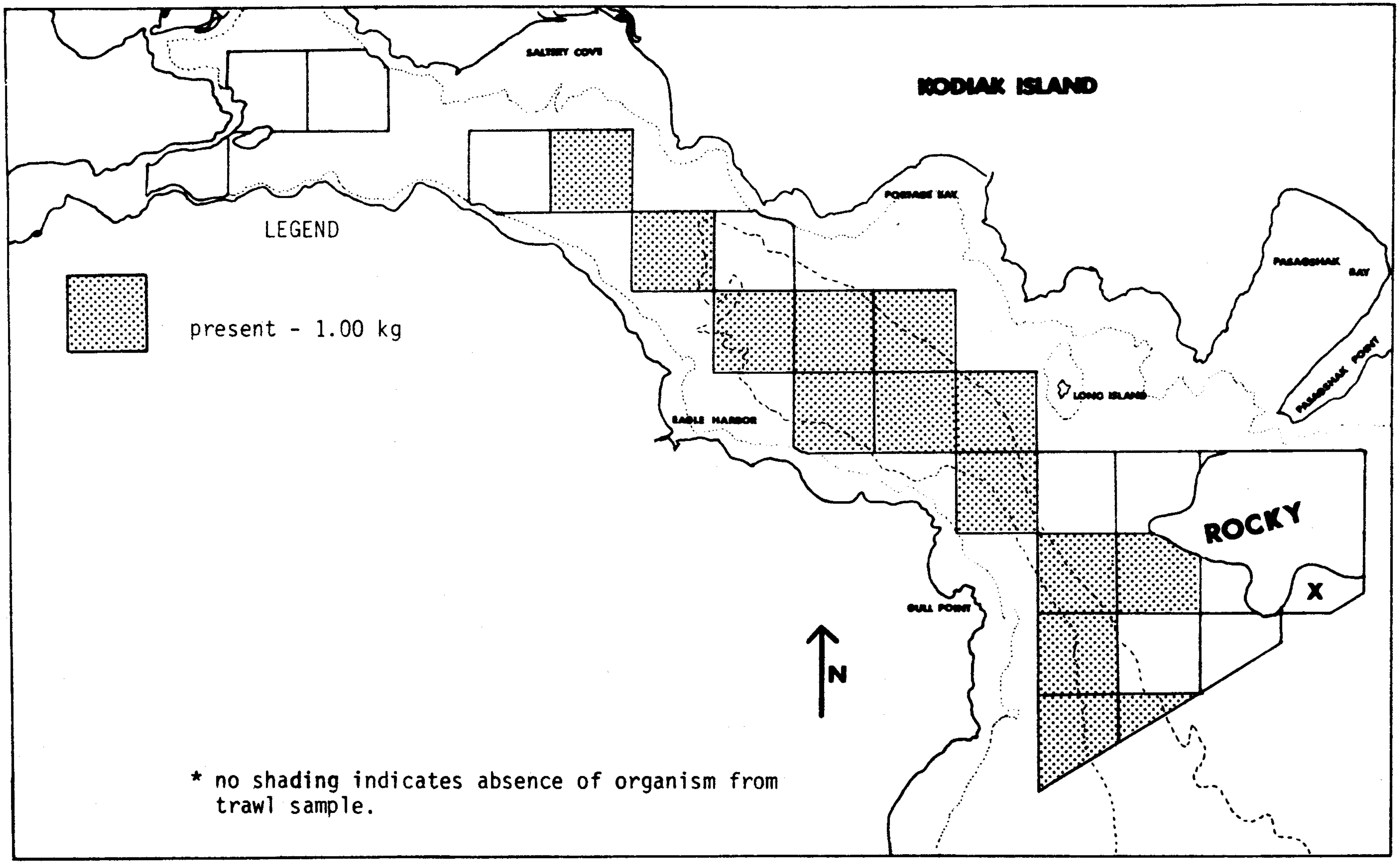
App. Fig. 55. Distribution and mean catch in kg per 20 minute tow of capelin in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



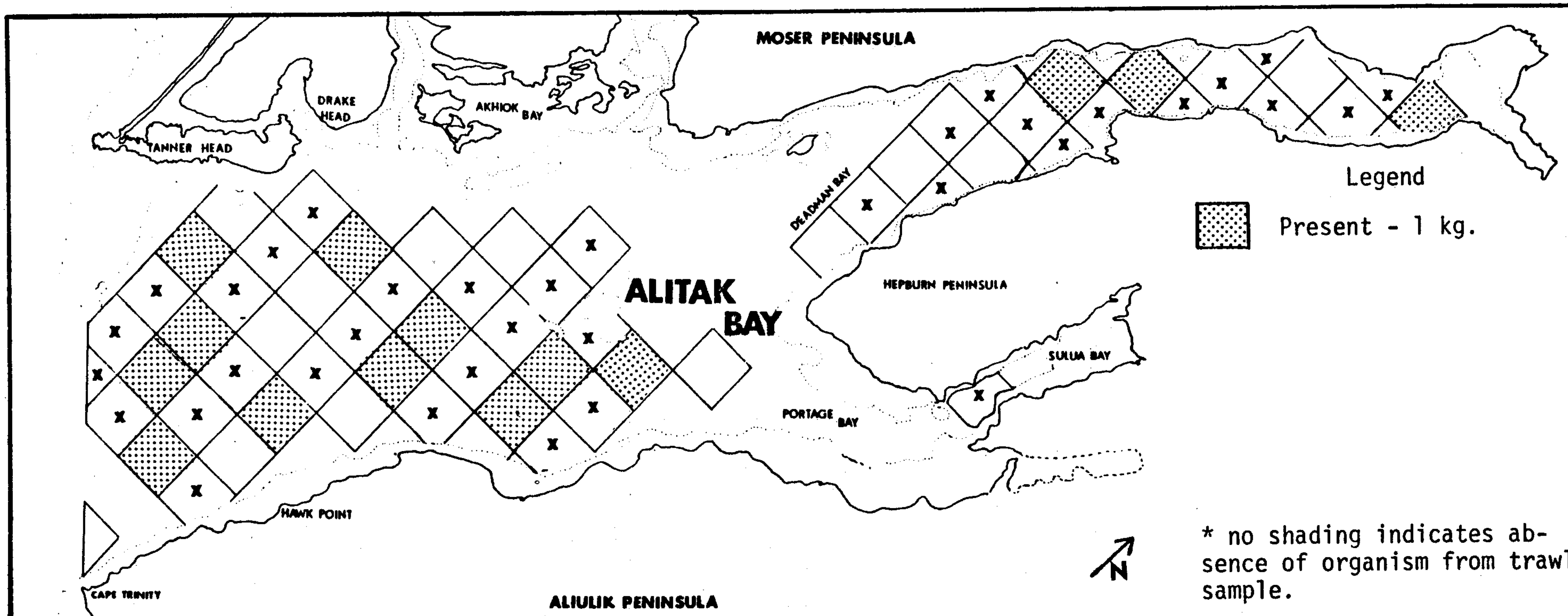
App. Fig. 56. Distribution and mean catch in kg per 20 minute tow of capelin in Alitak Bay during March, 1977. X indicates station not sampled.



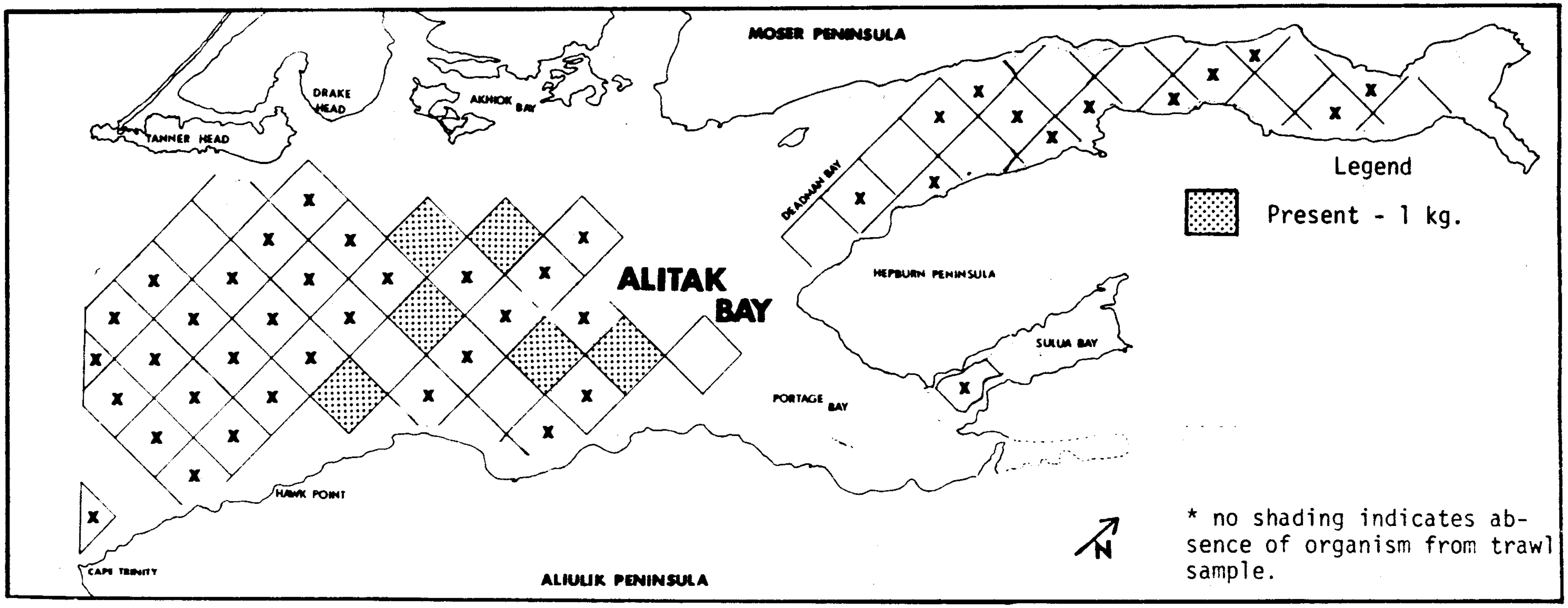
App. Fig. 57. Distribution and mean catch in kg per 20 minute tow of eulachon in Ugak Bay during June, July, August and September, 1976.



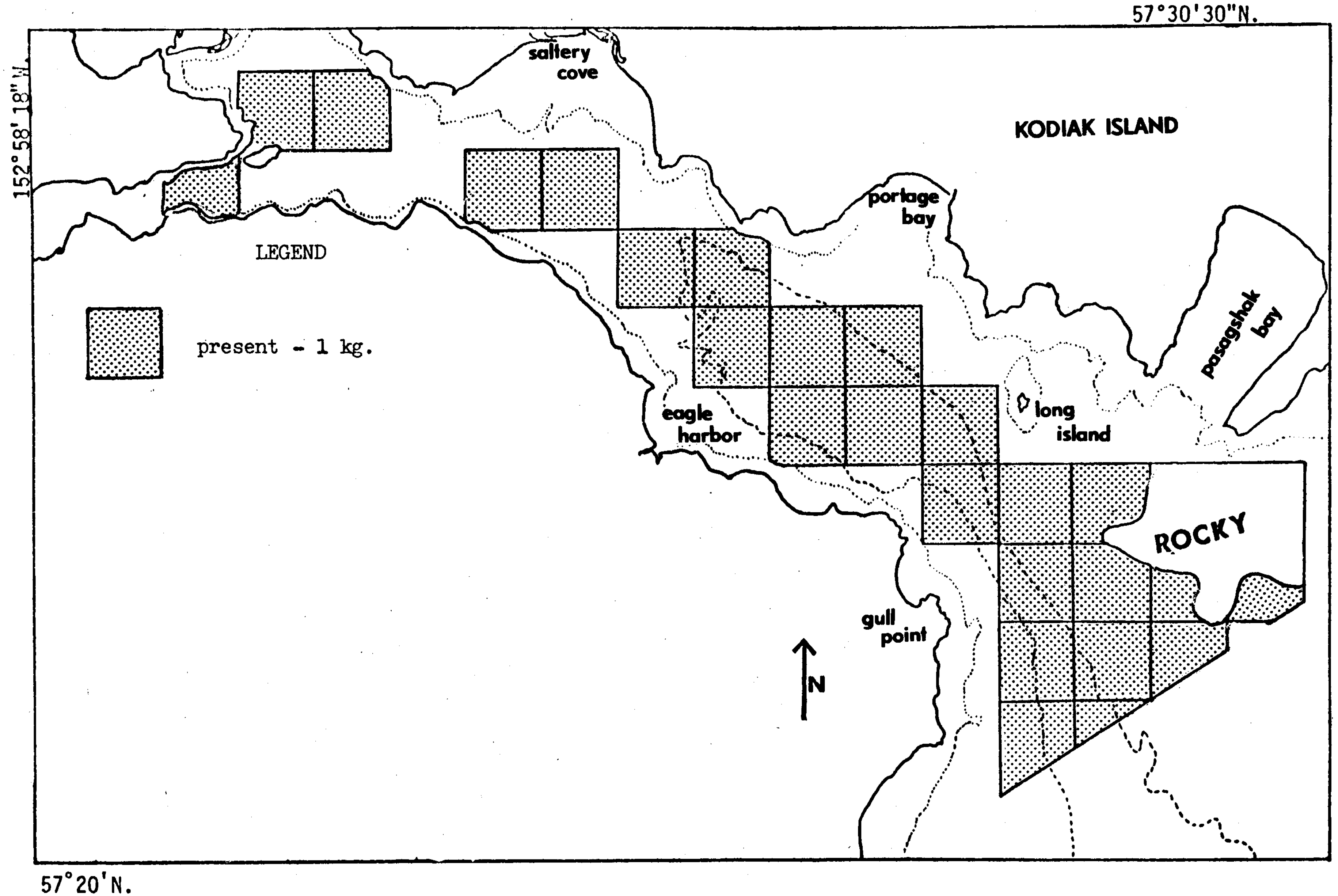
App. Fig. 58. Distribution and mean catch in kg per 20 minute tow of eulachon in Ugak Bay during March, 1977. X indicates station not sampled.



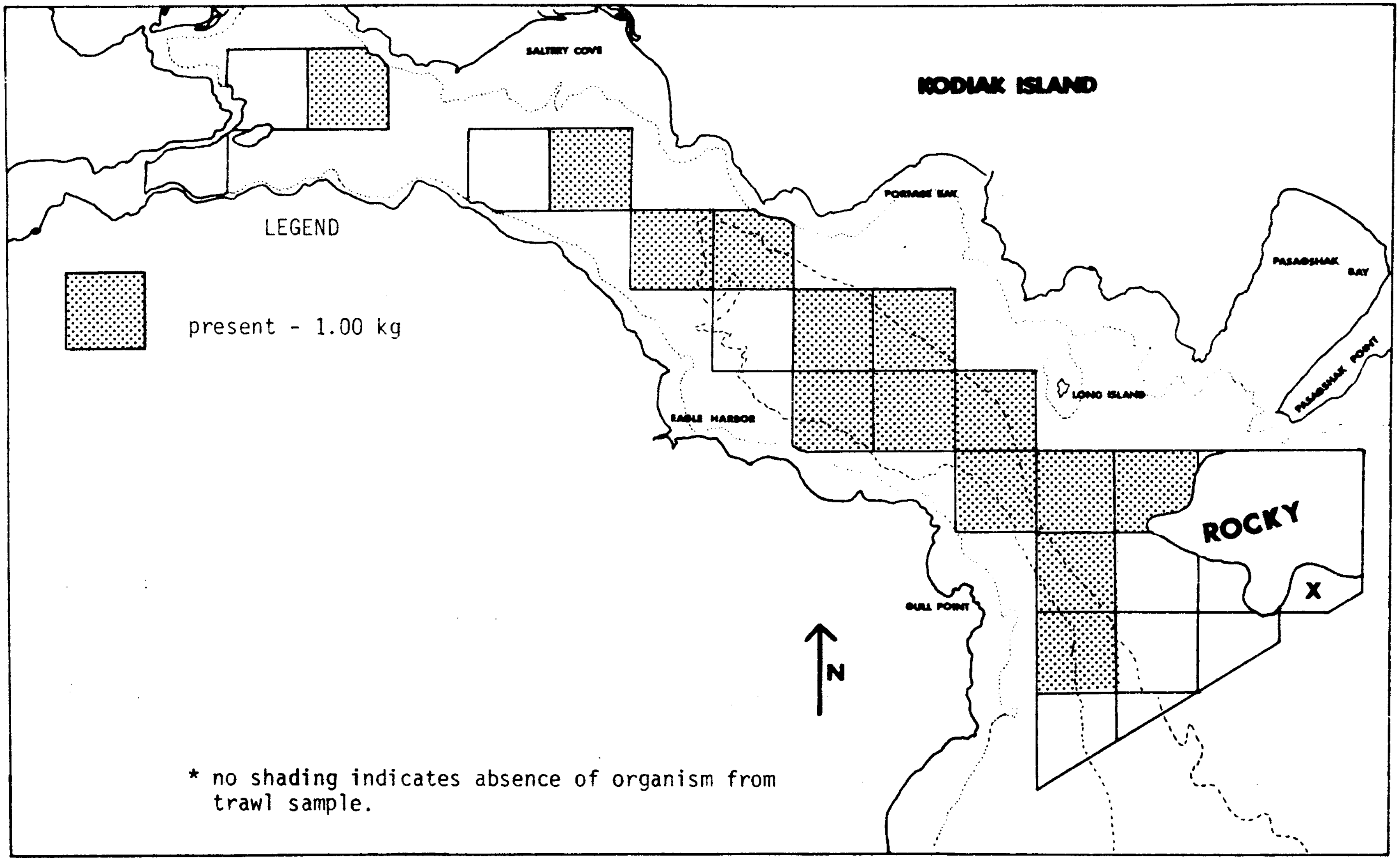
App. Fig. 59. Distribution and mean catch in kg per 20 minute tow of eulachon in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



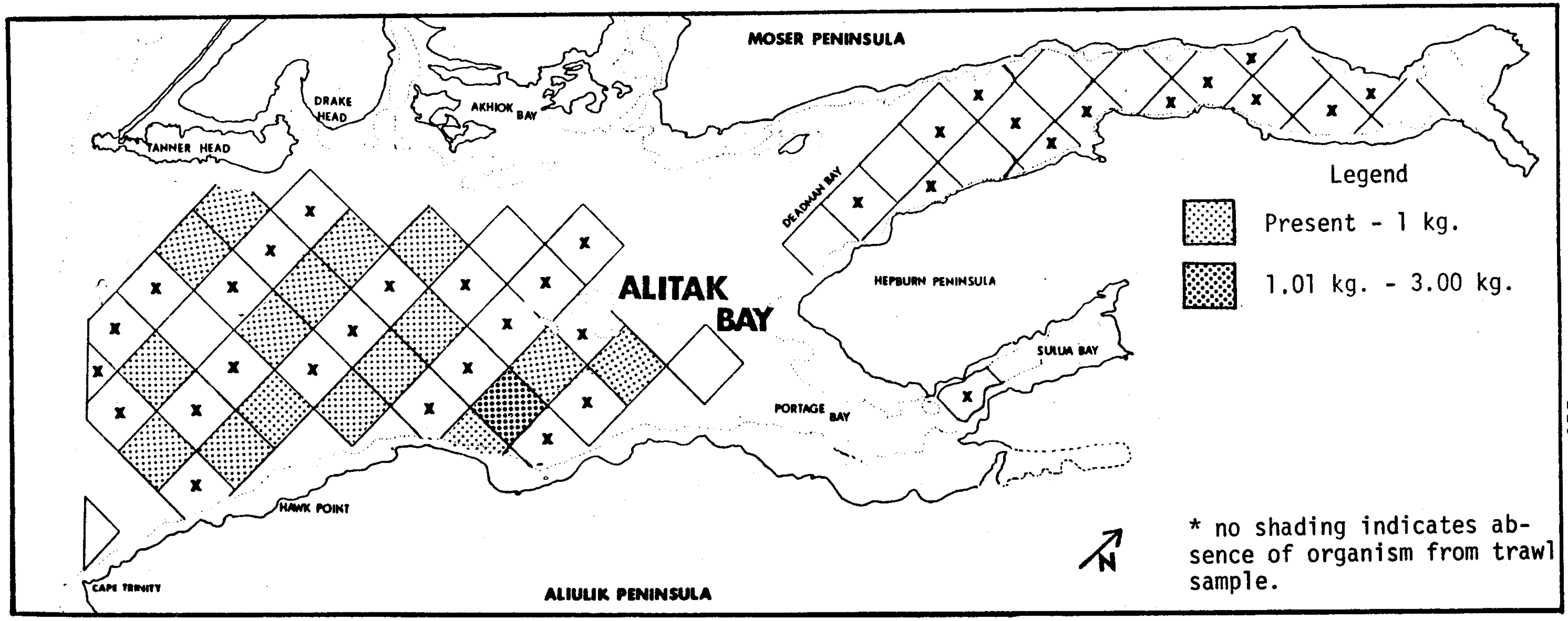
App. Fig. 60. Distribution and mean catch in kg per 20 minute tow of eulachon in Alitak Bay during March, 1977. X indicates station not sampled.



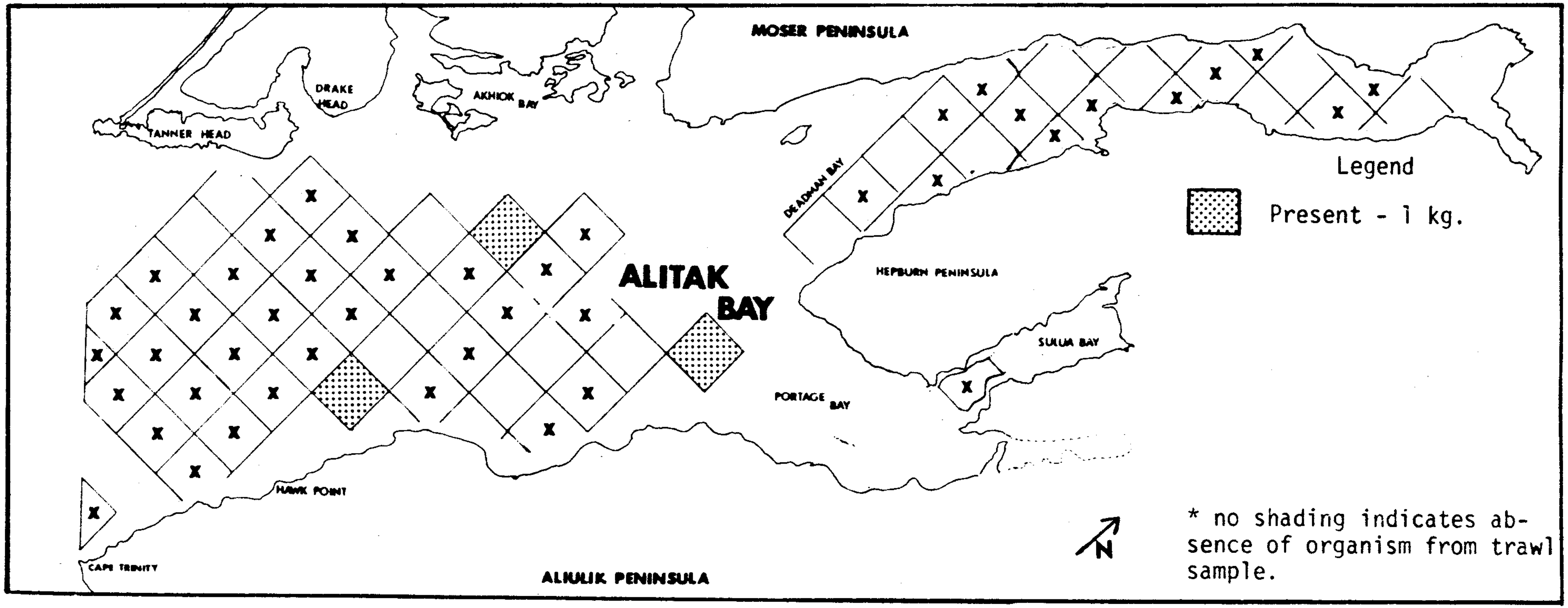
App. Fig. 61. Distribution and mean catch in kg per 20 minute tow of Pacific sandfish in Ugak Bay during June, July, August and September, 1976.



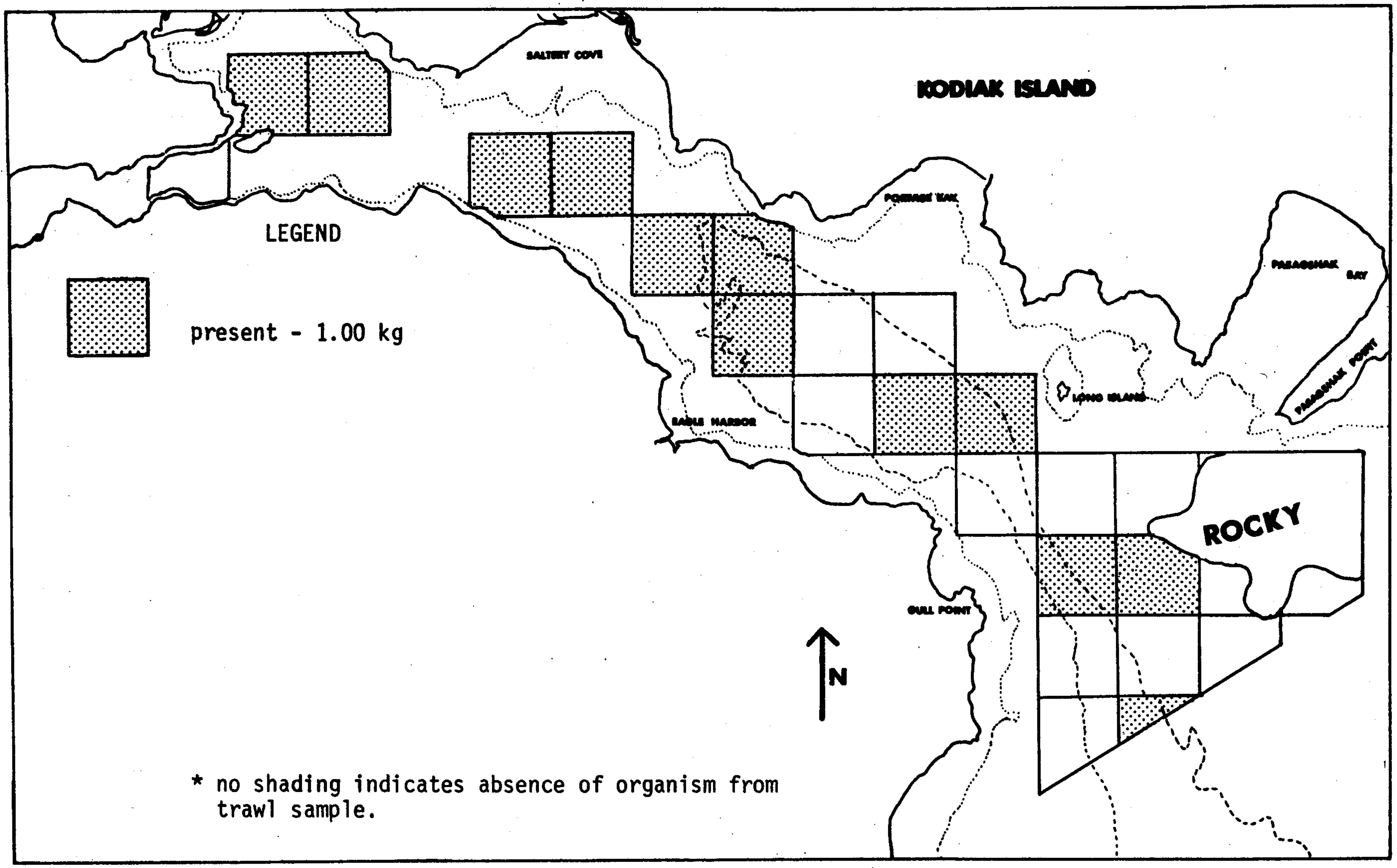
App. Fig. 62. Distribution and mean catch in kg per 20 minute tow of Pacific sandfish in Ugak Bay during March, 1977. X indicates station not sampled.



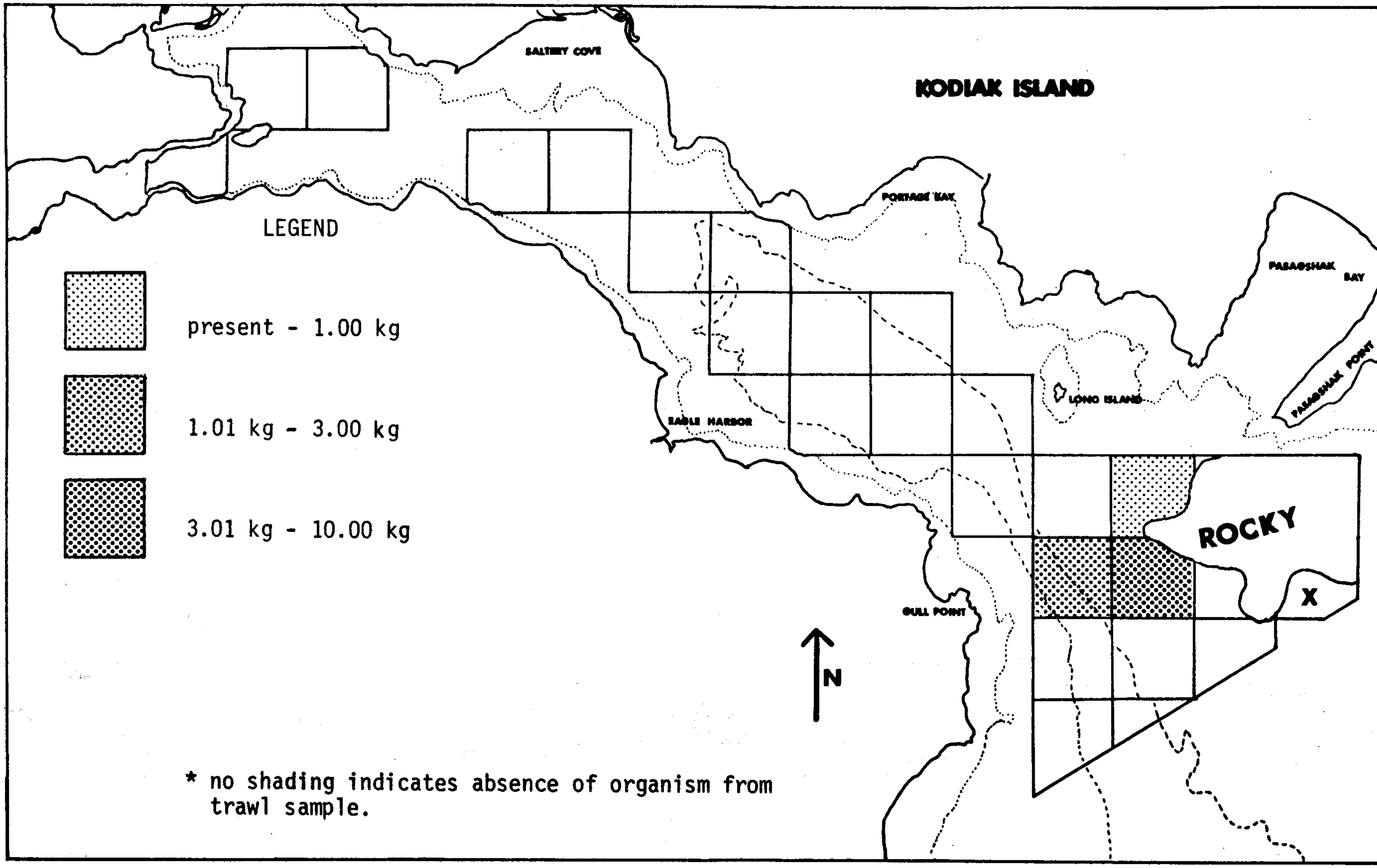
App. Fig. 63. Distribution and mean catch in kg per 20 minute tow of Pacific sandfish in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



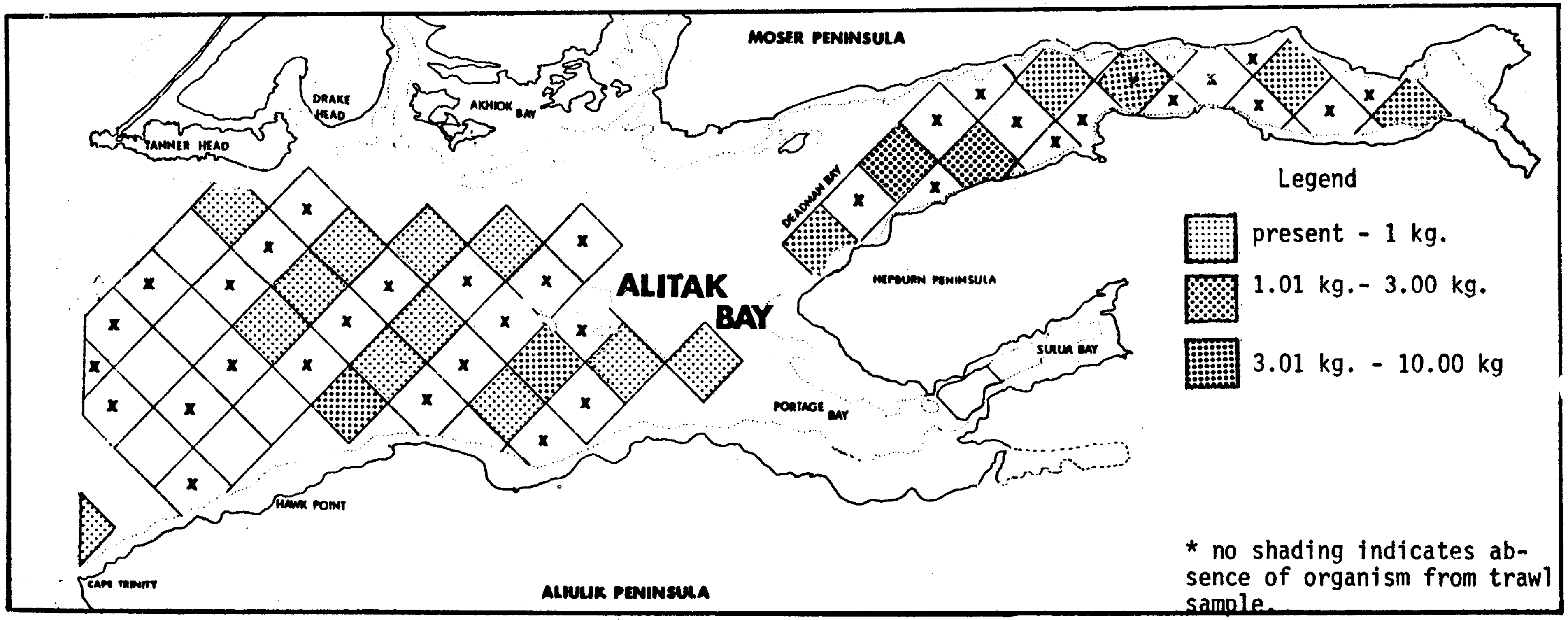
App. Fig. 64. Distribution and mean catch in kg per 20 minute tow of Pacific sandfish in Alitak Bay during March, 1977. X indicates station not sampled.



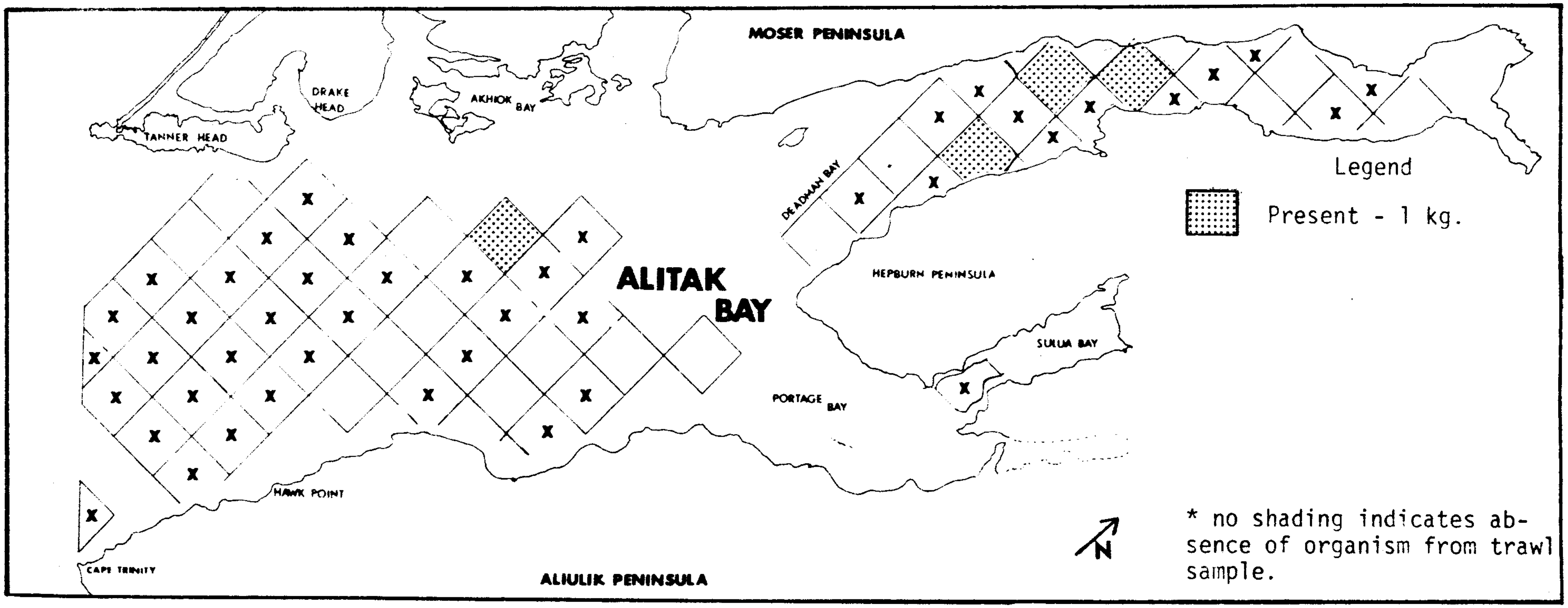
App. Fig. 65. Distribution and mean catch in kg per 20 minute tow of snailfish in Ugak Bay during June, July, August and September, 1976.



App. Fig. 66. Distribution and mean catch in kg per 20 minute tow of snailfish in Ugak Bay during March, 1977. X indicates station not sampled.



App. Fig. 67. Distribution and mean catch in kg per 20 minute tow of snailfish in Alitak Bay during June, July, August and September, 1976. X indicates station not sampled.



App. Fig. 68. Distribution and mean catch in kg per 20 minute tow of snailfish in Alitak Bay during March, 1977. X indicates station not sampled.

APPENDIX I

Simenstad, Charles A. (1977). "ADF&G-OCS Fish Food Habits Analysis," Annual Reports of Principal Investigators for the year ending March 1979, NOAA/OCSEAP, 4:411-438.

APPENDIX II

McLean, Robert F., Kevin J. Delaney and Beverly A. Cross (1976) "A Fish and Wildlife Resource Inventory of the Cook Inlet - Kodiak Areas," Alaska Department of Fish and Game. 155 pp.

✡ U. S. GOVERNMENT PRINTING OFFICE 1980 - 677-096/1230 Reg. 8